A publication of the North American Lake Management Society

LakeLine

Volume 44, No.1 • Spring 2024

Lake Rehabilitation

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Call for Abstracts

44th International Symposium of the North American Lake Management Society

November 5–8, 2024

NALMS 2024
SOUTH LAKE TAHOE
CALIFORNIA/NEVADA

Flood & Drought, Fire & Ice: Managing Lakes Under Changing Climates

NALMS and the California Lake Management Society are pleased to invite you to join us at one of the world's deepest and clearest lakes – Lake Tahoe. But like many lakes in the American West, Lake Tahoe also faces significant challenges, including increasing surface water temperatures, decreasing snowpack, increasing occurrence of cyanobacteria, wildfires, microplastics, and increased development and tourism in its watershed. These topics and more will be discussed during the conference, which will feature workshops, field trips, presentations, networking events, and vendor displays.

We encourage you to explore the Lake Tahoe region and its abundance of outdoor recreation opportunities before and after the conference. With many affordable lodging options, South Lake Tahoe and Stateline serve as a good starting point for your explorations. Average high temperatures in South Lake Tahoe during the conference period are in the low 50s F, but snow is bound to be nearby at higher elevations.

Important Deadlines

Abstract Submission Deadline
May 3, 2024

Registration Opens
Late Spring 2024

Presenter Registration Deadline
August 23, 2024

Hotel Group Rate Block Closes
October 13, 2024

Prospective Program

There will be technical workshops all day Tuesday, November 5. Beginning Wednesday, November 6, three days of presentations will be organized into themed tracks and sessions. We encourage oral and poster presentations on any aspect of lake and reservoir management, but especially invite valuable insights on the following:

- HABs
- Nutrients
- Invasive Species
- Monitoring and Remote Sensing
- Oxygenation
- Paleolimnology
- Modeling and Mapping
- Reservoirs and Dams
- Dredging
- Emerging Technology
- Urban Lakes
- Fisheries
- Emerging Contaminants
- Habitats and Wetlands
- Source Water Protection
- Climate Change Impacts and Management
- Community Engagement
- Regulations and Permitting
- Lake Recreation Management
- Any Other Lake-Related Topic

Contact Us

www.nalms.org/nalms2024

nalms2024@nalms.org

Photo by David Mullins on Unsplash

LakeLine

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On the cover:
"Blue-green Bay on Lake Champlain" by Frances Pick. Photo submitted as an entry for the NALMS 2024 photo contest. This photo won "Editor's Choice" in the contest.

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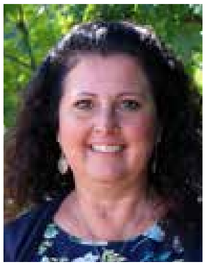
From Amy P. Smagula the Editor

This spring issue of *LakeLine* looks at some lake and watershed restoration and rehabilitation projects in different lakes across the upper tier of the United States, including one from Minnesota, two projects from the State of Maine, and another from Washington state.



Jeff Strom, **Amy Timm**, **Jesse Anderson**, and **Scott MacLean** share an article summarizing and reflecting on more than 20 years of data from Minnesota, related to lake impairments, and trends in delisting of waterbodies that were once on the state's list of impaired waterbodies. The authors review the state's assessment and delisting process and discuss physical and chemical characteristics of the lakes that were delisted. They include a great breakdown of the various best management practices that were used on each waterbody. This is an excellent summary of the work being done to improve water quality and rehabilitate lakes that were once impaired. The authors also share several links to online sources of information from Minnesota that guide their process with lake and watershed work.

Robert Kennedy, **Linda Bacon**, and **Aaron Englander** outline the history of nutrient loading to Lily Pond in Rockport and Camden, Maine. They review historical land uses and nutrient sources to the pond, and best management practices that were utilized in the watershed to reduce those nutrients. Water quality monitoring over time documents reductions in nutrient load and chlorophyll-*a* in the pond and increases in transparency.

Jennifer Jespersen shares information about degrading water quality and algal blooms in Georges Pond in Franklin, Maine. Her article focuses on bringing in stakeholders and project partners to plan for monitoring, and using the data generated from that monitoring to implement both an in-lake and watershed-based restoration plan for Georges Pond. Restoration efforts included two aluminum doses and several watershed projects.

Shannon Brattebo, **Marisa Burghdoff**, and **Jen Oden** provide the details of water quality in Lake Ketchum, a small lake north of Seattle, Washington. Because of historic nutrient loading from agricultural land use practices, the lake water quality declined, and persistent cyanobacteria blooms were a major problem. With a strategy of watershed phosphorus reductions and regular (annual) aluminum treatment to the lake, water quality has rebounded in the lake and continues to improve each year.

In the *LakeLine* Student Corner, **Kaitlyn Button**, a graduate student at Paul Smith's College, shares her work on the impacts of saltwater intrusion on freshwater macroinvertebrates in the Herring River system in Wellfleet, MA.

To collect data for projects like these, many of us now use continuous data loggers to allow us to collect data real-time at intervals we choose, even down to the minute, and then upload it to a cloud to make it readily available for our use. Our NALMS Lakespert, **Steve Lundt**, adds his thoughts about these data loggers and realities for integrating their use into lake monitoring and restoration projects.

Also included in this issue is an update from the NALMS 314 Working Group about their efforts to build momentum to restore funding to Section 314 of the Clean Water Act. A re-allocation of funding to this program can lead to implementation of even more projects focused on lake rehabilitation and even protection and preservation efforts to limit future lake water quality decline.

Finally, our NALMS Board of Directors met in March for their mid-term meeting. A summary of their discussions is included in this issue.

Enjoy!

Amy P. Smagula is a limnologist with the New Hampshire Department of Environmental Services, where she coordinates the Exotic Species Program and special studies of the state's lakes and ponds.

UPCOMING IN *LAKELINE*

Summer 2024: Waterfowl are synonymous with waterbodies of all types. Love them, hate them, hunt them (but please don't feed them), why not share an article about them? Articles related to waterfowl and lakes are welcome. Topics could include managing waterbodies for waterfowl, mitigating impacts of waterfowl, discouraging waterfowl, lake related occurrences and impacts on waterfowl (aquatic vegetation related HABs and waterfowl impacts), and more. Draft articles for the summer issue of LakeLine are due by June 15, 2024, for publication in July 2024.

Draft articles for the summer issue of *LakeLine* are due by June 15, 2024, for publication in July 2024.

Fall 2024: Ballast boat sports are very popular these days, riding both waves and wakes for recreational pursuits. The fall issue of LakeLine is open to articles on topics related to ballast sports. If you have an article that you would like to include

*(**Upcoming** issues, continued on p. 13 . . .)*

From Kellie Merrell the President

Our societal expectations for the water quality and health of our lakes and reservoirs aren't keeping up with our capacity to protect and restore or rehabilitate them. We need look no further than the United States Clean Water Act for an example of this. According to Robert W. Adler (2010), reports out of the United States congressional committees sponsoring the Clean Water Act legislation in 1972, "*reflect a belief that the path to ecological integrity lay in the return to an optimum biological state or equilibrium condition that existed prior to human disturbance of aquatic ecosystems, and that any deviation from that pristine condition is presumptively bad and must be reversed.*"

While both the International Commission on Stratigraphy and International Union of Geological Sciences have not approved the term "Anthropocene" as an official subdivision of geologic time, we must acknowledge that in this era of human impact on our planet, managing our waters back to a 'pristine' state is unrealistic. As much as this pains me to say it, it is the truth we are facing as lake and reservoir managers. That said, we have developed a suite of tools that when applied in the right places, at the right times, informed by good monitoring and data, they can prevent further deleterious impacts and enhance the resilience of our lentic systems. Along those lines I'd like to put a plug in for the MoReCo Lake Management Framework published in the latest issue of *Lake and Reservoir Management*, which lays out a universal approach to pulling together all the necessary steps and tools to successful lake management (Cianci-Gaskill et al. 2024).

As lake managers, we know that prevention and protection is less costly than restoration work, and we must do more to save "the best of what's left." Yet, typically, protection takes a back seat to restoration and there is good reason for that, with 69 percent of U.S. lakes and reservoirs either eutrophic or hypereutrophic as of the 2017 U.S. Environmental Protection Agency National Lakes Assessment. We have moved beyond the protection phase and firmly into the rehabilitation phase for most of our lakes and reservoirs. Still, as we focus much of our limited time and resources on the great challenge of rehabilitating so many waterbodies, we must find a way to apply the "both/and" approach to the restoration and protection of our lakes and reservoirs.

Vermont is fortunate to have long-term water quality data sets going back to 1977 and to have developed several tools to address non-point source runoff, the treatment of sewage, removal of aquatic invasive species, treatment of internal loading, and protection of littoral habitat. In a 2018 *Lake Line* article, my fellow scientists and I at the Vermont Department of Environmental Conservation reported on the trends in phosphorus we were seeing in Vermont lakes by what trophic condition they were in the 1980s (Matthews, Merrell, and Thomas 2018). What we saw was that our efforts to rehabilitate and restore our eutrophic lakes were working and phosphorus was declining. We took this as evidence Vermont's efforts to implement the Clean Water Act were working, while not returning them to a "pristine" state, we were helping them achieve a healthier, more resilient state. But all that focus on eutrophic lakes came at a cost to our oligotrophic lakes: We found that the vast majority of our oligotrophic lakes were increasing in phosphorus.

Six years later I'm happy to report that Vermont has embraced the "both/and" approach and several Lake Watershed Action Plans are focusing the use of tools developed for eutrophic lakes on the oligotrophic lakes with increasing phosphorus with the aim of turning these increasing trends around. Meanwhile, the efforts to restore impaired lakes in Vermont has not waned. Efforts are still strong to work at both the watershed and in-lake scales to rehabilitate lakes, yet like elsewhere, resources are limited to effectively "both/and" in lake management.

That's why I'm excited that the NALMS board of directors voted to allocate funding to hire a government affairs consultant to help NALMS advocate for more funding for lakes and reservoirs at the U.S. national scale. I encourage you to read the update from the 314 Working Group, which highlights the progress being made to help NALMS forge more partnerships and build our organization's capacity to not only advocate on behalf of U.S. lakes and reservoirs, but ultimately for North America's lakes and reservoirs as well.

Kellie Merrell has been an aquatic ecologist with the Vermont Department of Environmental Conservation since 2001, where she monitors Vermont's inland lakes for compliance with the Clean Water Act. Prior to that she worked for the Environmental Protection Agency monitoring estuaries from Maine to Virginia and in environmental consulting. At University of Maryland's Horn Point Laboratory, she conducted submerged aquatic vegetation surveys and studied Vallisneria americana for her MS degree. She loves skijoring with her dogs in Vermont, hiking the White Mountains of New Hampshire, and gunkholing with her small sailboat in Maine.

NALMS NEWS

NALMS Board of Directors Mid-Term Meeting Summary

Prepared by Danielle Wain and Kellie Merrell

On March 23, 2024, the NALMS Board of Directors (BOD) had their virtual Midterm Board Meeting, with all current BOD members present.

In addition to regular board business, the meeting started with breakout discussions on improving inclusivity and retention of active members, advocacy, and allocation of the new Ann St. Amand Early Career Fund to support attendance at the national symposium, starting with the symposium in November in Lake Tahoe.

The BOD also updated our Non-Disclosure Policy and got a report from the newly formed Personnel Committee, which is tasked with addressing staff-related issues such as the leave policy and cost of living pay increases.

Finally, we ended the day with a discussion of NALMS Symposia and conference-related activity through 2028. We set the registration rates for the Tahoe Symposium and discussed formation of the Host Committee for 2025 in Myrtle Beach, SC (NALMS members in the southeast are encouraged to get involved!).

We heard more about potential Canadian locations for 2026 and Midwest and New England locations for 2027. We also got an update on the likely midwestern location of the 2025 National Water Quality Monitoring Conference which NALMS coordinates.

Despite the challenges of an all-day virtual meeting, the NALMS BOD had a productive day and we look forward to the Annual Board Meeting on Monday November 4th in Tahoe! All members are welcome to sit in for the meeting!

NALMS 314 Workgroup Updates

Chris L. Mikolajczyk, CLM and Benjamin Rhoades

NALMS continues to take on a mission of continued protection of our lakes and reservoirs with the 314-working group (WG). As you may/may not know, The Clean Lakes Program was established in 1972 as section 314 of the Federal Water Pollution Control Act, to provide financial and technical assistance to states in restoring publicly owned lakes.

The program has funded a total of approximately $145 million of grant activities since 1976 to address lake problems, but there have been no appropriations for the program since 1994. The section 314 Clean Lakes Program was reauthorized in September 2000 as part of the Estuaries and Clean Water Act of 2000, but no funds have been appropriated.

The 314 WG is seeking the restoration of funding specifically to section 314 of the program, along with the current section 319 funding, which addresses non-point source watershed management. In the last six months the 314 working group has:

- Provided EPA comments on EPA's draft revision of the Section 319 Non-Point Source Program guidelines for states and territories.
- Sought out and contracted with Drue Banta Winters (DBW) for government affairs consulting.
- Began review of data collected by Callista Smith and Skye Embray, previous NALMS interns.
- Drafted a data and storytelling tool (ESRI StoryMap) for clean lakes advocacy outreach.

In the next six months, we seek to:

- Work with DBW to better understand the federal advocacy landscape and NALMS.
- Continue to review data collected by Callista Smith and Skye Embray.
- Initiate targeted state outreach with goals set in collaboration with DBW.
- Continue ESRI StoryMap development.

NALMS has long understood, and Drue has confirmed, that the campaign for enhanced lakes funding at the federal level, particularly through Section 314, will be a long-haul mission. The 314 WG is also underscoring the identification of partner organizations that have the capacity to lobby, something that we cannot do as a non-profit organization. The 314 WG will prioritize the valuable time we have with DBW as we assess her success in networking us with congressional allies and additional nonprofit partners.

The 314 Working Group is very excited to start this new chapter – NALMS goes to Washington, DC, Summer 2024.

Stay tuned!

Please take a moment to ensure NALMS has your correct email and mailing address. Log into the member-only area of www.nalms.org to view the information we currently have on file.

Send any corrections to membershipservices@nalms.org

LAKES APPRECIATION MONTH

POSTER CONTEST

Three posters will win a $300 cash prize!
$250 to the artist's school or organization /
$50 to the artist

July has been Lakes Appreciation Month for the past 26 years! To help us celebrate, appreciate, and bring attention to lakes, students of all ages are encouraged to submit posters reflecting how important lakes are to all of us!
Submitted artwork will be a big part of NALMS' celebrations through July across North America.
https://www.nalms.org/lakes-appreciation-month/poster-contest/

Instructions:

All grades K -12 welcome to participate!

Send an electronic version of your poster artwork to **lakesappreciation@nalms.org**

Each entry must include student name, grade, school, and contact information

Prizes will be awarded to the top entry in each grade division

Deadline: June 14, 2024

July 2024
www.nalms.org
Lakes Appreciation Month

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- ❑ Early Career* $85
- ❑ Professional $140
- ❑ Lake Leader $75
- ❑ Emeritus** $75

*For individuals with less than 5 years in the field - the stepping stone to the Professional level!
**For individuals who are retired, over the age of sixty, and have maintained a membership for five years.

Organization

- ❑ Affiliate $330
- ❑ Lake/Watershed Association*** $165
- ❑ Non-Profit****... $330
- ❑ Corporate $650

*** For organizations with a yearly budget of under $50K
****For organizations with a yearly budget of over $50K

Do you want to help protect lakes? A donation will help ensure that NALMS' mission to foster the management and protection of lakes continues.

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G. Dennis Cooke Symposium Fund .... $______

Lake Givers Club (for general donations) .... $______

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Rev. 1/19

Twenty years of lake nutrient impairment **Delistings in Minnesota**

Jeff Strom, Amy Timm, Jesse Anderson, and Scott MacLean

According to Minnesota's 2024 inventory of impaired waters, a total of 64 nutrient impaired lakes have been removed ("delisted") from Minnesota's 303(d) list of impaired waters. The first delisting of a nutrient impaired lake in Minnesota occurred 20 years ago, in 2004. This article provides an opportunity to reflect on these successes by providing a brief overview of Minnesota's lake assessment and delisting process, a discussion of some common characteristics of Minnesota's delisted lakes, and the management activities that led to the delistings. Finally, we conclude with a summary of the lessons learned and a look ahead at the future of lake management and delistings in Minnesota.

Assessment and delisting process

Minnesota's lake eutrophication standards were enacted in 2008, after decades of research and monitoring (summarized in Heiskary and Wilson, LRM 2008). Minnesota was one of the first states with Environmental Protection Agency (EPA) approved lake nutrient criteria, stratified by ecoregion. From 2002-2022, the Minnesota Pollution Control Agency (MPCA) used these standards to assess approximately 3,500 of the state's 12,000 lake basins greater than ten acres. About 700 (20 percent) of the assessed lakes are impaired by nutrients.

A lake nutrient assessment requires:

- Data from a minimum of two years during the past 10 years
- At least eight paired total phosphorus (TP), chlorophyll-a (chl-a), and Secchi transparency measurements collected from June through September.

A lake is considered impaired when mean TP and at least one response variable (mean chl-a or Secchi transparency) exceeds their respective standards. Once a lake is impaired, additional studies and plans are developed through Minnesota's Watershed Approach to help guide implementation. A Total Maximum Daily Load (TMDL) study determines the assimilative capacity of the waterbody, and estimates the impairment sources and the reductions needed to meet standards. In Minnesota, approximately 600 lake TMDLs have been completed to address nutrient impairments. Watershed Restoration and Protection Strategy (WRAPS) reports identify high-level strategies to improve water quality at a watershed (HUC 8) level and are completed in conjunction with TMDL reports. Finally, comprehensive local water management plans created through the One Watershed One Plan and seven-county metropolitan area surface water management frameworks that identify waterbodies that will be prioritized for focused restoration activities.

The following data and information are needed for a lake to be considered for delisting:

- A minimum of two years of data after the impairment designation date.
- At least eight paired TP, chl-a, and Secchi measurements collected from June through September.
- Mean TP and at least one response variable (chl-a or Secchi transparency) meets the standard.

MPCA consults with local water resource managers to review restoration practices. The delisting is categorized as due to either "restoration activities" or "unknown reasons" based on this discussion. Of the 64 delisted lakes, 45 lakes (70 percent) have been delisted due to restoration activities, 15 (24 percent) due to unknown reasons, and 4 (6 percent) due to new data and/or the adoption of a new standard. The unknown reasons designation is typically assigned to lakes that have experienced environmental factors (e.g., aquatic invasive species (AIS), fish kills, climate influences) and delistings could not be conclusively tied to restoration activities based on the 'Best Professional Judgement' (BPJ) of MPCA's delisting review team.

Overview of Minnesota's delisted lakes

Figure 1 provides the location of lake delistings throughout the state. A majority

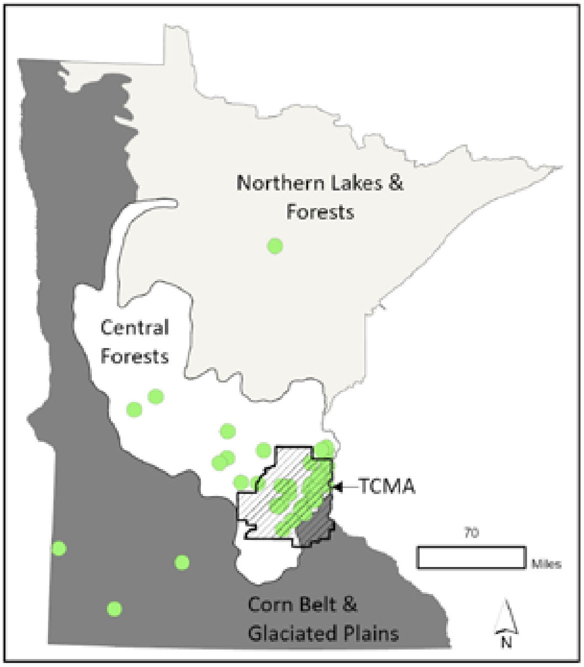

Figure 1. Map of Minnesota's delisted lakes (solid green circles) in relation to ecoregions and the Twin Cities Metro Area (TCMA).

of Minnesota's delisted lakes are located within the North Central Hardwood Forest (NCHF) Ecoregion and within the Minneapolis-St. Paul Twin Cities Metropolitan Area (TCMA; Table 1). To date, only 27 percent of the lakes delisted due to restoration activities and unknown reasons are outside the TCMA. Additionally, most of the delisted lakes (83 percent) are located within the jurisdictional boundary of a Watershed Management District or Organization. These governing entities can levy taxes to finance projects aimed at managing and improving the surface waters within a watershed. The groups are governed by elected and/or appointed board members from units of government (i.e., counties, municipalities) with land in the watershed.

As shown in Figure 2, the number of delistings in Minnesota has increased in recent years. Of the 64 lakes delisted to date, approximately half occurred in the last two assessment cycles (2022 and 2024). All the delisted lakes were originally assessed as impaired prior to 2015 and a majority (~80 percent) were added to the impaired waters list between 2002 and 2008. Thus, many delisted lakes were among the earliest lake impairment listings and, as a result, some of the first lakes to receive TMDL studies. The average time between impairment listing and delisting for Minnesota's delisted lakes has been about 13 years. However, most of the lakes exhibited degraded water quality conditions for several years or even decades before their original impairment listing, and therefore this number does not reflect the true amount of time the lakes were impaired. For many of the impaired lakes the process of listing the waters and developing TMDLs and WRAPS helped kickstart restoration activities that led to their delisting.

Table 1 presents analysis of several common lake and watershed characteristics for lakes delisted due to restoration activities and unknown reasons. Some of the trends and key takeaways of this analysis are:

Table 1. Characteristics and features for Minnesota lakes delisted due to restoration activities and unknown reasons.

Category	Lake feature/attribute	Description	Lake count	Percent of total
Location	Ecoregion[1]	NCHF	57	95 percent
		WCBP & NGP	3	5 percent
		NLF	--	0 percent
	Twin Cities Metro Area (TCMA)[2]	within TCMA	44	73 percent
		outside TCMA	16	27 percent
	Watershed Management Authority	yes	50	83 percent
		no	10	17 percent
Lake characteristics	Lake type	shallow/mixed[3]	35	58 percent
		deep/stratified	25	42 percent
	Lake size (acres)	<100	37	62 percent
		100 – 500	18	30 percent
		>500	5	8 percent
Watershed characteristics	Watershed size (acres)	<5,000	46	77 percent
		5,000 – 10,000	8	13 percent
		>10,000	6	10 percent
	Watershed-to-lake area ratio	<10	25	42 percent
		10 – 25	18	30 percent
		25 – 50	8	13 percent
		>50	9	15 percent
Water quality for NCHF ecoregion lakes (N=57)	Mean listing period TP for shallow/mixed lakes[3] (Standard: <60 µg/L)	<90	20	62 percent
		90 – 120	7	22 percent
		>120	5	16 percent
	Mean listing period TP for deep/stratified lakes (Standard: <40 µg/L)	<60	20	80 percent
		60 – 80	3	12 percent
		>80	2	8 percent

1. NCHF = north central hardwood forest; WCBP = western cornbelt plains; NGP = northern glaciated plains; NLF = northern lakes and forest
2. TCMA = 7-county Twin Cities Metropolitan Area which includes Anoka, Ramsey, Washington, Dakota, Scott, Carver, and Hennepin Counties
3. Shallow/mixed lakes are typically defined as having a maximum depth of less than 15 feet and a littoral area greater than 80 percent of the total surface area of the lake

- Slightly more of the lakes are shallow/mixed (58 percent) compared to deep/stratified (42 percent).
- Most of the lakes (92 percent) have surface areas less than 500 acres and a majority (62 percent) are less than 100 acres.
- Approximately 77 percent of the lakes have relatively small drainage areas - less than 5,000 acres.
- Watershed to lake area ratios for 58 percent of delisted lakes are greater than 10 to 1 indicating a mix of surface water and groundwater dominance (Minnesota DNR 2022).
- In general, mean listing period TP concentrations were not far (i.e., within a factor of two) from meeting state standards for shallow/mixed lakes (60 µg/L) and deep/stratified lakes (40 µg/L) in the NCHF ecoregion.

Management strategies contributing to Minnesota's lake delistings

With the high cost of implementing Best Management Practices (BMPs), it is important to have funding available to partners who are doing the work. In Minnesota, having a completed TMDL study, WRAPS report, and comprehensive management plan can lead to increased opportunities for local, state, and federal funding and grant programs. Minnesota's reported spending on implementation projects to support clean water has more than doubled over the past two decades from just under $200 million per year in the early 2000s to around $400 million per year in the early 2020s (source: Clean Water Fund and MPCA Healthier Watersheds website). Local partners can leverage water quality implementation programs to help fund management efforts that lead to better water quality and delistings. Detailed information on the total cost of BMPs were typically not submitted by local partners during the delisting process, but a further review of this information could be helpful for water resource managers.

We reviewed all the lake delisting submittals received by MPCA over the past 20 years and grouped the reported management activities into one of two general categories (external/watershed strategies and internal strategies). Figures 3 and 4 show a breakdown of ten specific management strategy subcategories and the number of lakes that implemented each strategy. While these categories and subcategories are rather broad, they do

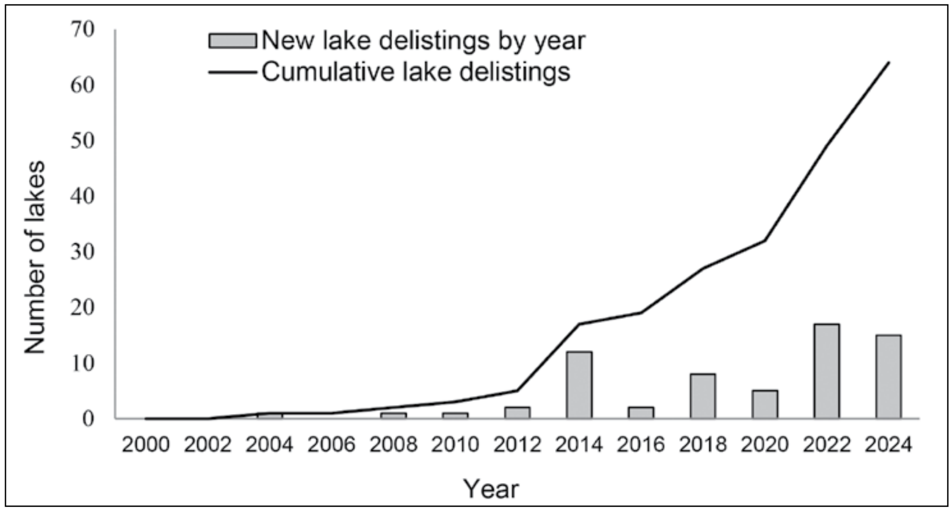

Figure 2. Minnesota lake delistings by year. Minnesota lake assessments and delistings are typically reported to the EPA bi-annually.

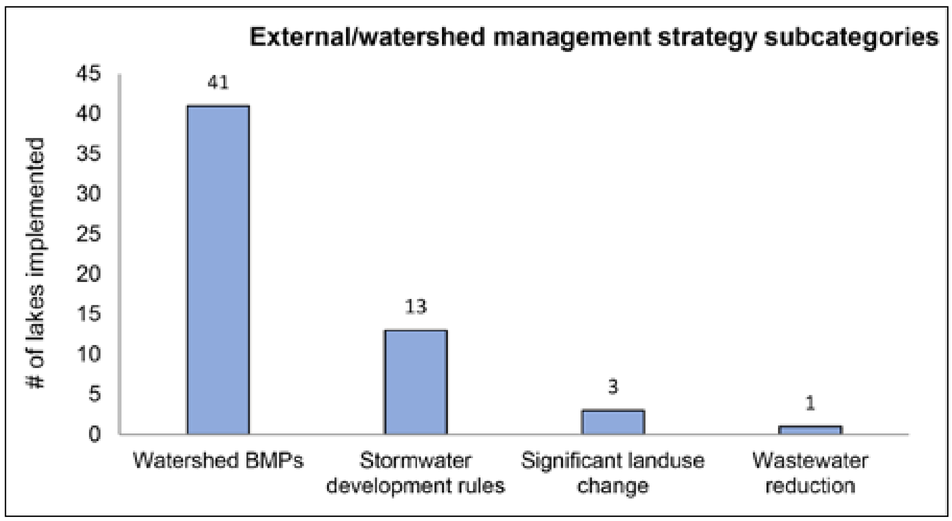

Figure 3. Types of external/watershed management strategies implemented for lakes delisted due to restoration activities.

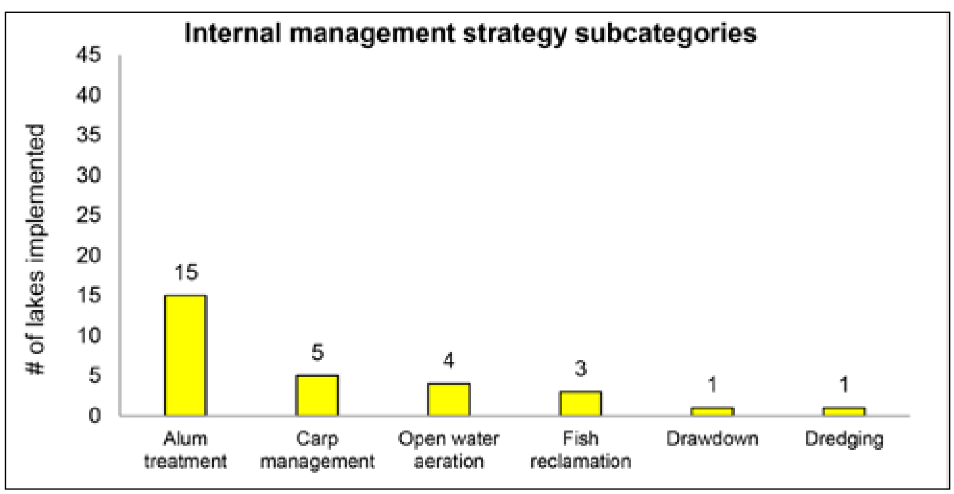

Figure 4. Types of internal management strategies implemented for lakes delisted due to restoration activities.

allow us to evaluate what specific strategy, or combination of strategies, have been most effective for delisting lakes. Common BMPs cited include:

- Urban watershed BMPs - raingarden and bioretention basins, stormwater ponds, shoreline stabilizations and restorations, increased street sweeping, iron enhanced sand filters, stormwater development rules, and wetland restorations and enhancements
- Agricultural watershed BMPs - cattle exclusion, feedlot runoff improvements, improved manure management, septic system upgrades, water and sediment control basins, grassed waterways, reduced tillage, wetland restorations, critical area plantings, and shoreline and streambank restorations
- Internal BMPs – aluminum sulfate (alum) treatments, carp management, open water aeration, and fish reclamation (i.e., rotenone treatment)

Watershed BMPs (both urban and agricultural) were by far the most common strategy subcategory implemented and were noted in 41 of the 45 lakes delisted due to restoration activities. Internal strategies were used on 23 of the 45 lakes (Figure 5). There were only three instances in which internal management was the only strategy cited by local partners. All three of these lakes have very small drainage areas and watershed-to-lake area ratios less than five to one. In general, the 15 delisted lakes treated with alum showed an immediate improvement in water quality conditions, often helping push the lake to meet water quality standards. A similar response was noted in some of the lakes in which biomanipulation techniques (i.e., carp management and fish reclamation) were used, particularly in shallow lakes with small drainage areas. In most cases (20 of 23 lakes), the local partners indicated that internal management strategies followed and/or were paired with a thorough investigation of external loading sources and implementation of watershed BMPs to reduce nutrient loads entering the lake.

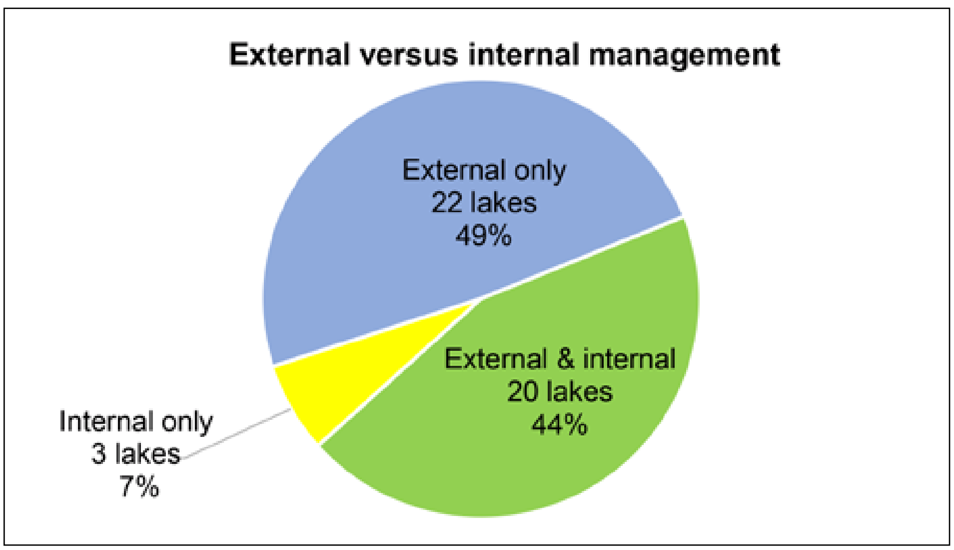

Figure 5. External versus internal management strategies applied in the 45 Minnesota lakes delisted due to restoration activities.

Lessons learned

Over the last five to ten years, Minnesota has experienced an encouraging upward trend in lake impairment delistings. While it's important to celebrate this achievement, it's also important to reflect on the management efforts that made this possible and share stories with others that are working to improve water quality in their lakes. Below is a summary of the key themes and lessons learned from 20 years of lake delistings in Minnesota.

- Many of Minnesota's delisting successes have been urban and suburban lakes in the TCMA with smaller drainage areas that were relatively close to meeting water quality standards when they were placed on the impaired waters list.
- External/watershed management strategies were implemented in 93 percent of the lakes delisted due to restoration activities and were a critical component of the restoration process.
- Internal management strategies were applied in 51 percent of the lakes delisted due to restoration activities and, with the exception of a few lakes, were paired with external/ watershed BMPs.
- There were no "quick fixes" or "silver bullets" to improving water quality. In most cases, multiple BMPs and strategies were needed for delisting.
- All of Minnesota's delistings took several years, and in most cases over a decade, to achieve the necessary nutrient reductions to meet water quality standards.
- Strategic planning, significant funding from multiple sources, and strong partnerships between citizen groups, local units of government, and state agencies were needed to make it all happen.
- In Minnesota, the assessment, TMDL, and delisting process serves as a helpful tool to identify problems, establish nutrient reduction goals, and kickstart restoration efforts.

Looking ahead

For a positive delisting trend to continue, significant improvements will need to be made to some of the state's more challenging impairments (e.g., bigger lakes, lakes with large drainage areas, and lakes in rural/agricultural settings –as exhibited by Lake Shaokatan (see Perleberg et al., 2023)). It is also important to continue to prioritize protection of high-quality waters (i.e., non-impaired lakes) due to the effort and cost of restoring waterbodies after they've become impaired. Finally, as threats to waterbodies increase (e.g., AIS, climate change, new emerging contaminants) collaboration amongst water managers and agencies will continue to be important to collect data and develop the tools and resources needed to assess and manage these threats. Fortunately, Minnesota has a long history of supporting state and local agencies with funding to monitor, assess, restore, and protect the state's abundant and diverse lake resources. We are proud of our accomplishments but recognize the hard work of lake management is on-going and evolving.

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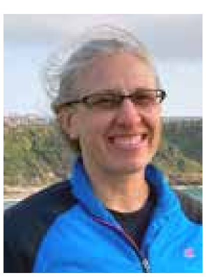

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*(**Upcoming** issues, continued from p. 4 . . .)*

related to this subject, consider submitting a draft to LakeLine for possible inclusion in the fall issue.

Draft articles for the fall issue of LakeLine are due by September 15, 2024, for publication in October 2024.

Please contact Amy Smagula, *LakeLine* Editor, with any questions, or to propose an article for one of the above-listed themes. Do you have a topic that doesn't match a theme? That's ok, we can include the article in any of these issues, or use it to build a themed issue.

Amy can be reached at **lakeline@nalms.org**

Watershed management and **rehabilitation of Lily Pond**

Robert H. Kennedy, Linda C. Bacon, and Aaron Englander

Lily Pond is a small (surface area = 12 ha; volume = 0.48 hm^3), shallow (mean and maximum depths are 4 m and 7 m, respectively) lake located in the towns of Rockport and Camden in the Mid-coast region of Maine (Figure 1). Abundant growths of submerged and floating macrophytes have long been notable characteristics of the pond, especially along the southern and eastern shore, covering approximately 40 percent of the pond's surface area during the summer months. Land uses in the 86-ha watershed (Figure 2) include pasture, mixed forest, and limited development. In the absence of permanent streams, groundwater flow and surface runoff are primary sources of inflow. Periodic outflows from the pond are conveyed south toward Rockport Harbor. The annual flushing rate is 1.2 times per year

In the late 1800s and early 1900s, Lily Pond was widely known for the clarity of its water and the quality of ice cut in winter and stored for shipment south in the summer. At that time, a local newspaper article boasted that a person could read the New York Times through a block of Lily Pond ice. However, marked deterioration in water quality was apparent by the 1970s, raising concerns locally and at the Maine Department of Environmental Protection (MDEP). This eventually resulted in the development of the *Phosphorus Control Action Plan and Total Maximum Daily (Annual Phosphorus) Load Report* (Action Plan) in 2005 (final USEPA approval in 2008). The report (1) identified elevated phosphorus concentrations as the cause of observed declines in water quality, which resulted in excessive chlorophyll-a concentrations and reduced water clarity; (2) set a target lake total phosphorus concentration of 15 µg/L; and (3) recommended a number of watershed management actions for reaching that target. The latter included reducing the inputs of phosphorus from two principal sources – riparian landuse activities at Aldermere Farm and runoff of nutrient-rich landfill leachate from the former Jacob's Quarry.

Figure 1. Lily Pond, Rockport and Camden, Maine with Aldermere Farm in the foreground. (Photo courtesy of Ken Woisard Photography.

Best management practices at Aldermere Farm

Aldermere Farm, a working farm now owned and operated by the Maine Coast Heritage Trust (MCHT), is located on 55 ha in northeast Rockport. The property includes limited development (including offices, barns and related farm buildings), wood lots, hay grounds, and grazing pastures for the farm's Belted Galloway herd, which ranges from 75 to 100 head depending on season. Only 7.8 ha of the land dedicated to grazing are within the Lily Pond watershed. Remaining areas drain either to Rockport Harbor or directly to Penobscot Bay.

Recognizing the potential for impacts to Lily Pond from farm operations, MCHT staff consulted state agencies in 2000 concerning Best Management Practices (BMPs) designed to reduce impacts to Lily Pond. Based on MDEP and Maine Department of Agriculture, Conservation and Forestry recommendations, fencing around a pasture abutting Lily Pond was repositioned to eliminate a 0.3-ha area popular with the cattle and having high potential for runoff. Setbacks for manure spreading in pastures were established and selected areas not located in the Lily Pond

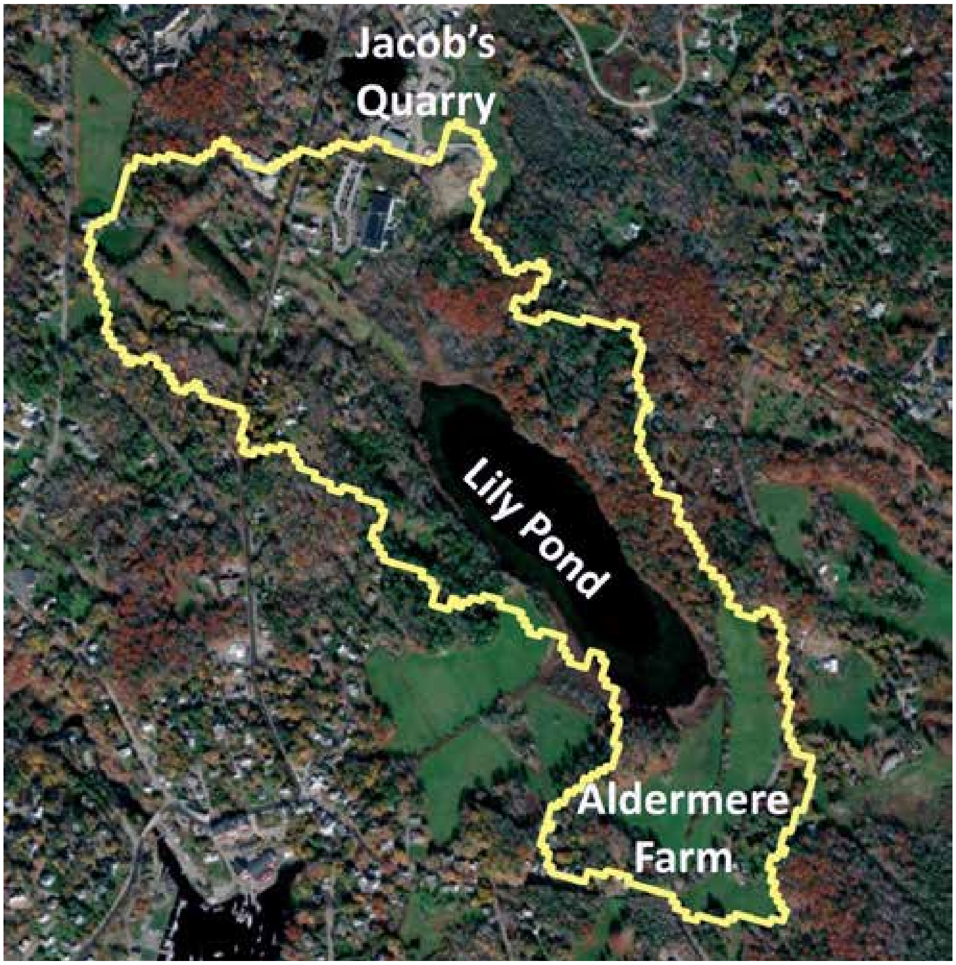

Figure 2. Lily Pond watershed boundary (yellow) and locations of Aldermere Farm and Jacob's Quarry.

watershed previously used for harvesting hay, were converted to grazing pasture to reduce grazing impacts and associated runoff from more vulnerable areas in the pond's watershed.

Farm staff developed a Nutrient Management Plan in 2007 that prescribed BMPs for managing soils, soil amendments and grazing, and recognized the protection of Lily Pond's water quality as a key management goal. Following state guidelines, the plan outlines practices that include comprehensive sampling and analyses of field soils and identifying amendments necessary for proper management of forages while minimizing impacts to Lily Pond. The Nutrient Management Plan was updated in 2023 to include increasing the pasture fence line setbacks to at least 7.6 m from drainages and 22.9 m from the shores of Lily Pond. Farm staff plan to establish native plant species in the riparian zone to enhance biodiversity and nutrient uptake.

Structural and operational changes at Jacob's Quarry

Jacob's Quarry, one of several limestone mining locations in Rockport, began operations in 1885. Early operations resulted in excavation of two primary pits. Much of the mined limestone was transported to nearby kilns, including those at Rockport Harbor. The resulting lime was shipped south by schooner for use in producing building plaster and mortar.

During the period of limited quarrying activity that followed in the early 1900s, pumps were required to remove accumulated drainage and seepage water from the two deep sections of the quarry. After cessation of operations in 1930, the quarry eventually filled with water and began overflowing toward Lily Pond. Starting in the 1940s, the Town of Rockport began using the quarry as a dump for municipal and industrial solid waste. In 1979, the quarry facility began serving three additional towns, eventually becoming managed and operated by the Mid-Coast Solid Waste Corporation. Cessation of municipal waste dumping was ordered by MDEP in 1983. Only the disposal of construction and demolition waste is currently allowed; household waste is either recycled or transferred offsite.

Leachate exported from the quarry site, either by groundwater flow or surface runoff, was identified in the Action Plan as a principal source of nutrient enrichment and the resultant deterioration of the pond's water quality. While historical data are limited, total phosphorus concentrations of surface water being discharged from the quarry toward Lily Pond were excessive when measured in April 1987 (1.8 mg/L) and August 1991 (0.145 mg/L).

In 1993, an *Administrative Consent Agreement and Enforcement Order* issued by MDEP dictated elimination of leachate export from the quarry site. To meet this requirement, pumping of groundwater from the quarry was initiated in 1994 to draw down the local water table thereby preventing or reducing groundwater movement off the quarry site. Connection to the local sewer system allowed extracted water and associated leachate to be treated at the Camden Wastewater Plant. The average pumping rate since initiation is 236.6 m^3/day. Measurements of groundwater levels indicate that the quarry currently acts as a groundwater sink preventing transport of leachate, associated nutrients and contaminants toward Lily Pond.

Additional efforts starting in 2009 addressed surface water runoff. The entire waste mass was reshaped, covered by 0.6 m of soil and seeded to reduce erosion. Slopes and added ditch work now allow diversion of most of the surface water from the facility to existing storm drains or to a detention pond, discharges from which are further detained in an adjacent wetland before draining toward Camden Harbor.

Water quality response

MDEP conducted water quality monitoring efforts from 1979 to 2008 to better describe water quality conditions, identify trends and formulate management options. These efforts included field measurements of Secchi disk transparency, water temperature and dissolved oxygen profiles, as well as collection of water samples for laboratory analyses for total phosphorus and chlorophyll-a. Water samples were variously collected either directly from the surface, at selected depths throughout the water column using a grab device, or by using a weighted tube to collect an epilimnetic core sample from the upper mixed layer. Values for the mixed layer were also calculated as the unweighted averages of values for depth-wise samples.

The Rockport Conservation Commission (RCC) conducted monitoring efforts starting in 2013, collecting much of the same type of information that was collected earlier by the MDEP. Most recently (2018 to present), a Lake Stewards of Maine (LSM) volunteer has been measuring water clarity weekly or biweekly during June through September, and periodically collecting 3-4 water samples from the surface for determining total phosphorus concentration.

MDEP applies the narrative standard that lakes shall have (1) a stable or decreasing trophic state based on such measures as total phosphorus, chlorophyll-a and Secchi disk transparency subject only to natural fluctuations, and (2) be free of culturally induced algae blooms which impair their potential use and enjoyment. Recommended numeric targets in the Action Plan to attain these water quality goals are total phosphorus ≤ 15 µg/L , chlorophyll-a < 8 µg/L and Secchi disk transparency > 2 m.

Marked improvements in these water quality measures were observed during the period 1979-2021. Notably, there has been a clear trend of decrease in epilimnetic and surface total phosphorus concentrations to levels near or below the 15 µg/L target (Figure 3). This trend spans the period when ground water pumping in Jacob's Quarry was initiated to depress the local water table and prevent leachate movement toward Lily Pond (1994 to present), and when BMPs designed to reduce nutrient loading to Lily Pond were implemented at Aldermere Farm (2000 to present). These two watershed management efforts appear to have resulted in a substantial reduction in the load of total phosphorus entering Lily Pond.

Lily Pond exhibited other positive changes in water quality linked to the observed reductions in total phosphorus. Secchi disk depths (Figure 4), while frequently shallow prior to about 1995, have increased steadily since then and now meet MDEP's recommended level of > 2 m. Similarly, positive changes were observed in chlorophyll-a concentrations (Figure 5). Concentrations prior to 2005 were excessive, with values as high as 30 µg/L observed, far in excess of the MDEP's recommended < 8 µg/L. Concentrations since 2005 have been consistently below this level.

Despite these dramatic changes in key water quality characteristics, dissolved oxygen concentrations in Lily Pond's bottom waters continue to be reduced during summer when the lake is thermally stratified. Under stratified conditions, there is limited upward mixing of cooler, denser bottom waters and therefore limited opportunity for replacing oxygen consumed due to decomposition of organic matter. This is especially problematic in lakes that are moderately to highly productive and/or receive excessive loads of organic matter from the watershed. A comparison of four temperature and dissolved oxygen profiles recorded during the month of July suggests slight improvement over the period 1979 to 2018 (Figure 6). The oxygen depletion does not extend into the water column quite as far, and the degree of depletion is not quite as severe.

Despite reductions in phytoplankton biomass based on observed changes in chlorophyll-a concentrations, there is very likely a legacy load of organic matter in the sediments that continues to consume oxygen during decomposition, which is anticipated to slowly decrease over the next few decades

Given the substantial improvements in water quality following implementation of BMPs by Aldermere Farm, structural and operational changes at Jacob's Quarry, and the small watershed area relative to the area of the lake, it seems unlikely that the watershed continues to be the major source of excessive organic matter loads to the pond.

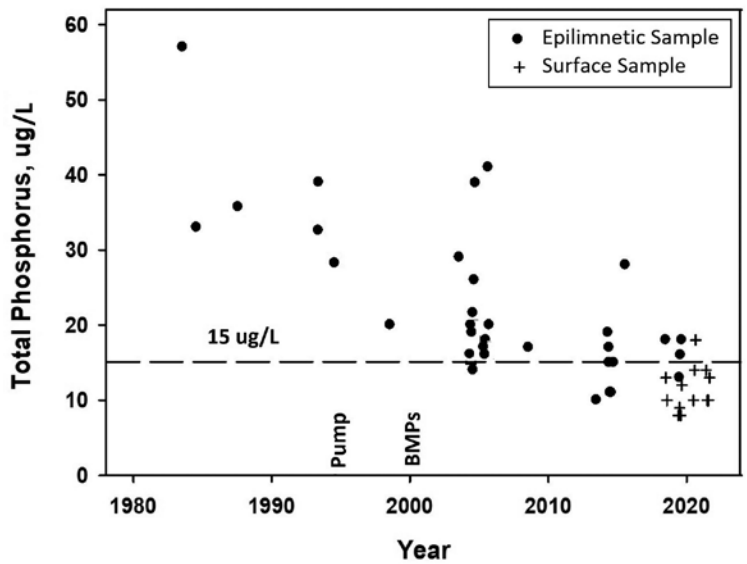

Figure 3. Changes in epilimnetic and surface total phosphorus concentrations relative to the Action Plan target of 15 µg/L (dashed line), and initiation of groundwater pumping and BMP implementation.

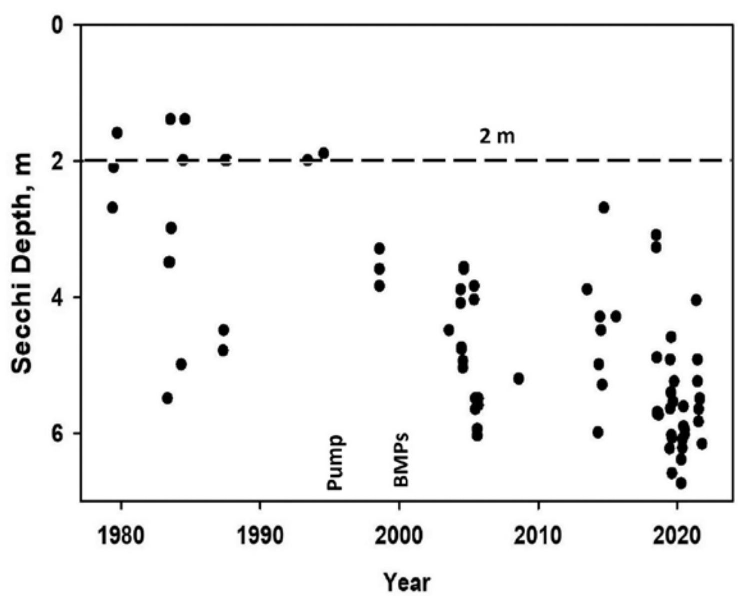

Figure 4. Changes in Secchi depth relative to the recommended value of > 2m (dashed line), and initiation of groundwater pumping and BMP implementation.

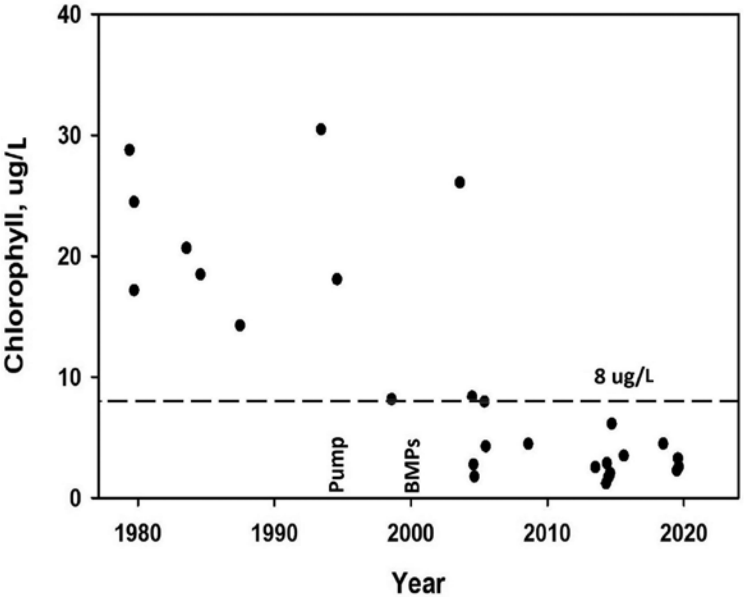

Figure 5. Changes in chlorophyll-a concentration relative to the recommended value of < 8 µg/L (dashed line), and initiation of groundwater pumping and BMP implementation.

In addition to legacy loads, there is more likely contributions from the pond's extensive and densely vegetated littoral area. High rates of plant productivity in these shallow waters likely add to the internal load of organic matter. The growth and subsequent senescence of littoral plants results in organic matter deposition, a portion of which is likely transported to deeper water sediments and contributing to the observed oxygen declines in bottom waters during stratified periods. Currently, available data are insufficient to quantify this source. However, littoral plants are an integral part of Lily Pond's ecosystem, providing nursery areas for fish, zooplankton, aquatic macroinvertebrates and amphibians. And the organic matter generated by aquatic plants is generally considered of higher quality than that from algae or external sources.

Implementation of management recommendations in the Action Plan by watershed partners has resulted in marked improvement in Lily Pond water quality. Based on monitoring data collected by MDEP and, most recently, by RCC and LSM, total phosphorus, chlorophyll-a and Secchi disk transparency now meet or exceed recommended values in the Action Plan. MDEP is currently considering a request to USEPA that Lily Pond be removed from the State's Section 303d list of impaired lakes. These concerted efforts demonstrate the importance of committed watershed partners to conserve and rehabilitate the region's legacy natural resources.

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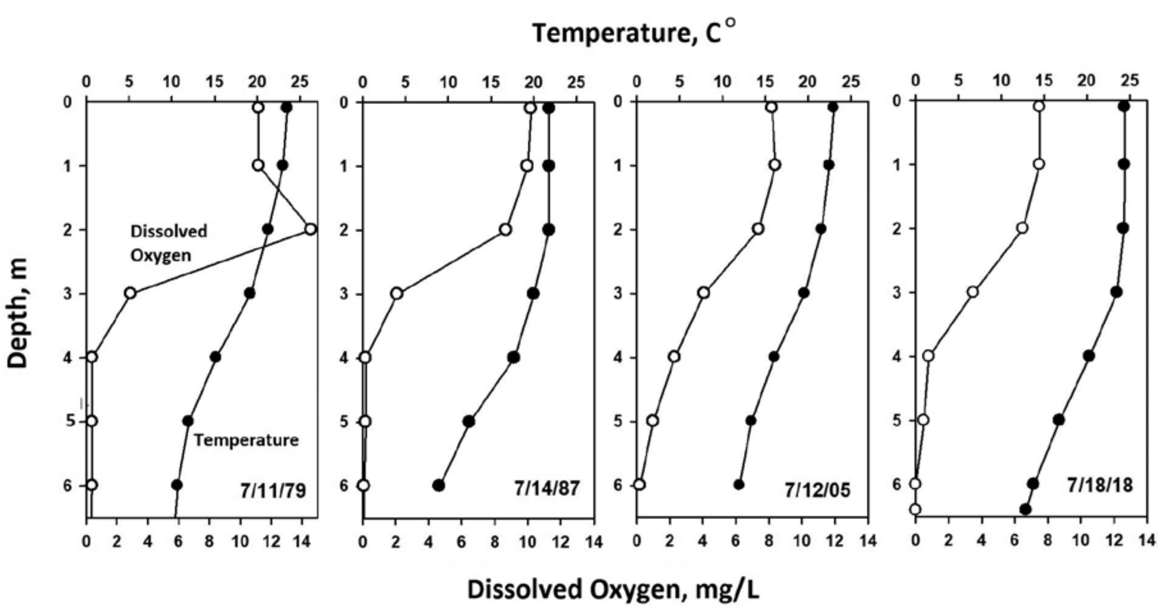

Figure 6. Vertical changes in temperature and dissolved oxygen observed in Lily Pond during July of selected years.

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Lake & watershed restoration at Georges Pond: **The little lake (association) that could**

Jennifer Jespersen

The lake & watershed

Georges Pond is a 358-acre Great Pond located in the Town of Franklin, Maine, approximately 45 minutes north of Bar Harbor and famed Acadia National Park. At its maximum depth, Georges Pond reaches 14 m, has an average depth of 4.3 m and a flushing rate of 0.45 flushes/yr. The lake is fed by several intermittent drainages and has a single outlet on the north end of the lake, Georges Brook (Figure 1).

The Georges Pond watershed is small relative to the size of the lake, covering just 1-square mile of land. Land cover in the watershed is primarily forested (53 percent), consisting mostly of mixed forest, followed by wetlands (19 percent), developed land (15 percent), open green spaces and meadows (7 percent), and agriculture (6 percent) (Figure 2). Logging accounts for approximately 8 percent of the forested area. Residential development accounts for the largest percentage of the developed urban land cover category at 10 percent, with gravel operations and roads making up 5 percent. Development is limited to roads and residential development, with 144 developed shoreline parcels, 92 percent of which are seasonal. Only about a dozen residents live on the shoreline year-round. It is estimated that 23 of the 144 shoreline dwellings meet or exceed the minimum shoreline zoning requirements established in Maine's 1971 Mandatory Shoreland Zoning Act, presumably because the non-conforming properties were built prior to 1971.

Water quality data at Georges Pond has been collected by volunteer monitors and the Maine Department of Environmental Protection (MDEP) since 1977. Georges Pond is on the Maine Department of Environmental Protection's (MDEP) Nonpoint Source Priority List as "Threatened" due to changes in water quality over the past decade, sensitive sediment chemistry that indicates it is susceptible to releasing iron-bound phosphorus when exposed to low levels of dissolved oxygen, and specifically because of nuisance algal blooms that started in 2012.

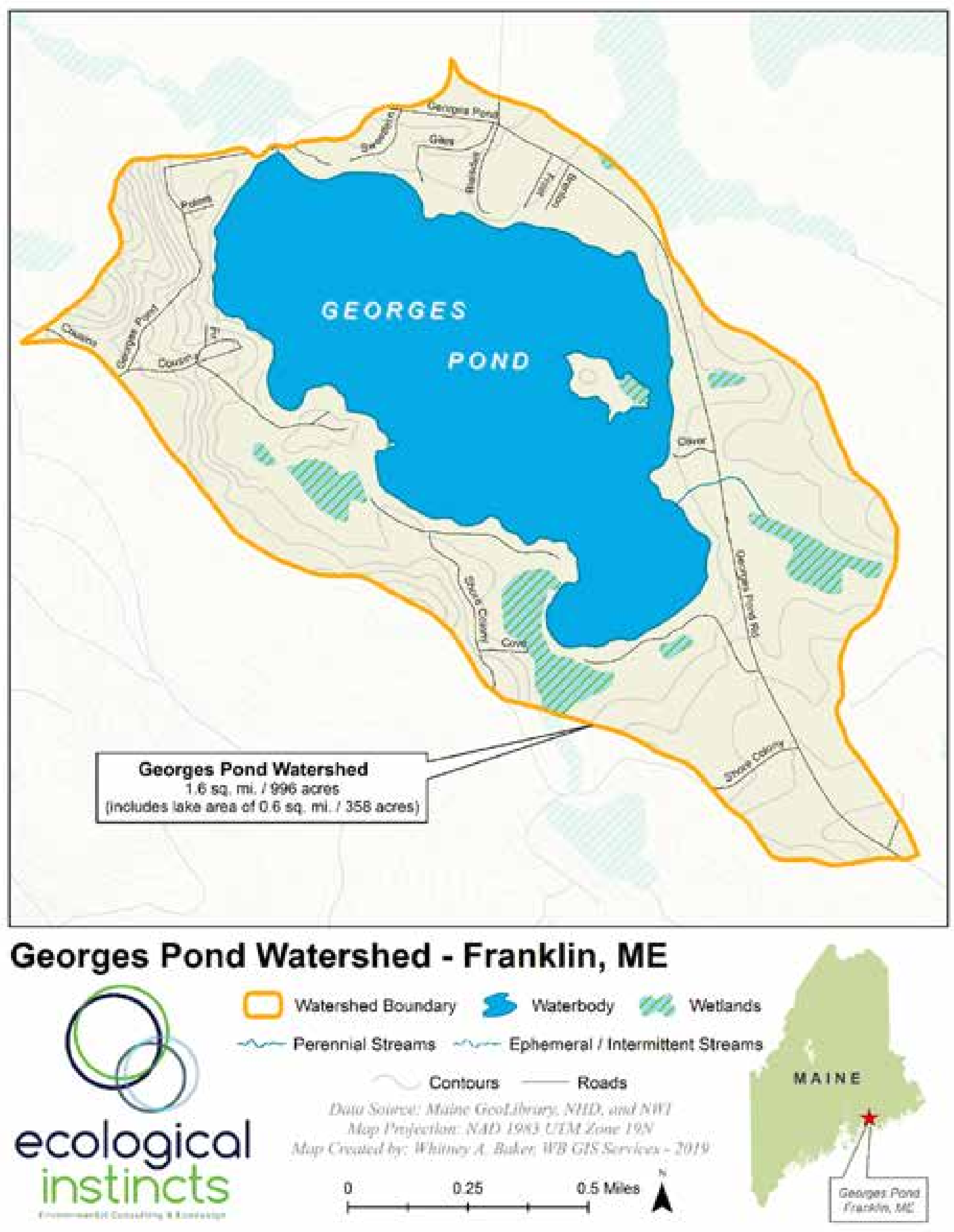


Figure 1. Watershed map.

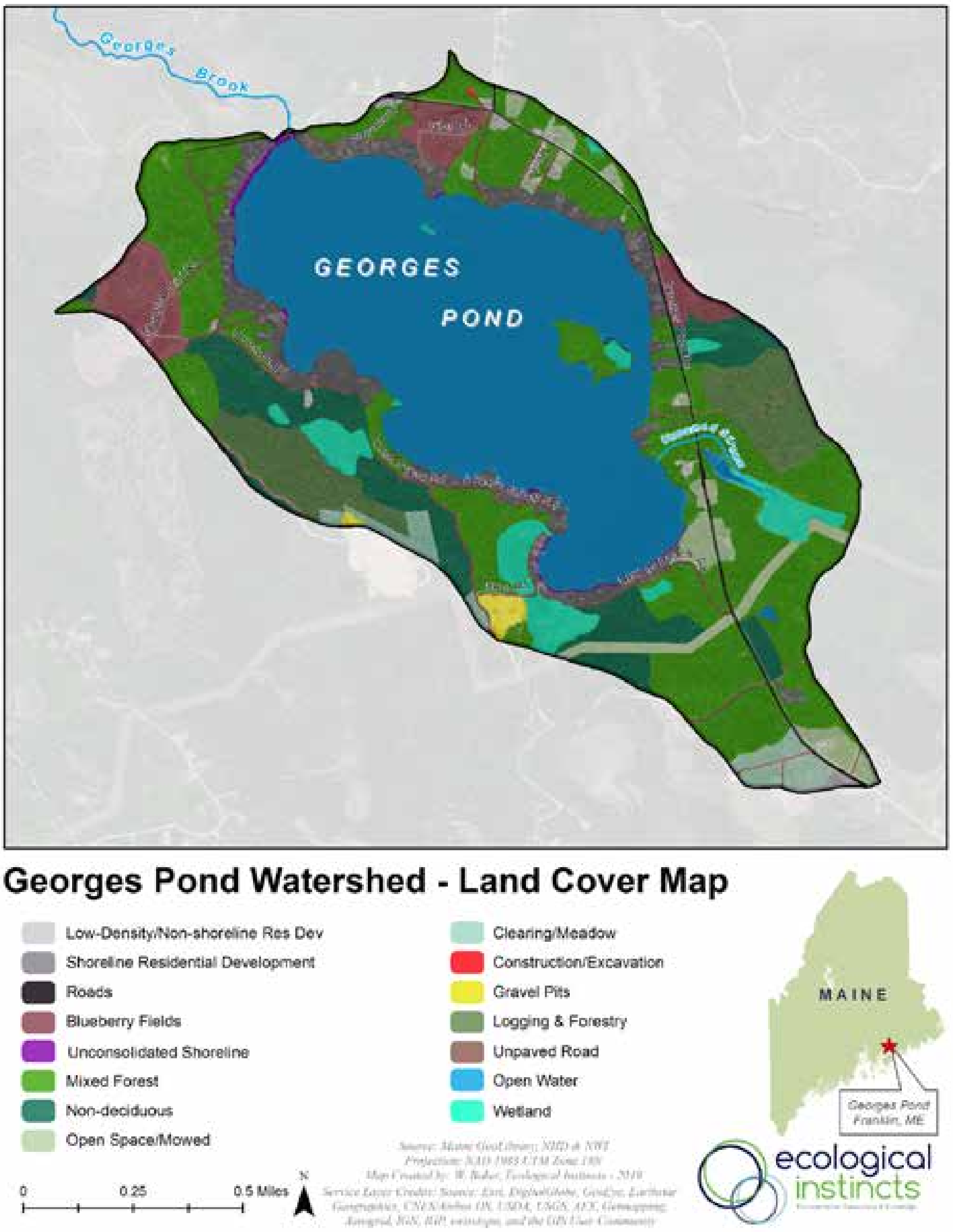


Figure 2. Land cover map.

Figure 3. Pea soup at Georges Pond.

A small lake with a big problem

Prior to 2012, the average total phosphorus concentrations in Georges Pond were 12 ppb and water clarity was 4.6 m. And then, the unthinkable happened. The lake experienced its first significant algal bloom in 2012 the likes of pea soup (Figure 3). Between 2012 and 2019 there were a total of four lake-wide algal blooms that resulted in significant changes in water quality including chlorophyll-a levels 10 times historic levels, an increase in the area of anoxia at the bottom of the lake from 8 m to just 4 m, and total phosphorus concentrations in surface water increased by 10 ppb from pre-bloom conditions. In October 2019, the phosphorus concentration at the bottom of the lake was 980 ppb.
The lake community was devastated, disheartened, and avoided spending time with family and friends at their beloved lake, many of which are multi-generational camps. The Georges Pond Association (GPA) needed a plan.

Make a plan

Between 2018-2019, the GPA consulted with professionals from MDEP, Water Resource Services, Inc., and Ecological Instincts to help determine why Georges Pond was experiencing nuisance cyanobacteria blooms and what to do about it. This work resulted in the development of the 2020 Georges Pond Watershed-Based Management Plan, designed to understand the unique factors in the lake and the watershed that were contributing to the algal blooms, and to prevent these blooms from occurring at Georges Pond in the future.

Water quality monitoring was an integral part of this process. The community was upset and pointing fingers to place blame on the problem without any science to back it up. With guidance from MDEP and GPA consultants, GPA trained volunteer monitors embarked on an intensive water quality monitoring program in 2019 to better understand the science behind the problem including the role of internal phosphorus recycling (aka, internal loading). Phosphorus samples were collected every other meter, every two weeks, from the surface to the bottom of the lake from May – October, along with Secchi disk transparency, and dissolved oxygen and temperature profiles. Bathymetric data was collected by GPA volunteers to assist with acquiring more accurate internal loading estimates. Sediment samples were collected from across the lake and analyzed by the University of Maine to gain a better understanding of the sediment chemistry and how Georges Pond sediments would respond to phosphorus inactivation (Figure 4).

Monitoring is key

Phosphorus inputs from the internal load vary depending on the depth of the thermocline and how much of the lake is anoxic and for how long. Thermal stratification in Georges Pond is typically between 6 and 8 m, and even shallower if mixing is not sufficient as occurred in 2012 when anoxia was as shallow as 4 m. The shallower the depth of anoxia, the greater the area of sediment available to release phosphorus.

Results of the 2019 monitoring and assessment effort confirmed that internal loading was the most significant contributor to the phosphorus load in Georges Pond. Combined with watershed modeling, it was determined that 56 percent of the phosphorus load in Georges Pond is from internal loading (105 kg/yr) compared to 44 percent from external sources such as watershed runoff (32 kg/yr), septic systems (20 kg/yr), atmospheric deposition (22 kg/yr) and wildlife (10 kg/yr) (Figure 5).

The goal

The Georges Pond Watershed-Based Management Plan (WBMP) set a goal of reducing the internal phosphorus load in Georges Pond by 90 percent and reducing the watershed load by 10 percent (90 kg/yr reduction in total load) with an in-lake water quality target of 10 ppb in order to prevent future algal blooms. At greater than 50 percent of the total load, addressing the internal load was determined to be a primary objective in order to restore water quality as well as ramping up water quality protection efforts throughout the watershed to mitigate NPS pollution, and monitoring improvements in water quality.

Fundraising

Well before a scientific analysis recommended an aluminum treatment, GPA assumed that it needed to raise up to $400,000 for restoration. Although the GPA sought additional money from MDEP, the Town of Franklin, and other independent grants, no outside funding was provided, and all funds were raised privately.

GPA adopted a fundraising approach utilized at East Pond (in Smithfield, ME) for their aluminum treatment; to ask all homeowners for a percentage of the value of their property (2 percent) over two years, suggesting that it would be a good return on investment, as property values would increase with cleaner water. People were asked to give what they could afford and were not held to the 2 percent request. First, 100 percent of the Board of Directors were asked to pledge. Then each Board member was asked to personally solicit a handful of potential donors. By the time GPA went public with fundraising requests it had obtained more than 50 percent commitment for its initial goal. Some of the largest donors were friends of the Pond – people with strong connections and memories, but not property owners.

Although meaningful commitments had been made, by early 2020 there were only sufficient funds for half of the total treatment. In addition, Covid was unfolding along with financial hardship and restrictions on contractors. GPA decided to move forward with a partial aluminum treatment. There was some hesitation to proceed with the second treatment, but the GPA moved forward and the success of the first treatment helped to raise the remaining funds.

The aluminum treatments

The goal of the Georges Pond aluminum treatment was to amend the lake's natural chemical balance by increasing the amount of available aluminum in the sediments that could bind to phosphorus. (Whereby increasing the aluminum:iron ratio in the sediments. It is the iron-bound phosphorus that is released during periods of anoxia.)

The multi-year aluminum treatment approach in 2020-2021 was designed to inactivate phosphorus in the top 10 cm of bottom sediment in all areas of the lake subject to anoxia (>5 m), and to knock the internal load down from 105 kg/yr to 10.5 kg/yr. A MDEP General Application for Waste Discharge License (WDL)/Maine Pollutant Discharge Elimination System MEPDES) Permit was required prior to the treatment (Figure 6).

Figure 4. GPA volunteer monitors Lisa Grant and Jim Ashmore.

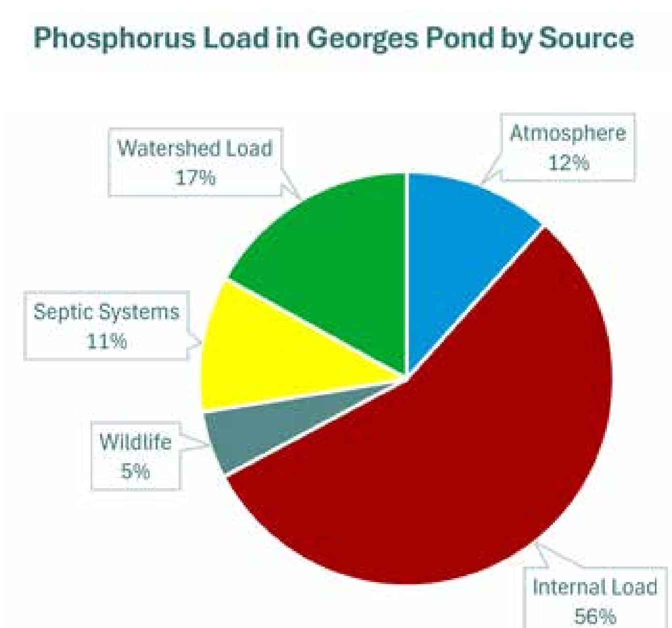


Figure 5. Phosphorus loading to Lake George.

A total of 131 acres, representing all areas deeper than 5 m in Georges Pond, was treated with 45 g/m^2 of aluminum sulfate and sodium aluminate on a barge which was injected below the water surface over the target area. This included a 25g/m^2 treatment in 2020, and a 20 g/m^2 treatment in 2021. The split treatment was partially to ensure funding was in place for the full treatment, but also had the added benefit of stripping phosphorus out of the water column during application each spring (Figure 7).

Monitoring results from 2020-2023 indicate that expected phosphorus reductions in the lake were realized. Secchi disk transparency readings in 2020, 2021 and 2023 exceeded 7.6 m, deeper than historical readings dating back to 1977 (Figure 8). The mass of phosphorus below 5 m was reduced by 81 percent from 32.8 g in 2019 (before aluminum treatments) to 6.1 kg after treatments. In 2021, the in-lake phosphorus concentration was 9.4 ppb, reaching the WBMP goal of 10 ppb.

It is common knowledge that phosphorus inactivation is not a permanent solution and overtime, phosphorus will build up in the sediment again. Preventing phosphorus from getting into the lake is the key to protecting the $300,000 local investment spent on the aluminum treatment.

Figure 6. Aerial image of aluminum treatment.

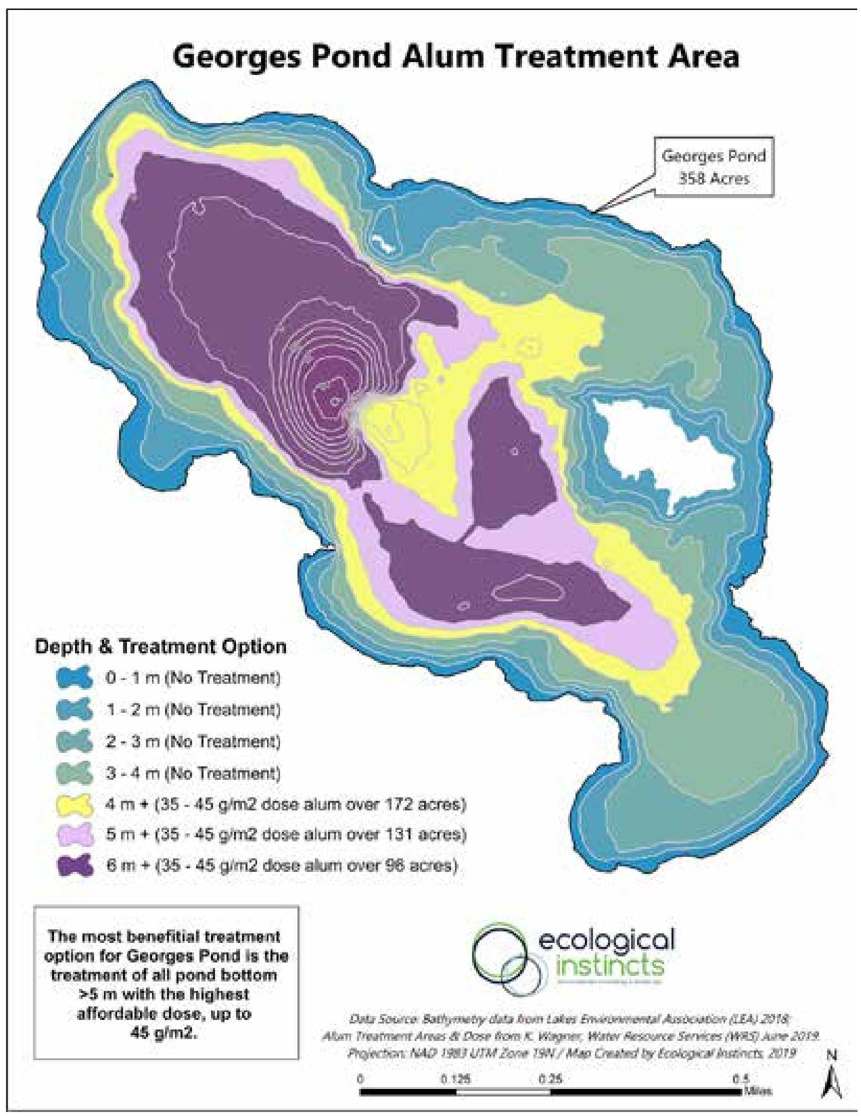


Figure 7. Aluminum treatment area.

Watershed work matters

GPA's two-pronged restoration approach to inactivate phosphorus in the sediments while simultaneously reducing phosphorus inputs from the watershed was realized through two Watershed Protection Grants from the US EPA and MDEP, ramping up GPA's LakeSmart program, and a Septic System Pilot Project and Incentive Program.

LakeSmart

GPA initiated a local LakeSmart program in 2018 with assistance from the statewide umbrella organization, Maine Lakes, who administers the program. Since 2018, trained LakeSmart volunteers from GPA have conducted evaluations for 88 of the 144 properties on the shoreline, helping raise awareness about NPS pollution and lake-friendly landscaping practices that prevent phosphorus from getting into the lake. To date, 28 LakeSmart awards have been issued making GPA one of only a handful of

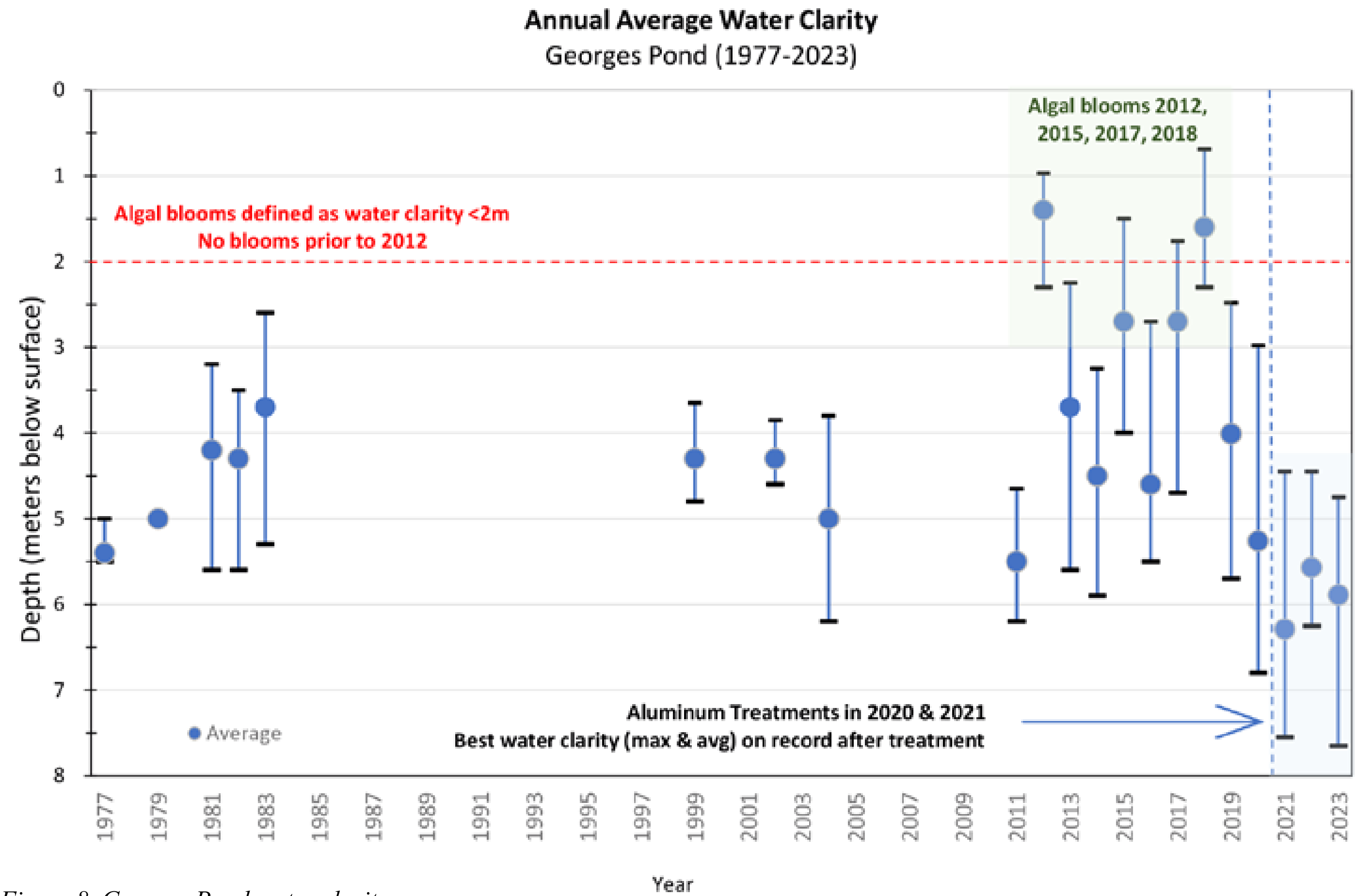


Figure 8. Georges Pond water clarity.

"LakeSmart Gold" lake associations for their LakeSmart efforts (Figure 9).

319 Grants

In Phase I (2020-2021), GPA completed erosion control projects on ten residential projects, two large gravel road projects, and hosted a "Beef Up Your Buffer" workshop to further engage shoreline property owners in the restoration proces. A total of $84,500 was invested in watershed projects including $45,960 in grant funding. To date in Phase II (2022-2024), fifteen residential property evaluations have been completed resulting in completion of nine residential projects (Figures 10a & 10b). Three gravel road projects have been completed, and a large restoration project at the town beach will be completed in the spring of 2024. The Phase II watershed project utilized $56,622 in grant funding and over $80,000 in local matching funds.

Septic Initiative

GPA's Septic System Pilot Project was partially funded by the Phase II grant, which included hosting two septic socials and providing free septic system and

Figure 9. Georges Pond residents with Lake Smart Award.

Figure 10a. Buffer planting workshop – steep slope before planting.

Figure 10b. Steep slope after planting.

biomat inspections for five seasonal and one year-round home on the shoreline which achieved the goal of gaining a better understanding of the possibility of septic systems affecting lake water quality. Only one of the six systems evaluated was found not to have a concern. Two of the older systems were determined to pose a substantial and immediate risk to water quality (Figure 11). This work highlights the need for a more comprehensive study of septic systems in the watershed. In 2023, GPA initiated a Septic System Incentive Program offering free inspections for pre-1974 systems (Maine plumbing code enacted), 50 percent discount for 1974-1995 systems or rentals, and will help schedule and coordinate inspections for post 1995 systems (rules amended to be more protective of systems in sandy soils). In 2023 GPA, helped coordinate four septic system inspections, all of which were well received.

A growing community of lake stewards

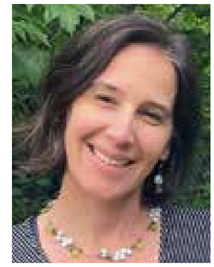
Since 2018 when GPA made it their primary mission to restore Georges Pond's water quality, GPA membership has increased from less than 50 to 200 members. GPA has developed an updated website with current information about water quality and watershed programs, completed 88 LakeSmart evaluations, published more than a dozen highly informative and educational newsletters, hosted numerous workshops on buffers and septic systems, started a septic system

Figure 11. Septic system inspection.

incentive program, and oversaw five years of grant-funded watershed work, and a two-year aluminum treatment project. Water quality in Georges Pond is the best on record, and stewardship among lake residents is at an all time high.

The Georges Pond WBMP developed in 2020 is well underway, and the goal of 10 ppb in-lake phosphorus was met early in the process thanks to immediate actions to address internal loading and watershed runoff. Ongoing watershed protection efforts are essential to keep phosphorus out of the lake and to protect the investment that has been spent on restoring the lake over the past 5+ years. One of the greatest challenges is ongoing efforts to change the culture to a "filtered view" of the lake rather than traditional lakeshore activities that clear trees for a view and working with the town to strengthen and enforce mandatory shoreland zoning regulations.

GPA has become a model and provides mentoring for other Maine lake associations facing similar internal loading challenges. The restoration effort at Georges Pond over the past 5 years is a testament to the leadership of the GPA executive board, ongoing landowner participation, and guidance from state agencies, nonprofits, and environmental consultants that helped guide GPA- and who in turn GPA inspired along the way.



Jennifer Jespersen is the owner of Ecological Instincts, a small woman-owned environmental consulting firm located in Manchester, ME. Jen is an ecologist and Certified Lake Manager, assisting lake associations and municipalities with watershed planning and freshwater restoration projects across the State of Maine. Jen is the lead author of the 2020 Georges Pond WBMP and has provided ongoing assistance to GPA for grant writing and project management support for their two recent watershed restoration grants. In her free time, Jen can be found biking the backroads of Maine and enjoying the splendor of all that Maine lakes have to offer.

NATIONAL LAKE BLITZ PROMOTIONAL PACKAGE

Living Lakes Canada Social Media Tags

Instagram: @livinglakesca • Facebook: @LivingLakesCanada • LinkedIn: @living-lakes-canada
Website link: https://livinglakescanada.ca/our-programs/lakes/lake-blitz/

Are you a lake lover who cares about the environment and wants to help track climate and other impacts? Living Lakes Canada [tag us] has the perfect opportunity for you!

Living Lakes Canada's 4th Annual National Lake Blitz is now open for registration! In this citizen science program, volunteers are equipped with simple tools and skills to monitor their chosen lake from May to September.

You have until April 26 to register and join a community of lake stewards this summer! Register today to get your free Lake Blitz Kit: https://livinglakescanada.ca/our-programs/lakes/lake-blitz/

Photo: Heather Benson

Lake Ketchum – A restoration success story

Shannon K. Brattebo, Marisa Burghdoff, and Jen Oden

Lake Ketchum is a 26-acre lake in Washington State located about 50 miles north of Seattle, just a few miles from Puget Sound (Figure 1). There are about sixty homes located on this beautiful public lake and it is heavily used for swimming, fishing and boating. Lake Ketchum is also home to a variety of birds and wildlife including bald eagles and osprey. Until the 1940s, Lake Ketchum was largely undeveloped and served as a reserve drinking water source for the nearby City of Stanwood. Unfortunately, lake water quality markedly deteriorated and for the last several decades Lake Ketchum was the most polluted lake in Snohomish County and one of the worst in the state.

The problem

For several years, Lake Ketchum was plagued by severe blooms of cyanobacteria. Thick growths of algae formed unsightly scums that covered the lake for months at a time, severely impairing the public use and enjoyment of the lake. Even worse, the algal blooms were frequently toxic, threatening the health of people, pets, and wildlife. For much of the year the lake was posted with recreational warnings that discouraged most lake uses (Figure 2 a-c). The liver toxin, microcystin, reached over 400 µg/L in the few years prior to restoration, well above the state's current recreational guidance value of 8 µg/L (www.nwtoxicalage.org).

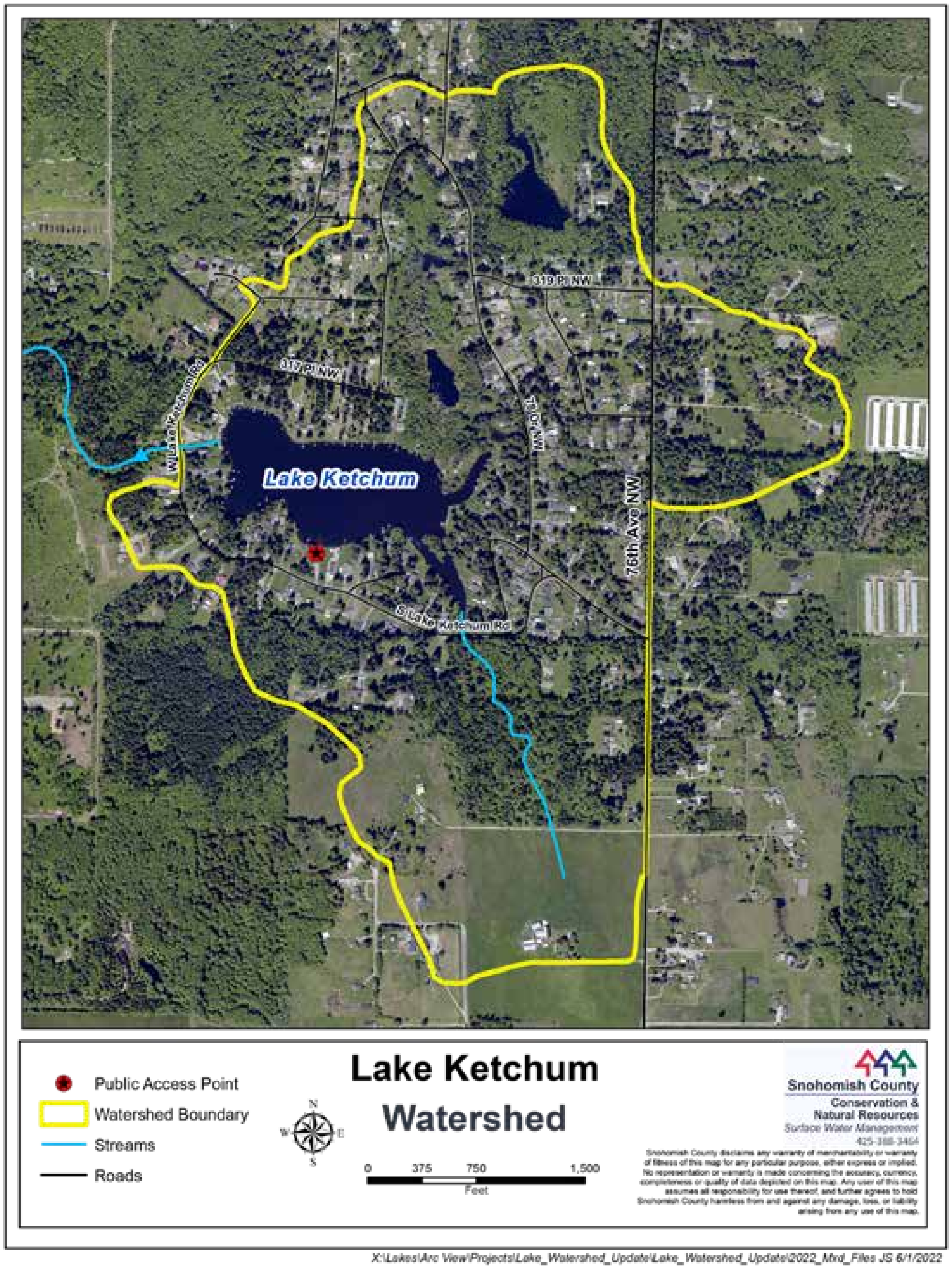


Figure 1. Lake Ketchum Watershed.

< *Figure 2 (a) Typical cyanobacteria bloom at Lake Ketchum prior to restoration; (b) Sample collection of thick cyanobacteria bloom at Lake Ketchum prior to restoration; (c) Toxic Algae Warning sign at Lake Ketchum prior to restoration.*

Snohomish County had a long-term volunteer monitoring program at the lake. Using data collected through that program, the county was able to determine that the harmful algal blooms were fueled by extremely high phosphorus levels (Snohomish County 2012). The 1996-2011 epilimnetic (upper water layer) total phosphorus (TP) concentration averaged 277 µg/L (Snohomish County, 2012). These values were some of the highest in the state and were 13 times higher than the regional standard. The summer hypolimnetic (lower water layer) TP average was over an order of magnitude higher at 1,746 µg/L. Seasonal peaks in the hypolimnion sometimes had TP values as high as raw sewage.

Early county and community efforts to identify the source of the problem found that the original source of phosphorus to the lake was from a former dairy farm (Entranco, 1997). The farm is in the southern portion of the watershed. The seasonal inlet stream that drains to the lake originates on the farm. At one point in time, the dairy farm served as an annual waste depository, leaving the soils on the farm heavily saturated with phosphorus. Over time, phosphorus entering the lake from the farm accumulated in the lake bottom and became a major source of phosphorus loading to the lake.

The solution

Unfortunately, early attempts to reduce the phosphorus load into the lake were confounded by lack of funding and feasible options. With mounting concerns regarding the toxic blooms, the county was able to secure funding to conduct an intensive lake study which was used to develop the Lake Ketchum Algae Control Plan (Snohomish County, 2012). The primary goal of the Plan was to reduce frequent harmful algae blooms caused by excessive phosphorus pollution.

The plan included a water and nutrient budget showing that the internal loading, or recycling of the phosphorus from the lake sediments, accounted for 73 percent of the annual phosphorus inputs.

While the TP from the stream had decreased substantially (1,500 ug/L in 1994/1995 to 646 µg/L in 2010-2011) the inlet was still contributing 24 percent of the total annual phosphorus load to the lake. Around 2 percent was coming from runoff from the homes around the lake with minor amounts coming from precipitation and groundwater.

The data were used to develop a phosphorus model for the lake, from which multiple restoration options were modeled to determine their impact to the lake. Solutions included treating the toxic algae itself, several lake aeration options and whole-lake and continuous injection of phosphorus inactivation products. Using the model results coupled with preliminary cost estimates, the community decided on a final action plan that included five main elements as follows:

- **Large-scale aluminum sulfate (alum) treatment** to inactivate the legacy phosphorus in the lake sediments. An initial treatment was planned to inactivate the upper lake sediments with a potential follow-up treatment in year 6 for deeper sediments.
- **Small annual alum treatments** to neutralize the large inflow of phosphorus from the lake inlet or other sources plus any additional phosphorus released from the lake sediments each year.
- **Wetland protection** to ensure wetlands near the lake inlet are preserved as they are instrumental in removing some phosphorus from the farm field and may also be a source of legacy pollution if disturbed.
- **Reduce phosphorus from lake residents** by encouraging landowners to make changes in lawn and yard care, septic system care and shoreline management via the county's LakeWise outreach program (www.lakewise.org).
- **Monitoring & adaptive management** to provide the necessary information to assess the efficacy of the plan as well as to adaptively manage the annual dosing of alum treatments.

It should be noted that there were also significant prior efforts to make improvements on the farm to prevent further pollution. In the 1990s the farm ceased application of animal waste and converted the field from cattle to hay production. The farm soil remained contaminated, yet the landowner was unwilling to take any further action, precluding additional watershed management options from being included in the plan.

Implementing the plan

Following the completion of the Lake Ketchum Algae Control Plan, the community and county worked for two years to obtain funding which was ultimately comprised of a state toxic algae grant, direct county contributions and an annual fee imposed on the lake community by the county (per the community's request), to pay for implementation of management alternatives.

In 2014, implementation kicked off with a large-scale whole-lake alum treatment. The initial alum dose was calculated to remove phosphorus from the water column and inactivate the majority of the phosphorus stored in the top 10 cm of lake sediments (Brattebo et al., 2017). In May 2014, contractors applied over 13,400 gallons of liquid alum and 7,400 gallons of sodium aluminate (buffer). Unfortunately, the application methodology used caused short-term impacts to lake pH and the treatment was not fully completed.

A second large-scale alum treatment was completed in March 2015 with revised application methodology which improved the mixing of alum and sodium aluminate to prevent pH impacts. In March 2015, another 13,000 gallons of alum and 8,100 gallons of sodium aluminate were applied to the lake. The 2015 large-scale treatment was completed with no impacts to lake pH or fish health.

The planned small annual alum treatments began in 2016 and are conducted each year with doses varying slightly based on the winter precipitation and budget limitations (Table 1). Overall, 50,734 gallons of alum and 29,390 gallons of sodium aluminate have been applied to the lake through 2023. Note that the 2020 annual alum treatment was delayed until the second week in May due to the COVID-19 pandemic.

The community has strongly supported implementation of the Algae Control Plan and have taken on additional efforts to improve the lake, especially through strong participation in the LakeWise program. The community has contributed countless hours to volunteer lake monitoring and residents have also worked to ensure the wetlands remain protected.

Water quality improvements

The first large alum treatments in 2014 and 2015 exceeded expectations at both reducing phosphorus in the water column and preventing internal phosphorus loading. The plan goal was to

Table 1. Aluminum dose and quantities of aluminum sulfate and sodium aluminate applied to Lake Ketchum from 2014-2021.

Year	Date	Dose (mg Al/L)	Alum Applied	Buffer Applied
2014	5/21/2014	19.5	13,484	7,415
2015	3/4/2015	20.4	13,000	8,118
2016	4/27/2016	4.4	2,900	1,705
2017	4/26/2017	6.1	4,050	2,380
2018	4/25/2018	4.4	3,000	1,800
2019	4/10/2019	4.4	3,000	1,800
2020	5/7/2020	4.4	3,000	1,800
2021	4/9/2021	4.4	3,191	1,572
2022	3/30/2022	3.14	2,629	1,430
2023	3/21/2023	3.0	2,480	1,370

reduce summer (Jun-Sept) TP concentrations in the epilimnion to 40 µg/L or less. The summer average TP in surface waters decreased from 80 µg/L in 2013 to 11 µg/L in 2015 and has stayed consistently low, well exceeding the plan goal (Figure 3).

In 2014, sediment phosphorus release was essentially eliminated following the alum treatment, decreasing from an average rate of near 25 mg/m^2 per day to zero (negative rates). Summer hypolimnetic average total phosphorus decreased from 1,844 µg/L in 2013, to 158 µg/L in 2014, to 14 µg/L 2015 (Figure 4). Since then, total phosphorus in the bottom waters remains low indicating that internal loading of phosphorus has been largely eliminated.

The primary goal of the Algae Control Plan was to reduce the frequency and duration of potentially toxic algae blooms. Chlorophyll concentrations did not dramatically improve, as was the case for TP, following the first alum treatment in 2014. Summer average chlorophyll in the epilimnion in 2014 was 55 µg/L, driven by a heavy bloom in June. However, starting in 2015 summer average chlorophyll concentrations fell to 12 µg/L and have largely remained low (Figure5).

Most importantly, toxic algal blooms have been virtually eliminated in Lake Ketchum since implementation of the plan began. There have not been any blooms with toxins exceeding the state's recreational guideline since the start of the annual small alum treatments in 2016. There has only been one posting of the lake which occurred in May 2020, but the bloom did not have high toxins associated with it. The bloom likely occurred as a result of the alum treatment being delayed due to the Covid-19 pandemic. It quickly dissipated after the treatment was conducted.

Water clarity improved slightly following the 2014 treatment to a summer mean of 2.1 m (Figure 6). After the second alum treatment in 2015, water clarity almost doubled to a summer mean of 4.0 m, with the Secchi disk sometimes reaching the lake bottom. Increased water clarity often follows alum applications, however, the increase in summer water clarity was mostly due to the overall decrease in algae in the water column.

Overall, long-term results show that implementation of the Algae Control Plan is meeting and exceeding the plan goals. Phosphorus concentrations have dramatically decreased leading to substantial reductions in algal growth, significantly clearer water and even improved dissolved oxygen. Most importantly, toxic algal blooms have been virtually eliminated. The treatment approach at Lake Ketchum has shown that the successful inactivation of sediment

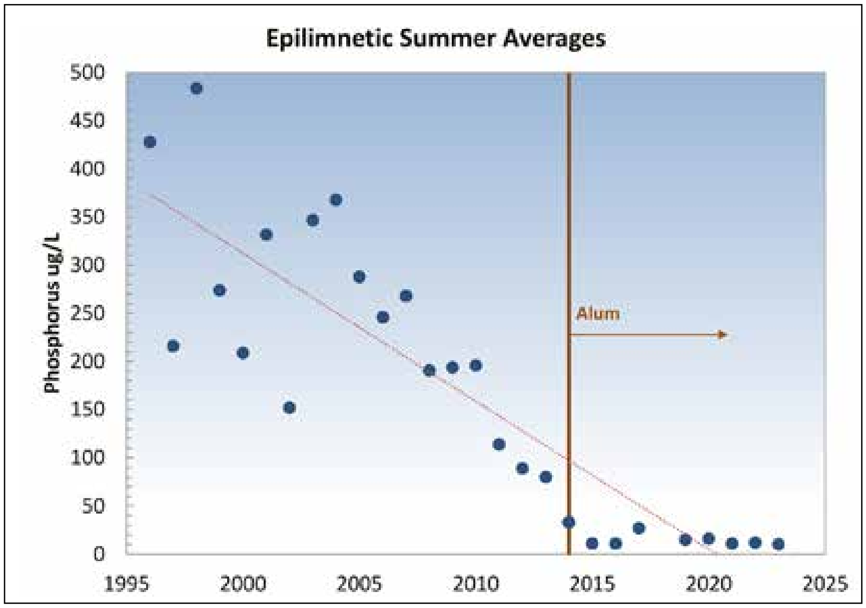


Figure 3. Lake Ketchum epilimnetic summer average TP, 1996-2023.

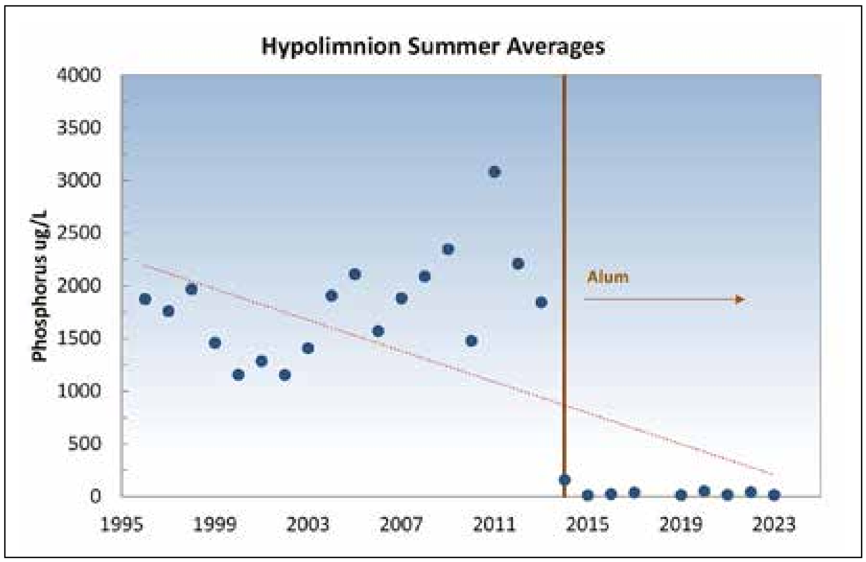


Figure 4. Lake Ketchum hypolimnetic summer average TP, 1996-2023.

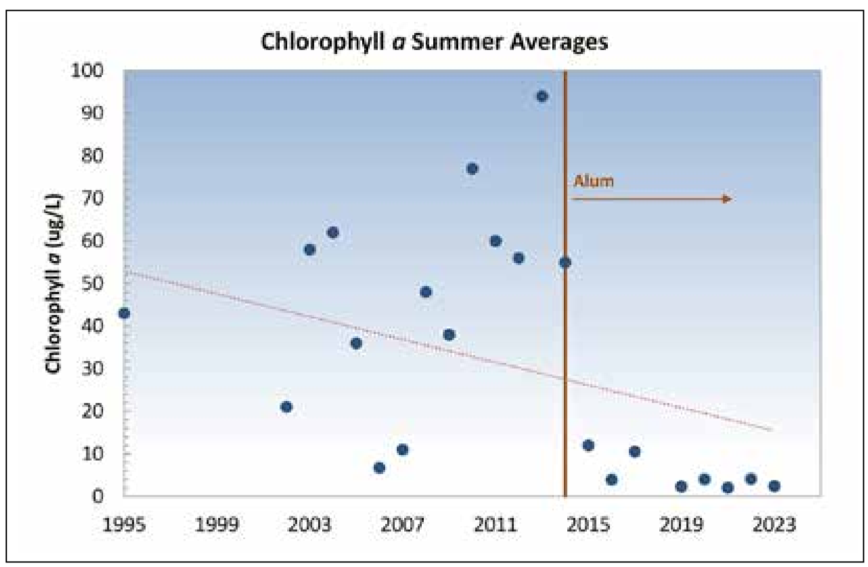


Figure 5. Lake Ketchum summer average chlorophyll, 1994-2023.

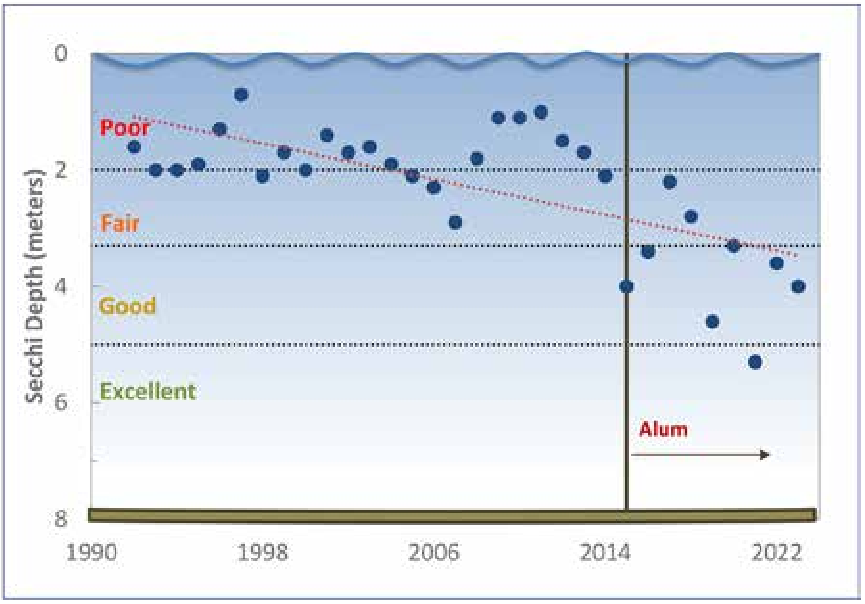


Figure 6. Lake Ketchum summer average water clarity, 1992-2023.

phosphorus using alum is both safe and effective.

Ecological improvements

Not only have toxic algae blooms disappeared from Lake Ketchum, but the overall food web dynamics of the lake have dramatically changed (Snohomish County 2024). Cyanobacteria are just one of several types of phytoplankton that form the base of the lake food chain. Compared to other phytoplankton species, cyanobacteria are largely inedible to zooplankton. Healthy zooplankton are important as they are the tiny animals consumed by fish and other aquatic organisms.

Since the alum treatments began, there has been a substantial reduction in cyanobacteria and a shift towards more desirable algal species (Snohomish County, 2024). The June to October average cell counts of cyanobacteria plunged from 25,547 cells/mL pre-treatment to 5,889 cells/mL in the first three years following treatment (Figure 7). In that same period phytoplankton diversity increased with the unique number of genera identified increasing from an average of 34.2 genera pre-treatment to 46.3 post-treatment. Overall, the phytoplankton community is more diverse with higher levels of desirable algae such as diatoms and green algae.

Changes in phytoplankton corresponded to a change in the zooplankton structure in the lake as well (Snohomish County 2024). While the pre-treatment data are limited to 2012-2013 for zooplankton, the lake was largely dominated by rotifers which rely heavily on organic particles and bacteria. Post-treatment the dominant zooplankton organisms transitioned to phytoplankton-grazers including copepods and cladocerans, which provide an important food source for fish.

Not only have restoration efforts improved the microscopic ecosystem, but also the lake's macrophyte community. Prior to the restoration efforts, the lake was a heavily algal dominated system with such heavy blooms that light was restricted, preventing the growth of most submergent aquatic plants. The state conducted a survey in 2010 and found only one small patch of rooted aquatic plants in the entire lake (https://apps.ecology.wa.gov/lakes). Even macroalgae such as Chara were absent. A follow up survey in 2019 showed the plant community had begun to rebound with four species of submergent plants found throughout the lake (Figure 8).

Unfortunately, there was not a pre-treatment survey to understand the impacts of the alum treatments on the fish community. However, not only has the zooplankton community improved, but summer dissolved oxygen conditions throughout the lake are more favorable for fish. Prior to alum treatments, much of the lake water column (any waters deeper

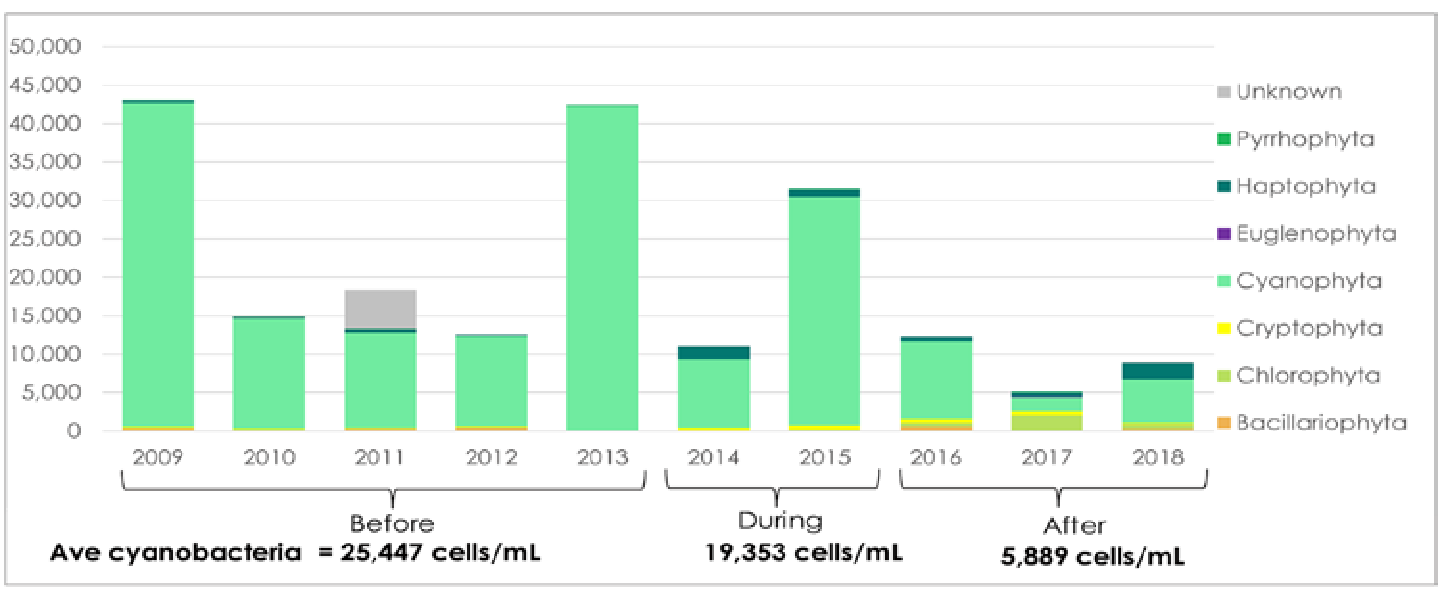


Figure 7. Lake Ketchum phytoplankton average annual cell count by algal group, 2009-2018 (June-October).

than 3 m) had very low dissolved oxygen concentrations and at times were completely anoxic. Much more telling is the happiness of anglers, which has certainly improved with the lack of constant toxic algae warnings.

Overall, the substantial changes in lake health have once again allowed residents and lake users to enjoy the lake for swimming, fishing, and boating throughout the summer. The lake community has significantly invested in this restoration program, both in time and direct financial contributions, and are seeing returns in their ability to enjoy the lake, increased property values and a closer lake community (Figure 9).

Future outlook and next steps

Despite the success of the Lake Ketchum restoration program, the work is not yet done. The inlet TP concentrations remain high causing annual winter spikes in lake phosphorus. Left untreated, the additional phosphorus each year is substantial enough to support frequent summer algal blooms as demonstrated in 2020 when the treatment was delayed. Without the annual alum treatments, it can be assumed that the chlorophyll concentrations in the lake would increase over the summer and there would be large, potentially toxic, blooms of cyanobacteria.

So, for now, the small annual alum treatments will continue into the foreseeable future. Someday, inlet concentrations may decrease enough to reduce the frequency or lower the dose of the annual treatments. A new landowner of the farm may also bring about future opportunities to work directly with the contaminated soils to reduce total phosphorus loading to the stream. In the meantime, there will be an ongoing financial commitment for the community, yet it is a comparatively small price to pay for a healthy toxin-free lake.
To learn more about the project visit https://snohomishcountywa.gov/2451/.

Figure 8. Resurgence of native aquatic plants following implementation of Algae Control Plan.

Figure 9. Lake Ketchum after implementation of Algae Control Plan.

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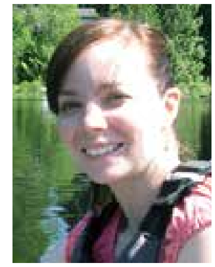
Shannon Brattebo has been an environmental engineer and limnologist for Tetra Tech, Inc. in Washington State since 1999. Shannon's work has focused on lake and reservoir water quality, restoration, and management both in the Pacific Northwest and across the nation. Shannon has B.S. in Civil/Environmental Engineering from Seattle University and an M.S.C.E in Civil/Environmental Engineering from the University of Washington. Shannon has been a member of NALMS since 2001 and is a current board member and past secretary of the Washington Lakes Protection Association (WALPA). Shannon is the current Treasurer of NALMS and was also a past Region 10 NALMS Director (2015 – 2018).

Marisa Burghdoff leads Snohomish County lake management program where she works on lake water quality and toxic algae monitoring, lake studies and restoration projects, invasive plant control and behavior change outreach programs. Marisa has a BS in biology from the University of Michigan and a Master of Science in Environmental Science and Master of Public Affairs from Indiana University. Marisa has been a NALMS member since 2004 and is a current board member and past president of the Washington Lakes Protection Association (WALPA).

Jen Oden has been working with Snohomish County, Washington's Lake Management Program for twelve years. In this role, she coordinates a volunteer monitoring program, manages water quality databases and implements lake restoration and invasive aquatic plant management projects. Jen has a BS in environmental science from Oregon State University. Jen has been a NALMS member since 2013 and is past president of the Washington Lakes Protection Association (WALPA).



Student Corner

Kaitlyn Button

Restoration efforts respond to climate change conditions in the Duck Harbor Basin of the Herring River, Wellfleet, MA

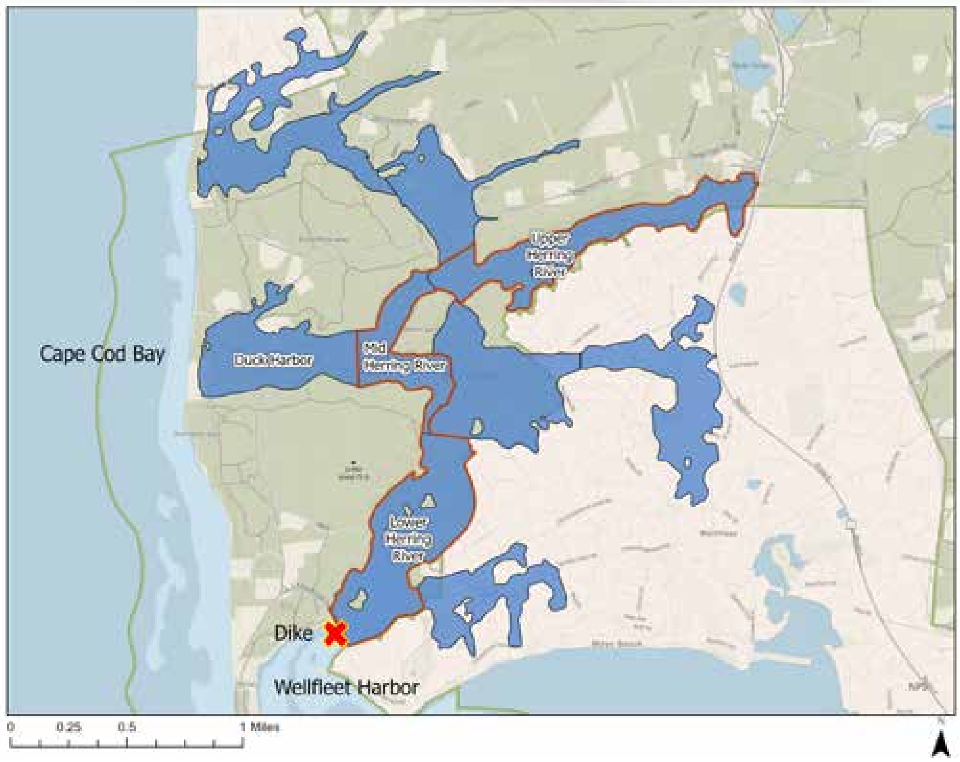


Figure 1. The 1,000-acre Herring River watershed was diked off from the Wellfleet Harbor in 1909 (blue). The red "X" represents the location at the mouth of the river where the historic dike currently exists. The main stem of the Herring River is outlined in orange. In addition to the main stem, the Herring River system contains several tributaries and sub-basins, including the Duck Harbor basin adjacent to Cape Cod Bay.

Introduction

While once thought of as wastelands, climate change has highlighted the social and economic importance of resilient salt marshes. Healthy salt marshes function as natural barriers to sea-level rise and storm surges, store carbon, and offer recreational opportunities to the public. Across New England, there has been an increase in efforts to restore the hydrologic function in degraded salt marshes that have been physically impacted by freshwater impoundments such as historical dikes and dams. One of the largest restoration efforts in New England to revive an impaired tidal salt marsh takes place in the Herring River in Wellfleet, Massachusetts. The Herring River watershed is in the towns of Wellfleet and Truro, Massachusetts, and spans 1,100 acres inside and outside the boundaries of Cape Cod National Seashore.

The Herring River watershed is dynamic in nature and consists of an interconnected ecosystem that begins at the headwater freshwater kettle ponds to estuarine tributaries that eventually converge with the saline waters of Wellfleet Harbor. The diverse ecosystems within the Herring River watershed provide crucial habitat for diadromous fish species, like alewife (*Alosa pseudoharengus)* and American eel (*Anguilla rostrata*), that use the Herring River corridor to complete their life cycles.

In 1909, a dike was constructed across the main stem of the Herring River that muted saltwater exchange from Wellfleet Harbor into the upper reaches of the river (Figure 1). In effect, the tidal exchange has been reduced from 10.3 feet on the seaward side to 2.2 feet on the upstream side of the dike (Mullaney et al. 2020). In response to the limited pulsing of saltwater upstream, the once expansive salt marsh transitioned into freshwater wetland and coastal forest habitat and conditions slowly degraded. The restricted tidal flushing has had adverse impacts on the upper Herring River that include increased fecal coliform bacteria, decreased water quality, impaired conditions for fish passage, increased mosquito habitat, and altered watershed plant communities (Mullaney et al. 2020, Portnoy and Allen 2006). Since 2003, the Herring River has been officially designated by the Environmental Protection Agency as an "impaired" system under the Clean Water Act.

In response to the degraded ecological function of the watershed, Cape Cod National Seashore (National Park Service) issued a Final Environmental Impact Statement and Record of Decision in 2016 (National Park Service 2016) to implement the Herring River Restoration Project. The goal of the Herring River Restoration Project is to replace the historical dike with a new bridge equipped with adjustable tide gates to gradually reintroduce saltwater into the now freshwater portions of the estuary. The restored tidal exchange will revitalize the ecological functions of the Herring River, including the herring run it is named after, and create an opportunity for scientists to study the ecological response of the watershed as conditions change.

The dynamics of Duck Harbor Beach, Wellfleet, MA

The Herring River watershed comprises multiple subbasins and includes the Duck Harbor Beach basin adjacent to Cape Cod Bay in Wellfleet, Massachusetts (Figure 1). As the name historically implies, Duck Harbor was once a harbor. Hand-drawn maps dating back to 1856 provide evidence that Duck Harbor was previously connected to Cape Cod Bay and included a tidal river system that traveled further landward (Baptista and Shumway 1998). Over time, the harbor mouth closed, and 3- to 5-meter-high dunes formed a protective barrier from Cape Cod Bay. As the barrier dunes developed, the low-lying basin behind the dunes transitioned from a salt marsh community to a mix of wetland shrubs and upland forest dominated by pitch pine (*Pinus rigida*).

In the fall of 2020, anecdotal reports of a tidal breach in the Duck Harbor dunes adjacent to Cape Cod Bay were reported and became evident by the winter of 2020 into 2021. As a result of rising sea levels in the adjacent Cape Cod Bay, the tidal breach allowed seawater from the bay to overwash and naturally inundate the low-lying wetland behind the dunes. Once the seawater overwashed into the Duck Harbor basin, the seawater flowed into the immediately adjacent freshwater portions of the Herring River through dilapidated mosquito ditches. The influx of seawater into the Herring River was detected on data loggers over a mile away from the breach and recorded the shift from oligohaline (0.5-5 ppt) to mesohaline (5- 18 ppt) and polyhaline (18-30 ppt) conditions (Figure 2). Since the initial breach reports, monthly higher high tides repeatedly overwash Duck Harbor beach and saltwater from Cape Cod Bay enters the upper Herring River and eventually exits out the dike.

Aside from instrumentation, the ecological response to saltwater pulsing became evident in the Duck Harbor vegetation composition. As the wetland shrubs and pitch pines were not able to recover from the repeated saline conditions, opportunistic salt marsh species began to colonize the basin beneath the remnants of the pitch pine forest. In a proactive effort to accelerate the recolonization of early successional salt marsh species in the basin, the dead standing pitch pines were manually cleared in the winter of 2023 and the wood chips were used as a substrate for the future marsh platform. Once light was able to penetrate the basin floor, early marsh colonizers, like sea blite (*Suaeda sp.)*, dominated the basin within the first growing season to begin the foundation for a hopeful trajectory toward self-sustaining salt marsh habitat (Figure 3). In addition to the immediate biological response of the plant community, American eels have been documented within the main marsh channel that transports seawater across the Duck Harbor basin.

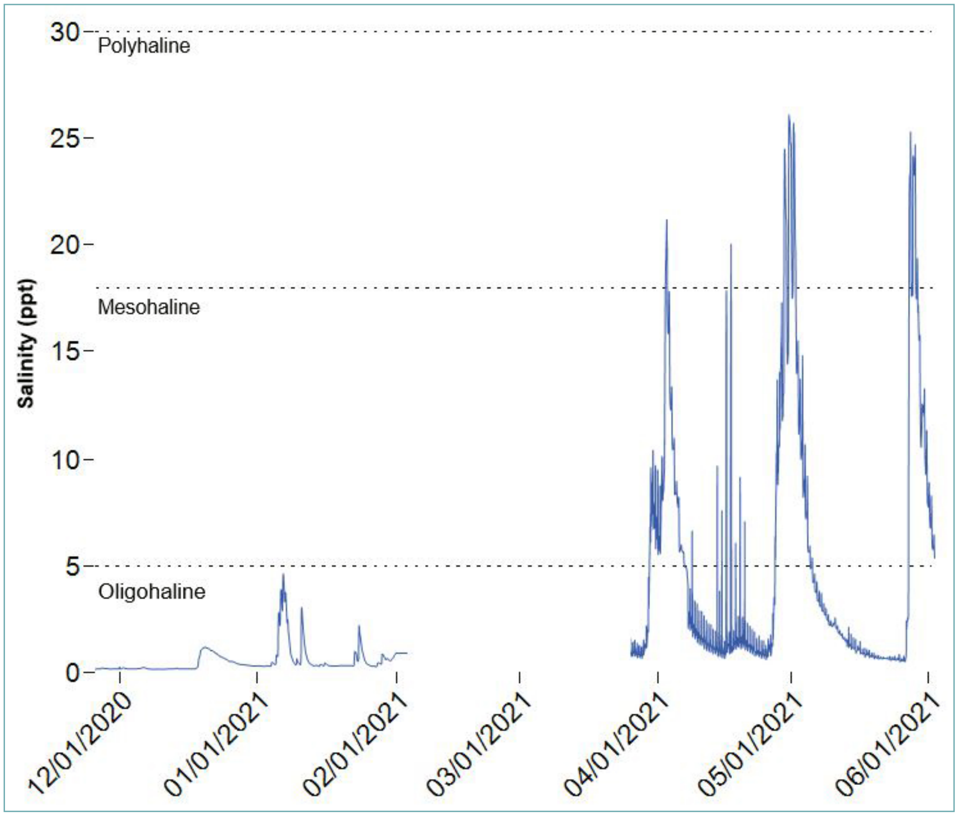


Figure 2. A continuous data logger within the Herring River initially detected the Duck Harbor tidal breach in December 2020 into February of 2021. In April 2021, the changes in salinity (ppt) from oligohaline to mesohaline and polyhaline during overwash events were evident within the Herring River Main stem.

Despite the introduction of saltwater from Duck Harbor into the Herring River, the overwash events are not associated with the Herring River Restoration Project. Instead, the Duck Harbor tidal breach creates a unique opportunity for scientists and collaborators to assess climate change impacts, such as sea level rise, on the Herring River system.

Macroinvertebrates as bioindicators

While the transition from a pitch pine forest to an early successional salt marsh is very visible to the naked eye, what happens to the communities that we cannot see such as benthic macroinvertebrates? Benthic macroinvertebrates are small aquatic organisms like worms, clams, and insect larvae that dwell on the river bottom. Macroinvertebrates are important because they play a key role in nutrient cycling, food web interactions, and can be used as bioindicators of water quality health. Although macroinvertebrates are widely used as bioindicators of water pollutants in streams, the impact of restored tidal flow on macroinvertebrates represents a gap in scientific literature.

Due to the importance of benthic macroinvertebrates in national water quality assessment standards, there is an


Figure 3. (Left) Low-lying wetland shrubs in the Duck Harbor basin in 2021 prior to the manual removal of trees. (Right) Early colonization of seablite in the first growing season in the Duck Harbor basin post manual removal of trees.

interest in the scientific community to determine the lethal and sublethal thresholds of saltwater influxes to freshwater macroinvertebrates. One challenge when assessing macroinvertebrates is the taxonomic level to which specimens are identified. In some instances, sensitive macroinvertebrate orders, such as mayfly larvae (Ephemeroptera), are known to include salt intolerant genera that may be missed when studies are identified to the higher order classification (Timpano et al. 2018). In further complexity, tolerance of taxa to saltwater can differ based on geographic region that speak to the need for macroinvertebrate studies in localized habitats such as the Herring River watershed.

Understanding the tolerance of taxa to saltwater intrusion is especially important in climate change scenarios where sea level rise and natural berm breaching can result in intrusion of saltwater into freshwater aquatic habitat. Sometimes this can unexpectedly precede planned management efforts. Climate change scenarios such as the tidal breach at Duck Harbor in Wellfleet, MA, create pertinent opportunities for scientists to better understand salinization impacts on freshwater macroinvertebrates, especially if baseline data already exist.

In anticipation of the ecological structure of the Herring River watershed changing, Cape Cod National Seashore implemented an adaptive management monitoring program in addition to hydrodynamic models to monitor baseline conditions in the system before and after the dike is removed and tidal flow is restored. The baseline monitoring occurred in 2013-2015 and included over 50 spatial locations located downstream of the dike that extended into the freshwater portion of the Herring River system. The purpose of this project was to document the spatial distribution of benthic macroinvertebrates, among other variables, within varying salinity gradients prior to restored tidal flow.

Future macroinvertebrate research in the Herring River

To better understand the recent impact of the Duck Harbor tidal breaches on the freshwater segments of the Herring River, a study is currently being undertaken to observe how intermittent fluxes of seawater affects the freshwater macroinvertebrate community in comparison to baseline data. In August of 2023 macroinvertebrates and water quality readings were collected at a subset of the baseline sampling locations at three salinity strata in the Herring River (Figure 4). The sampling locations were divided into three categories to include the Duck Harbor tidal breach impact zone, one marine reference zone, and one freshwater reference zone. The results from this project will provide insight on the biological response of

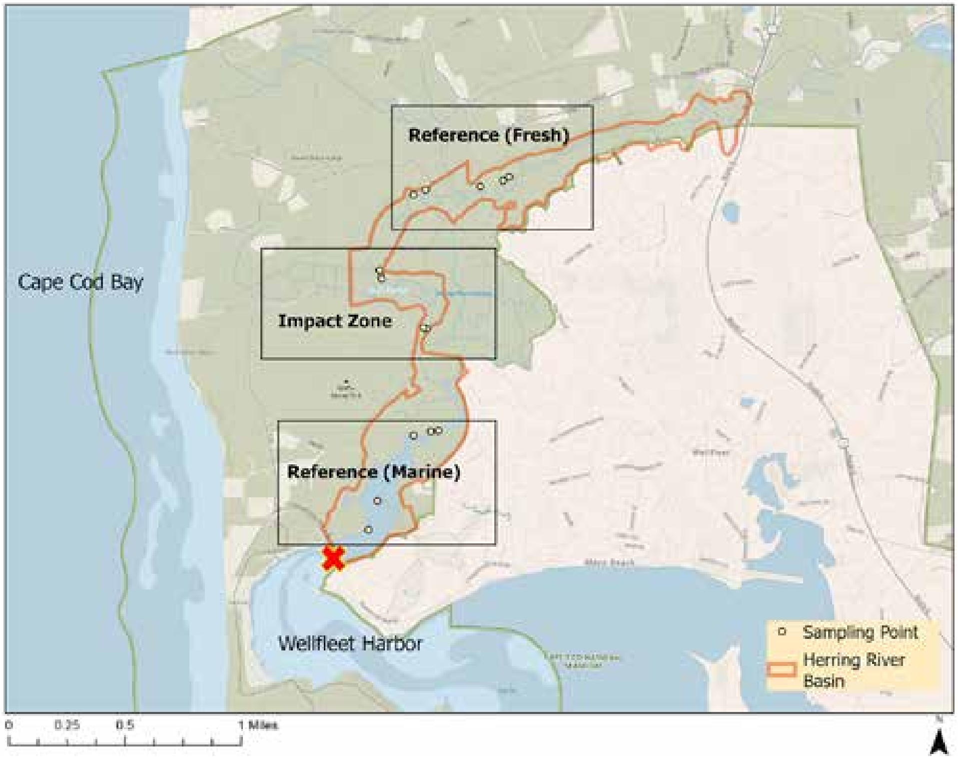


Figure 4. The location of 15 sampling points surveyed in August of 2023 for macroinvertebrate and water quality readings. The sampling locations were located throughout the marine reference zone, the Duck Harbor impact zone, and the freshwater reference zone.

macroinvertebrate community to partial tidal restoration as a result of the Duck Harbor tidal breach in the Herring River. On a larger scale, the results can inform the model and management on what to expect when the full tidal exchange is restored to remaining portions of the river.

Conclusions

In response to increased sea levels in Cape Cod Bay, a tidal breach formed at Duck Harbor Beach in Wellfleet, MA, in the winter of 2020/2021 that resulted in the intrusion of seawater into the low-lying basin and freshwater portions of the Herring River. Cape Cod National Seashore proactively responded to the repeated overwashes by manually removing salt-killed vegetation to accelerate the recolonization of early successional salt marsh species. The immediate response of the plant and biological community within the basin provides hope for the return of a functional salt marsh. Although the return of the salt marsh plant community allows the basin to appear as a salt marsh, how can we determine if the restored area will function like a salt marsh too? These functions can be measured by the chemical and physical response of the salt marsh that are imperative for ecological functions and long-term success in the Duck Harbor basin. The National Park Service has teamed up with U.S Geological Survey and local scientists to assess the cumulative responses and changes in the Duck Harbor system to include variables such as macroinvertebrate structure, nutrient loading, and geomorphology of the overwash. In effect, these successful partnerships create a unique opportunity to collect data at different scales and share research findings that can offer solutions in response to climate change impacts.

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Kaitlyn Button is currently finishing her Master of Science degree innatural resource conservation at Paul Smith's College. In her most recent role as a biological science technician at Cape Cod National Seashore, she has monitored coastal aquatic resources, including the Herring River, for the past four years. She is interested in learning how climate change scenarios like increased water temperatures and sea level rise impact natural resources within the National Seashore and other protected lands. Her final master project focuses on the impact of saltwater intrusion on freshwater macroinvertebrates in the Herring River, Wellfleet, MA.

"Lakespert" – Is continuous, in-lake monitoring a gadget or a backup camera?

When it comes to lake management and lake rehabilitation projects, we like to be in the now. We gather water quality data to see if our efforts mattered. One way to do this is with continuous, in-lake sensors. Sonde companies have been developing and selling monitoring pieces of equipment that collect real-time data and load it to "the Cloud" for a few years now. My question, besides what really is "the Cloud," is when is it appropriate, helpful, or worth the time and money to collect minute-by-minute water quality data for a lake? Is this a form of gadgetry that most lakes don't need, or will it be like our car's backup camera and become essential to our daily lives?

In early March, I helped install a couple of buoyed, monitoring stations (inlet and outlet) in a reservoir that I regularly sample. These pricey devices collect 1-meter data (water temperature, pH, and dissolved oxygen) every 30 minutes and upload to the Internet every 12 hours. At first, I thought this was a great idea and quickly found another reason to log on to a website more often than I needed to. Don't get me wrong. The graphs are amazing. It is interesting to see the difference between the locations and the diurnal swings. But I still find myself asking the why question.

We are more than ever a technologically driven society with our updating apps on our aging smart phones from 2021, and drones that can do just about anything (even collect lake samples). As lake managers and rehabilitators, we need to make sure we are collecting the right data and the right amount of data. For my routine lake monitoring program, the data are used for lake standards assessment. Now we have data around the clock for two separate locations. I don't think I can use 2:00 a.m. inlet pH data for assessment purposes. So, what can I use all this data for?

High frequency data does show how conditions change during the night, which is when I am typically sleeping. Remote monitoring does cut down on driving time and emissions. I have an oxygen sensor that can now tell me exactly when the hypolimnion goes anoxic. I know weather and algae can change by the minute, and it is interesting to see how the lake responds in a prompt fashion.


Long-term deployment buoy with telemetry. Monitoring equipment are fixed at 1-meter and about 8-meter depths to collect data every 30 minutes. The data is uploaded to a website every 12 hours.

I will say that continuous, in-lake data is not helpful for standards assessment. It's data overload with plenty of room for misinterpretation. It's like having a fancy watch on your wrist (a gadget for most) that monitors your heart all day long. That's interesting and all, but your visits to the doctor are when they collect your important vitals.

I just don't want to get caught up in gadgetry. Then it defeats the purpose. At the same time, I don't want to be the old timer that doesn't keep up with the times. My kids would laugh at me when I looked over the shoulder as I backed the new family car down the driveway. Fast forward five years, and it seems I can't live without a backup camera. When does a gadget become a necessity and is that subjective?

To wrap up, make sure you are collecting the right data and the right amount. Do it because it helps and not because it is a novelty. Once you think it through, then you can decide just how advanced you want to get with in-lake monitoring.

Steve Lundt, Certified Lake Manager, has monitored and worked to improve water quality at Barr Lake (Denver, Colorado) for the past 19 years. Steve is active with the Colorado Lake & Reservoir Management Association and is a past Region 8 director for NALMS and an active member since 1998.