Loon Lake Water Quality Standing Committee
Deep Water Analysis and Aeration Pilot Project
Submitted Summer 2024

Contents

Loon Lake Water Quality Improvement Standing Committee

Final Pilot Report (2020-2023)
May 2024

Committee Members

Joe Carlson
Doris Gross
Maureen Morsch
Joe Harrington/Cathy Saxton
Alice Publow
Paula Thoma
Bernie Thoma

Contents

Executive Summary:

The Water Quality Committee's Pilot Project addressed concerns of shoreline algae blooms, and accumulation of muck as well as evaluating lake trends in regard to sources of nutrients in the water column. The committee established two goals:

Goal 1 Deep-Water Study

Deep water analysis shows:

- Significant legacy phosphorus
- Low dissolved oxygen measurements in summer months resulted in reducing conditions that release trapped nutrients and more potential for algal blooms
- Chlorophyll-a is a prime indicator for algal formation
- Increasing presence of dissolved nitrogen which along with phosphorus is a trigger for algal blooms

Goal 2 Effectiveness of Aeration to Decrease Blooms and Reduce Muck

Aeration analysis shows:

- Aeration improved water quality at pilot sites
- Aerators circulation disrupted the formation of algae blooms
- Aeration had minimal effect on muck accumulation rates

Committee Recommendations:

Continued periodic deep-water study to monitor nitrogen/ammonia concentrations and dissolved phosphorus throughout the water column since these nutrients are potential triggers of harmful algal blooms.

Develop educational opportunities and procedures for HAB identification

Monitor non-native and invasive species.

Aeration provides some benefit by reducing blooms along your shoreline but may not be viewed as a cost-effective solution.

Aeration's effect on muck reduction was minimal over the study period. This was due to the short length of time and the measurement process used. Aeration will not be beneficial in reducing muck until muck accumulation can be reduced through nutrient management.

General Background Information

Formation of the Water Quality Committee rose out of interest by residents who were concerned about overall lake water-quality trends, more frequent development of shoreline blooms, and accumulation of muck in many areas of the lake. Several NYSFOLA members had attended recent conferences and shared information on the Nine Elements/NYS HAB study and techniques for water quality improvement through aeration techniques. Information sessions were held with Solitude Representatives, NYSFOLA, area lake stakeholders, and SUNY Environmental Science Teams from Brockport and Geneseo.

Project Development Information

- Lakes are unique ecosystems with unique problems and therefore unique needs
- Deep-water conditions particularly legacy phosphorus accumulation is key to lake health and in the development of Harmful Algae Blooms (HABS).
- Deep-water aeration and applications of alum (bentonite) are techniques being studied in larger lakes. Both applications are very costly and unproven at this point.
- Shoreline blooms are related to deep-water conditions, and lake structure
- Visible shoreline HAB activity can be treated with algaecide applications (Solitude). However, the use of algaecide would have tangible, visible, short-term results, and must be periodically reapplied. This procedure is of higher risk for unintended consequences in a small lake. It was not recommended by teams form Brockport and Geneseo.
- Nano oxygenation was researched as a type of aeration. Although this type of aeration is the most effective type of aeration, it is cost prohibitive.
- A submerged aeration system model was presented by Solitude. These diffuser systems could be installed by groups of residents from contiguous properties. Results could be used to inform lake associations and property owners of potential benefits. If a lake-wide system were considered, the project would require approximated 20 units at about $5K per unit plus electricity at about $80 per month.
- In June 2012, Darryl Miller conducted research of a lakeside aeration system, CleanFlo. He visited Shickshinny Lake, PA where units were in service. Representatives of Shickshinny Lake had collected no data. Due to lack of recorded data and high cost, LLWIA decided not to pursue this system. (A copy of Darryl's report is available from Alice Publow.)
- Several residents made a site visit to Wolf Lake in the Catskills, where Solitude had installed diffused aeration systems in two cove areas of the lake. The goal was to irradicate algae blooms from swimming areas of the lake. Management personnel felt the system was successful based on observational data of reduced algae blooms that impaired swimming.
- Muck has been an issue for Loon Lake residents. Muck depth has been increasing over the years. As lakes age, years of organic material accumulates from runoff such as grass clippings, leaves, branches, as well as dead and decaying aquatic weeds and algae, fertilizers, leaking septic waste, and so on. As these materials begin to decay, they

utilize the oxygen available in the water. As the organic material builds, more oxygen is used, and muck develops. An oxygenation system can provide and maintain aerobic decay. Once oxygen is available, microorganisms and enzymes can be very effective in reducing the build-up of muck that results from anaerobic decay in lakes.

- Solitude and local limnologist from A-TIP had recommended aeration as a technique for reducing muck. Aeration reduces muck by fueling bacteria that process decaying matter. Pellets, as used in ponds, were also mentioned as an option. These pellets sink into the water, releasing bacteria that begin cutting through the muck and buildup. Pellets were not formally considered for this project.
- A goal-oriented committee with representatives from both associations as well as residents at large would broaden project support.

Committee Formation

Loon Lake Association and The Watershed Improvement Alliance approved the following:

- Water Quality Improvement Standing Committee

2 Loon Lake Association Board Representatives
2 Watershed Improvement Alliance Board Representatives
3 Loon Lake Residents

- Budget of $13,000.
    - $10,000- ($5,000 from each association)
    - Purchase and Installation of Aeration system $6,142.00
    - Sampling and Analysis by SUNY Brockport $6,858.00
    - Private Donation $3,000 for SUNY Graduate Student

- Pilot Program 2021-20-23 Goals

  Goal 1

  Conduct a Deep-Water Study

    - Determine the Status of Internal Loading of Phosphorus
    - Identify potential/viable techniques for improvement

  Goal 2

  Determine the Effectiveness of Diffused Aeration to

    - decrease the occurrence of shoreline blooms and to
    - reduce loose sediment (muck)

Procedural Team

An alliance was formed with Dr. Michael Chislock and students in the SUNY Brockport Environmental Studies Program to implement and interpret testing, and to compile a final report at the need of the project.

Committee members supported Dr. Chislock, gathered observational data, and oversaw equipment over the length of the program.

Equipment Acquisition

- Bidding Process

The following was sent out to 6 potential bidders. Three proposals were received. Cost ranged from $4,675 to $9,855. The two low bids were basically the same cost for equipment, but the lowest bidder had lower installation cost. A-TIP Control from Dansville, NY was selected.

  - Vertex HF3 XL2 High Flow Aeration System or similar system
  - 3⁄4 hp Compressor, 115V or 230V.
  - Pressure Gauge and Pressure Relief Valve;
    an aluminum quiet aeration cabinet with exhaust fan.
  - **three (3)** Dual Disk Air Stations
    500 ft. underwater self-weighted air delivery tubing
    Installation

Site Selection

- It was determined that one of three northern coves would be the best location for the Aeration Project. This was based upon the structure of the lake. The prevailing fetch of the lake waters tend to concentrate algae blooms in the northern coves.
- All property owners were contacted, provided information concerning the project, and asked if they might be interested in hosting the aeration equipment.
- Several property owners expressed some interest in being the host, but declined for reasons such noise, liability, and closeness of neighbors. A larger property was located that allowed for isolation of the compressor.
- Due to site being further away from buildings that had electric service, a source of electricity had to extended to the compressor.

Installation Budget

System and Installation	$4,675
Filters	$ 56
Electric Extension	$1,411
Total	$6,142

A-Tip to provide a price for solar power, which would have eliminated the need to extend the electric. The cost was $8,045.

The compressor was placed on a bank about 10’ above the water. The three diffusers were placed in the lake ranging from 8’ to 12’ depth (Spring depth). The diffusers were placed about 50’ to 60’ from shore, with about 40’ between the diffusers.

Committee Findings/Understandings

Goal 1 Conduct a Deep-Water Study

- Determine the Status of Internal Loading of Phosphorus
- Identify potential/viable techniques for improvement

Deep water analysis shows:

- Significant legacy phosphorus
- Low dissolved oxygen measurements in summer months resulted in reducing conditions that release trapped nutrients and more potential for algal blooms
- Larger measurements of chlorophyll a levels across the water column over time
- The increase in oxygen depleted/ dead zones encroaches on the area for survival of zooplankton (particularly algae-eating daphnia)
- Increasing presence of dissolved nitrogen which along with phosphorus is a trigger for algal blooms

Goal 2 Determine the Effectiveness of Diffused Aeration to

- decrease the occurrence of shoreline blooms and to
- reduce loose sediment (muck)

Aeration data shows

- Aeration improved water quality as measured at pilot sites across the water column next to the aerators.
- No HABS were noted and tested during a bloom event
- Aerators slowed/stopped the formation of algae movement
- The lack of nutrient management reduced the positive effects of aeration on muck accumulation rates
- Long term aeration could result in other forms of non-toxic algal formations
- Aeration could be effective/turned on at shoreline or designated beach areas during weather and lake-condition events that typically cause HABs allowing for periodic use of aerators

Recommendations and Take-Home Message

Excerpt from SUNY Brockport Limnology Report on Internal Loading and Aeration by Dr. Michael Chislock (Full Report Addendum)

There is a need to assess other sources of nutrients to the lake.

- It is important to collect more recent watershed data.
- The contribution of nutrients from groundwater springs to the lake is unknown.
- A survey study looking at potential septic system leakage around the lake is another important next step.
  - This could be done as part of an undergraduate summer (or fall) research project looking for indicators of this type of contamination.
  - Optical brighteners, which are added to products such as laundry soaps, detergents, or other cleaning agents, can be detected by fluorescence analysis of water samples.
  - A study looking at optical brighteners in water samples collected around the lake could be informative of potential contamination.
  - If sources are identified, remediation efforts should occur to limit this potentially important source of nutrients to the lake.

- Recent CSLAP reports have indicated that concentrations of dissolved nitrogen (i.e., ammonia, NH_3) may be increasing in the bottom layer of the lake during the summer. We recommend regular (e.g., every 2-3 years) monitoring of ammonia concentrations throughout the water column, in addition to levels of dissolved phosphorus since both nutrients are potential triggers of harmful algal blooms. In particular, increased availability of ammonia is linked with the development of blooms of toxic species that do not have the ability to fix atmospheric nitrogen (e.g., *Microcystis*).
- Consider thermistor array and/or dissolved oxygen sensors to monitor temperature and oxygen to predict bloom risk.
  - Buildup of bottom-layer nutrients will be highest in summers when stratification sets up earliest.
  - These arrays could be "synced" with the nearshore aerators so that homeowners could turn on the units during high-risk periods (e.g., disturbance of stratification patterns during high winds and storm events).
- Evaluate costs and benefits of installation of aerators – potentially install in high-risk areas/bays.
  - Aeration will likely not be beneficial in reducing muck until overall productivity rates and muck accumulation can be reduced through nutrient management.
  - Aeration seemed to enhance algal productivity in some instances. The algal taxa that were enhanced did not appear to be harmful (i.e., toxic cyanobacteria).
  - Sampling did not occur during any cyanobacterial bloom events, so we were unable to evaluate potential effects of the aerators on species distribution, abundance, and composition.

- Regularly monitor zooplankton and macrophyte assemblages for changes.
    - Continue efforts and emphasis on preventing introductions of non-native, invasive species.
    - Introduction of invasive invertebrates (e.g., spiny water flea, *Bythotrephes* species and fish hook water flea, *Cercopagis* species) that predate on native zooplankton and/or fishes (e.g., Eurasian Rudd, *Scardinius erythrophthalmus*) would have devastating ecosystem level effects on the lake.
- Consider future fish survey supported by SUNY. This could occur as a potential joint effort by students from SUNY Brockport and Geneseo during fall semesters.
- Create a lake management plan with a rotating list of priorities that are assessed on a regular basis.

Post-Project Positive Outcomes

Heightened Lake Knowledge and Environmental Involvement
Provided Springboards for Future Projects
Combined Short-Term Committees Were an Effective Format
Prompted an Updated Lake Management Plan
Provided Validation of Value of Past and Future Lake Projects
Highlighted Community Concerns-Living Together on the Lake

Acknowledgements

Loon Lake Association
Loon Lake Watershed Improvement Alliance
Property Owners on Lindenwood Point
Donors for Summer Intern
John and Elly Hayden, Alice and Andy Publow, Joe and Maggie Carlson, Maureen Morsch, Doug and Jean Whitney, Paula and Bernie Thoma
SUNY Brockport Faculty and Students

SUNY BROCKPORT

Loon Lake Watershed Improvement Alliance

And the
Loon Lake Association

I. Hypoxia, Anoxia, and Internal Loading of Nutrients in Loon Lake, Steuben County, NY (2020-2022)

by

Brayden Link, Dan Beers, Bennett Amberger, Riley Lindberg, and
Michael Chislock

II. Evaluation of Potential Effects of Nearshore Aeration on Water Chemistry, Algal Biomass, and Accumulation of Muck

by

Brayden Link, Dan Beers, Connor Hannig, Jenna Inglese, and
Michael Chislock

SUNY Brockport Limnology Lab
Department of Environmental Science & Ecology
State University of New York at Brockport
350 New Campus Drive, Brockport, NY 14420

Submitted to
The Loon Lake Association and the Loon Lake Watershed Improvement Alliance

May 2024

Acknowledgments: Alice Publow (photo below), Paula Thoma, and Bernie Thoma all provided support for field work. Bernie Thoma was the boat pilot for numerous trips during the summer and fall from 2020-2023. LLA, LLWIA, and the Summer Undergraduate Research Program at SUNY Brockport all provided funding to support this research.

I. Hypoxia, Anoxia, and Internal Loading of Nutrients in Loon Lake, Steuben County, NY (2020-2022)

Introduction

The consequences of nutrient enrichment and associated cultural eutrophication are well known and include blooms of cyanobacteria (e.g., harmful algal blooms, HABs), tainted drinking water supplies, degradation of recreational opportunities, and hypoxia. Sources of nutrients contributing to cultural eutrophication in lakes include (1) the watershed (i.e., surface and groundwater) and linkages to land use; and (2) legacy sources that are stored in the sediments of lakes. There are many examples of remediation of the effects of cultural eutrophication by reducing watershed-level inputs. However, legacy sources of nutrients also often prevent further improvements in water quality despite substantial progress in reducing external, watershed-level sources. **A major goal of the pilot program on Loon Lake was to evaluate temporal trends in regard to legacy sources of nutrients.**

Dense blooms of algae that reduce water clarity, accumulate on shorelines, and reduce overall water quality is the most conspicuous effect of cultural eutrophication. However, when algal blooms die and organic matter accumulates at the bottom of lakes, microbial decomposition severely depletes dissolved oxygen, creating hypoxic or anoxic 'dead zones' lacking sufficient oxygen to support most organisms. These dead zones are found in many freshwater lakes including the Laurentian Great Lakes (e.g., central basin of Lake Erie) during the summer. Similar hypoxia events are particularly common in marine coastal environments surrounding large, nutrient-rich rivers (e.g., Mississippi River and the Gulf of Mexico; Susquehanna River and the Chesapeake Bay). In general, this accumulation of "muck" and organic matter can be a major legacy source of nutrients in lake ecosystems. Furthermore, the magnitude of low oxygen areas, driven by microbial decomposition, is an important symptom for the management of nutrient enrichment in lakes. **A secondary goal of the pilot program was to evaluate the prevalence of seasonal hypoxia and anoxia in the water column of Loon Lake.**

Fundamentally, seasonal hypoxia and storage/release of legacy nutrients in lakes is linked to lake stratification. Lake stratification occurs when density differences in the water column create distinct layers. Density differences are a function of both water temperature and salinity. During lake stratification, dissolved oxygen in the bottom layer of productive lakes decreases due to microbial decomposition, which results in conditions favoring release of legacy phosphorus trapped in lake sediments (i.e., internal loading) as well as increased concentrations of ammonia/ammonium. When the lake mixes, it brings legacy phosphorus and ammonia to the surface waters of lakes. Increased availability of these key nutrients can trigger rapid development of algal blooms. **Therefore, a major focus of the pilot program was to evaluate temporal patterns of nitrogen and phosphorus in relation to stratification, seasonal hypoxia, and subsequent reducing (i.e., redox) conditions.**

Methods
During each of the three years of sampling, a calibrated YSI ProDSS was used to measure water quality parameters at approximately every meter of the water column (water temperature, dissolved oxygen (DO), pH, specific conductivity (SPC), oxidation-reduction potential (ORP), *in vivo* chlorophyll *a*, and phycocyanin). Water temperature, DO, and ORP provide *in situ* data that are strongly linked to development of stratification, subsequent hypoxia, and concomitant reducing conditions that favor the release and build-up of phosphorus in the bottom depths of the lake. Chlorophyll *a* provides an indicator of algal abundance, and phycocyanin is related to the abundance of cyanobacteria. We also used a van Dorn sampler to collect water samples at discrete depths throughout the water column. Samples for analysis of dissolved nutrients (e.g., nitrate + nitrite (NO_x) and orthophosphate) were filtered immediately on site using 0.45-µm syringe filters. We also collected water samples for lab analysis of total nitrogen (TN), total phosphorus (TP), and chlorophyll *a*. All samples were stored protected from light on ice in coolers prior to delivery to the analytical lab.

Findings
- The timing of the onset of thermal stratification varied in 2021 and 2022, with stratification occurring earlier in 2022 (Fig. 1).
- Deep-water hypoxia and anoxia (Fig. 2) lead to reducing conditions (Fig. 3, 4) during summer of all three years, leading to a large accumulation of dissolved and total phosphorus in the bottom layer (Fig. 5).
- We observed a consistent "deep chlorophyll maximum across years, especially during the summer of 2022 (Fig. 6).
- There was an indirect effect of the increased volume of the low dissolved oxygen layer in summer 2022 (vs. summer 2021) (Fig. 2).
- This deep-water layer is an important refuge for large-bodied herbivorous zooplankton (e.g., *Daphnia* species).

- We observed red-pigmented *Daphnia* concurrently with the large decrease in deep-water dissolved oxygen as well as reduced overall *Daphnia* abundance during 2022 (Fig. 7).

Figures and Tables

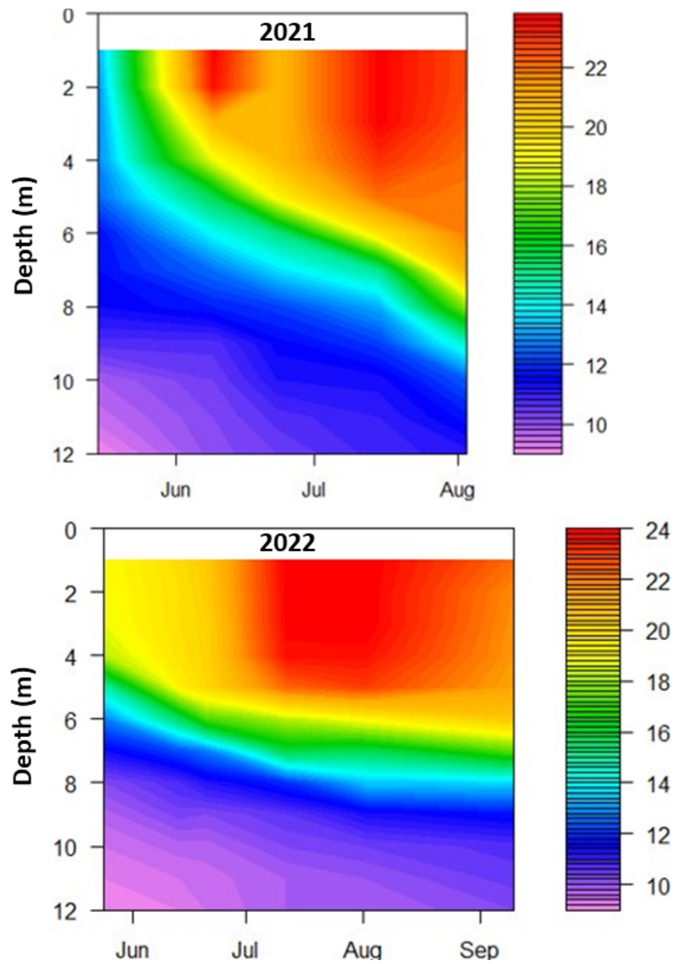

Figure 1. Vertical profiles of lake water column temperature patterns during the summers of 2021 and 2022 for the Deep Lake site.

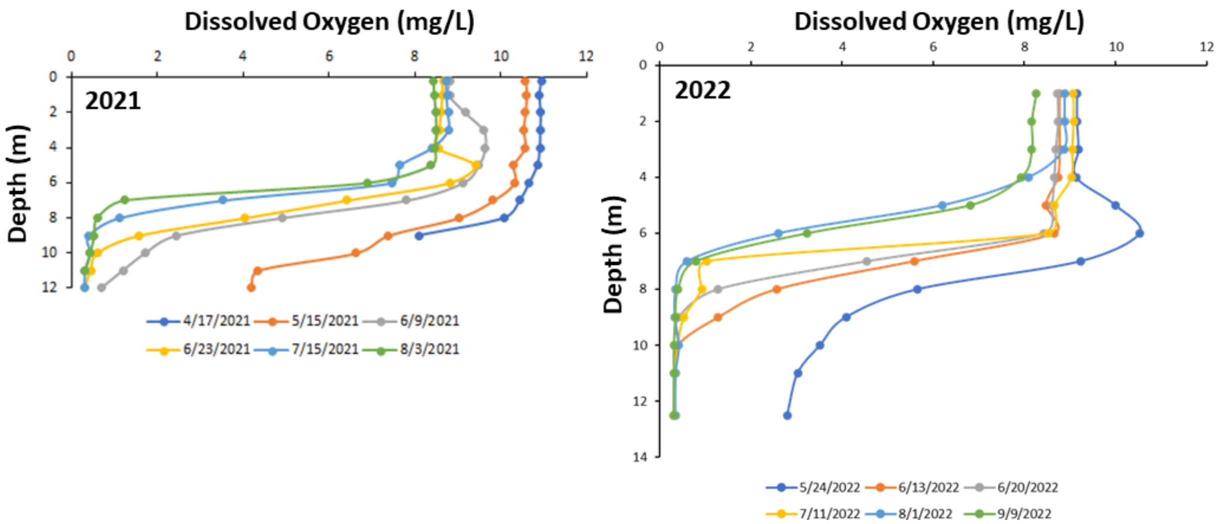

Figure 2. Vertical profiles of lake water column dissolved oxygen during the summers of 2021 and 2022 for the Deep Lake site.

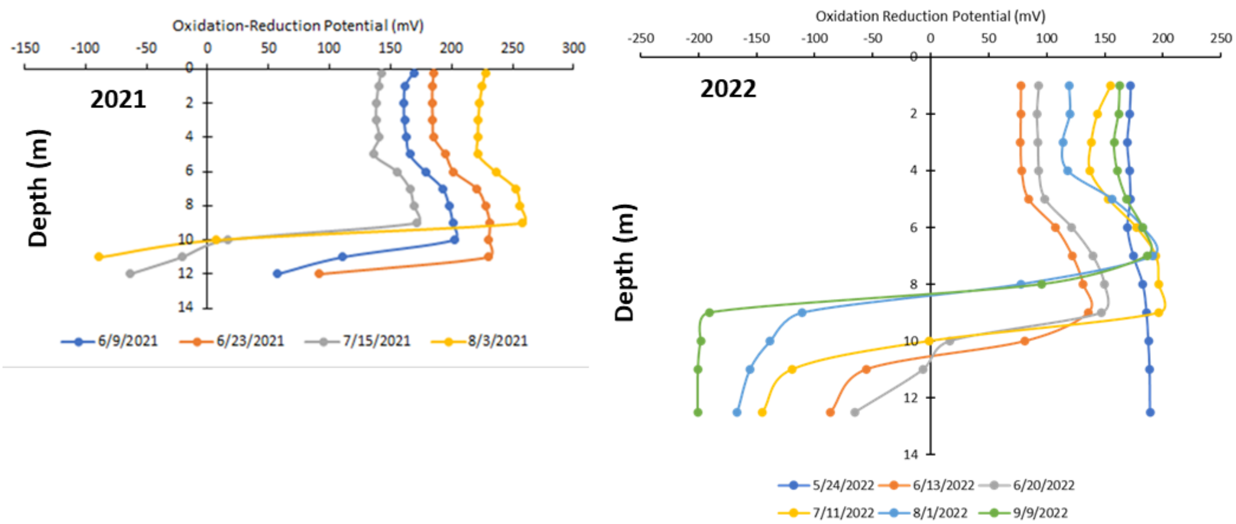

Figure 3. Vertical profiles of lake water column oxidation-reduction potential (ORP) during the summers of 2021 and 2022 for the Deep Lake site.

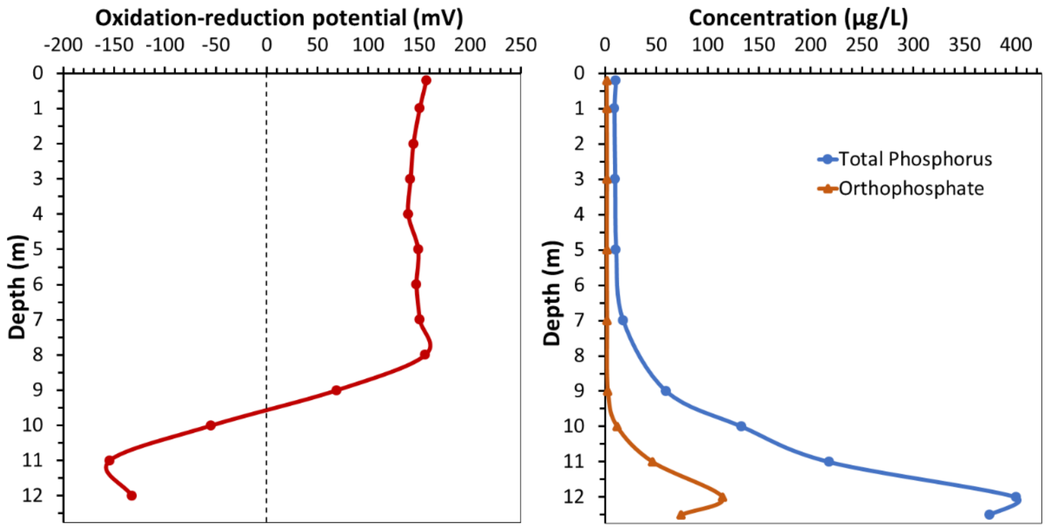

Figure 4. Vertical profiles of oxidation-reduction potential (ORP) and orthophosphate/total phosphorus on 8/20/2020 at the Deep Lake site. ORP values above 0 represent oxidizing conditions, while negative values are indicative of reducing conditions.

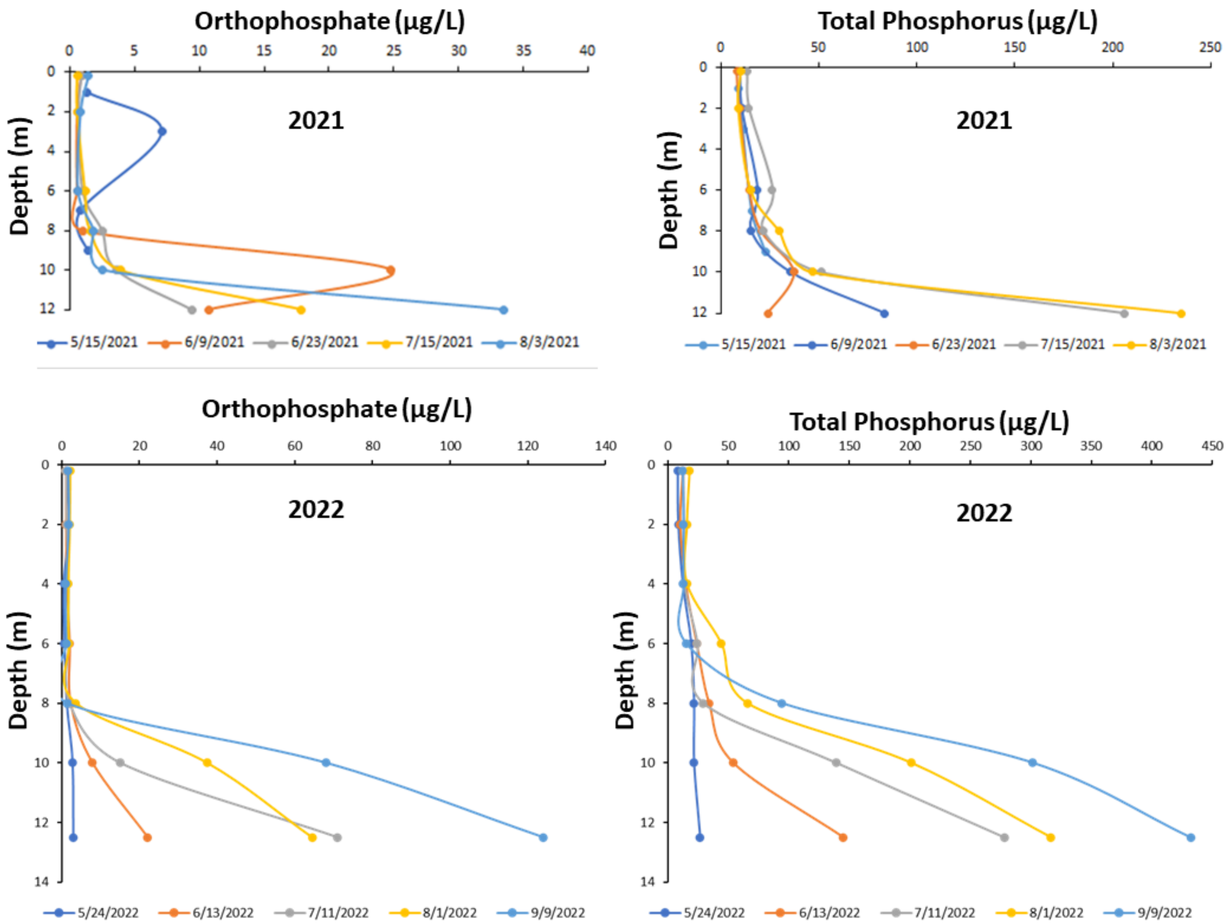

Figure 5. Vertical profiles of orthophosphate and total phosphorus during the summers of 2021 and 2022 for the Deep Lake site. Note the different scales in different years and for orthophosphate and total phosphorus.

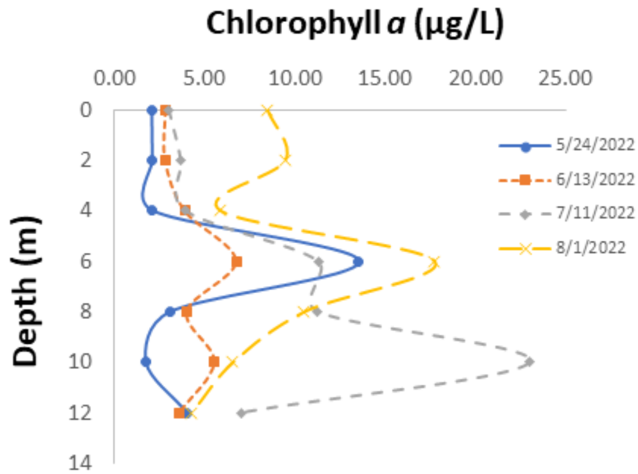

Figure 6. Vertical profiles of algal biomass as chlorophyll *a* during the summer of 2022 for the Deep Lake site.

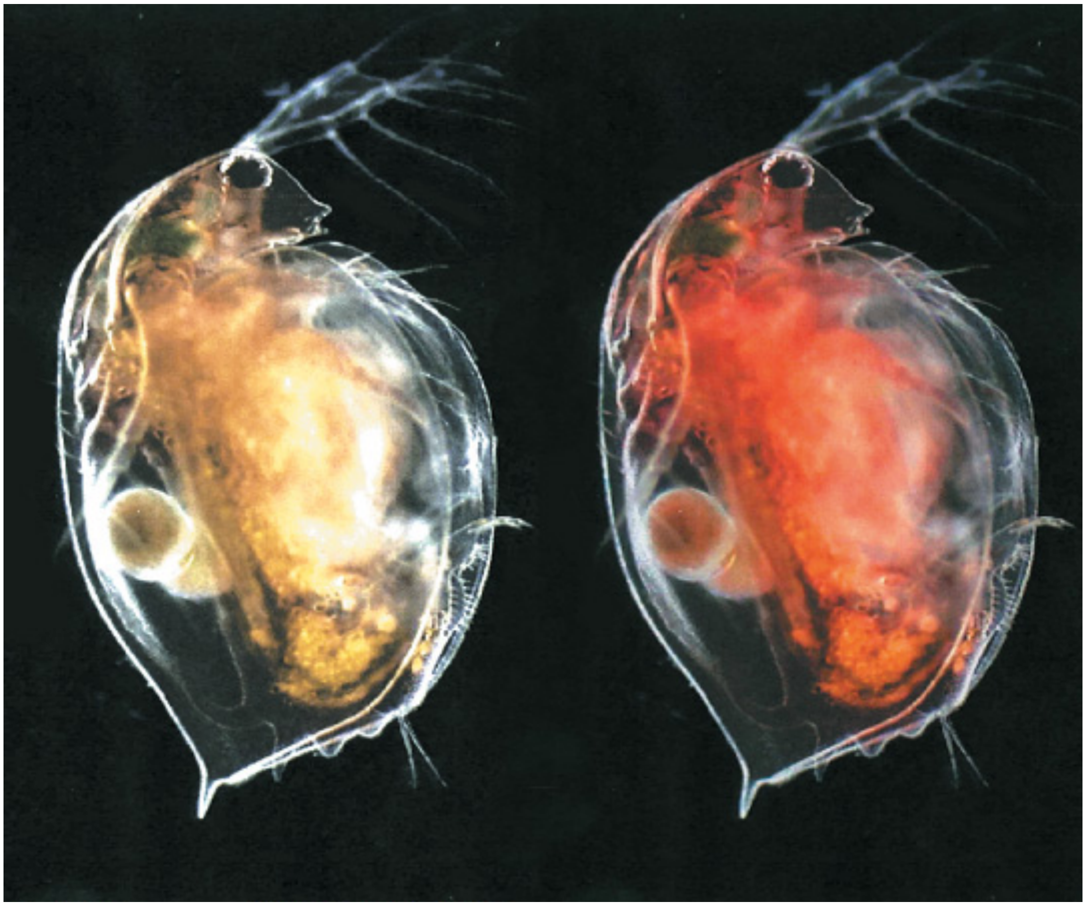

Figure 7. *Daphnia* species can adapt to low-oxygen environments and produce varying amounts of hemoglobin. The daphnid on the left is from an oxygen-rich environment; the daphnid on the right is from an oxygen-poor environment. This adaptation is critically important for the survival of the keystone herbivore in nutrient-rich lakes. These microcrustaceans are critically important to the health of Loon Lake, and continued efforts to prevent invasion of predatory zooplankton (e.g., *Bythotrephes* and *Cercopagis* species) is important. Photo Credit: Shinichi Tokishita and MacMillan Higher Ed)

II. Evaluation of Potential Effects of Nearshore Aeration on Water Chemistry, Algal Biomass, and Accumulation of Muck in Loon Lake, Steuben County, NY (2021-2023)

Introduction

Given the risks posed by cyanobacterial blooms, there are several common physical and chemical control measures that can be utilized to reduce the magnitude, extent, or frequency of blooms. Each method has its own pros and cons. Ultimately, the most effective way to reduce the risk of freshwater harmful algal blooms is via nutrient pollution mitigation and control of sources of limiting nutrients in the watershed. This approach is especially effective when combined with food web-based approaches designed to enhance herbivory by large-bodied microcrustaceans in lakes (Fig. 7). However, in cases where nutrient sources cannot be easily reduced such as when there are large amounts of legacy nutrients stored in lake sediments, physical and chemical controls are frequently utilized. Aeration is one of the most often utilized physical and chemical control measures in eutrophic lakes.

Depletion of bottom-layer dissolved oxygen (DO) of stratified lakes is one of the first symptoms of eutrophication. Anoxia often occurs due to high rates of respiration associated with decomposition of accumulated organic matter ("muck") by aerobic microorganisms. Aerobic decomposition leads to depletion of most or all the bottom-layer dissolved oxygen. An indirect effect of this decomposition is other undesirable impacts to lake water quality, including accelerated internal loading and cycling of nutrients limiting algal productivity; solubilization of metals that can sometimes be toxic to organisms; and loss of habitat for invertebrates and fishes, especially cold-water species.

Hypolimnetic (i.e., bottom-layer) aeration and oxygenation are often used as a lake management technique to reduce the extent of hypoxia and anoxia and associated issues in eutrophic lakes. Aeration is safer than oxygenation (i.e., flammable oxygen tanks are not needed); however, oxygenation is more efficient (i.e., ~4-5 times as much air needs to be pumped to have the same effect on dissolved oxygen concentrations as pumping oxygen). In particular, microbubbling diffusers are effective at reducing hypoxic conditions in deep water, while minimizing disruption to the thermocline. Application of aerators that disrupt the thermocline and associated stratification often also have unintended consequences as they mix the nutrient-rich deep-water layer with warmer surface waters, creating optimal conditions for algal blooms.

Aerators operate by pumping air through a diffuser often near the bottom of a waterbody, resulting in the formation of plumes that rise to the surface. These plumes can create circulation and water flow outward from the aerator. It is hypothesized that this mixing of the water may disrupt some bloom-forming cyanobacterial species. Certain cyanobacteria can migrate vertically in the water column (e.g, *Microcystis*, *Oscillatoria*, *Dolichospermum* species), which allow access to light-rich surface waters for photosynthesis as well as nutrient-rich deeper waters. The aerators may disturb the vertical migration abilities of these cyanobacterial species.

In addition to potential direct and indirect effects on harmful algal bloom taxa, aerators are deployed for a variety of other reasons. (1) Aerators often improve water quality. In addition to increasing dissolved oxygen concentrations, aerators also help to stabilize temperature, pH, oxidation-reduction (i.e., redox) potential, as well as reduce nutrient concentrations. (2) Aeration can facilitate microbial decomposition of organic matter, leading to potential reductions in "muck" accumulation. An indirect effect of enhanced muck decomposition is also increased availability of nutrients that can potentially limit growth of plants and algae. (3) If aeration alters redox and reduces release of nutrients from lake sediments, reduced growth of plants and algae is another indirect effect. The goal of this study was to examine water quality parameters across depth at reference and aeration sites to assess potential effects.

Methods

Aeration of the water column can interrupt the cycle of internal nutrient loading of phosphorus from sediments, which can decrease algal blooms and plant growth. This also indirectly may lead to less "muck" accumulation in areas around the aerators. Aeration can also facilitate aerobic decomposition of organic matter, which may reduce buildup of the existing muck layer. Based on our background knowledge of Loon Lake, we hypothesized that aeration would create well-oxygenated conditions from the surface to bottom of near the aerators, which would enhance microbial decomposition. However, we also predicted that this would lead to elevated dissolved nutrient concentrations in the water column as nutrients are released during muck breakdown. Ultimately, the effect of aeration on muck accumulation is dependent on the magnitude breakdown rate is enhanced versus the rate of muck accumulation in the lake. As Loon lake is mesotrophic-eutrophic (eutrophic based on deep water chlorophyll concentrations) (Fig. 6), muck accumulation rates are likely very high and may “swamp” any positive effects of aeration on decomposition.

Our study objectives were to (1) monitor water quality parameters (e.g., temperature, dissolved oxygen, pH, SPC, *in vivo* chlorophyll *a*) across depths at reference and aeration sites to assess potential effects. (2) Compare algal abundance (as extracted chlorophyll *a*) and nutrient concentrations as indicators of productivity at the reference and aeration sites. (3) Determine the feasibility of monitoring changes in “muck” over time at the aeration site.

In 2021, three coves were selected to determine potential effects of aeration on shallow water areas in the lake. Three aerators were installed at Serenity Cove (“Aeration sites”). Antler’s Inn and Laf-a-Lot coves were used as Reference sites. Similar *in situ* water chemistry measurements and water samples were collected as in the Deep-Water study. A steel rod type “push pole” was used to determine approximate muck depth (to the nearest inch) in locations around the aerator. In 2022, the first year of the aeration study was completed, with six sampling events occurring biweekly-monthly from June to September. In 2023, we focused on finer scale spatial sampling around each of the three aerator units in Serenity Cove.

Findings

- In general, dissolved oxygen concentrations were more variable at Reference locations. This is especially apparent for the reference sites on 9 June and 15 July 2021 (Fig. 8).
- We observed more consistent dissolved oxygen levels across depth at the Aeration sites, with DO approximately constant as a function of temperature-determined saturation throughout the summer (Fig. 8).
- Similar contrasting patterns for dissolved oxygen were observed for Reference and Aeration sites in 2022 (Fig. 8).
- Concentrations of dissolved nutrients (e.g., orthophosphate) were typically highest near the Aeration sites – particularly for the deeper sites (Fig. 9).
- Finer-scale spatial sampling in 2023 revealed elevated levels of total phosphorus (TP), total nitrogen (TN), and chlorophyll *a* with increasing depth near the Aeration sites (Fig. 10).
- Muck depth around the aerators is highly variable. However, muck depth tended to decrease for measurements closer to shore. The deepest muck depths were closest to the aerator (Fig. 11).

- Overall, muck depths appeared to increase from June to August 2023 (Fig. 11).
  The deepest muck depths were observed in September of 2022 (Fig. 11). We suspect that this is further evidence of a net accumulation of muck at the Aeration sites because of enhanced productivity and settling of organic matter vs. aerobic decomposition.

Recommendations and Take-Home Message

- There is a need to assess other sources of nutrients to the lake.
  - It is important to collect more recent watershed data.
  - The contribution of nutrients from groundwater springs to the lake is unknown.
  - A survey study looking at potential septic system leakage around the lake is another important next step.
    - This could be done as part of an undergraduate summer (or fall) research project looking for indicators of this type of contamination.
    - Optical brighteners, which are added to products such as laundry soaps, detergents, or other cleaning agents, can be detected by fluorescence analysis of water samples.
    - A study looking at optical brighteners in water samples collected around the lake could be informative of potential contamination.
    - If sources are identified, remediation efforts should occur to limit this potentially important source of nutrients to the lake.
- Recent CSLAP reports have indicated that concentrations of dissolved nitrogen (i.e, ammonia, NH_3) may be increasing in the bottom layer of the lake during the summer. We recommend regular (e.g., every 2-3 years) monitoring of ammonia concentrations throughout the water column, in addition to levels of dissolved phosphorus since both nutrients are potential triggers of harmful algal blooms. In particular, increased availability of ammonia is linked with the development of blooms of toxic species that do not have the ability to fix atmospheric nitrogen (e.g., *Microcystis*).
- Consider thermistor array and/or dissolved oxygen sensors to monitor temperature and oxygen to predict bloom risk.
  - Buildup of bottom-layer nutrients will be highest in summers when stratification sets up earliest.
  - These arrays could be "synced" with the nearshore aerators so that homeowners could turn on the units during high-risk periods (e.g.,

disturbance of stratification patterns during high winds and storm events).

- Evaluate costs and benefits of installation of aerators – potentially install in high-risk areas/bays.
    - Aeration will likely not be beneficial in reducing muck until overall productivity rates and muck accumulation can be reduced through nutrient management.
    - Aeration seemed to enhance algal productivity in some instances. The algal taxa that were enhanced did not appear to be harmful (i.e., toxic cyanobacteria).
    - Sampling did not occur during any cyanobacterial bloom events, so we were unable to evaluate potential effects of the aerators on species distribution, abundance, and composition.
- Regularly monitor zooplankton and macrophyte assemblages for changes.
    - Continue efforts and emphasis on preventing introductions of non-native, invasive species.
    - Introduction of invasive invertebrates (e.g., spiny waterflea, *Bythotrephes* species and fish hook waterflea, *Cercopagis* species) that predate on native zooplankton and/or fishes (e.g, Eurasian rudd, *Scardinius erythrophthalmus*) would have devastating ecosystem level effects on the lake.
- Consider future fish survey supported by SUNY. This could occur as a potential joint effort by students from SUNY Brockport and Geneseo during fall semesters.
- Create a lake management plan with a rotating list of priorities that are assessed on a regular basis.

Figures and Tables

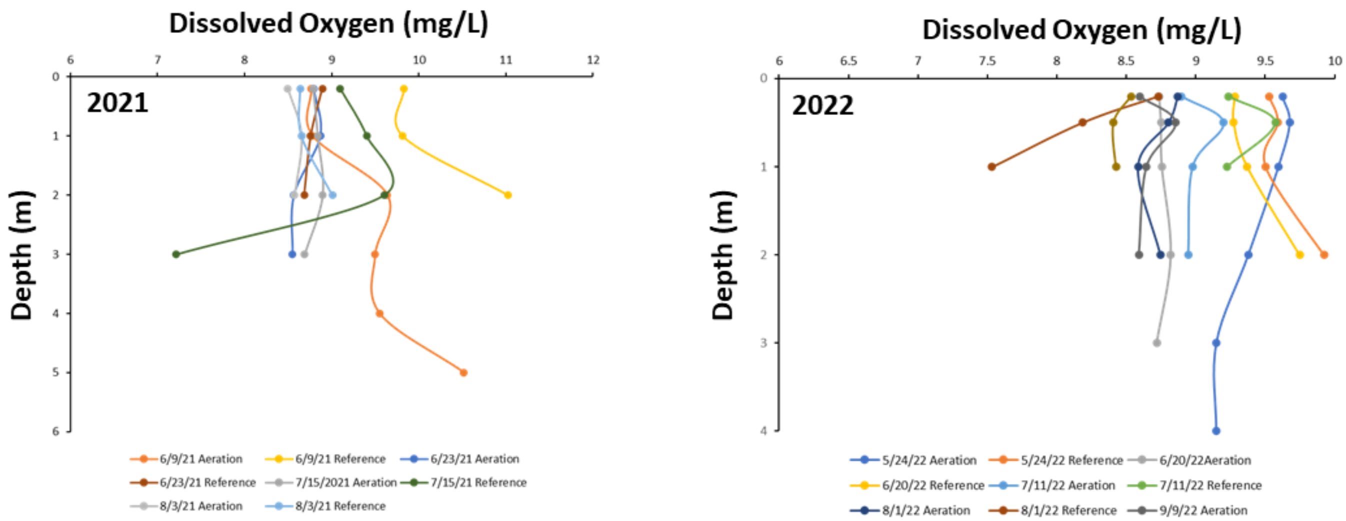

Figure 8. Vertical profiles of dissolved oxygen (DO) at Aeration and Reference sites during summers 2021 and 2022. DO for reference sites and DO for aeration sites were averaged for each sampling date.

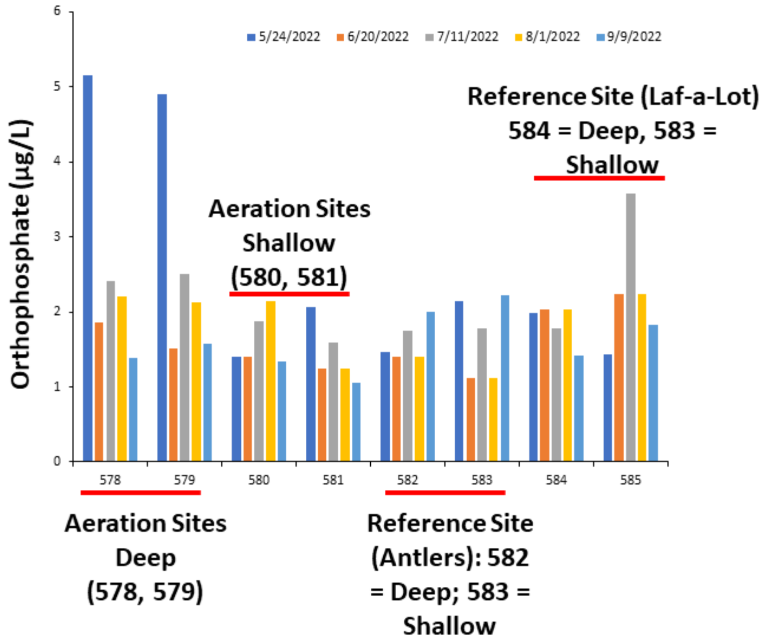

Figure 9. Orthophosphate concentrations in deep vs. shallow water areas for Aeration and Reference sites.

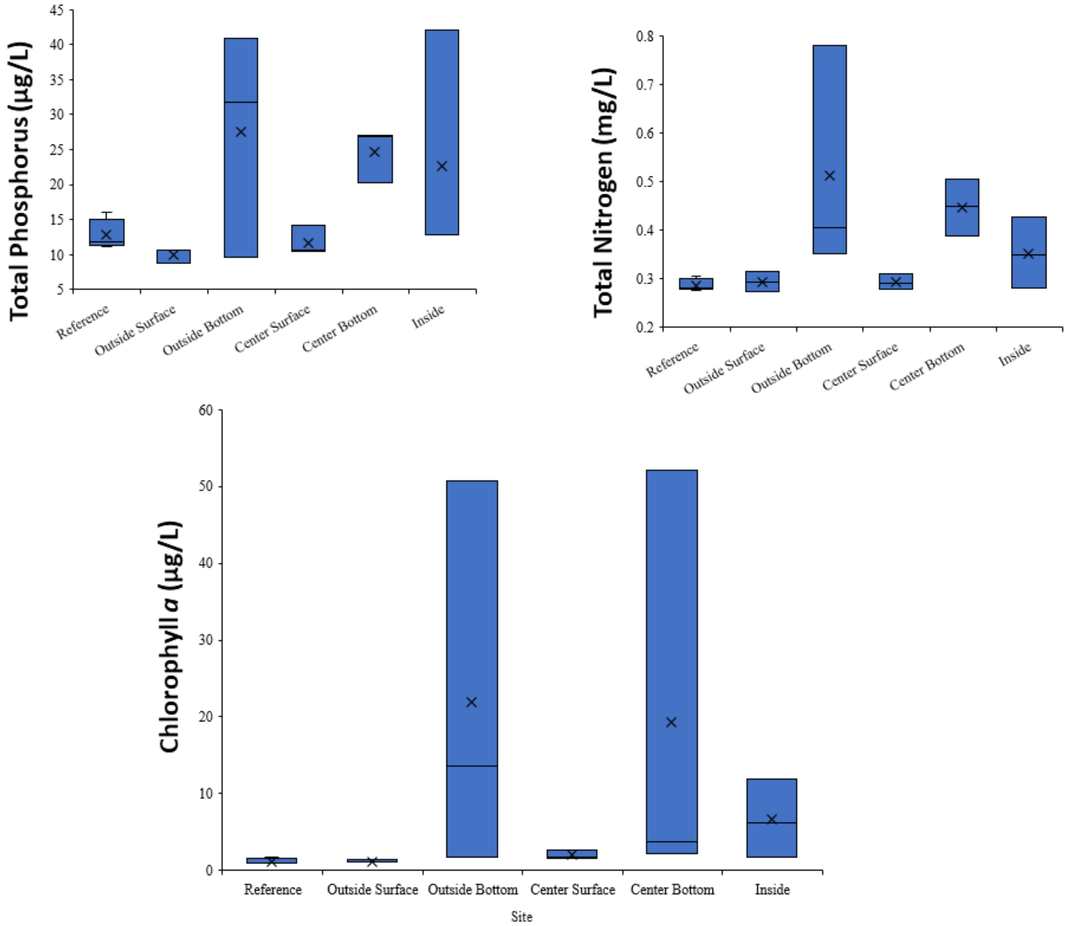

Figure 10. Surface versus bottom concentrations of total phosphorus, total nitrogen, and algal biomass as chlorophyll *a* at Aeration sites in 2023.

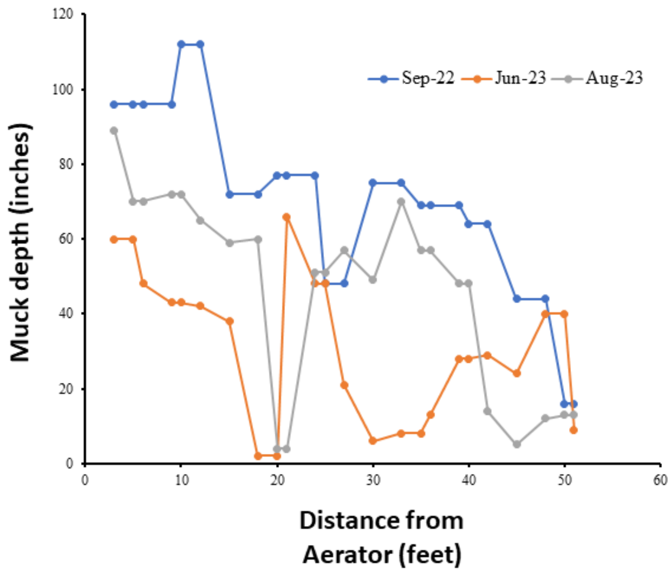

Figure 11. Spatial and temporal patterns of muck depth at the Aeration site. Muck depth was measured starting at the aerator to the shore in September 2022 as well as June and August of 2023.