Stantec

Shingle Creek and West Mississippi 2023 Annual Monitoring Report

2023

April 2024

Prepared for:

Shingle Creek Watershed Management Commissions West Mississippi

Prepared by:

Katie Kemmitt
Grace Neumiller
Ali Stone

Contents

1.0 MONITORING PROGRAM

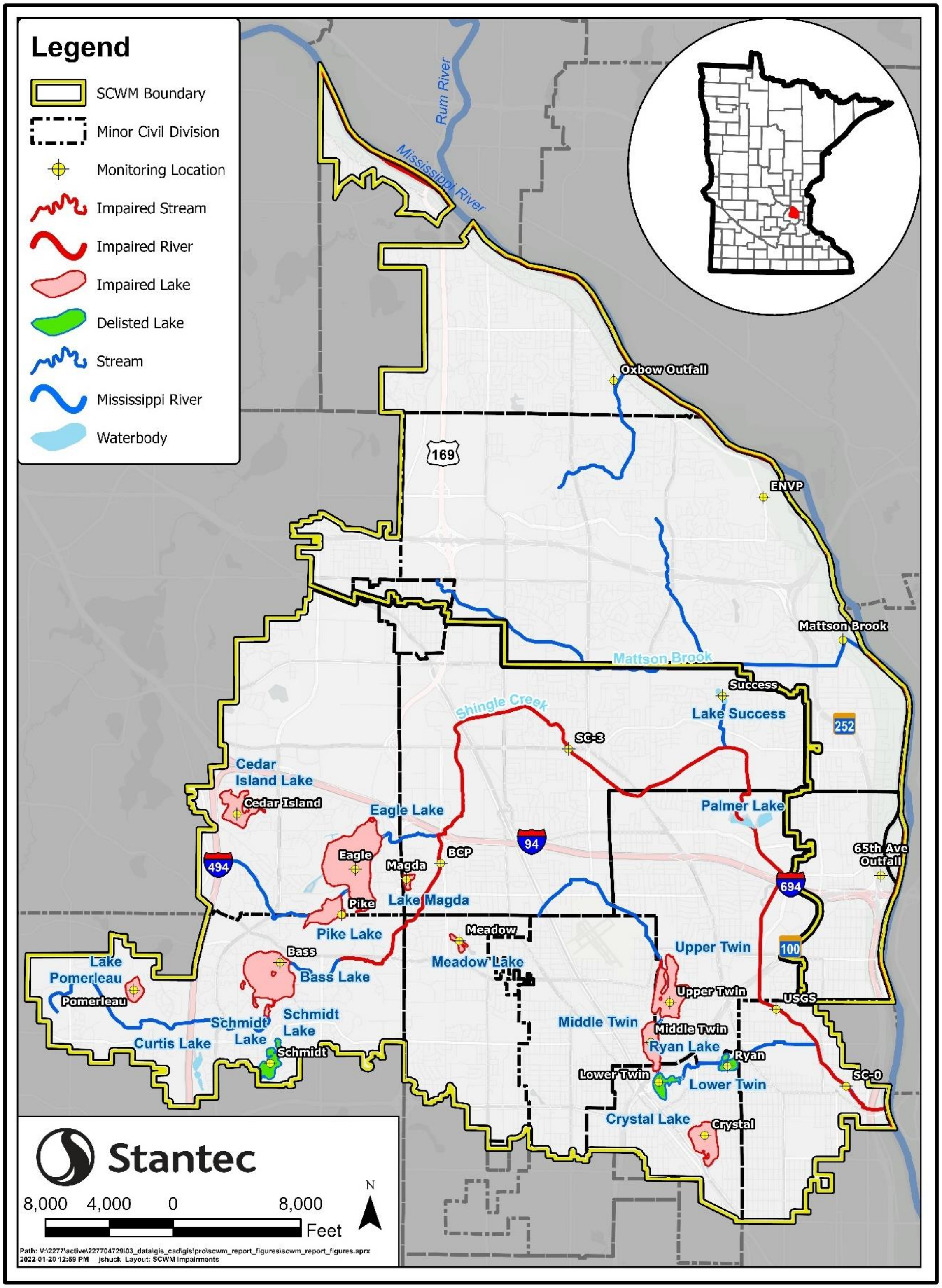
The Shingle Creek and West Mississippi Watershed Management Commissions annually monitor water quality in the lakes, streams, and outfalls of the watersheds. Data has been collected from Shingle Creek since 1996 and at West Mississippi River outfalls since 2010. In 2012, Shingle Creek expanded its volunteer-based lake monitoring program to start systematic detailed lake monitoring. The program has expanded to incorporate fish, macroinvertebrate, and aquatic vegetation monitoring in the lakes and streams. Student and adult volunteers collect additional lake water quality and stream macroinvertebrate data. A Water Quality report summarizing current and historic conditions in the watersheds has been published annually since 1998.

Surface water quality in the watersheds is typical of urban lakes and streams in the Twin Cities metropolitan area. Agriculture followed by urban development have changed drainage patterns, increased pollutants to the waters, and reduced habitat for aquatic and terrestrial life. Both Shingle Creek and Bass Creek do not meet state water quality standards for chloride, bacteria, and dissolved oxygen, and they have severely impacted fish and macroinvertebrate communities. Thirteen of the sixteen lakes were listed as Impaired Waters of the State because of their high concentrations of phosphorus. Diagnostic and feasibility studies completed between 2007 and 2011 have identified actions that can be taken in the watersheds to help improve water quality.

More than ten years since the diagnostic and feasibility studies, the results have been heartening. Three of the impaired lakes **now meet state standards** and have been removed from the list of Impaired Waters. Two other lakes now meet the standards and are scheduled for removal in 2024. Long-term stream water quality monitoring shows a **clear improvement** in suspended sediment and nutrient concentrations in both Shingle Creek and Bass Creek: a result of ongoing efforts to stabilize streambanks, increase the frequency of street sweeping, enhance erosion control on construction sites, and install Best Management Practices to treat stormwater before it is discharged into the streams. However, chloride concentrations in the streams, mostly from road salt applied in the winter for snow and ice control, continue to be high.

Why Do We Monitor?

- To quantify the **current status** of streams and lakes throughout the watershed and compare to water quality standards.
- To quantify **changes over time**, or trends, in stream and lake water quality
- To **identify problem areas** for potential BMPs
- To quantify the **effectiveness** of implemented BMPs throughout the watershed


Legend
SCWM Boundary
Minor Civil Division
Monitoring Location
Impaired Stream
Impaired River
Impaired Lake
Delisted Lake
Stream
Mississippi River
Waterbody
Rum River
Mississippi River
Oxbow Outfall
ENVP
Mattson Brook
Mattson Brook
Success
Lake Success
Shingle Creek
SC-3
Cedar Island Lake
Cedar Island
Eagle Lake
Palmer Lake
Eagle
Magda
BCP
Pike
Lake Magda
65th Ave Outfall
Pike Lake
Meadow
Meadow Lake
Upper Twin
Bass
Bass Lake
Lake Pomerleau
Pomerleau
Upper Twin
USGS
Schmidt Lake
Schmidt Lake
Middle Twin
Middle Twin
Curtis Lake
Schmidt
Ryan Lake
Ryan
Lower Twin
Lower Twin
SC-0
Crystal Lake
Crystal
Stantec
8,000 4,000 0 8,000
Feet
N

1.1 WHAT'S IN THE WATERSHED?

West Mississippi

- 25 square miles
- High impervious urban development (25%) and low-moderate impervious urban development (38%)
- 4 stream sites and 18.3 miles of streams
- No lakes, few wetlands

Middle Shingle Creek

- 15 square miles
- High impervious urban development (45%) and low-moderate impervious urban development (28%)
- 1 stream and 10.34 miles of streams
- 2 lakes: Success and Palmer

Upper Shingle Creek

- Headwaters of Shingle Creek
- 13 square miles
- High impervious urban development (28%) and low-moderate impervious urban development (26%)
- 3 streams and 16.2 miles of streams
- 8 lakes: Bass, Pomerleau, Schmidt, Cedar Island, Pike, Eagle, Magda, Meadow

Lower Shingle Creek

- Shingle Creek discharges to the Mississippi River
- 17 square miles
- High impervious urban development (71%) and low-moderate impervious urban development (8%)
- 2 streams and 18.9 miles of streams
- 5 lakes: Upper Twin, Middle Twin, Lower Twin, Crystal, and Ryan

1.2 2023 MONITORING

1.2.1 Stream Monitoring

Routine Flow and Water Quality: Three sites along Bass and Shingle Creek were monitored biweekly from April through October: near the stream's outlet to the Mississippi River in Minneapolis (SC-0); mid-watershed in Brooklyn Park (SC-3); and in Bass Creek (BCP) in the upper watershed. Winter chloride was sampled monthly from November through March at the three locations mentioned and the USGS gage site (SC-1). In the West Mississippi Watershed, Environmental Preserve (ENVP) was monitored monthly April through October, and 65th Avenue was monitored year-round.

River Watch: Stream macroinvertebrates are typically monitored by high school students at two sites on Shingle Creek through the Hennepin County River Watch program; however, the program has been affected by the COVID-19 pandemic. Shingle Creek at Park Center High School has been monitored for 24 years by science students from the school. Shingle Creek at Webber Park was monitored by students from Patrick Henry High School between 2001 and 2012, then in 2018, 2019, and 2021 by students from the Avail Academy. No River Watch monitoring occurred in 2023.

1.2.2 Lake Monitoring

Routine Water Quality: Water quality in Middle Twin Lake, Upper Twin Lake, and Meadow Lake was monitored biweekly from June through September as part of Shingle Creek's annual monitoring program. Aquatic vegetation was surveyed once in late spring and once in late summer on both lakes.

Staff finds Northern (Pike) while conducting fish survey on Schmidt Lake in 2019, Plymouth MN.

CAMP: Each year the Commission sponsors volunteer lake water quality monitoring through the Met Council's Citizen Assisted Monitoring Program (CAMP). Ryan, Lower Twin, and Schmidt Lakes were monitored in 2023.

Grant Projects: Meadow Lake was monitored for water quality three times in late summer/early fall. Meadow was scheduled for CAMP monitoring, but due to low water levels and trouble accessing the lake, CAMP volunteers were unable to collect water samples in spring and early summer. Meadow Lake underwent a drawdown in November 2021 to reduce fathead minnows and consolidate loose sediment. An aluminum sulfate (alum) treatment was applied to Meadow in 2023 to remove phosphorus from the water column.

2.0 PRECIPITATION

This summary provides an overview of findings and conditions in the two watersheds in 2023. A more detailed assessment and data are available in the technical appendices, which can be found at shinglecreek.org/water-quality.html.

Water quality in lakes, streams and wetlands is heavily influenced by precipitation and storm water runoff. 2023 was a dry, average year (Figure 1.2-a). Precipitation in 2023 in the Shingle Creek and West Mississippi watersheds was well below the historic average (1990-2022) in May-July and November, and well above the historic average (1990-2022) for January-March, September, October, and December. Total rainfall in 2023 was 37.8 inches, 4.6 inches above the historic average of 33.1 inches.

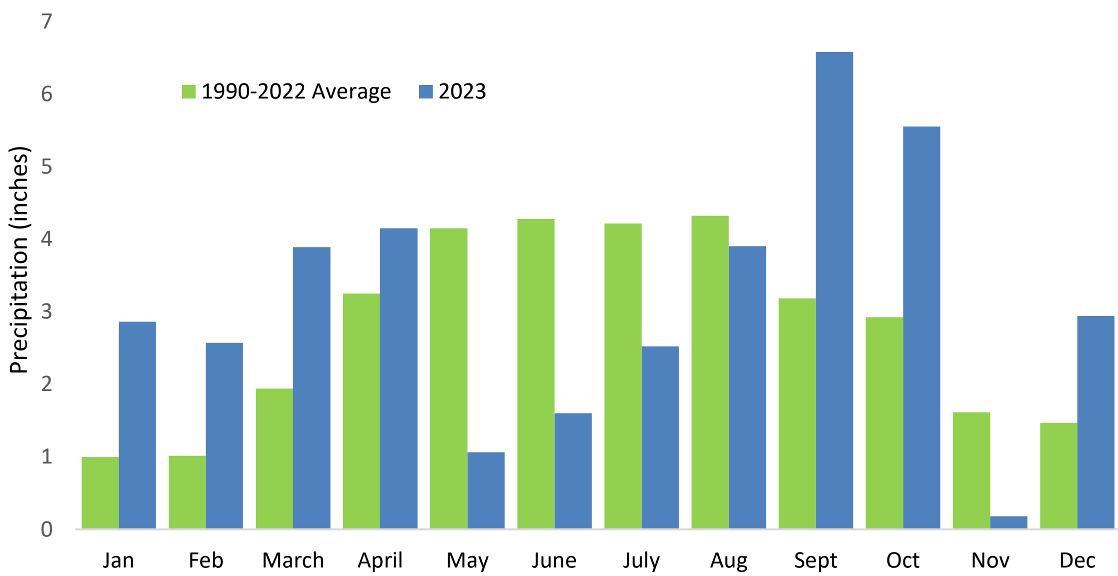


Figure 1.2-a. Monthly precipitation totals at the New Hope weather station for 1990-2022 (average) and 2023 (total).

3.0 STREAMS

Stream sites in Shingle Creek and West Mississippi Watersheds are monitored during normal, baseflow conditions (routine monitoring) and during rainfall events (storm monitoring) when flow is higher. Runoff during storms carries pollutants into the stream and can contribute to downstream water body impairments. Stream water quality during storms is often worse than during routine monitoring.

3.1 SHINGLE CREEK

Fluctuations in flow at all the monitored Bass and Shingle Creek sites (BCP, SC-3, SC-0) and at the USGS gage site were similar across sites. Fluctuations were largely driven by rainfall events in the watershed and significant snowmelt in April. 2023 was overall a wetter year compared to historic precipitation averages. However, May, June, and July were significantly drier than average, and September and October were significantly wetter than average (Figure 1.2-a). The increased rainfall in 2023 compared to the last three years runoff resulted in high TP and TSS loading to the watershed. Additionally, the snowy winter likely contributed to higher chloride loading due to additional salting events.

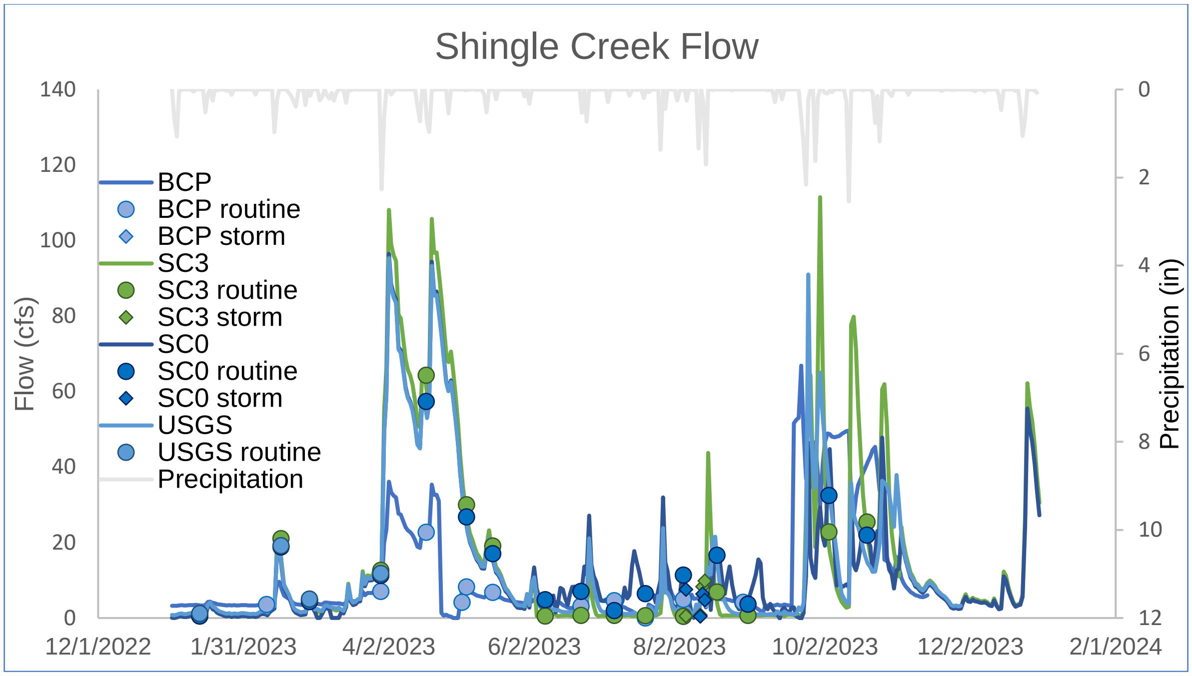


Figure 3.1-a. Flow, sample timing, and precipitation at monitored stream sites in the Shingle Creek Watershed during 2023.

Water quality at the Shingle Creek stream sites is generally worse during storm event monitoring (Figure 3.1-a). Average concentrations of E. coli, TP, and TSS during storm events were higher than during routine monitoring. Chloride samples were collected year-round but were highest during winter routine monitoring when road salt application occurs.

Annual pollutant loads of TP, TSS, and chloride were estimated for each monitoring site by multiplying the mean pollutant concentration by the annual volume of runoff at each site. Loads are highest near the Shingle Creek site SC-3, like due to flow being highest at this site. BCP has historically had the highest chloride concentrations, possibly resulting from its proximity to chloride discharge points near the road. Additionally, BCP is higher in the watershed, so there is less volume for dilution.

Table 3.1-a. Annual pollutant loads at each Shingle Creek routine monitoring site.

Site	TP Load (lbs/acre/year)	TSS Load (lbs/acre/year)	Chloride Load (lbs/acre/year)
BCP	0.21	10.9	431
SC-3	0.27	47.0	243
SC-0	0.11	16.7	100

4.0 LAKES

The Shingle Creek Fourth Generation Watershed Management Plan includes a rotating schedule of intensive monitoring on all lakes in the Shingle Creek Watershed. The primary purpose of the intensive lake monitoring program is to evaluate protection efforts for lakes that are not impaired, and to assess progress towards achieving the TMDLs and state water quality standards for all impaired lakes throughout the watershed. Activities in the intensive lake monitoring program include water quality monitoring, aquatic vegetation surveys, and fish sampling coordinated with the Minnesota Department of Natural Resources (DNR).

4.1 SAMPLING METHODS

4.1.1 Water Quality

Lakes are central to Minnesota's economy and are a valuable component of the ecosystem, making it imperative that we protect our high-quality lakes and work to restore those with poor water quality. The Minnesota Pollution Control Agency (MPCA) monitors and assesses lakes around the state to determine if they meet water quality standards. The agency relies on local partners, including soil and water conservation districts, watershed districts, tribal entities, nonprofit groups, and citizens to help monitor more than 10,000 lakes in the state. Shingle Creek Watershed Management Commission (Commission) is an active participant in aiding the MPCA with sampling and collecting information on the state of water quality of its lakes. The Commission is focused on sampling total phosphorus (nutrient), chlorophyll-a (a pigment in algae), and Secchi depth (a measure of water clarity). In addition to these parameters for water quality standard comparison, the Commission collects certain chemical and physical parameters on its lakes.

Routine lake sampling occurs on a rotating basis. For a lake that is selected for sampling in a given year, water samples are typically collected twice per month starting in May or June and ending in September. For all lakes, surface water samples are collected and assessed for total phosphorus (TP), soluble reactive phosphorus (ortho-P), total suspended solids (TSS), and chlorophyll-*a* (chl-*a*). In some of the deeper lakes, a hypolimnetic (deep) water sample is collected and tested for TP and ortho-P. In addition to these chemical parameters, a physical profile of the lake is assessed in the deepest part of the lake. A profile typically consists of water quality measurements at the water's surface and at each meter below the surface throughout the entire water column. A YSI or similar multimeter probe is used to collect these measurements. Parameters measured include dissolved oxygen (DO), dissolved oxygen percent saturation, temperature, pH, oxidation reduction potential (ORP), and specific conductivity. Additionally, a Secchi depth reading is taken during every assessment to record the relative water transparency.
Lake profiles are used to better understand the chemical and nutrient cycling processes occurring within the lake, in addition to stressors that may be contributing to biological impairments. The surface water chemical information is used for many reasons, such as comparison to the North Central Hardwood Forest (NCHF) ecoregion water quality standards established by the MPCA (Table 4.1-a).

Table 4.1-a. MPCA water quality standards for the NCHF ecoregion by lake type.

	Depth Class	TP (ug/L)	Chl-*a* (ug/L)	Secchi depth (m)
North Central Hardwood Forest	Deep	40	14	1.4
	Shallow*	60	20	1.0

*Shallow lakes are defined as those with maximum depths of 4.5 meters (15 feet) or less, or where 80 percent or more of the lake is littoral (≤ 4.5 meters).

4.1.2 Submersed Aquatic Vegetation

In healthy lake ecosystems, aquatic vegetation will grow throughout the littoral area (≤ 15 feet depth) and consist of a diverse native community (Figure 4.1-a). A well-vegetated littoral area promotes and facilitates the health of a lake's ecosystem by providing critical spawning, foraging, and nursery habitat for aquatic insects, amphibians, birds, and fishes. The littoral area is also important for human recreation and aesthetic enjoyment.

Figure 4.1-a. Biotic community health continuum portrayed using submersed aquatic vegetation.

4.1.3 Point Intercept Methods

To assess the presence, abundance, and health of the lake's aquatic vegetation community, two point-intercept surveys are typically conducted: an early season (May/June) and a late season (August) survey. During each point-intercept survey, all submerged, floating leaf, and emergent species are identified at each survey point. Early season surveys are primarily conducted to understand the presence and distribution of *Potamogeton crispus* (curly-leaf pondweed, CLP), an aquatic invasive species (AIS) with high spring growth and early senescence. Late season surveys target the greatest assessment of SAV (submerged aquatic vegetation) community, abundance, and spatial distribution because the community is ideally at peak diversity.

Point-intercept survey locations were replicated from previous surveys performed by Stantec and served as predetermined sampling locations for each lake. These points were originally developed by overlaying a grid across the entire lake according to the point-intercept methods presented in Madsen 1999. To limit sampling of vegetation where it is not expected to grow, all deep lakes within Shingle Creek are capped to a maximum sampling depth of 20 feet or more (lake specific), therefore, all sampling points in depths beyond the designated cap are removed from the sampling grid. Thus, the sampling protocol and reporting of each lake is similar, allowing comparisons to be made across systems and between years.

At each survey location a double-sided, weighted 14-tine rake was thrown from the boat, allowed to sink, and pulled across the lake bottom to represent approximately 1 square meter of lake area. We refer to this process as a rake toss. For each rake toss, vegetation is removed from the rake, identified to the species level, placed in a perforated bucket, weighed, and assigned a proportion of the total biomass based on visual approximation (e.g., 80% of total weight was CLP and 20% was coontail). All biomass values are reported in wet weights (kg). Emergent plant species, lily species, duckweed species, and filamentous algae are not included in any biomass measurements due to difficulty in collecting a representative sample with the sample rake. However, their presence and location are still recorded.

Continuous sonar readings were also collected during each survey trip using a Lowrance Elite 7 Sonar/GPS unit. This data was processed using CiBioBase (BioBase) software (https://www.cibiobase.com/) that allows for mapping water depth, bottom hardness, and plant biovolume. Biovolume differs from biomass in that it provides context to vegetation water column saturation. The higher the biovolume, the more saturated the water column is with vegetation. Sonar readings in depths <2 feet are subject to extreme 'sonar noise' and therefore are not always accurate. Sonar readings do not detect surface floating vegetation (i.e., pad of lily species, duckweed). BioBase interpolates sonar readings between boat tracks to estimate biovolume. Variation in boat tracks during surveys sometimes results in areas where biovolume cannot be estimated because boat tracks were not dense enough. There are a few cases of missing biovolume estimates in this report described in the results.

Point-intercept survey data can be used to calculate various survey metrics and indices to assess the health of the SAV community and easily compare across survey years and lakes. The metrics total point sampled during the survey, total littoral (<15 feet deep) points sampled, percent of littoral points with vegetation, maximum depth of plant growth, and species richness (i.e., the number of species observed) were calculated for each lake. In addition, the key indices used to assess the SAV survey results in this study and previous studies were Floristic Quality Index (FQI), biomass estimates, Simpson's Diversity Index (Simpson's D), and Aquatic Macrophyte Community Index (AMCI). Typha sp. (cattail), emergent wetland plants that often grow in shoreline and littoral areas in lakes and wetlands, are not included in SAV survey metrics in this report.

4.1.4 SAV Community Metrics

Floristic Quality Index (FQI). The FQI is an assessment tool used to determine the biological health of the SAV community. The FQI uses species richness and the habitat specificity (C-score) of each species identified to score community health (Equation 4.1-a). C-score is an index of how desirable a particular species is and how tolerant it is to stressors. Minnesota Department of Natural Resources (DNR) standard C-scores range from 1 to 10 with 1 being the least desirable and most tolerant to stressors, and 10 being the most desirable and least tolerant to stressors.

Equation 4.1-a. Definition of the DNR's Floristic Quality Index (FQI).

$$FQI = \overline{C_{Score}} * \sqrt{No. of\ Species}$$

Lakes with higher FQI scores and taxa richness are typically comprised of diverse, native communities with abundant plant growth across the entire littoral area. As stressors to the SAV community increase, we typically see reduced species diversity, introduction of invasive species, more monodominant stands of vegetation, and decreased late-season SAV abundance and density within the littoral area. Extremely degraded lakes become void of plant growth and become dominated by algae, which can sometimes be harmful during blooms.

The DNR developed thresholds for FQI and species richness to assess the health of lake vegetation communities and compare communities across lakes (Radomski and Perleberg 2012). Thresholds for deep and shallow lakes in the Central Hardwood Forest and Western Corn Belt Plains ecoregions are presented in Table 4.1-b. All surveyed lakes are in the Central Hardwood Forest ecoregion.

Table 4.1-b. FQI and species richness thresholds for deep and shallow lakes in the Central Hardwood Forest ecoregion.

	Depth Class	FQI threshold	Species Richness Threshold
North Central Hardwood Forest	Deep	18.6	12
	Shallow	17.8	11

Vegetation Biomass. We developed a model to estimate the total SAV biomass within each lake. Depth was stratified into four intervals (0-5, 5-10, 10-15, >15 feet) to more accurately account for spatial variation in vegetation growth and improve model accuracy. For each species we calculate a depth interval specific FQI, an average rake toss biomass, and a depth interval lake area. Multiplying these three parameters results in a species-specific total biomass/depth interval. All species-specific depth interval biomasses are then summed within each depth interval to calculate depth-specific biomasses and all depth intervals are summed to calculate a total lake biomass (Equation 4.1-b). The total lake biomass estimation uses the individual surveyed data point information to extrapolate coverage estimates across the entire basin. This is not meant to serve as an exact biomass calculation, rather, this estimate is useful to 1) make relative comparisons to other observed species, 2) be used to compare to future sampling efforts, and 3) provide general information to assist aquatic vegetation management planning.

Equation 4.1-b. Definition of total in-lake submersed aquatic vegetation biomass.

$$Total\ Lake\ Biomass = \sum ([Depth\ Interval]\ (Species\ Biomass * Species\ \%\ Occurence * Basin\ Area))$$

Biomass data were collected for this study; however, the data are not presented in this report. Biomass data will be kept for use with future management efforts.

Simpson's Diversity Index. Data collected during the point-intercept surveys was used to calculate the Simpson's Diversity Index (Simpson's D) (Simpson 1949) (Equation 4.1-c). Simpson's D is a measure of community diversity that accounts for the relative abundance of each species rather than just the community composition. This index is useful in assessing communities that have a high abundance of only a few species and low abundance of other species, giving more weight to more abundant species. The index ranges from 0–1 with 1 representing high diversity and even abundance across species and 0 representing low diversity and disproportionate abundance.

Equation 4.1-c. Simpson's Diversity index.

$$D = 1 - \left(\frac{\sum n\,(n-1)}{N\,(N-1)} \right)$$

n = the total number of organisms of a particular species
N = the total number of organisms of all species

Aquatic Macrophyte Community Index (AMCI). The Aquatic Macrophyte Community Index (AMCI) is a metric used to assess the biological quality of lake aquatic plant communities (Nichols et al. 2000). The AMCI combines maximum depth of plant growth, percent of littoral zone vegetated, Simpson's D, the relative frequencies of submersed, sensitive, and exotic species, and taxa number. AMCI ranges from 0-70, with higher values representing higher quality plant communities. The AMCI was calculated for each point-intercept survey using the methods described by Nichols et al. (2000).

4.2 UPPER TWIN LAKE

Upper Twin Lake (Public Water No. 27004200) is in the cities of Crystal and Brooklyn Center within Hennepin County, MN. Upper Twin Lake has an approximate surface area of 116.1 acres, all of which are in the littoral area (i.e., area less than 15 feet deep), 3.23 miles of shoreline, and a maximum depth of 3 meters. Upper Twin Lake is classified as a shallow lake or reservoir. The list below summarizes the year in which each type of sampling was most recently performed on Upper Twin Lake:

- Water Quality - 2023
- SAV – 2023
- Phytoplankton/Zooplankton – Not assessed
- Fisheries – Not assessed
- Carp – 2017

4.2.1 Water Quality

Water quality data was collected biweekly from late May through late September 2023 in Upper Twin Lake (Figures 4.2a-e). Seasonal water quality trends are as follows: Total phosphorus (TP) did not meet the Minnesota North Central Hardwood Forest (NCHF) shallow lake TP standard of 60 ug/L in June, early July, and early August, but it did meet the standard in late July, late August, and mid-September (Figure 4.2-a). Other than a peak in late July at 44 ug/L, chlorophyll-a met the standard of 20 ug/L throughout the summer (Figure 4.2-b). The increase in chlorophyll-a occurred simultaneously with decreased water clarity, and when chlorophyll-a levels fell in mid-August, water clarity improved concurrently. Water clarity remained above the standard 1-meter Secchi depth all summer and into the fall (Figure 4.2-c). Seasonal ortho-phosphate increased steadily throughout the summer, with a peak at 0.49 mg/L in early August (Figure 4.2-d). Total suspended solids (TSS) peaked in early August as well at 7 mg/L before dropping off sharply in late August (Figure 4.2-e).

Historic monitoring data show dramatic improvements in total phosphorus concentration, chlorophyll-*a* concentration, and Secchi depth in 2023 (Figures 4.2f-k). In 2023, Secchi depth reached 1.75 meters, improving past the NCHF shallow lake Secchi depth standard for the first sampling year since 1998 and improving by 1.25 from sampling 2 years prior (Figure 4.2-i). In addition, for the first sampling year since 1998, chlorophyll-a reached the shallow lake water quality standard of 20 ug/L (Figure 4.2-h), and TP dropped almost to the state water quality standard of 60 ug/L (Figure 4.2-f).

Total suspended solids and ortho-phosphate have been monitored less frequently than TP, chlorophyll-*a*, and Secchi depth. Over the 4 available years of sampling data (2012, 2018, 2019, and 2023), TSS dropped significantly in 2023 (Figure 4.2-k), while ortho-phosphate remained at a similar range to previous years of data (Figure 4.2-j).

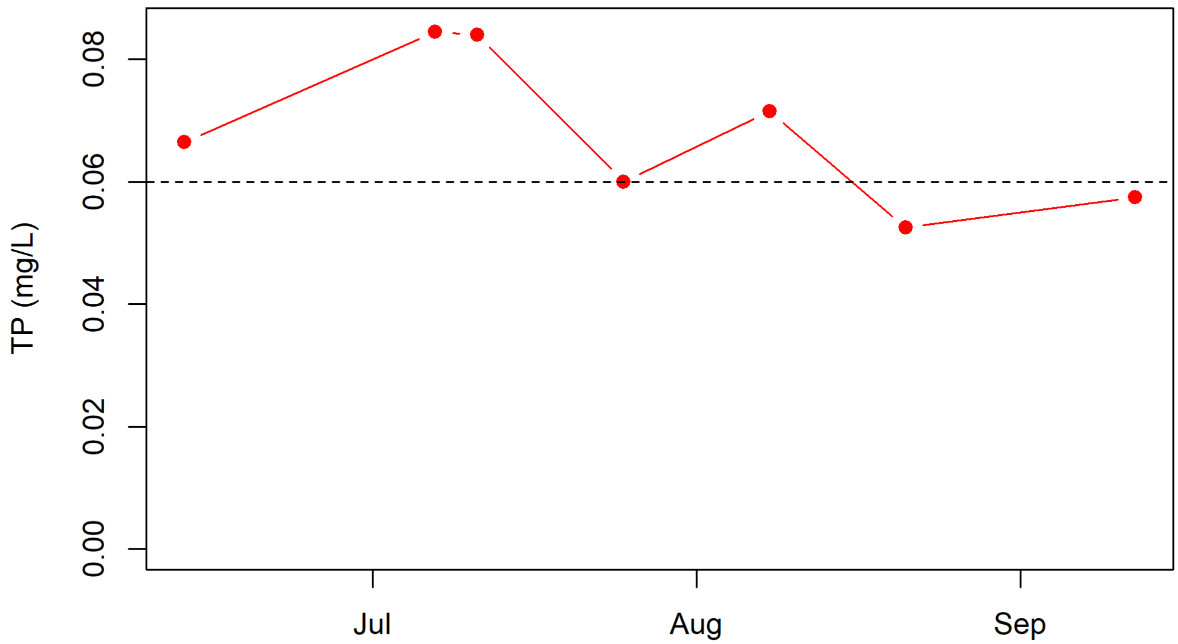


Figure 4.2-a. Upper Twin Lake 2023 seasonal total phosphorus concentration.
State surface water TP standard for shallow lakes (black dashed line).

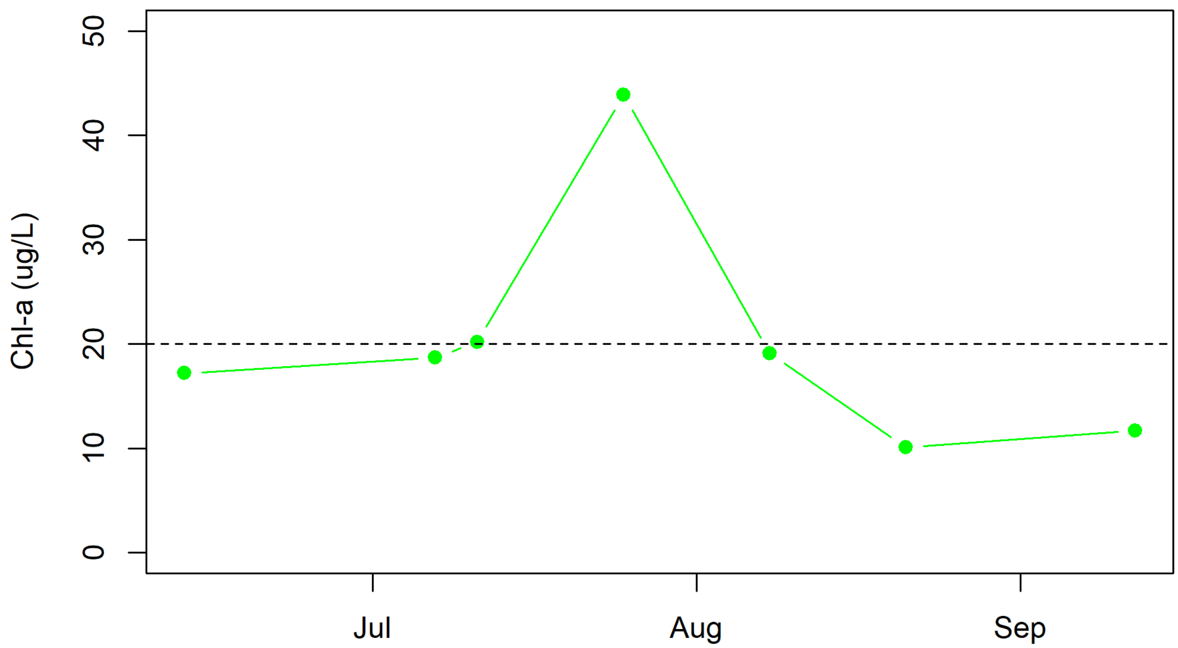


Figure 4.2-b. Upper Twin Lake 2023 seasonal chlorophyll-*a* concentration.
State surface water chl-*a* standard for shallow lakes (black dashed line).

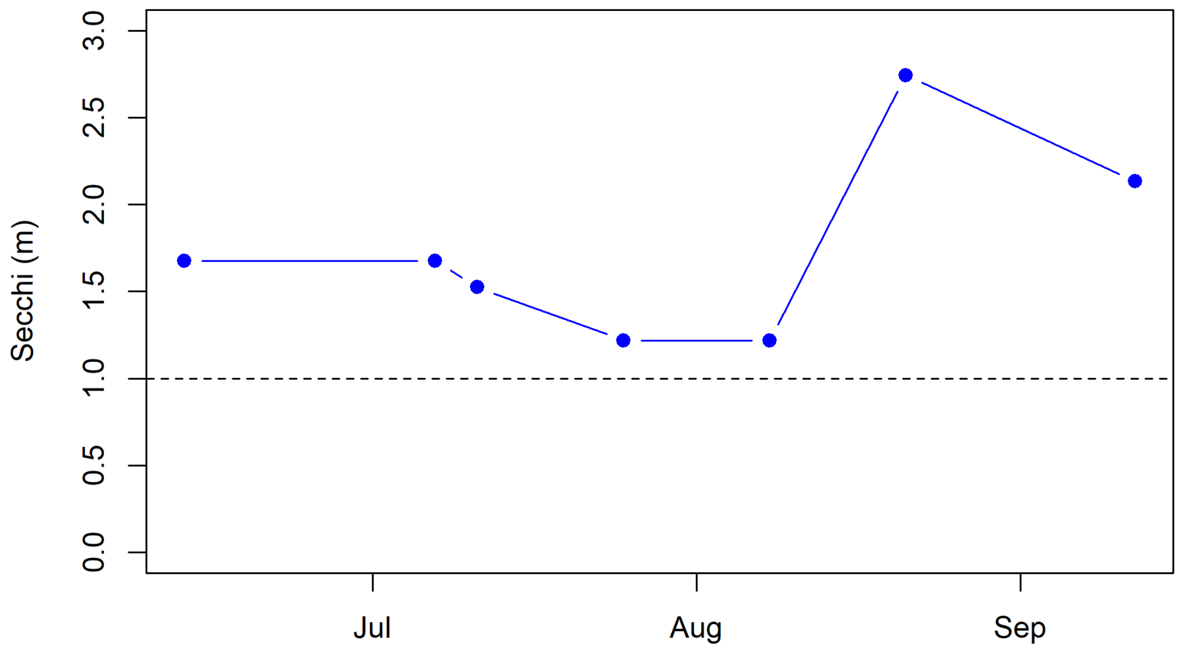


Figure 4.2-c. Upper Twin Lake 2023 seasonal Secchi depth.
State surface water and Secchi depth standard for shallow lakes (black dashed line).

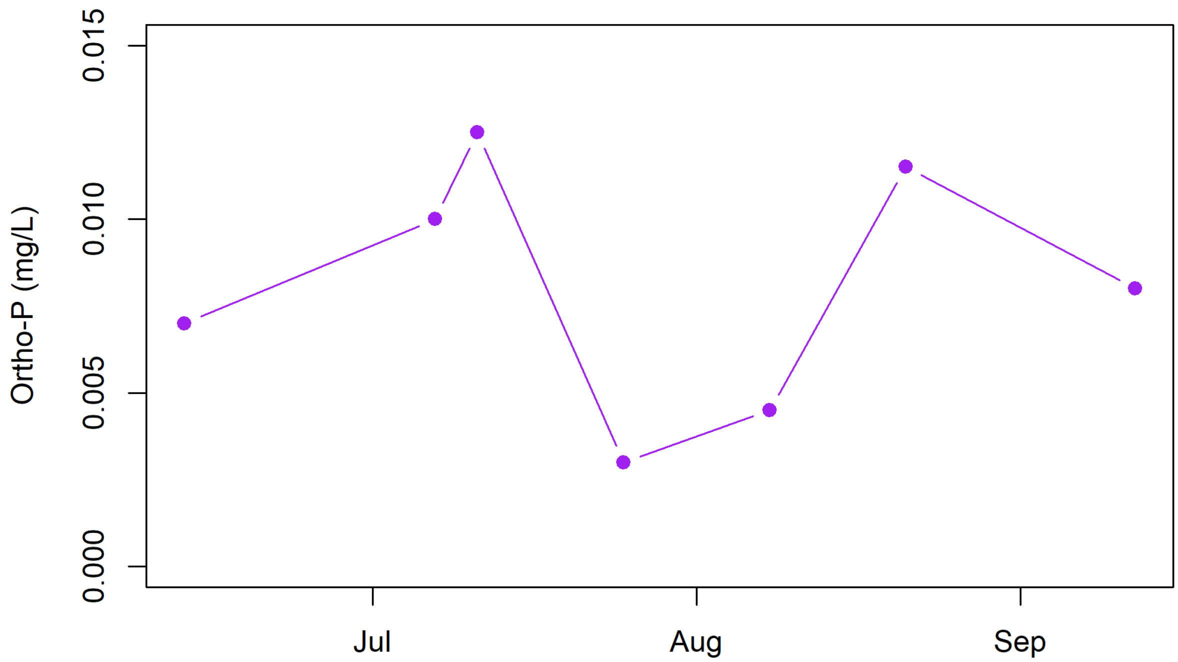


Figure 4.2-d. Upper Twin Lake 2023 seasonal ortho-phosphate (OP) concentration.
Note: There is no state surface water standard for ortho-phosphate.

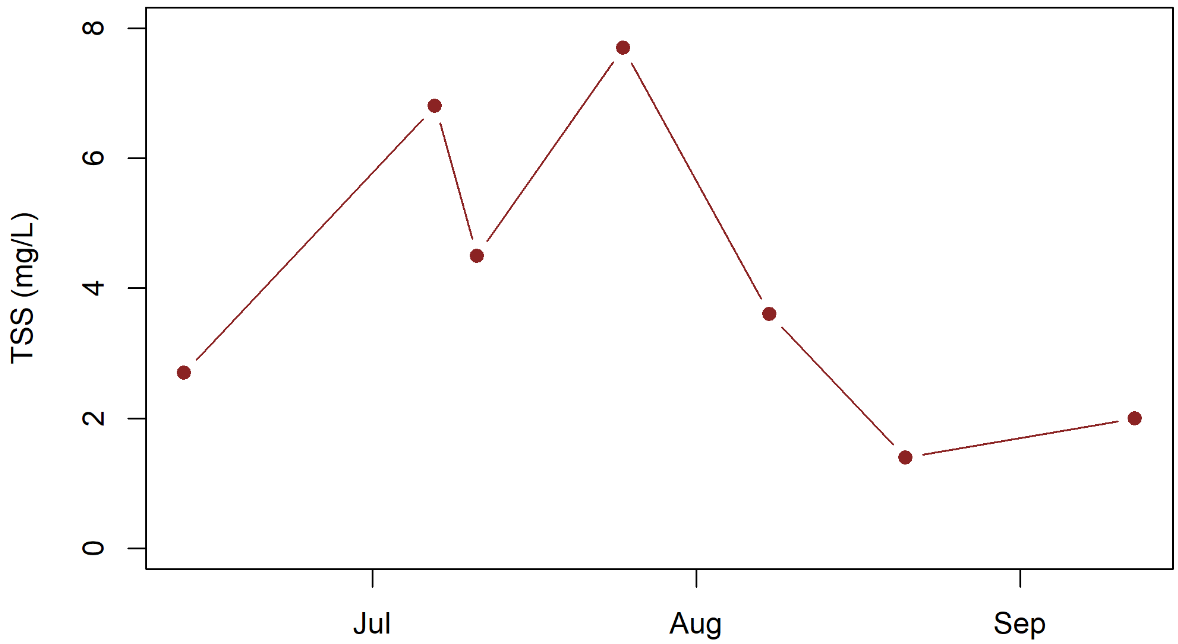


Figure 4.2-e. Upper Twin Lake 2023 seasonal total suspended solids (TSS) concentration.
Note: There is no state surface water standard for TSS.

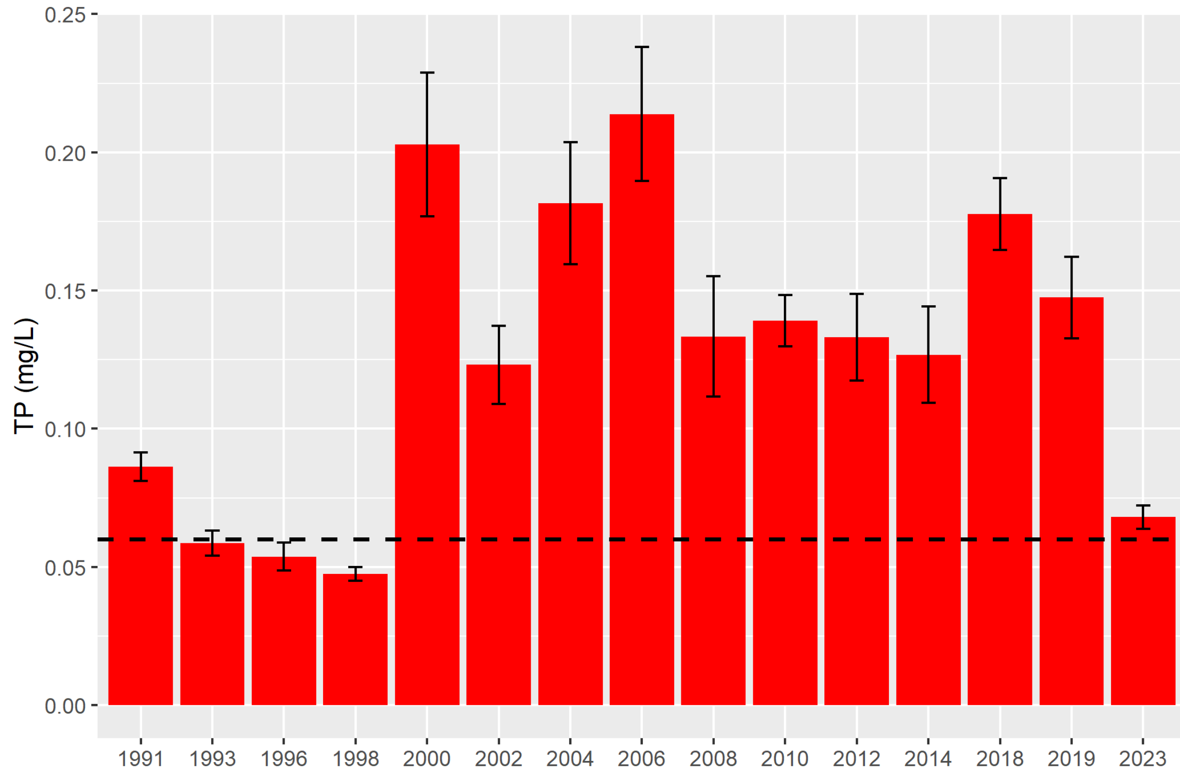


Figure 4.2-f. Upper Twin Lake growing season average total phosphorus concentration.
State shallow lake TP standard (black dashed line) for reference.

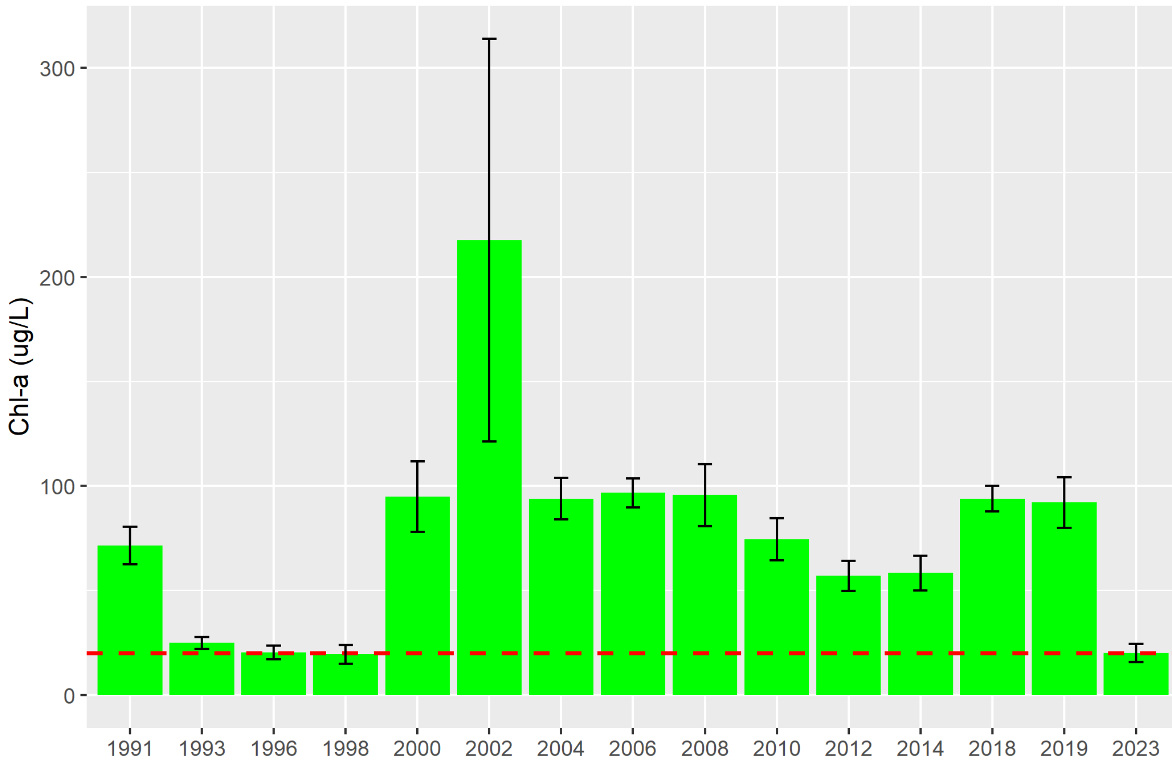


Figure 4.2-g. Upper Twin Lake growing season average chlorophyll-*a* concentration.
State shallow lake chlorophyll-*a* standard (red dashed line) for reference.

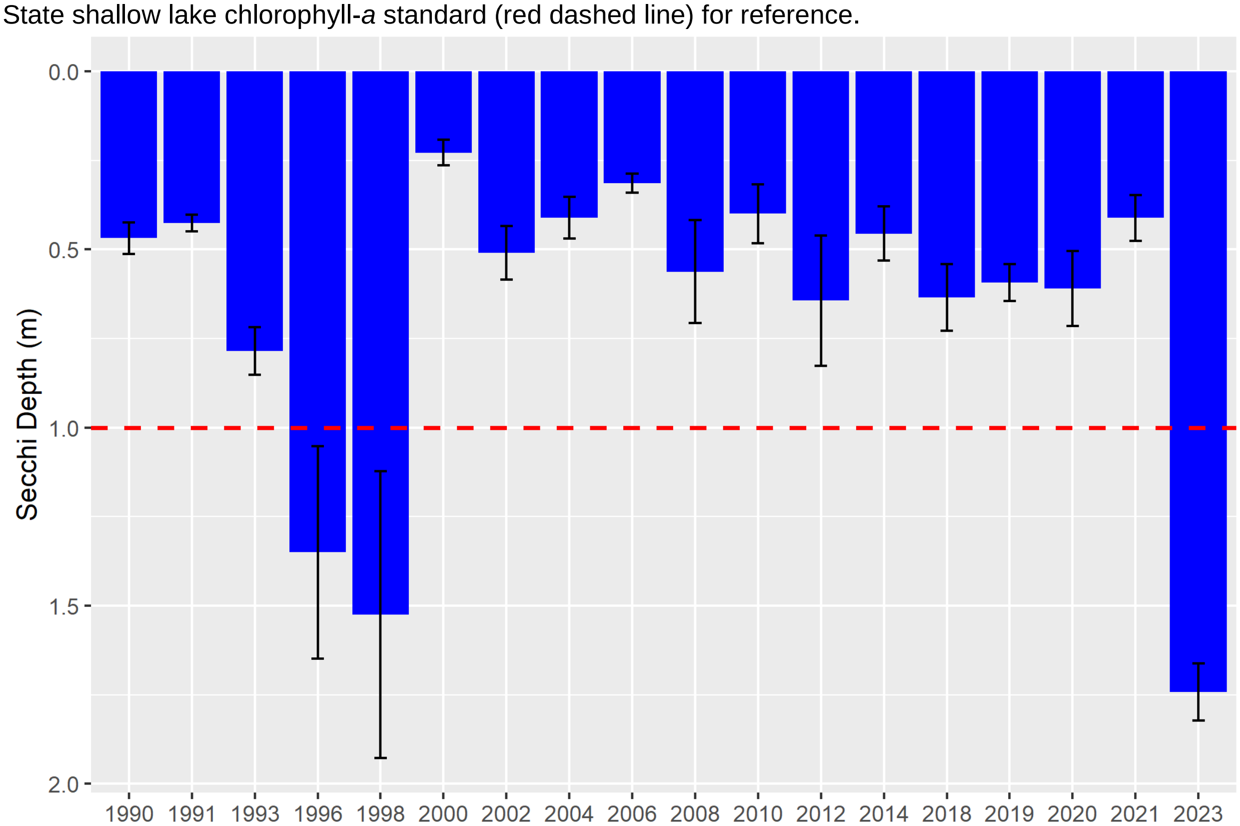


Figure 4.2-h. Upper Twin Lake annual growing season average Secchi depth.
State shallow lake Secchi depth standard (red dashed line) for reference.

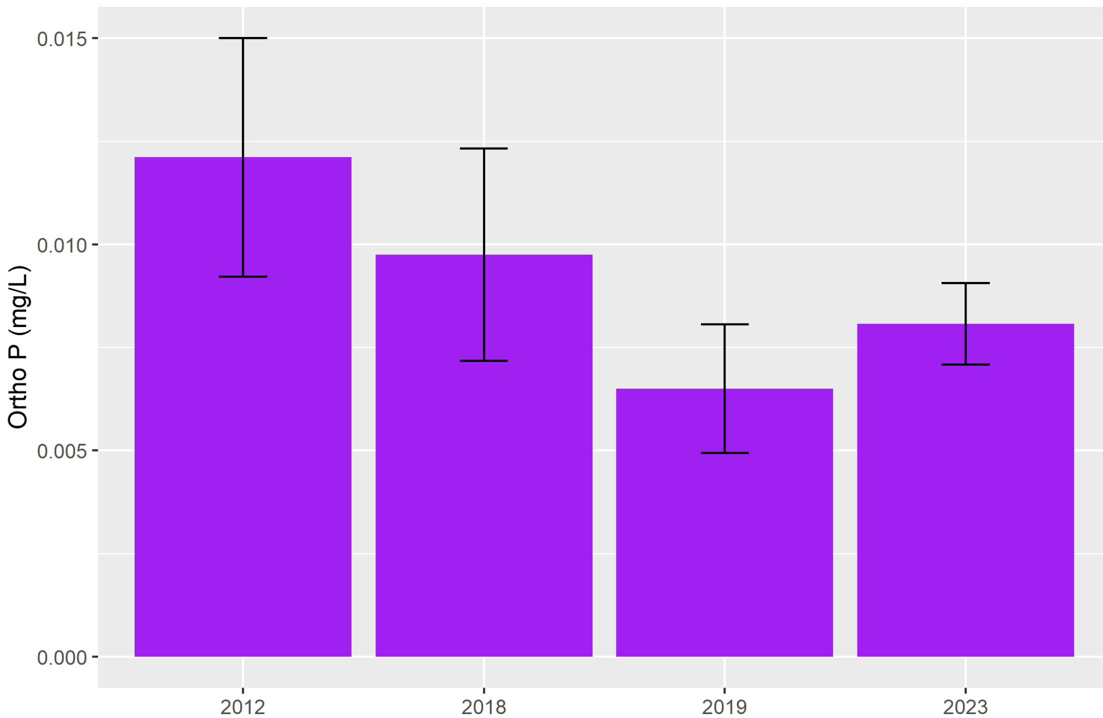


Figure 4.2-i. Upper Twin Lake growing season average ortho-phosphate concentration.
Note: There is no state surface water standard for ortho-phosphate.

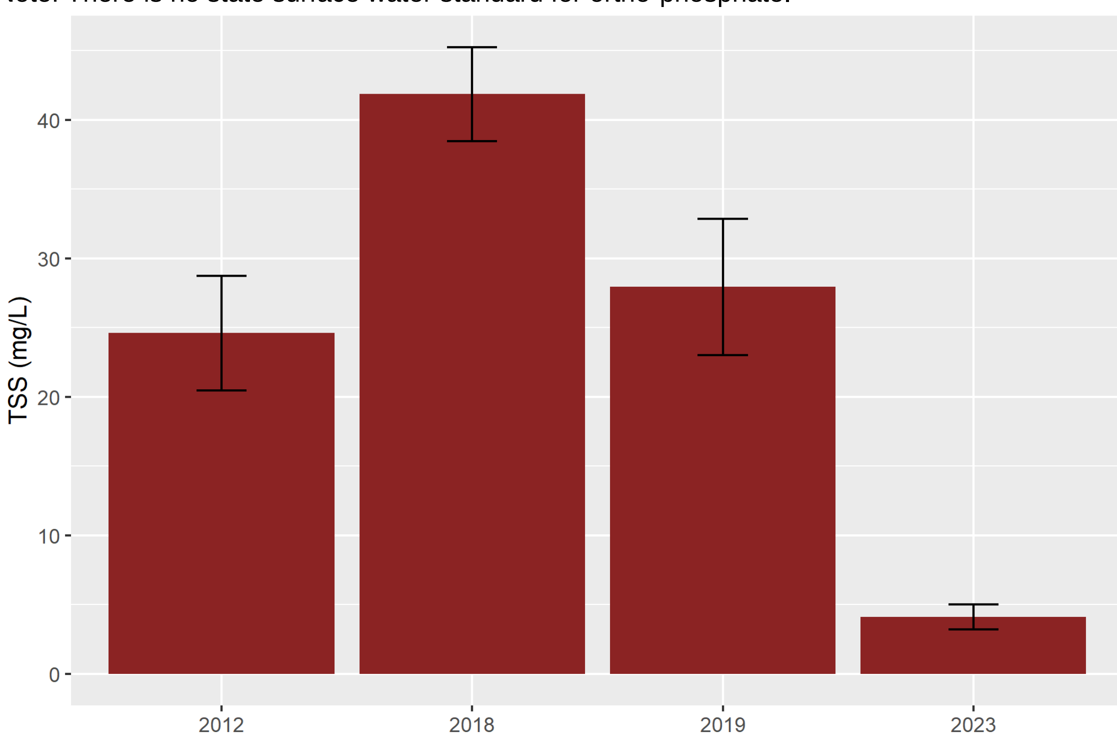


Figure 4.2-j. Upper Twin Lake growing season average total suspended solids concentration. Note: There is no state surface water standard for TSS.

4.2.2 Submersed Aquatic Vegetation

Point intercept aquatic vegetation surveys were conducted June 22nd-23rd and August 15th-16th, 2023 to document the early and late season submersed aquatic vegetation (SAV) in Upper Twin Lake. These surveys will be referred to as the early and late season surveys. Below are two tables outlining survey results and associated metrics and indices (Table 4.2-a, Table 4.2-b.2-b). Maps include early and late season BioBase maps of vegetation biovolume (Figure 4.2-k), number of taxa at each sample point (Figure 4.2-l) and CLP location and density (Figure 4.2-m). No Eurasian watermilfoil was found in Upper or Middle Twin in 2023.

Table 4.2-a. Upper Twin Lake SAV metrics and indices.

	June 22 – 23, 2023	August 15 – 16, 2023
LAKEWIDE METRICS		
Total Points Sampled	93	95
Total Littoral Points Sampled	93	95
% Littoral with Vegetation	75.3	87.4
Max depth of plant growth (ft)	8.9	9.7
Shallow Lake Species Richness Threshold	*11*	
Species Richness	12	11
COMMUNITY INDICES		
Shallow Lake FQI Threshold	*17.8*	
Floristic Quality Index (FQI)	17.54	15.89
Simpson's Diversity Index	0.865	0.812
Aquatic Macrophyte Community Index (AMCI)	50	49

*Typha (cattail) is not included in Taxa or Community Indices calculations as it does not have a C value.

Table 4.2-b. Upper Twin Lake plant taxa and littoral frequency of occurrence from 2023 surveys.

Taxa	Common Name	June 22 – 23, 2023	August 15 – 16, 2023
SUBMERSED TAXA			
Chara sp.	musk grass	1	1
Ceratophyllum demersum	coontail	34	66
Elodea canadensis	waterweed (Canadaian)	1	4
Myriophyllum spicatum	**water milfoil (Eurasian)**	--	--
Nuphar variegata	bullhead pond-lily	27	1
Nymphaea odorata	American white waterlily	27	25
Potamogeton crispus	**curly-leaf pondweed**	22	3
Potamogeton foliosus	leafy pondweed	27	55
Potamogeton pusillus	lesser pondweed	32	--
Potamogeton zosteriformis	eel-grass pondweed	--	1
Spirodela polyrhiza	common duckmeat	15	29
Stuckenia pectinata	sago pondweed	2	--
Wolffia sp.	watermeal	8	15
FLOATING TAXA			
Lemna minor	common duckweed	15	29

*Taxa shown in bold are considered Aquatic Invasive Species (AIS).

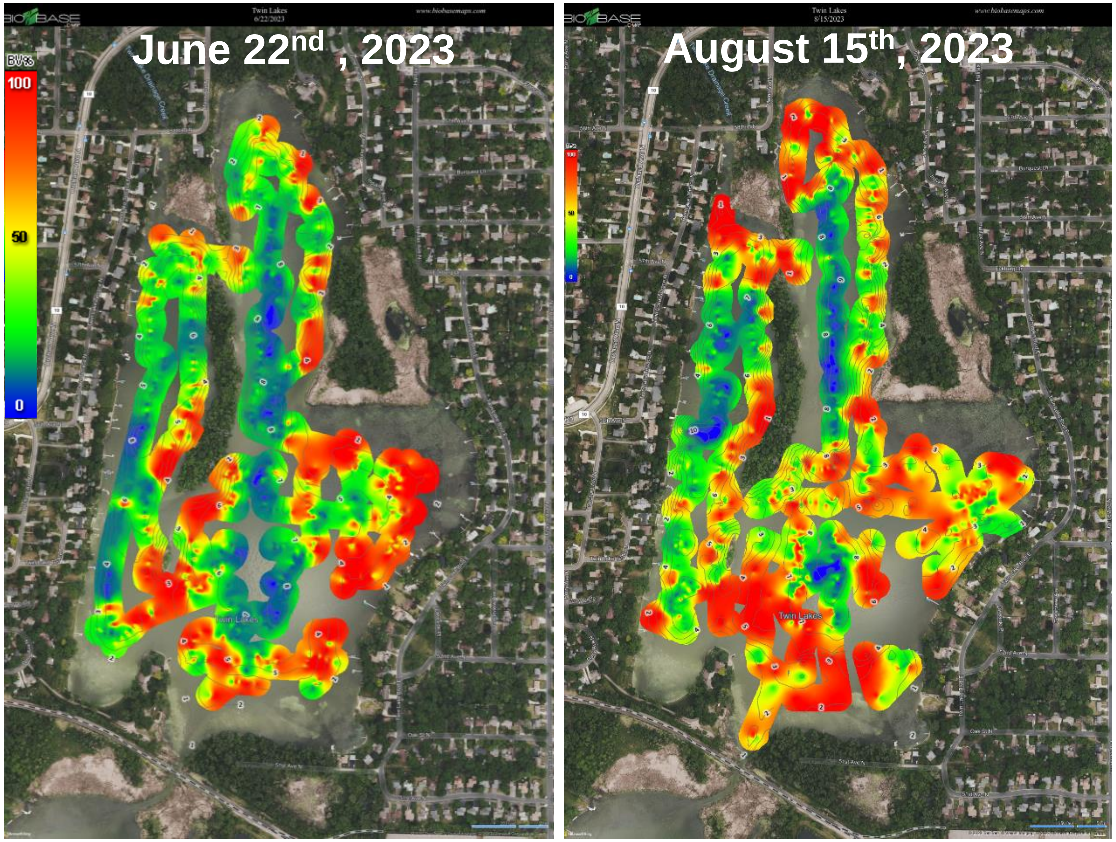


Figure 4.2-k. Biovolume heat maps for Upper Twin Lake during the June 22nd (left) and August 15th (right) 2023 surveys.

Note: Biovolume refers to the percentage of the water column taken up by vegetation. On the colored scale, red indicates 100% biovolume and blue indicates 0% biovolume.

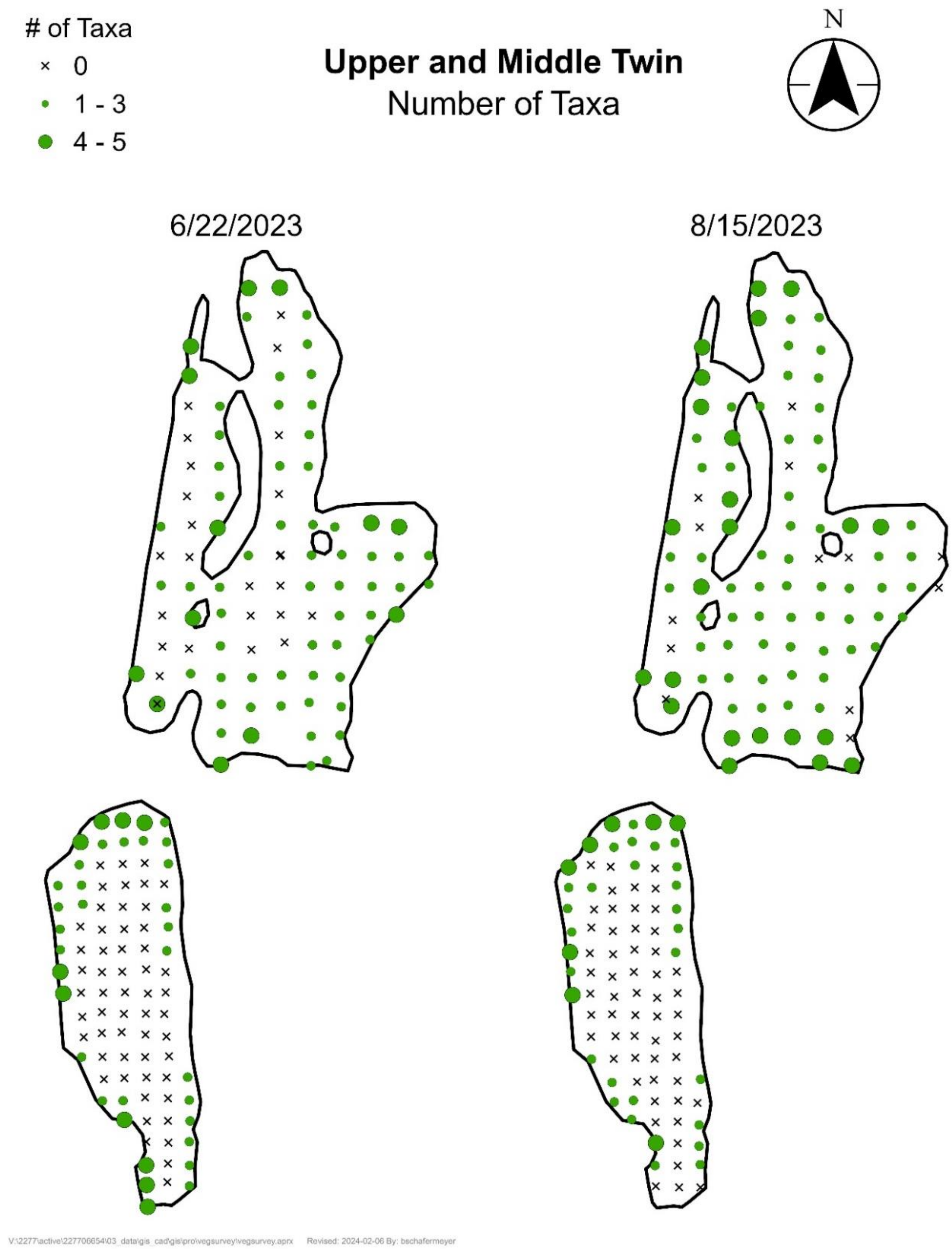


Figure 4.2-I. Map of the Number of taxa found at each point in Upper and Middle Twin Lake.

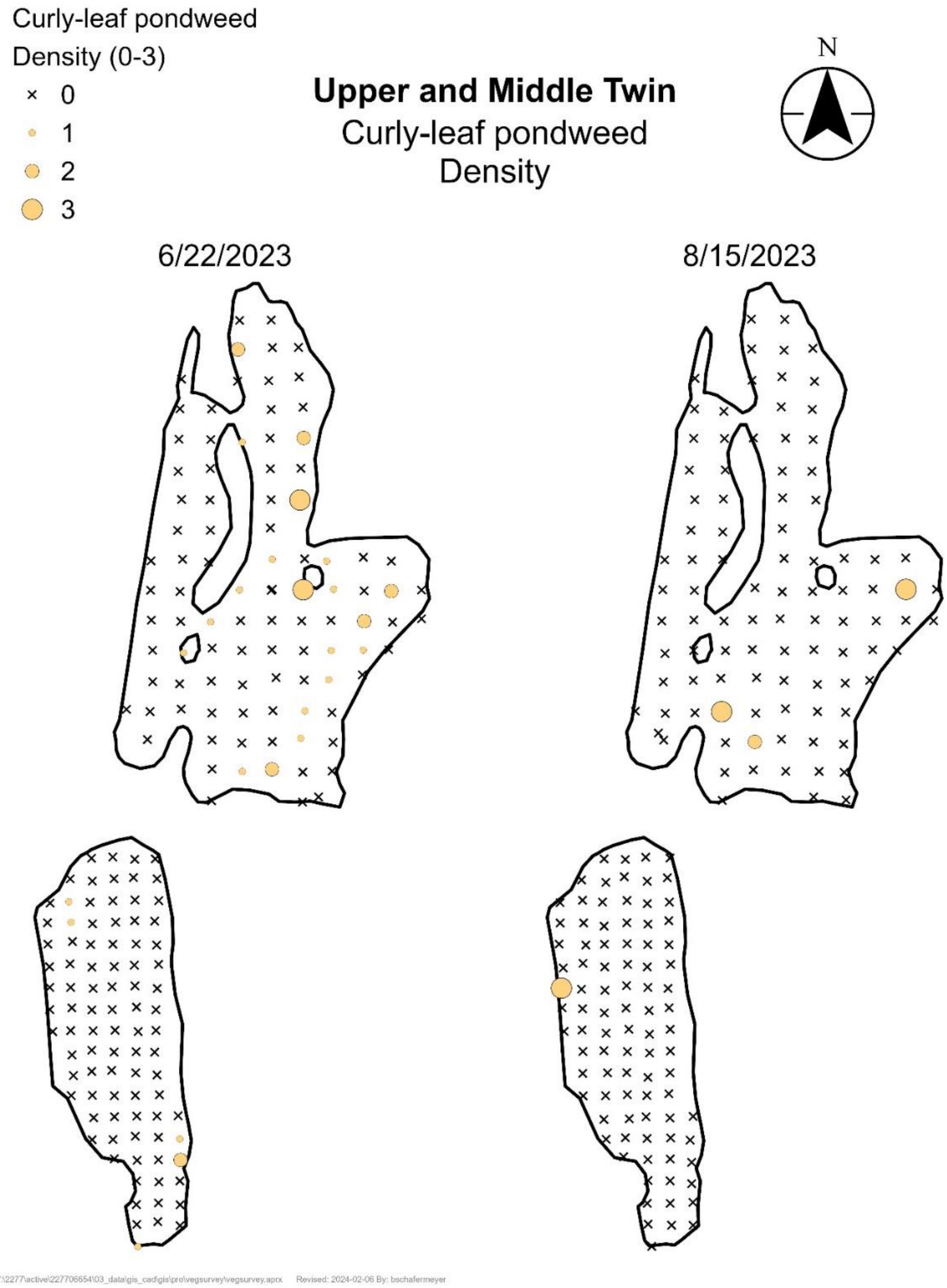


Figure 4.2-m. Map of the CLP rake density found at each point in Upper and Middle Twin Lakes.

4.3 MIDDLE TWIN LAKE

Middle Twin Lake (Public Water No. 27006500) is in the cities of Crystal and Brooklyn Center within Hennepin County, MN. Middle Twin Lake is classified as a deep lake and has an approximate surface area of 55.7 acres. Out of its 55.7 acres, 32.3 acres of Middle Twin Lake are in the littoral zone (i.e., <15 feet deep). The list below summarizes the year in which each type of sampling was most recently performed on Middle Twin Lake:

- Water Quality - 2023
- SAV – 2023
- Phytoplankton/Zooplankton – Not assessed
- Fisheries – Not assessed
- Carp – 2017

4.3.1 Water Quality

Water quality data was collected biweekly from late May through late September 2023 in Middle Twin Lake (Figures 4.3a-f). TP did not meet the state standard of 60 ug/L for the entire monitoring period (Figure 4.3-a). TP concentration climbed steadily starting in June, before peaking in early August. Middle Twin Lake epilimnetic (surface) TP is significantly lower than hypolimnetic (deep water) TP throughout the summer (Figure 4.3-b). Chlorophyll-*a,* a measure of algal abundance in lake water, remained below the standard for most of the monitoring period except for early June and mid-August, where it peaked at 45 ug/L before falling back down below the standard in late August (Figure 4.3-c). Water clarity, measured as Secchi depth, peaked in early July at about 3.3m, fell to 1.25m in early August, and climbed again to 2.8 m in mid-September (Figure 4.3-d).

Figures 4.3g-k show historic average water quality concentrations collected during the growing season for TP, chl-*a*, Secchi depth, ortho-P, and TSS. Middle Twin Lake TP annual average remains well above the standard at similar levels to the previous 2 years of sampling in 2018 and 2019 (Figure 4.3-g). In contrast, chl-*a* dropped to near the state standard of 14 ug/L for the first sampling year since 2008 (Figure 4.3-h). Annual average Secchi depth increased by almost 1.25 m from 2021 to 2023, reaching the best recorded water clarity since 1985 (Figure 4.3-i). Middle Twin Lake ortho-P remained at similar levels to 2018 and 2019 (Figure 4.3-j), while TSS decreased significantly from concentrations in 2012, 2018, and 2019 (Figure 4.3-k). There are no Minnesota state standards for ortho-P or TSS for comparison.

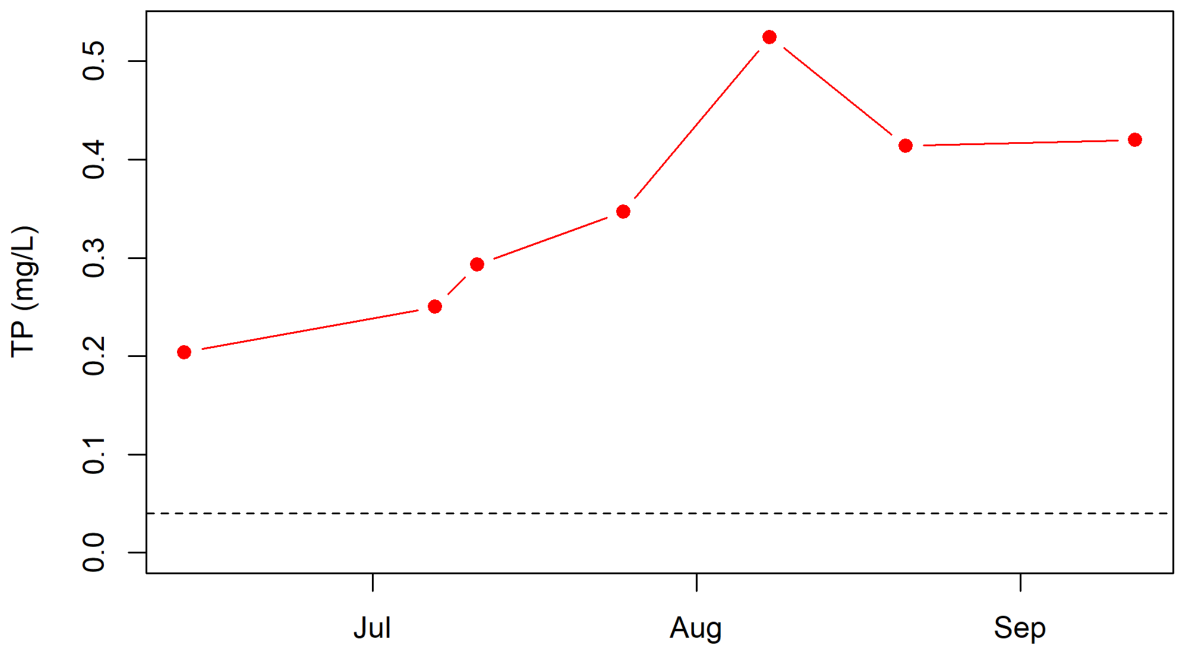


Figure 4.3-a. Middle Twin Lake 2023 seasonal total phosphorus concentration.
State surface water TP standard for shallow lakes (black dashed line).

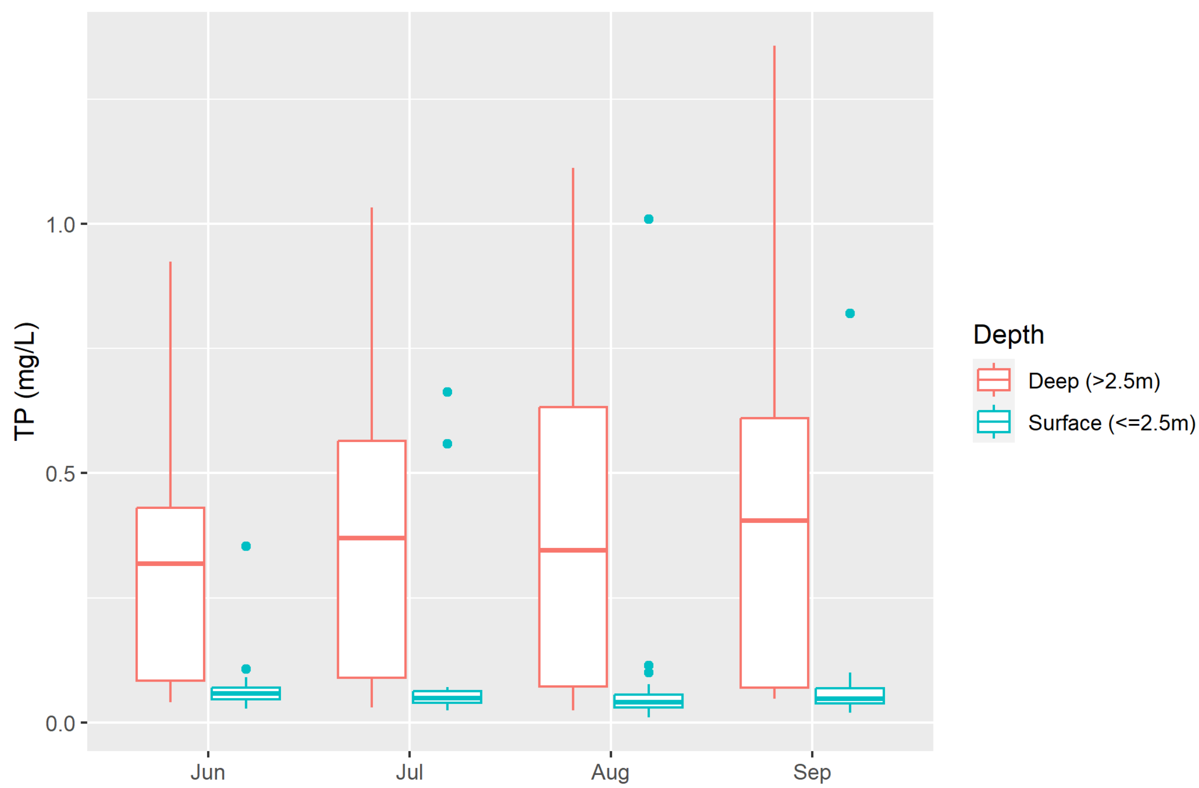


Figure 4.3-b. Middle Twin Lake 2023 summer epilimnetic (surface) vs. hypolimnetic (deep) TP. Data are grouped in boxplots by month.

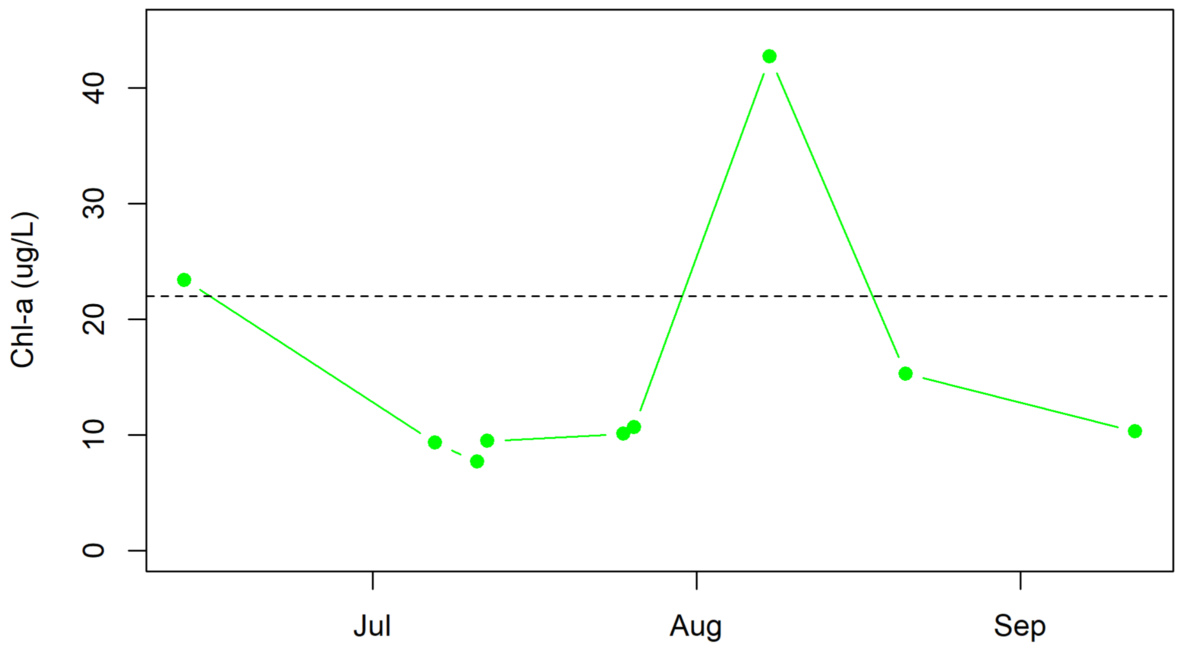


Figure 4.3-c. Middle Twin Lake 2023 seasonal chlorophyll-*a* concentration.
State surface water chl-*a* standard for shallow lakes (black dashed line).

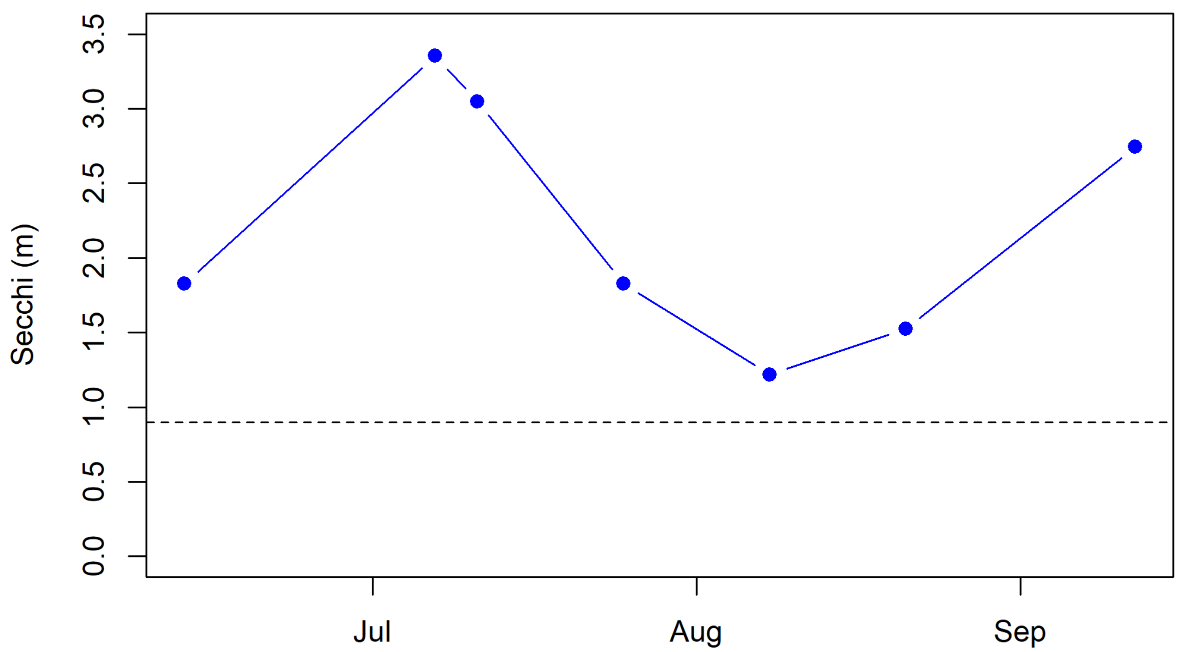


Figure 4.3-d. Middle Twin Lake 2023 seasonal Secchi depth.
State surface water Secchi depth standard for shallow lakes (black dashed line).

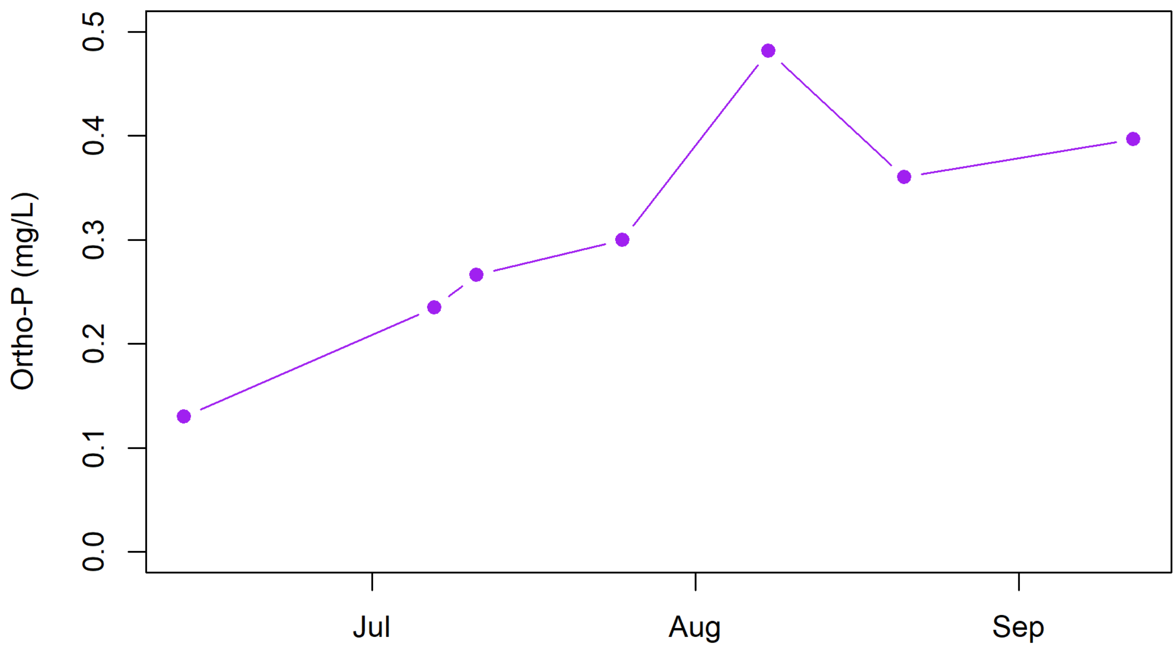


Figure 4.3-e. Middle Twin Lake 2023 seasonal ortho-phosphate (OP) concentration.
There is no state surface water standard for ortho-phosphate.

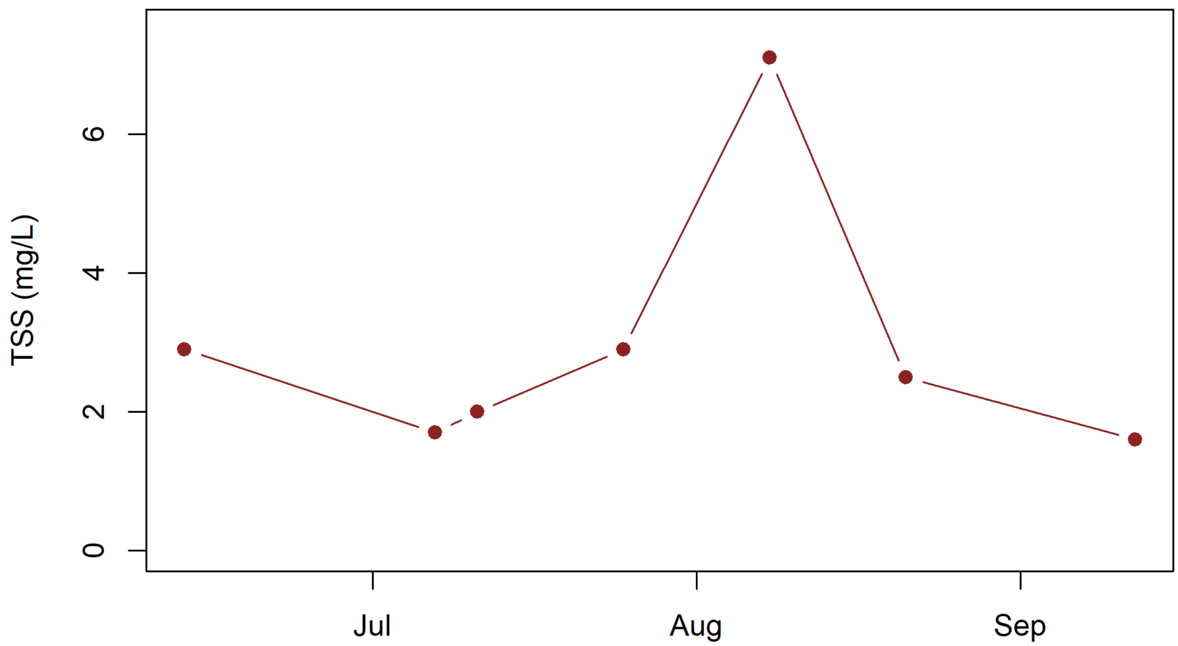


Figure 4.3-f. Middle Twin Lake 2023 seasonal total suspended solids (TSS) concentration.
Note: there is no state surface water standard for TSS.

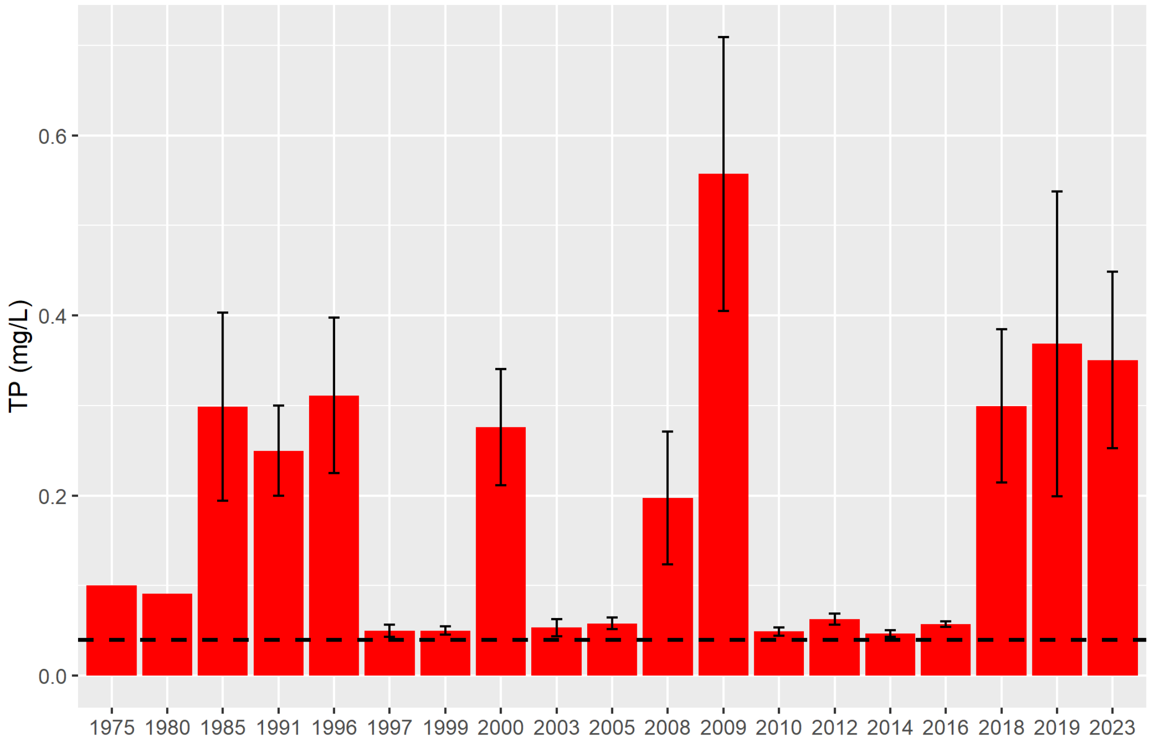


Figure 4.3-g. Middle Twin Lake annual growing season average total phosphorus concentration. State deep lake TP standard (black dashed line) for reference.

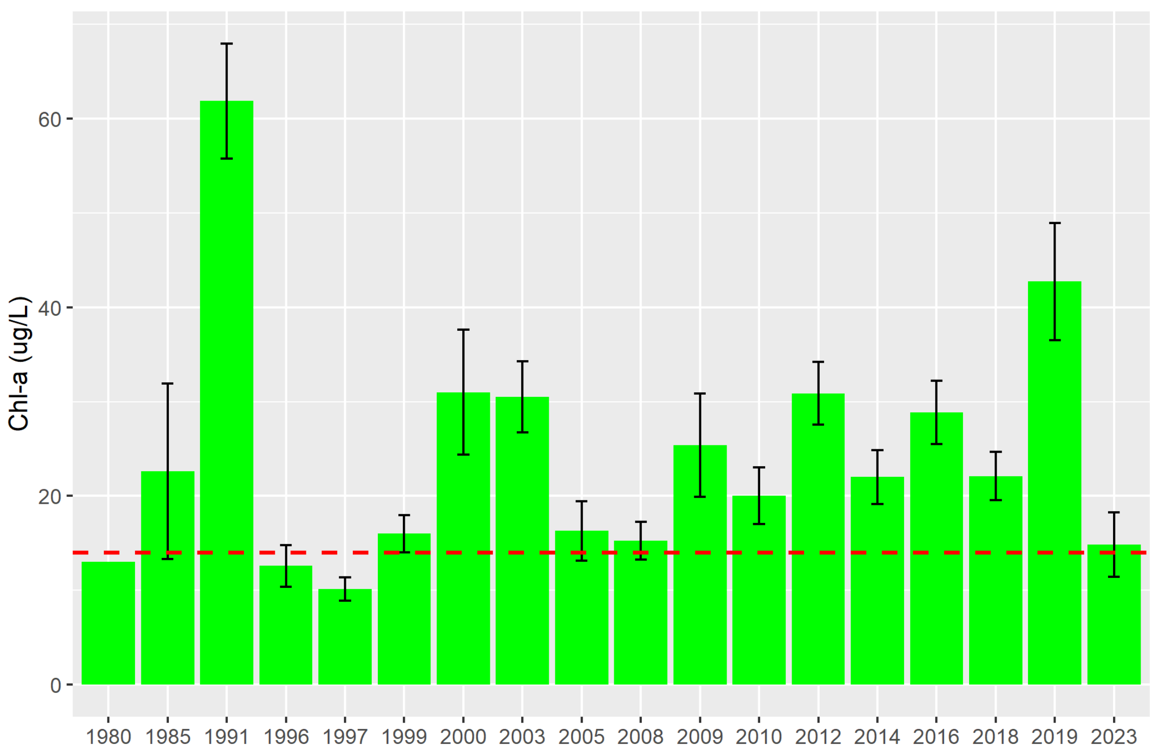


Figure 4.3-h. Middle Twin Lake growing season average chlorophyll-*a* concentration. State deep lake chl-*a* standard (red dashed line) for reference.

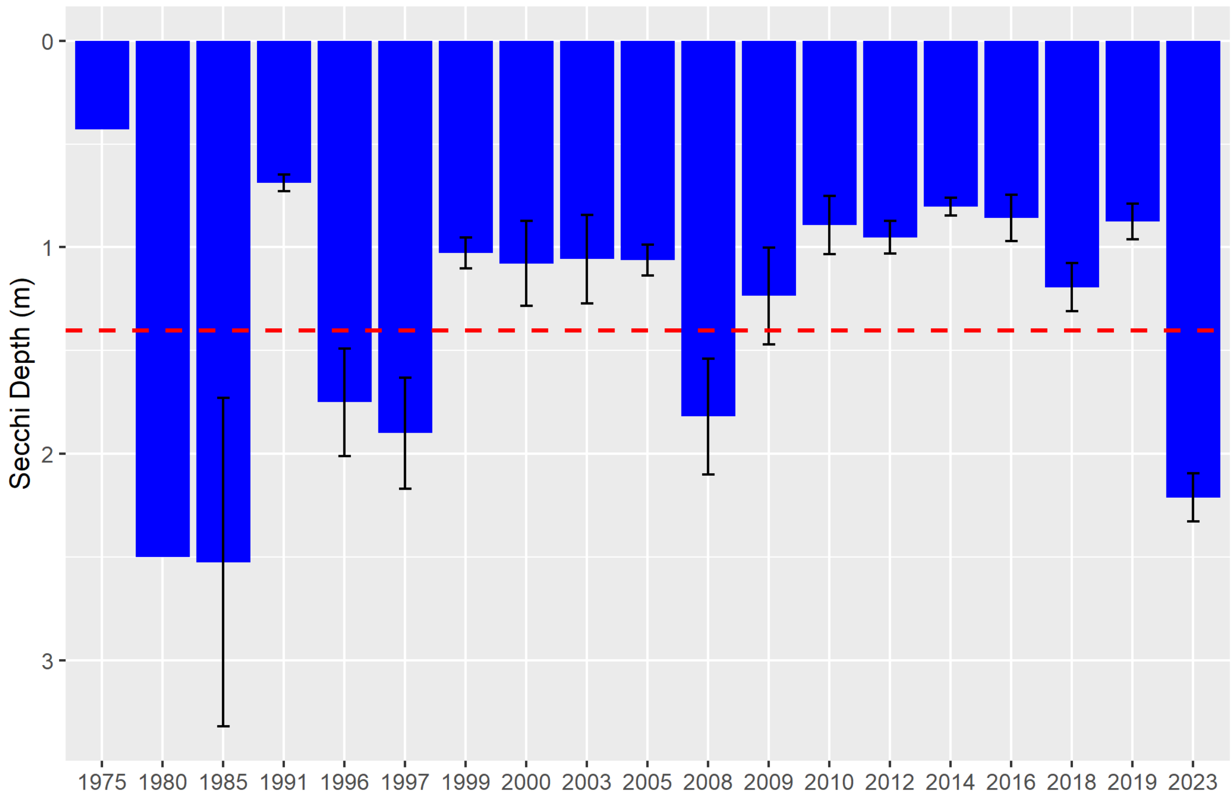


Figure 4.3-i. Middle Twin Lake growing season average Secchi depth concentration.
State deep lake Secchi depth standard (red dashed line) for reference.

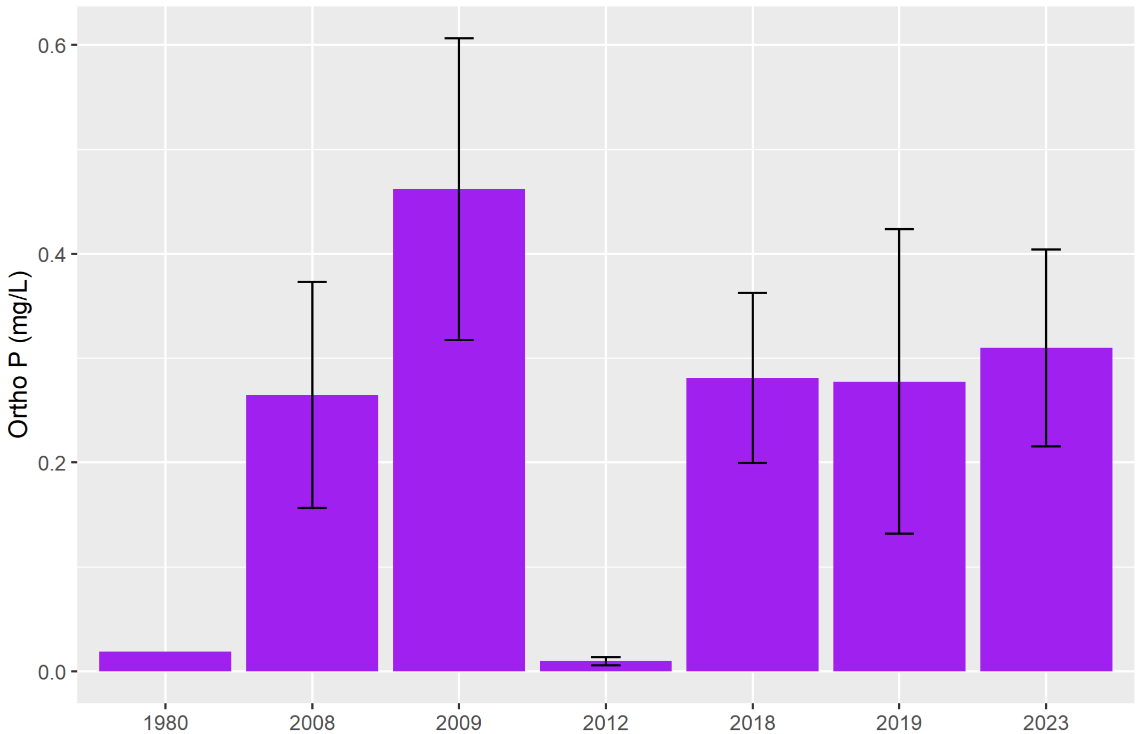


Figure 4.3-j. Middle Twin Lake growing season average ortho-phosphate concentration.
Note: There is no state surface water standard for OP.

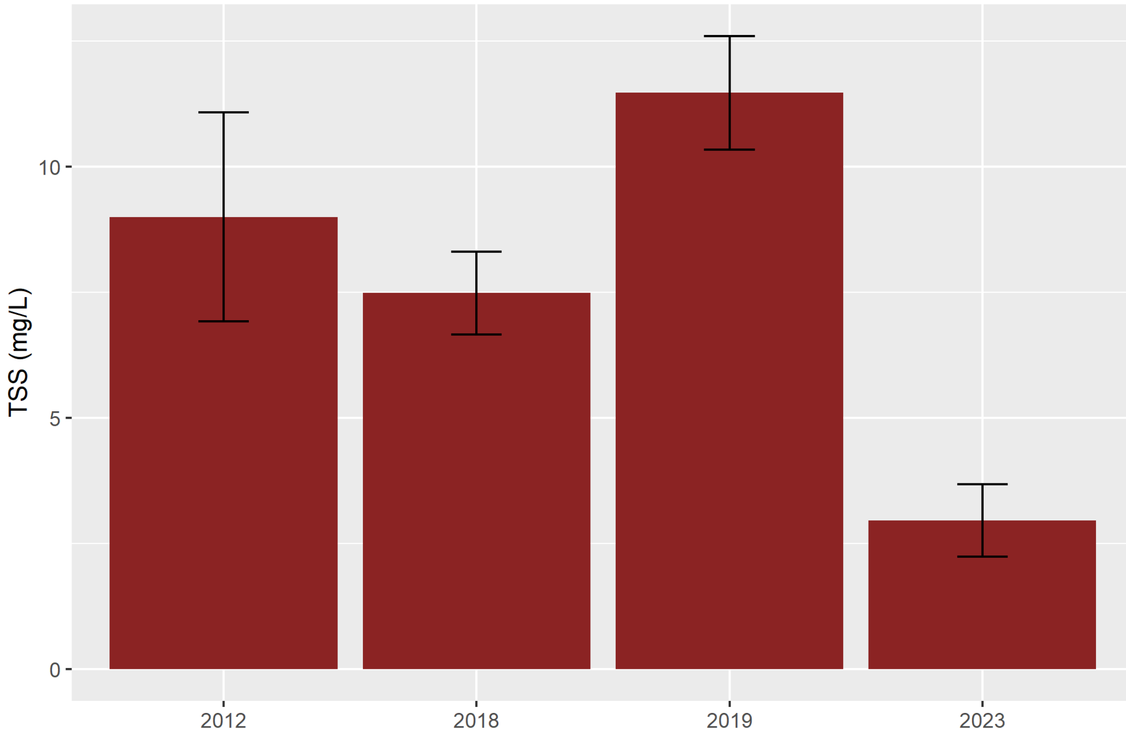


Figure 4.3-k. Middle Twin Lake growing season average total suspended solids concentration. Note: There is no state surface water standard for TSS.

4.3.2 Submersed Aquatic Vegetation

Two point-intercept aquatic vegetation surveys were conducted on June 22nd, 2023 and August 15th, 2023 to document the submersed aquatic vegetation in Middle Twin Lake. Below are two tables outlining survey results and associated metrics and indices (Table 4.3-a and Table 4.3-b). Upper Twin Lake maps including the number of taxa at each sample point (Figure 4.2-a) and the CLP location and density (Figure 4.2-b) are located in Section 4.2 with the Upper Twin Lake maps. Biobase maps showing early and late season survey sonar data are below (Figure 4.3-l). No Eurasian Watermilfoil, an Aquatic Invasive Species (AIS), was found in the survey.

Table 4.3-a. Middle Twin Lake SAV metrics and indices.

	June 22nd, 2023	August 15th, 2023
LAKEWIDE METRICS		
Total Points Sampled	90	90
Total Littoral Points Sampled	41	41
% Littoral with Veg	87.8	85.4
Max depth of plant growth (ft)	18.4	17.3
Shallow Lake Species Richness Threshold	*11*	
Species Richness	9	10
COMMUNITY INDICES		
Shallow Lake FQI Threshold	*17.8*	
Floristic Quality Index (FQI)	13.3	14.6
Simpson's Diversity Index	0.796	0.797
Aquatic Macrophyte Community Index (AMCI)	40	40

Table 4.3-b. Middle Twin Lake plant taxa and littoral frequency of occurrence from 2023 surveys.

Taxa	Common Name	June 22nd, 2023	August 15th, 2023
SUBMERSED TAXA			
Ceratophyllum demersum	hornwort	76	61
Heteranthera dubia	water stargrass	--	5
Elodea canadensis	water milfoil (northern)	5	2
Nuphar variegata	**curly-leaf pondweed**	--	7
Nymphaea odorata	American white waterlily	34	37
Potamogeton crispus	curlyleaf pondweed	12	2
Potamogeton foliosus	leafy pondweed	--	2
Potamogeton pusillus	small pondweed	2	--
Potamogeton zosteriformis	eel-grass pondweed	5	--
FLOATING TAXA			
Lemna minor	lesser duckweed	32	29
Spirodela polyrhiza	greater duckweed	32	29
Wolffia sp.	duckweed	17	10

*Taxa considered Aquatic Invasive Species (AIS) are listed in bold.

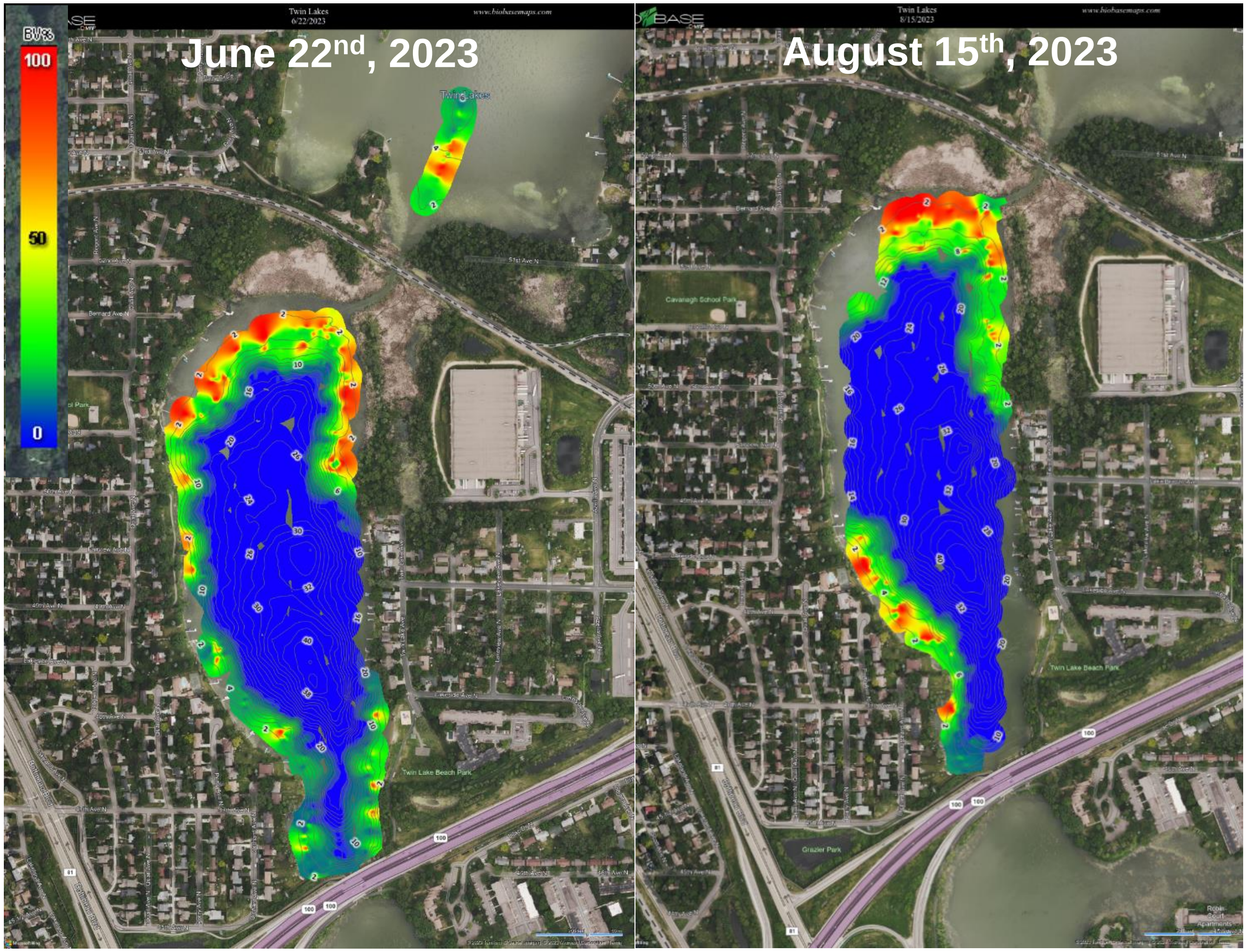


Figure 4.3-I. Early (left) and late (right) season BioBase map of vegetation biovolume in Middle Twin Lake.

4.4 MEADOW LAKE

Meadow Lake (Public Water No. 27005700) is located in the city of New Hope within Hennepin County, MN. Meadow Lake is classified as a shallow lake and has an approximate surface area of 10.4 acres, with 100% of the lake in the littoral zone (< 15 feet deep). The list below summarizes the year in which each type of sampling was most recently performed:

- Water Quality – 2023
- SAV – 2023
- Phytoplankton/Zooplankton - 2022
- Fisheries - 2022
- Carp – NA

4.4.1 Water Quality

In 2023, Meadow Lake was only sampled for water quality in September. Because of this, Meadow Lake seasonal TP, chl-*a*, Secchi depth, ortho-phosphate, and total suspended solids graphs are not included in this report.

Figures 4.4a-f show historical annual growing season average TP, chl-*a*, Secchi depth, ortho-P, and TSS data for Meadow lake. Water quality in Meadow Lake has been improving since monitoring began in 1996. In 2023, annual average TP dropped significantly from 2022 levels below the state standard of 20 ug/L, likely due to the 2023 aluminum sulfate (alum) treatment (Figure 4.4-a). The alum applied to the lake removed phosphorus from the water column and formed a floc, which settled on the lake bottom where it inactivated the release of phosphorus from the bottom sediments, thus lowering the overall amount of TP in the water column. Chl-*a* has remained below the state shallow lake standard of 20 ug/L for the past 3 years of monitoring (Figure 4.4-b). Meadow Lake Secchi depth improved to almost 1m, almost reaching the state Secchi depth standard of 1m (Figure 4.4-c). This is higher than annual average Secchi depths previously measured in Meadow Lake, but it does not include summer measurements that would typically lower the overall average. Ortho-P levels dropped significantly from 2016 and 2022 (Figure 4.4-d), and TSS concentrations remained low, similar to 2022 levels (Figure 4.4-e).

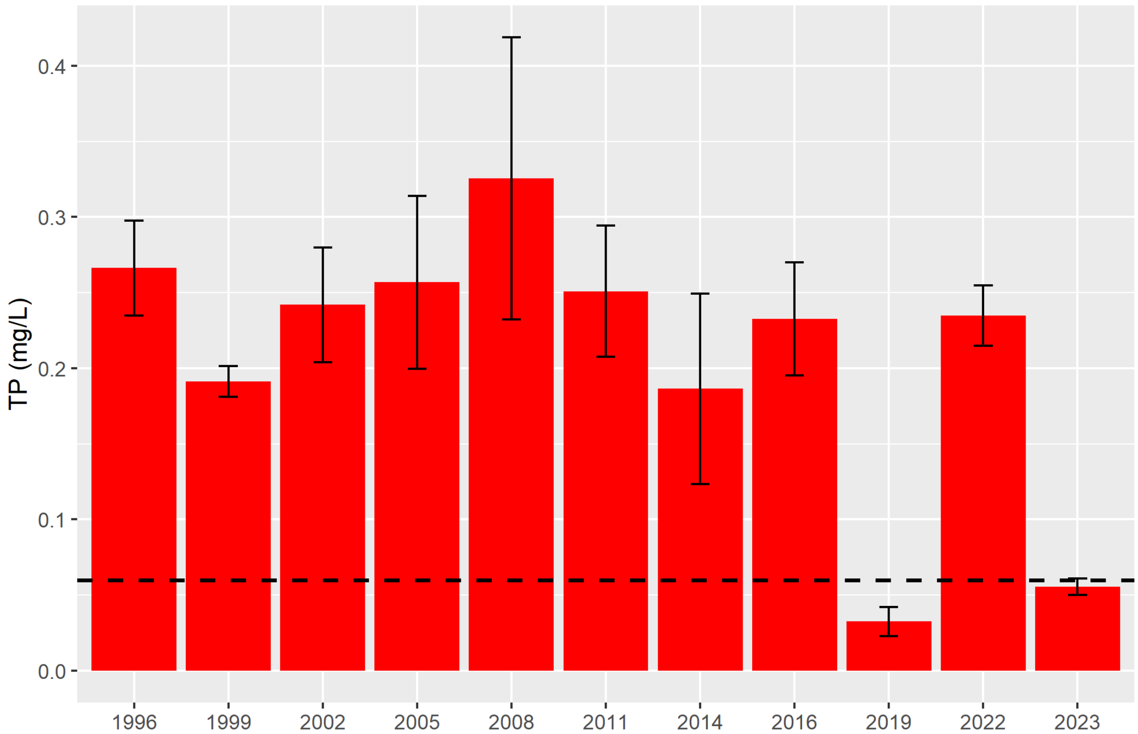


Figure 4.4-a. Meadow Lake growing season average total phosphorus concentration.
State shallow lake TP standard (black dashed line) for reference.

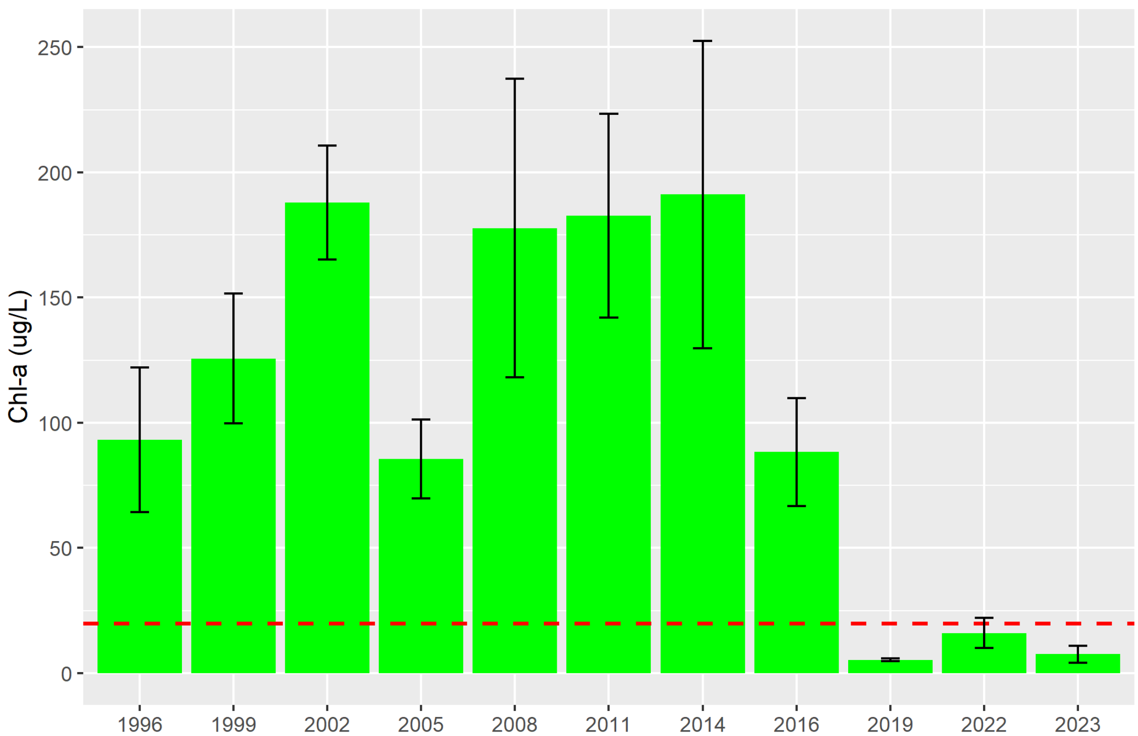


Figure 4.4-b. Meadow Lake growing season average chlorophyll-*a* concentration.
State shallow lake chl-*a* standard (red dashed line) for reference.

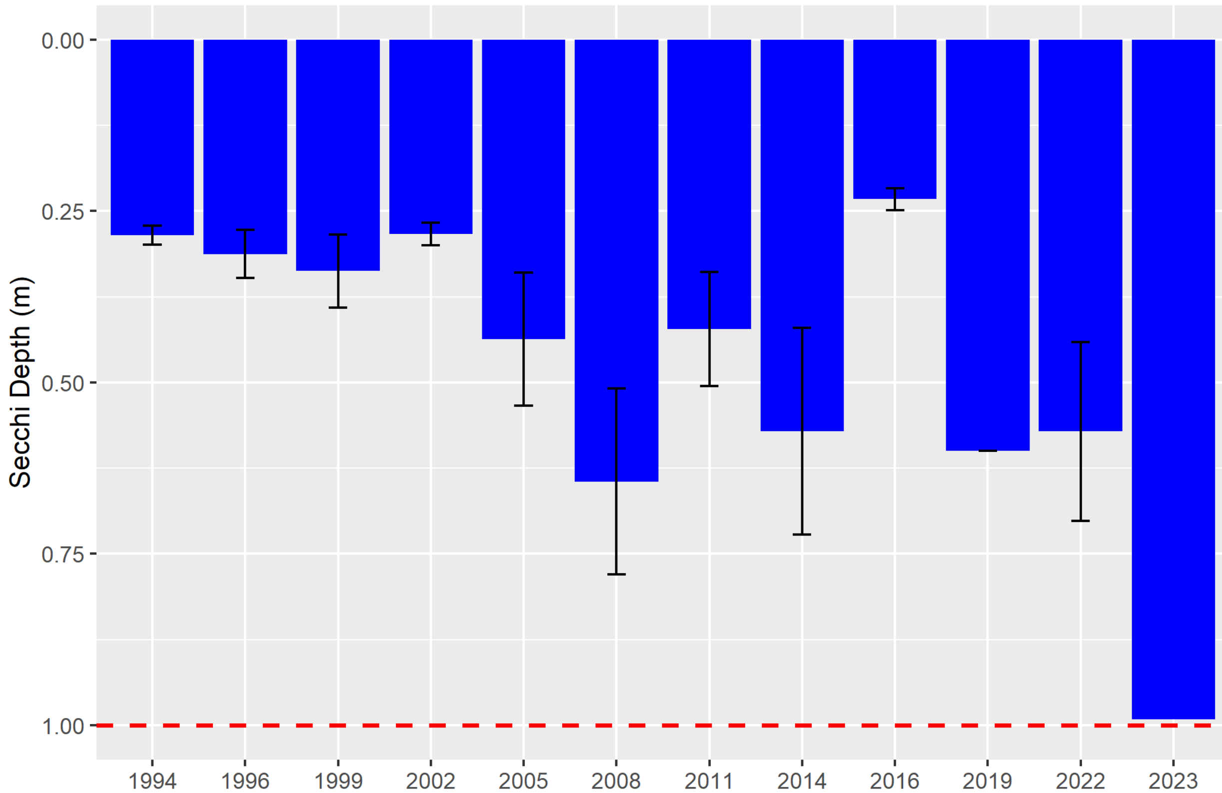


Figure 4.4-c. Meadow Lake annual growing season average Secchi depth.
State shallow lake Secchi depth standard (red dashed line) for reference.

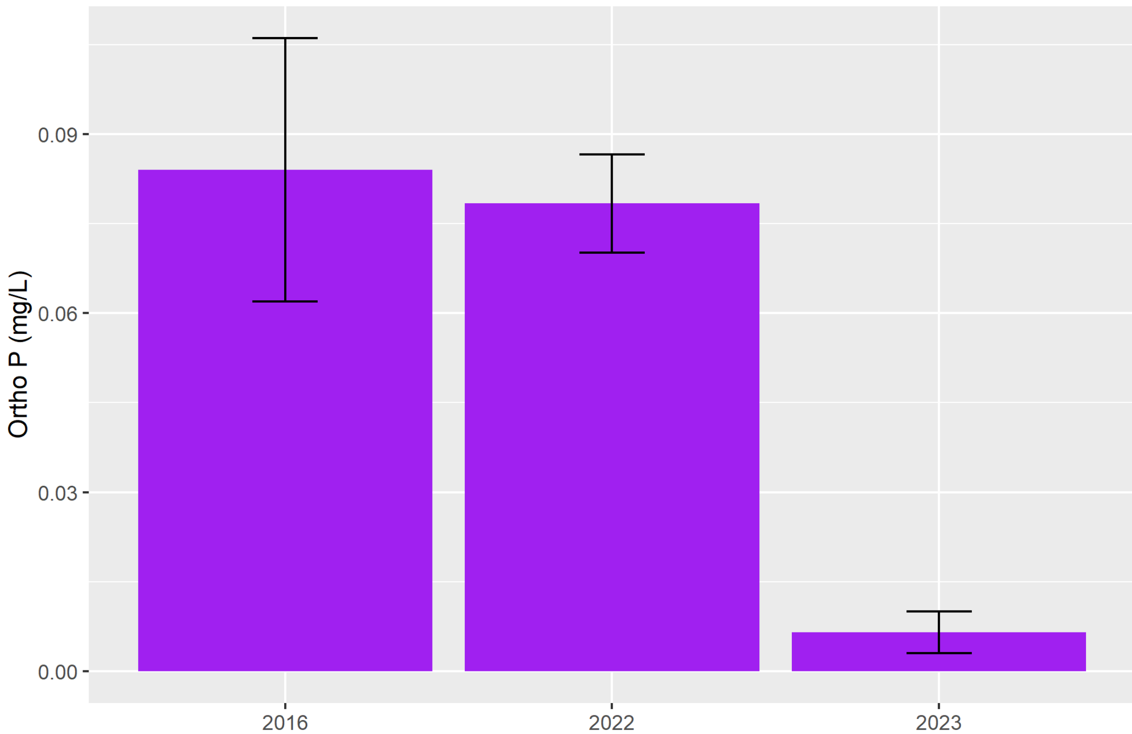


Figure 4.4-d. Meadow Lake annual growing season average ortho-phosphate.
Note: There is no state surface water standard for ortho-P.

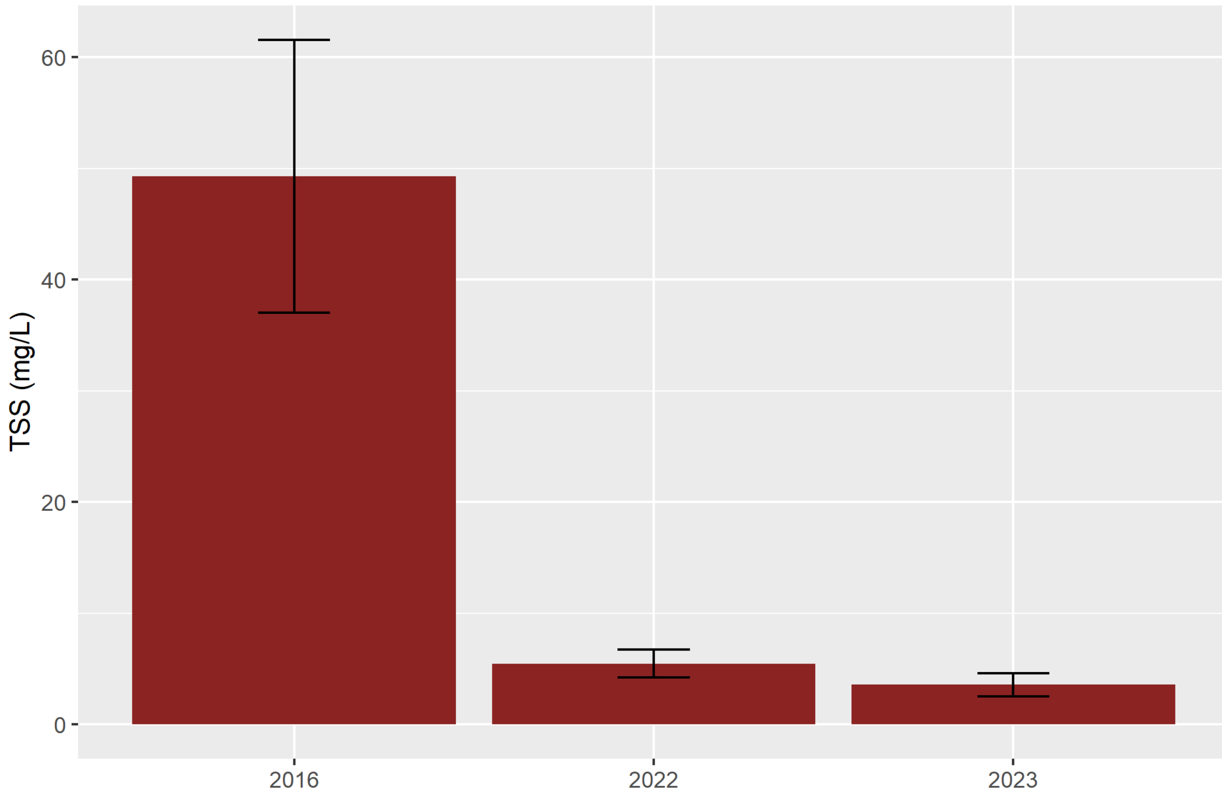


Figure 4.4-e. Meadow Lake annual growing season average total suspended solid concentration. Note: There is no state surface water standard for TSS.

4.4.2 Submersed Aquatic Vegetation

Two point-intercept aquatic vegetation surveys were conducted on June 19th, 2023 and August 14th, 2023 to document the submersed aquatic vegetation in Meadow Lake. Below are two tables outlining survey results and associated metrics and indices (Table 4.4-a) and plant taxa littoral frequency of occurrence (Table 4.4-b). Meadow Lake BioBase maps of taxa location and density were not included in this report due to low water levels that prevented accurate sonar data collection. No Eurasian Watermilfoil was found in the SAV survey.

Table 4.4-a. Meadow Lake SAV metrics and indices.

	June 19, 2023	August 14, 2023
LAKEWIDE METRICS		
Total Points Sampled	55	55
Total Littoral Points Sampled	55	55
% Littoral with Veg	54.5	70.9
Max depth of plant growth (ft)	1.9	2.2
Shallow Lake Species Richness Threshold	*11*	
Species Richness	6	7
COMMUNITY INDICES		
Shallow Lake FQI Threshold	*17.8*	
Floristic Quality Index (FQI)	13.6	14.27
Simpson's Diversity Index	0.734	0.764
Aquatic Macrophyte Community Index (AMCI)	29	33

Table 4.4-b. Meadow Lake plant taxa and littoral frequency of occurrence, 2023 surveys.

Taxa	Common Name	June 19, 2023	August 14, 2023
SUBMERSED TAXA			
Chara sp.	muskgrass	15	--
Ceratophyllum demersum	coontail	2	7
Najas flexilis	bushy pondweed	4	35
Potamogeton pusillus	small pondweed	15	16
FLOATING TAXA			
Lemna minor	lesser duckweed	36	40
Lemna trisulca	ivy-leaved duckweed	--	2
Spirodela polyrhiza	greater duckweed	35	42
Wolffia sp.	duckweed	--	2

4.5 EAGLE LAKE

Eagle Lake (Public Water No. 27011101) is in Maple Grove, MN within Hennepin County. Eagle Lake is classified as a deep lake and has an approximate surface area of 285 acres, 56 acres of littoral area (i.e., area less than 15 feet deep), an average depth of 9.8 feet, and a maximum depth of 39 feet. Eagle Lake is classified as a deep lake due to less than 80% of the lake being classified in the littoral zone. Eagle Lake was monitored for submersed aquatic vegetation as part of the Eagle Lake Subwatershed and Internal Load Study. The list below summarizes the year in which each type of sampling was most recently performed on Eagle Lake:

- Water Quality - 2020
- SAV – 2023
- Phytoplankton/Zooplankton - 2020
- Fisheries – Not assessed
- Carp – Not assessed

4.5.1 Water Quality

Water quality samples were not collected from Eagle Lake in 2023.

4.5.2 Submersed Aquatic Vegetation

Table 4.5-a presents survey and community metrics for Eagle Lake 2023 surveys. Eagle Lake has excellent plant diversity and biotic integrity, as measured by FQI. Species richness was 18 in early summer and 19 in late summer and exceeds the proposed threshold for deep lakes in the North Central Hardwood Forest (NCHF) ecoregion. FQI was 23.3 and 24 in early and late summer, respectively and exceeds the deep lake NCHF threshold of 18.6. The AMCI of Eagle Lake is high compared to other Metro Area lakes.

Table 4.5-b outlines point-intercept survey results from Summer 2023 lake vegetation surveys. Coontail and flat-stem pondweed had the highest abundance of all plant species in 2023. Curlyleaf pondweed and Eurasian Watermilfoil, Aquatic Invasive Species, were not observed in the lake during either the early or late season survey. Maps below include BioBase maps of vegetation biovolume (Figure 4.5-a), number of taxa found at each point (Figure 4.5-b), and CLP location and density (Figure 4.5-c).

Table 4.5-a. Eagle Lake SAV metrics and indices.

	June 20 – 21, 2023	August 16-18, 2023
LAKEWIDE METRICS		
Total Points Sampled	125	125
Total Littoral Points Sampled	107	108
%Littoral with Veg	64.5	73.1
Max depth of plant growth (ft)	10.9	10.2
Deep Lake Species Richness Threshold	*12*	
Species Richness	18	19
COMMUNITY INDICES		
Deep Lake FQI Threshold	*18.6*	
Floristic Quality Index (FQI)	23.32	23.96
Simpson's Diversity Index	0.896	0.891
Aquatic Macrophyte Community Index (AMCI)	59	62

Table 4.5-b. Eagle Lake plant taxa and frequency of occurrence from 2023 surveys.

Taxa	Common Name	June 20-21, 2023	August 16-18, 2023
Ceratophyllum demersum	Coontail	28	35.2
Chara sp.	Stonewart	10.4	12
Heteranthera dubia	Water stargrass	6.4	1.6
Myriophyllum sibiricum	**Eurasian watermilfoil**	6.4	8
Najas guadalupensis	Common water nymph	--	0.8
Potamogeton illinoensis	Illinois pondweed	1.6	3.2
Vallisneria americana	Eelgrass	0.8	9.6
Potamogeton zosteriformis	Flat-stem pondweed	32.8	45.6
Najas flexilis	Slender naiad	--	3.2
Potamogeton pusillus	Small pondweed	2.4	1.6
Potamogeton friesii	Fries' pondweed	0.8	--
Stuckenia pectinata	Sago pondweed	0.8	1.6
Potamogeton crispus	**Curly-leaf pondweed**	--	--
Utricularia vulgaris	Greater bladderwort	4	7.2
Lemna trisulca	Star duckweed	22.4	27.2
Nymphaea odorata	White waterlily	8.8	10.4
Lemna minor	Small duckweed	10.4	11.2
Spirodela polyrhiza	Large duckweed	9.6	11.2
Wolffia sp.	Duckweed	11.2	8
Nuphar variegata	Spatterdock	16.8	15.2
Brasenia schreberi	Watershield	P	--
Typha sp.	Cattail	P	--
Nitellopsis obtusa	Starry stonewart	P	--
Spirogyra sp.	Filamentous algae	--	P
Schoenoplectus tabernaemontani	Softstem bulrush	4	3.2

*****Taxa considered to be Aquatic Invasive Species (AIS) are shown in bold.

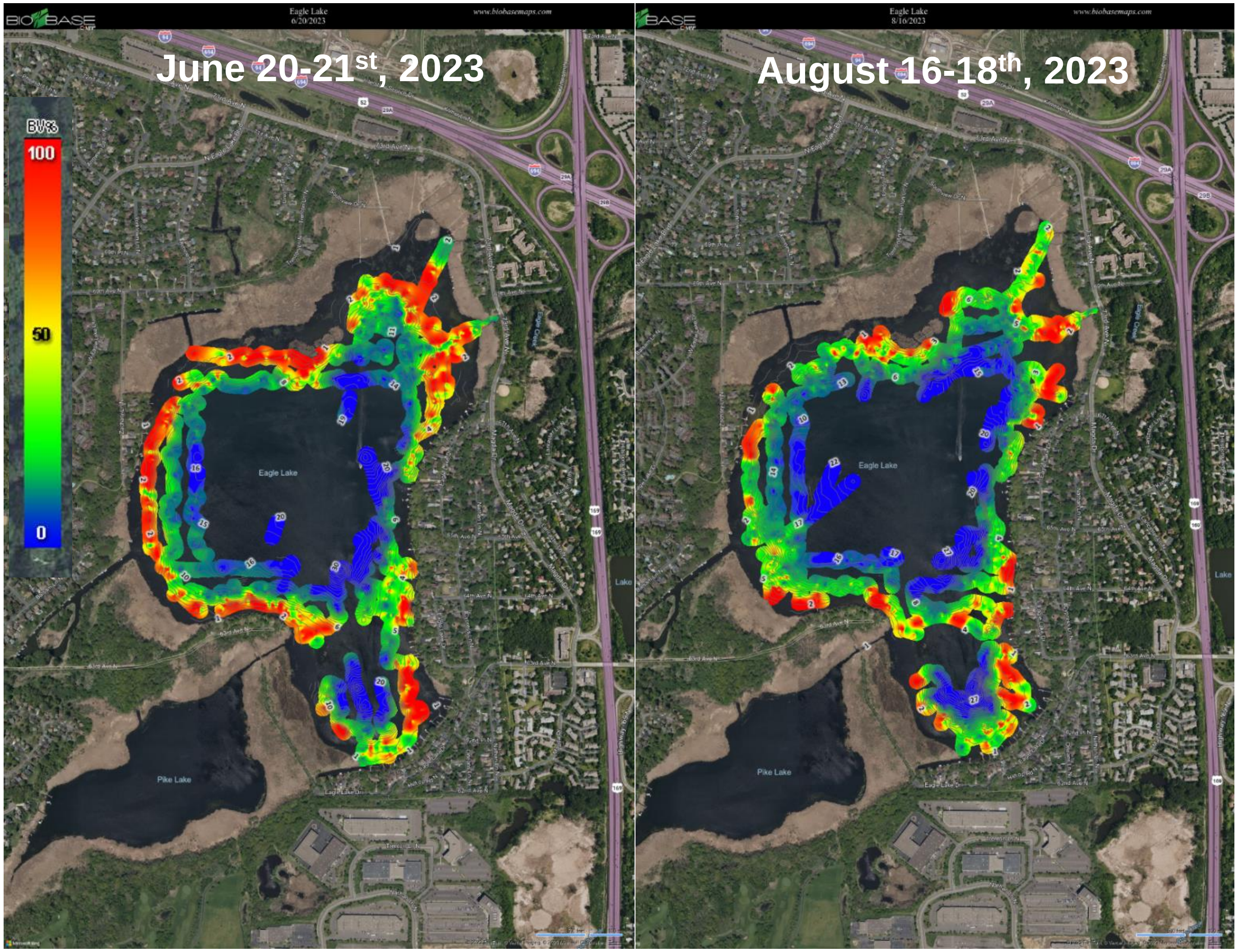


Figure 4.5-a. Early (left) and late (right) season BioBase map of vegetation biovolume in Eagle Lake.

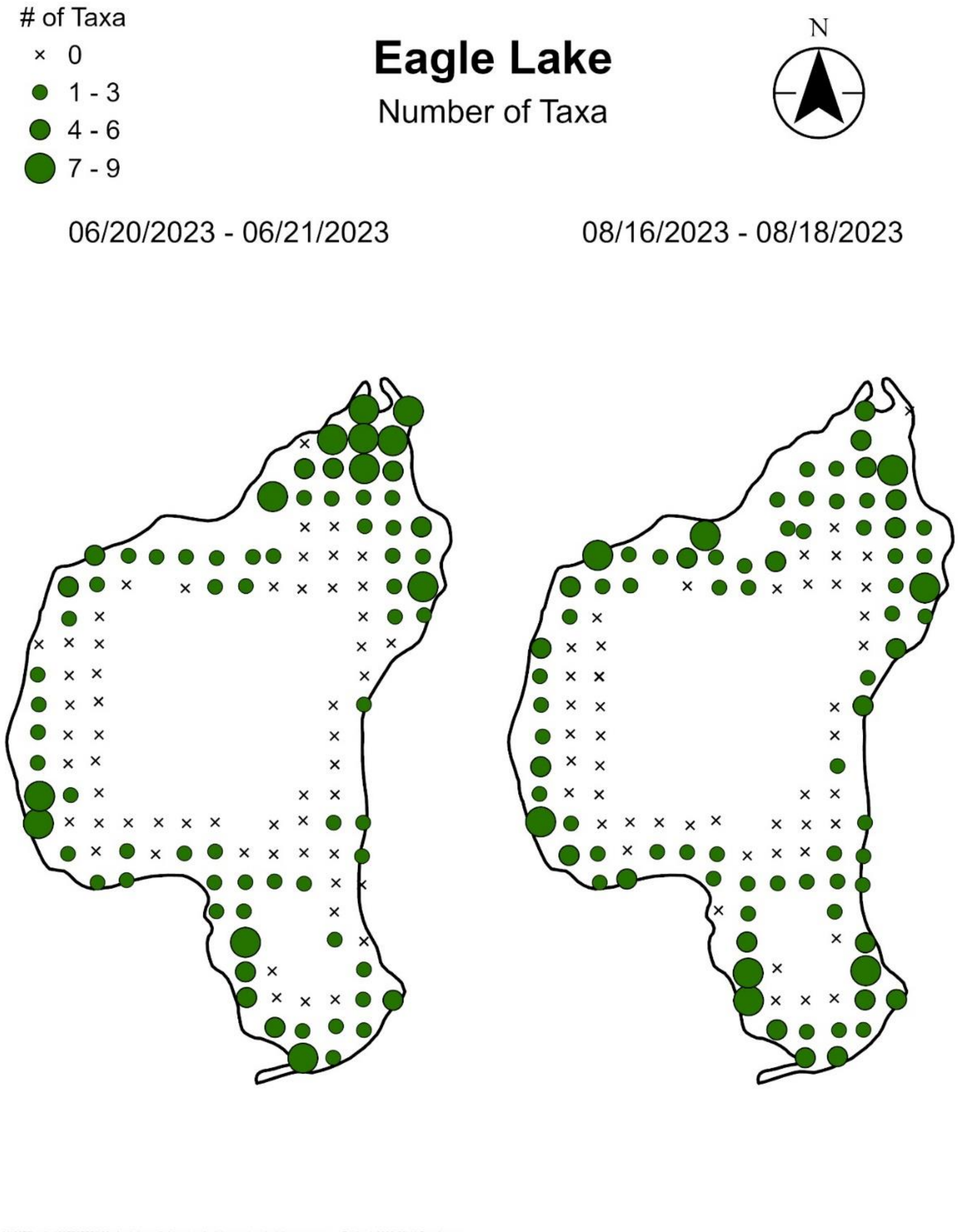


Figure 4.5-b. Early and late season number of plant taxa found in Eagle Lake.

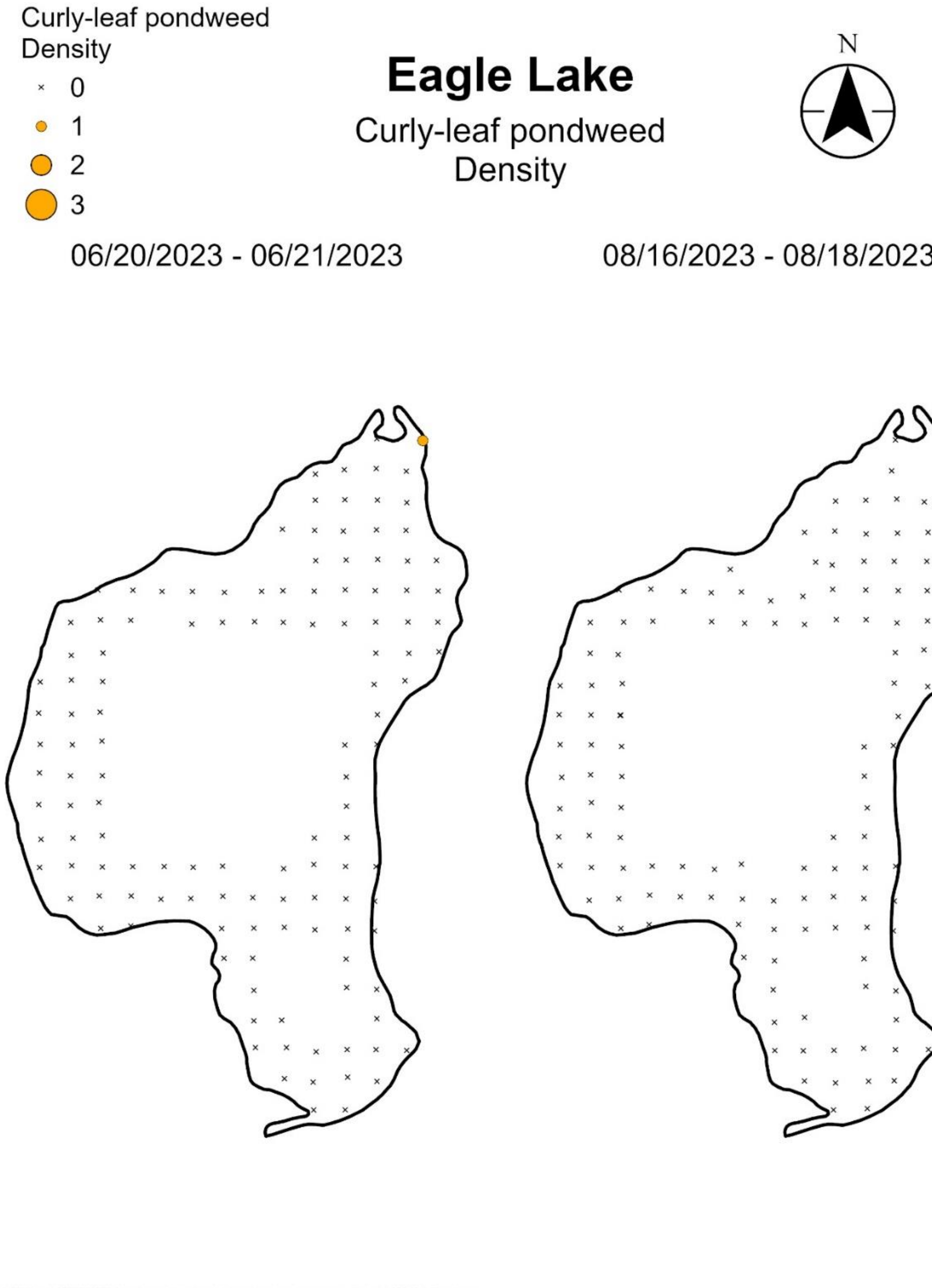


Figure 4.5-c. Early and late season curly-leaf pondweed density found in Eagle Lake.

4.6 PIKE LAKE

Pike Lake (Public Water No. 27011102) is located in the cities of Maple Grove and Plymouth within Hennepin County, MN. Pike Lake is classified as a shallow lake and has an approximate surface area of 55.53 acres. It is classified as a shallow lake due to >80% of the lake being classified in the littoral zone (i.e., <15 feet deep). Pike Lake has a maximum depth of 22 feet. The list below summarizes the year in which each type of sampling was most recently performed:

- Water Quality – 2020
- Phytoplankton/Zooplankton - 2020
- SAV – 2023
- Fisheries – Not assessed
- Carp – Not assessed

4.6.1 Water Quality

Water quality samples were not collected from Pike Lake in 2023.

4.6.2 Submersed Aquatic Vegetation

Table 4.6-a presents survey and community metrics for Pike Lake 2023 surveys. Pike Lake has good plant diversity and biotic integrity, as measured by FQI. Species richness was 11 in early summer and 10 in late summer, exceeding the proposed threshold for shallow lakes in the North Central Hardwood Forest (NCHF) ecoregion in early summer only. FQI was 16.5 and 15.6 in early and late summer, respectively. FQI is just below the deep lake NCHF threshold of 17.8. The Simpson's Diversity Index of Pike Lake is similar to that of Eagle Lake.

Table 4.6-b outlines point-intercept survey results from 2023 lake vegetation surveys in Pike Lake. Coontail had the highest abundance of all plant species in 2023, similar to Eagle Lake. Other abundant species include white waterlily, duckweed, and watermeal. Curlyleaf pondweed (CLP) was observed in both the early and late season surveys, but in very low abundance (frequency of occurrence of 3.7 and 1, respectively). Maps below include BioBase maps of vegetation biovolume (Figure 4.6-aFigure 4.6-a), number of taxa found at each point (Figure 4.6-b), and CLP location and density (Figure 4.6-c).

Table 4.6-a. Pike Lake SAV metrics and indices.

	June 21, 2023	August 16-18, 2023
LAKEWIDE METRICS		
Total Points Sampled	107	105
Total Littoral Points Sampled	101	101
% Littoral with Veg	55.4	42.6
Max depth of plant growth (ft)	14.5	13.3
Shallow Lake Species Richness Threshold	*11*	
Species Richness	11	10
COMMUNITY INDICES		
Shallow Lake FQI Threshold	*17.8*	
Floristic Quality Index (FQI)	16.45	15.55
Simpson's Diversity Index	0.850	0.844
Aquatic Macrophyte Community Index (AMCI)	43	44

Table 4.6-b. Pike Lake plant taxa and frequency of occurrence from 2023 surveys.

Taxa	Common Name	June 21, 2023	August 16-18, 2023
Ceratophyllum demersum	Coontail	51.4	40
Potamogeton zosteriformis	Flat-stem pondweed	12.1	8.6
Potamogeton pusillus	Small pondweed	0.9	--
Elodea canadensis	Canadian waterweed	1.9	1.9
Potamogeton crispus	**Curly-leaf pondweed**	3.7	1
Lemna trisulca	Star duckweed	34.6	17.1
Nymphaea odorata	White waterlily	20.6	23.8
Lemna minor	Small duckweed	24.3	17.1
Spirodela polyrhiza	Large duckweed	25.2	17.1
Wolffia sp.	Watermeal	31.8	19
Nuphar variegata	Spatterdock	4.7	4.8

*****Aquatic Invasive Species (AIS) are shown in bold.

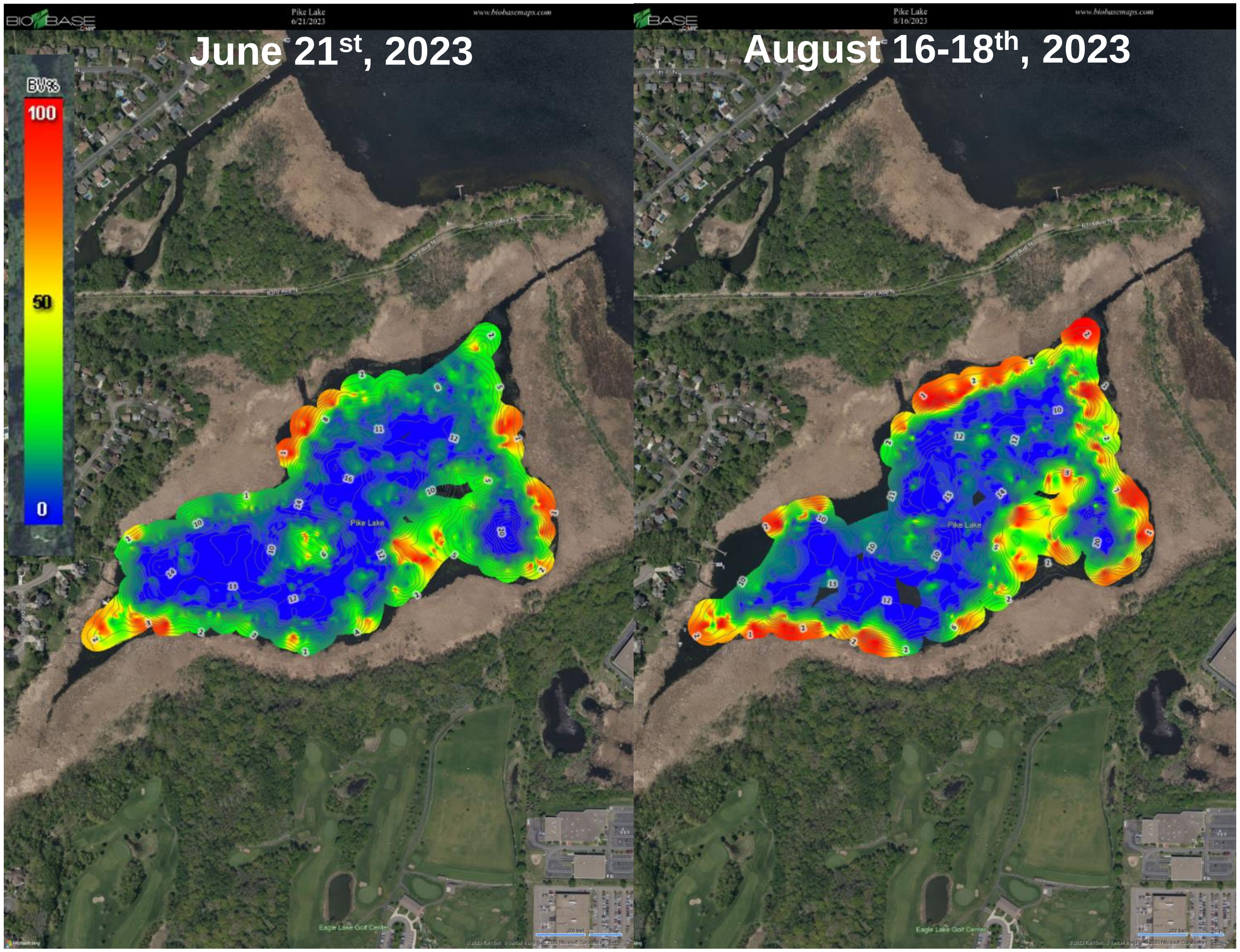


Figure 4.6-a. Early (left) and late (right) season BioBase map of vegetation biovolume in Pike Lake.

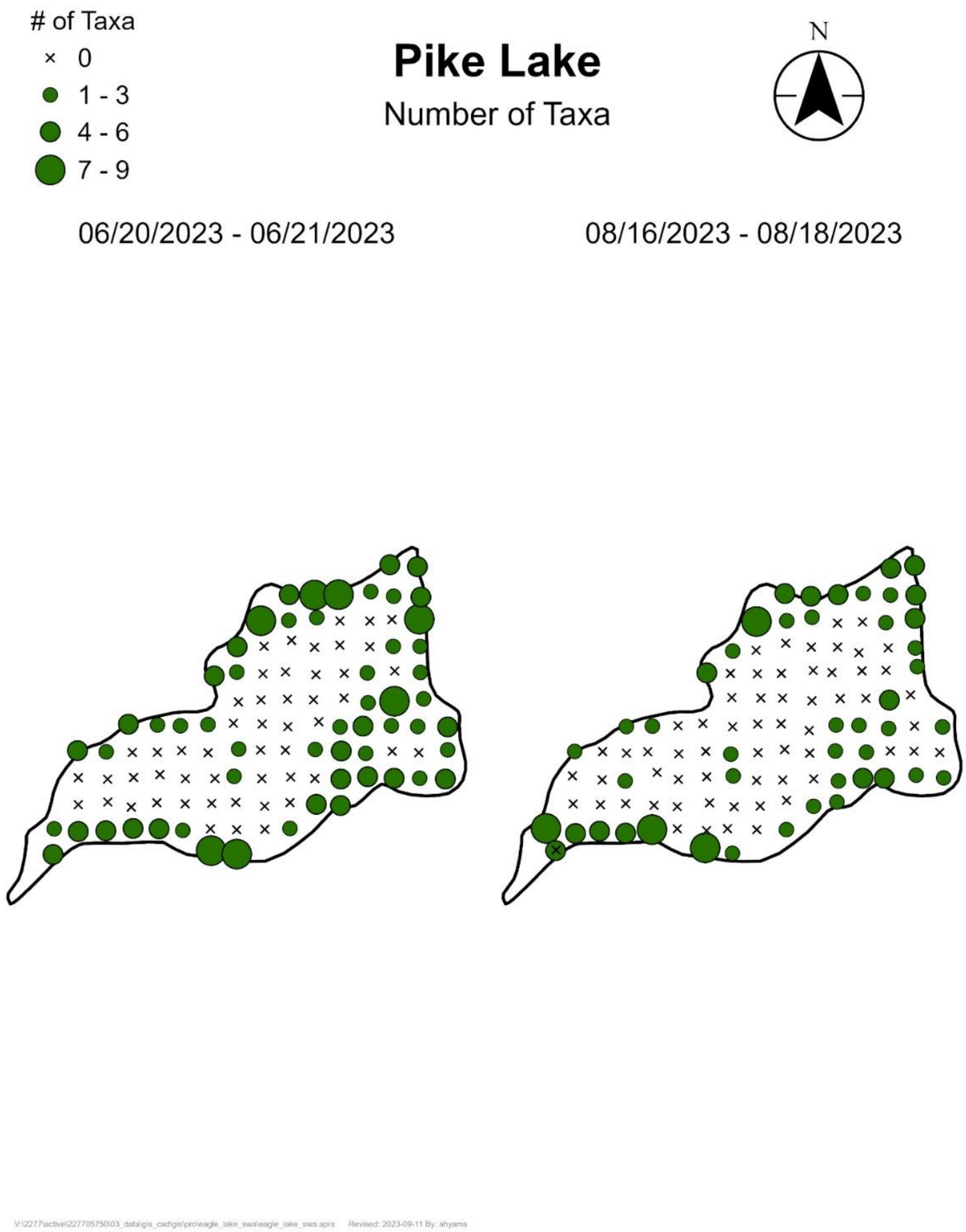


Figure 4.6-b. Early and late season number of plant taxa found in Pike Lake.

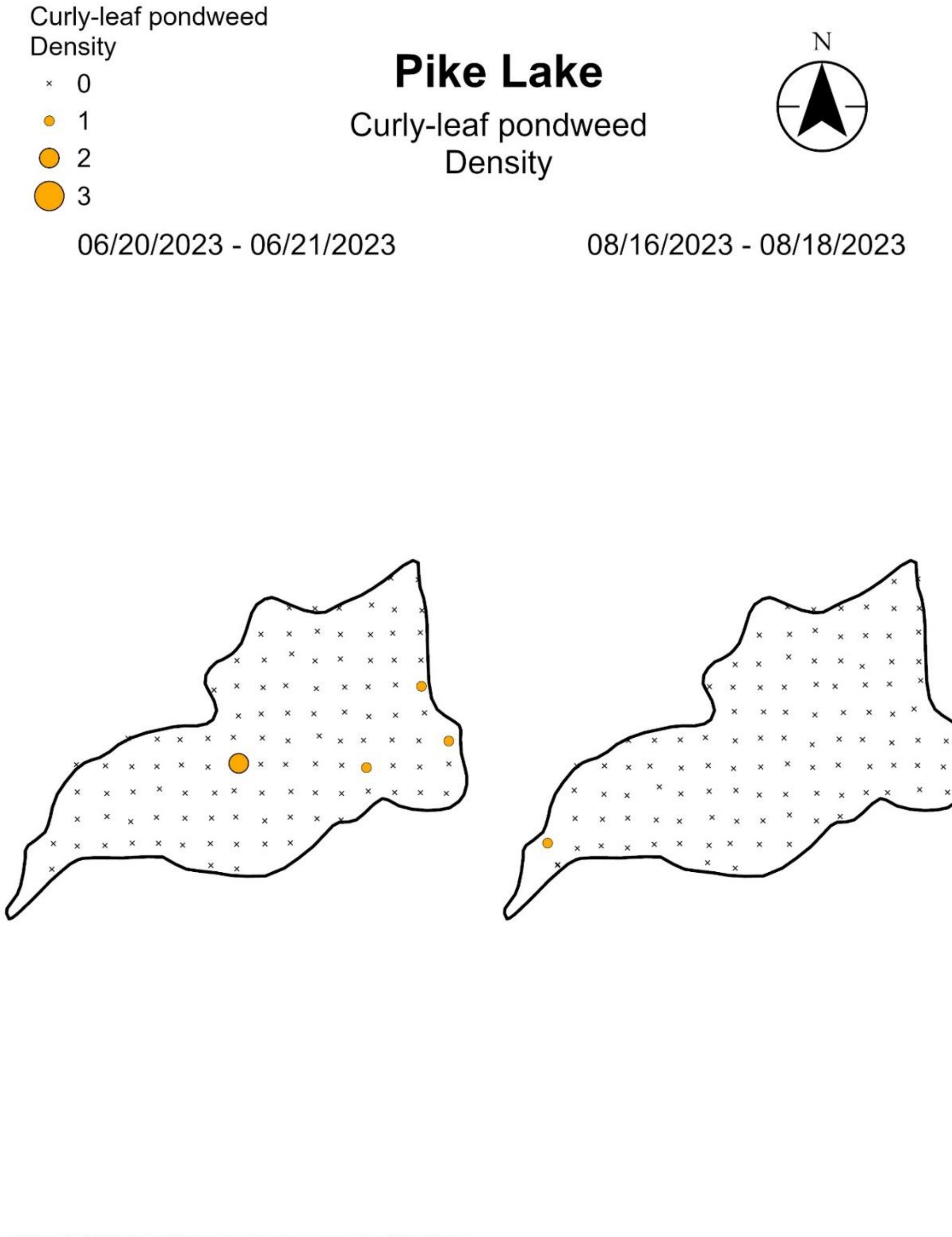


Figure 4.6-c. Early and late season Curly-leaf pondweed density found in Pike Lake.

5.0 MOVING FORWARD

Routine monitoring and storm monitoring will continue on Bass and Shingle Creeks in 2024. The 65th Ave outfall and the Mattson Brook stream in West Mississippi will also be monitored by the Commission.

Eagle and Pike Lakes will undergo routine lake monitoring in 2024 ahead of alum treatments planned for Fall 2024. Early and late summer SAV surveys will be done on both lakes. Phytoplankton and zooplankton community monitoring will continue. Volunteer monitoring through the CAMP program are planned for Cedar Island, Bass, and Pomerleau Lakes. As part of ongoing active management projects, an additional year of carp removals will occur on Crystal Lake. Curly-leaf pondweed management is planned for Bass Lake. Meadow Lake will be monitored for water quality and vegetation.