Lake water quality and sediment internal phosphorus loading response to alum treatments in Half Moon Lake, Wisconsin

PROPOSAL OF RESEARCH

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Benefits of monitoring water quality and sediment trajectories during alum treatment management

1. Multiple management approaches over the last 20 years have led to substantial improvements in water clarity, reduced internal phosphorus loading, lower cyanobacteria biomass, control of nuisance Curlyleaf Pondweed and Eurasian Watermilfoil, and increased recreation and enjoyment of the lake.

2. While alum treatments have been effective in controlling internal phosphorus loading, additional applications will probably be needed in 2026 and 2028 to continue to immobilize the mobile phosphorus pool in the sediment.

3. Continued water and sediment chemistry monitoring will be important in making adaptive management decisions to address any future changes in lake condition.

4. This proposal provides an outline of essential monitoring needs for Half Moon Lake 2025-2030.

Background

The overall management goal for Half Moon Lake has been to improve water quality to State of Wisconsin standards and increase water clarity to promote the re-establishment of healthy native submersed macrophyte communities. Strategies to accomplish this goal have been two-fold: 1) reduce infestations of canopy-forming CLP and EWM and 2) control internal P loading from sediment to limit cyanobacterial productivity and improve underwater PAR condition. First, gas-powered

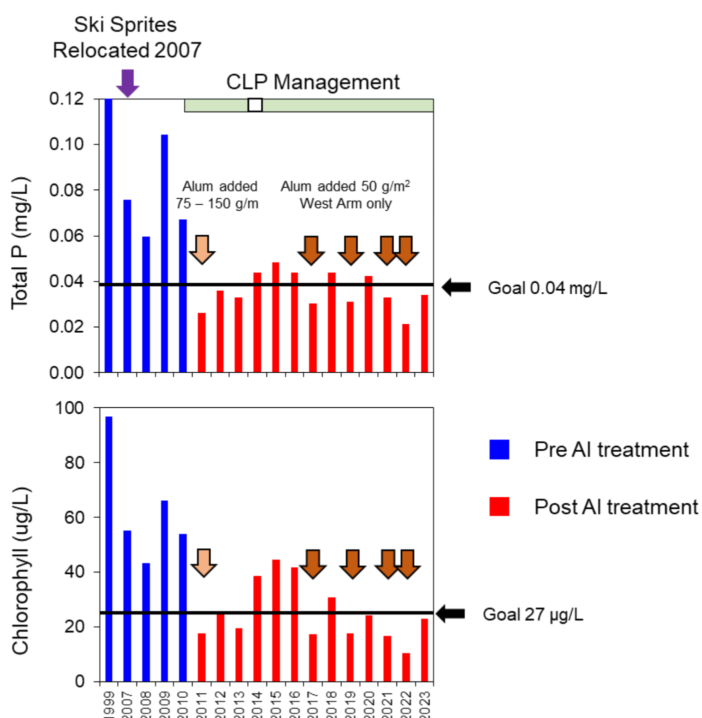

Figure 1. Management timeline for Half Moon Lake

motorboat activity was restricted on the lake in 2007 to reduce P resuspension and internal P loading (Fig.1). Second, as part of previous Aquatic Invasive Species (AIS) Control Grants, shading and P recycling caused by CLP decomposition have been addressed by annual early spring herbicide (Endothall) treatments during the years 2009-2013 and 2015-2023 to selectively target this species with minimal impact to native plants (Netherland et al. 2000, Poovey et al. 2002, Skogerboe et al. 2008; Johnson et al. 2012). Similar selective control of EWM was also accomplished in 2009 under the grant. Finally, Internal P loading from sediments has been managed in June 2011 (whole lake treatment) and June 2017, May 2019, June 2021, June 2022, and July 2024 (west arm sediments only) via application of buffered alum-aluminate, to drive algal productivity toward P-limited growth and increase light penetration for native macrophyte communities.

To assess and evaluate water quality and native macrophyte community response to these management measures, extensive limnological monitoring has been conducted between 2008 and 2024. In situ (i.e., temperature, dissolved oxygen, pH, and conductivity) measurements, phosphorus, and chlorophyll were monitored at six stations in the lake between 2008 and 2024 to assess improvement in underwater light habitat for comparison with the native macrophyte community response (Figure 1). Urban watershed P inputs from selected storm sewers draining portions of the City of Eau Claire have been monitored to assess the impacts of BMPs on P loading to the lake. Sediment cores were collected at 2 stations (station 10 and 30) annually between 2008 and 2023 to evaluate the impacts of the Al treatment on sediment mobile P pools (i.e., P fractions related to recycling and diffusive flux) and rates of diffusive P flux from anaerobic sediment. Finally, macrophyte species biomass and frequency of occurrence have been monitored in June and August of

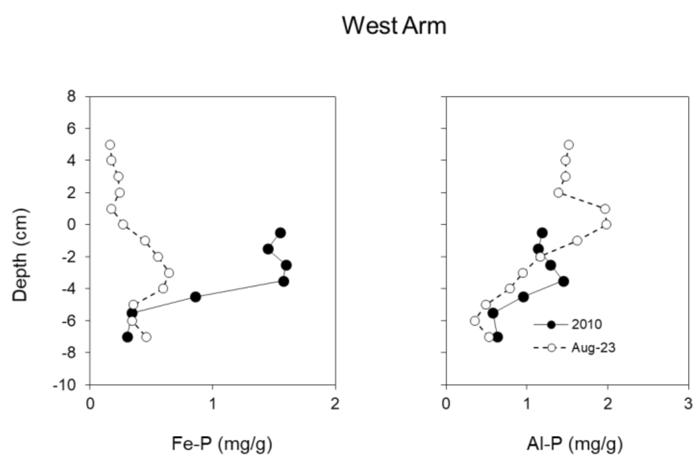

Figure 2. Variations in sediment iron-bound phosphorus (left panel) and aluminum-bound P (right panel) for west arm sediments before alum application (2010) and as of 2023, after 4 alum applications to the west arm of the lake.

each year using point-intercept sampling techniques to evaluate the effectiveness of the herbicide treatments in controlling CLP and EWM and to quantify native macrophyte community response to changes in water quality and management of the targeted invasive species. Description of methods and results of these monitoring efforts can be found in James (2023).

Al treatments, particularly to the west arm, have been effective in reducing iron-bound P (the sediment fraction most related to internal P loading, Fig. 2). Iron-bound P concentrations in the surface sediments of the west arm have declined substantially from pretreatment maxima of 1.6 mg/g, among the highest sediment iron-bound P concentrations in the State of Wisconsin (Fig. 2). Aluminum-bound P, reflecting P bound to the alum floc layer, has increased substantially, indicating binding of P diffusing from sediment below this layer. Laboratory-derived anaerobic

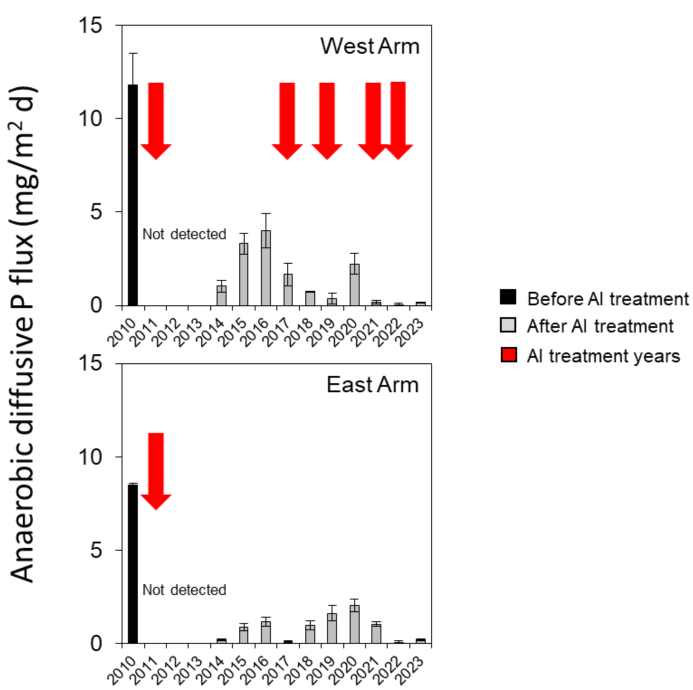

Figure 3. variations in anaerobic P flux from sediments before and after alum application.

diffusive P flux from west arm sediment has been effectively controlled by successive Al treatments (Fig. 3). Anaerobic diffusive P flux from east arm sediments, which exhibited much lower historical iron-bound P concentrations compared to the west arm, has been effectively controlled as of 2023 by the 75 g/m^2 Al treatment that occurred in 2011(Fig. 3).

Even though Al treatments have been effective in controlling diffusive P flux under anaerobic conditions, the re-emergence of algal species that have resting stages in the sediments is still a concern. Germination of algal resting spores, cysts, and akinetes residing in the sediment, luxury uptake of P in the sediment porewater, and inoculation of the water column provides a potential mechanism of direct access to sediment P. Mean JUL-SEP chlorophyll concentrations have generally met target goals of < 27 μg/L during treatment years but still exceed this target during nontreatment years (Fig. 1). This pattern suggests that although substantially reduced by the alum applications, the mobile sediment P pool still represents a source to cyanobacteria growth. Continued P binding in the Al floc should reduce this P source to algal resting stages over time and the magnitude of algal blooms derived from sediment germination.

Half Moon Lake is an important resource to the City of Eau Claire and City government and citizens have invested in lake management and improvement for over 20 years. The lake is scheduled for possible 25 g/m^2 alum applications to the west arm sediments in 2026 and 2028 on an as needed basis. Continued limnological monitoring of Half Moon Lake through this period (2025 through 2030) will be critical in gauging water quality trajectory response to management and the need for future maintenance to preserve improvements. Analogous to City infrastructure and operation, periodic maintenance will be needed when State of Wisconsin water quality standards are not met. Continued monitoring will provide important information for future decision-making purposes regarding the need for management. The objective of this proposal is to outline baseline monitoring needs for Half Moon Lake to evaluate water quality and sediment internal P loading on an annual basis.

Approach

Lake Water Quality Monitoring and Evaluation

WQ stations 10 and 30 will be visited biweekly from June through September for measurement of temperature, dissolved oxygen, pH, conductivity, and Secchi transparency (Fig. 4). In situ variables will be collected at 0.5-m intervals using a YSI 6600 WQ monitor (Yellow Springs Instruments).

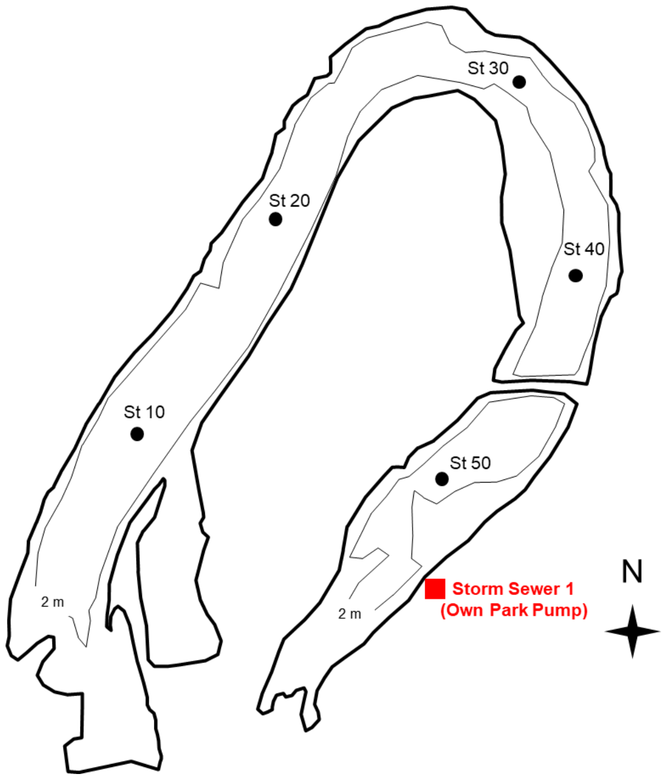

Figure 4. Lake water quality station locations in Half Moon Lake.

A 1-m integrated sample will be collected for analysis of water chemistry. Samples will be analyzed for total phosphorus (P), soluble reactive phosphorus (SRP), and chlorophyll (Table 1). Total P will be predigested with potassium persulfate in an autoclave and analyzed via the ascorbic acid method (APHA 2020). Samples for chlorophyll will be filtered through a glass fiber filter, extracted in 90% acetone, and analyzed on a Turner Designs fluorometer.

Table 1. Limnological variables
Water temperature
Dissolved oxygen
pH
Conductivity
Total phosphorus
Soluble reactive phosphorus
Chlorophyll

Sediment Chemistry and Internal Phosphorus Loading

Sediment cores will be collected at station 10 and 30 during the summer for determination of sediment P fractions and rates of P flux under anaerobic conditions. A core from each station will be sectioned at 1- to 2.5-cm intervals for determination of loosely-bound, iron-bound, and aluminum-bound P using methods described in Hieltjes and Lijklema (1980), Psenner and Puckso (1988), and Nürnberg (1988). Additional subsamples will be dried at 105 °C to a constant weight and burned at 550 ^{o}C for determination of moisture content, sediment wet and dry bulk density, and organic matter content (Håkanson and Jansson 2002).

Three replicate cores will also collected at each station for determination of P flux from sediment under anaerobic conditions. The cores will be drained of overlying water and the upper 10 cm of sediment transferred intact to a smaller acrylic core liner (6.5-cm dia and 20-cm ht) using a core remover tool. Surface water collected from the lake will be filtered through a glass fiber filter (Gelman A-E) and 300 mL siphoned onto the sediment contained in the small acrylic core liner without causing sediment resuspension. Sediment incubation systems will be placed in the darkened environmental chamber and incubated at a constant temperature (20 ^{o}C). The oxidation-reduction environment in the overlying water will be controlled by gently bubbling nitrogen (anaerobic) through an air stone placed just above the sediment surface in each system.

Water samples for soluble reactive P will be collected from the center of each system using an acid-washed syringe and filtered through a 0.45 µm membrane syringe filter (Nalge). The water volume removed from each system during sampling will be replaced by addition of filtered lake water preadjusted to the proper oxidation-reduction condition. These volumes are accurately measured for determination of dilution effects. Soluble reactive P will be measured colorimetrically using the ascorbic acid method (APHA 2011). Rates of P flux from the sediment (mg/m^2 d) will be calculated as the linear change in mass in the overlying water divided by time (days) and the area (m^2) of the incubation core liner. Regression analysis will be used to estimate rates over the linear portion of the data.

Annual interim report

A results summary report with interpretation and suggested decisions regarding any management needs will be provided annually. In addition, email summaries of summer water quality conditions and any alerts will be sent biweekly to monthly during the summer.

UW-Stout cost breakdown							
Task	Analysis		Unit price ($)	Sampling: Events	Sample #	Sample total	Cost
Lake Limnology	Field Sampling		$350	8	1	8	$2,800
	Chemistry	Total phosphorus	$28	8	2	16	$448
		Soluble reactive P	$25	8	2	16	$400
		Chlorophyll	$30	8	2	16	$480
Sediment monitoring	Chemistry	Textural	$30	1	16	16	$480
		P fractions	$190	1	15	15	$2,850
	P flux		$560	1	6	6	$3,360
Reporting		Data reduction and interpretation	$100	1	10	10	$1,000
Total							**$11,800**