2023 Nearshore Monitoring in Wisconsin's Lake Superior coast for nutrient conditions leading to Harmful Algal Blooms (HABs)

"Dawn at Cave Point" by Michael Knapstein 2018 Great Lakes Photo

Office of Great Waters -- Northern Region

Wisconsin Department of Natural Resources

Project Coordinators/Principal Investigators:

Ellen Coffman
WDNR, Lake Superior Sediment and Monitoring Coordinator
Superior, WI

Madeline Magee
WDNR, Bureau of Water Quality Monitoring Technical Lead
Madison, WI

Acknowledgments:
Emma Holtan, DNR Water Resource Management Specialist
Janane Widiker, DNR Natural Resource Research Technician

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WISCONSIN DEPT. OF NATURAL RESOURCES

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Abstract

Since 2012 there has been an increase in cyanobacterial bloom observations along the south shore of Lake Superior. These blooms, defined as the rapid growth of cyanobacteria that can form surface accumulations and are a potential toxin-producing phylum, have included the species *Dolichospermum lemmermannii.* The potential for toxin production could impact summer tourism, public health, and recreational users in nearshore areas. We do not currently understand the conditions leading to bloom formation or where initial bloom development occurs. Changing climate conditions are thought to be a driver of the recent increase in bloom observations.

Our project objectives included 1) obtaining baseline surface water quality parameters associated with algal bloom formation in Wisconsin's Lake Superior shoreline, 2) collecting water quality data before and during algal bloom events, and 3) determining the spatial and temporal distribution of algal bloom events.

The dataset captured a cooler than average air temperature season and lower than average precipitation. We observed the maximum chlorophyl a concentration, 2.1 µg/L, near Wisconsin Point occurring early in the sampling season (June). The sites furthest east experienced greater water clarity with deep Secchi depths and low total phosphorus concentrations when compared to sites further west. While no cyanobacteria blooms were observed during routine monitoring at set sites, cyanobacteria species were detected at all sampled locations (6 sites) and were seen to comprise of more than half the phytoplankton population (cells/mL) at certain time points (September). Cyanobacteria represented a larger portion of the algal community towards the end of the sampling season (end of August to early September; 9-21 °C). There was no strong association observed between presence of cyanobacteria and nutrient concentrations.

Blooms of cyanobacteria were detected in the St. Louis River Estuary and the Wisconsin south shore of Lake Superior. Blooms are considered visible accumulation of cyanobacteria; they can look like grass clippings or paint spills depending on species presence. Cyanobacteria can be present in the phytoplankton community without being considered a bloom if there is not visual evidence of an accumulation of cells. Blooms occurred later in the season August, September and through the beginning of October. Samples collected during the Barker's Island bloom were dominated by *Aphanizomenon*, while the blooms along the south shore were dominated by *Dolichospermum*.

Toxin data is not available for all blooms observed. Two of the Barker's Island blooms were analyzed for algal toxins and found to have microsystin toxin concentrations of 1.9 and 0.21 µg/l which is below the US EPA Recreation Advisory level of 8 µg/L

Introduction

Lake Superior is the largest freshwater lake in the world. It is considered to be of the highest condition and quality among the Laurentian Great Lakes, supporting a wide range of species and providing numerous ecosystem services, including multiple recreational opportunities, all of which rely on the health of the ecosystem (Reinl et al., 2025). While Lake Superior remains in relatively high condition, it has experienced significant changes including chemical pollution, invasive species, and harmful algal blooms (HABs) (Reinl et al., 2025). As an oligotrophic system, Lake Superior is especially vulnerable to climate change, with rapidly warming water temperatures, increased nutrient inputs from extreme storm events, and shifts in habitat and food web structure, among other impacts (Reinl et al., 2025). The Lake Superior nearshore zone is more dynamic and sensitive to change than the offshore zone. Factors such as direct watershed influence and longshore currents can contribute to greater variability in nearshore water quality, temperature, and nutrient levels compared to the more stable conditions of the offshore (Marcarelli et al., 2019). The nearshore zone is particularly vulnerable to environmental pressures, highlighting the need for focused monitoring and management strategies to address these localized but critical changes (Reinl et al., 2025). This area is also where people interact most with the lake, meaning such changes directly affect communities that depend on Lake Superior for recreation, fishing, and drinking water. Understanding current conditions and trends in nearshore nutrient dynamics will help improve management of the lake now and better prepare for the future (Reinl et al., 2025).

Lake Superior has experienced an increase in cyanobacterial bloom observations reported in the past 10 years, that threaten the recreational uses of the nearshore area. We do not understand conditions leading to bloom formation on Lake Superior or where initial bloom formation occurs. Blooms are typically associated with increased loading of nutrients to the nearshore environment (Lürling et al., 2018; Schindler, 1975; Steinberg and Hartman, 1988), particularly phosphorus in freshwater systems, which is the limiting nutrient for Lake Superior. Changing climate is thought to be a driver for the recent increase in bloom formation observations, especially a change in precipitation patterns and rapid surface water warming (Austin and Colman, 2007). Extreme rain events and large fluxes of nutrients and sediment to the western arm of Lake Superior proceeded late summer algal blooms (2012, 2016, 2018) (Cooney et al., 2018 and Minor 2014). In Lake Superior, blooms were observed weeks after extreme storms; the lag times observed have ranged from 25 to 53 days (Sterner et al., 2020). The blooms generally occur from mid-July to the end of August (Sterner et al., 2020), likely because this is when the surface waters are warmest. Lake Superior has been warming at the fastest rate compared to the other Laurentian Great Lakes (Austin and Colman, 2007; O'Reilly et al., 2015), and warming epilimnetic temperatures are thought to influence the increasing presence of cyanobacteria on Lake Superior (Konopka and Brock, 1978; Kosten et al., 2012; Paerl and Huisman, 2009; Robarts and Zohary, 1987).

Blooms have been reported along the southern shore of Lake Superior since 2012, with more activity occurring after large storm events (2023 Bloom Bulletin). A potential toxin-producing species, *Dolichospermum lemmermannii* (identified by Gina LaLiberte, Wisconsin Department of Natural Resources- Statewide Harmful Algal Bloom Coordinator & Applied Limnologist), have been identified in multiple bloom events since 2012 (2023 Bloom Bulletin) . Blooms are considered visible accumulation of cyanobacteria; they can look like grass clippings or paint spills depending on species presence. Cyanobacteria can be present in the phytoplankton community without being considered a bloom if there is not visual evidence of an accumulation of cells. While toxins were not observed in all blooms along the south shore, these blooms are a concern to the public due to their increased occurrence, as well as their ability to potentially impact summer tourism, public health, and recreation.

These observations have led to renewed interest in the role of watershed inputs in the nearshore nutrient cycle and biogeochemical cycling of the lake (Reinl et al., 2025). It is thought that tributary fluxes of suspended sediment, nutrients (especially particulate phosphorus), and cyanobacteria play a significant role in driving nearshore blooms along the southwestern shore of oligotrophic Lake Superior (Kreiling et al., 2025). Storm flows were identified as key drivers of sediment and nutrient export, with suspended sediment acting as a source of bioavailable phosphorus (Kreiling et al., 2025). Cyanobacteria, including toxin-producing strains, have been found in tributaries in water and sediment (Wood et al., 2025). This shows the importance of investigating the role of fluvial transport in nutrient-driven algal blooms in the nearshore (Reinl et al., 2025). Despite localized blooms and the presence of toxin-producing taxa, blooms are not yet widespread (Reinl et al., 2025). It is important to conduct proactive monitoring and data collection to mitigate future risks under changing climatic conditions.

The goal of this project was to characterize pre- and during bloom water quality conditions in the Wisconsin Lake Superior nearshore. The collection of this information was a first step in understanding the blooms and developing management actions to minimize their occurrence and impact. Data was collected at 15 sites, 6 times throughout the field season (June-September).

Methods

Experimental Design

Nearshore HAB'S Sampling Sites

Figure 1: Map of sampling sites. 15 sites spanning from Superior to Miwakuie Bay.

Sampling locations were chosen to replicate previous studies conducted in 2019, 2021 and 2022, which focused on source tributary mouths and areas where previous blooms have occurred. These sites provide us with sufficient spatial distribution to understand where potential sources of nutrients leading to bloom conditions are entering the lake. Surface water samples were collected at the 5 m contour (Figure 1, Tables 1 and 2). In 2019 the Lake Superior Nearshore monitoring group determined that the 5 meters depth contour was most appropriate for sampling, as it balances interests in sampling the very nearshore (since that is where blooms have been observed) and provides a broader scale perspective of the distribution of nutrients throughout the 55 miles of the south shore region.

Sampling sites were visited 6 times, approximately every other week from mid- June through September. This time frame allowed us to capture water quality conditions throughout the potential growing season. The collection of samples was generally split into two groups, sites 1-7 and sites 8-15, and completed over two days to allow time for overnight shipping. When weather conditions restricted sampling, algal ID sites and sites further east were prioritized, as these areas are where historic blooms occurred.

Table 1: Dates of sample collection for each mobilization.

Sampling Round	Date
1	June 27th
2	July 17th and 18th
3	July 31st and August 1st
4	August 30th
5	September 5th
6	September 20th and 21st

Table 2: Details of sampling locations.

Station	SWIMS Station ID	SWIMS Station Name	Latitude	Longitude
1	10040814	Lake Superior – Point off Schaffer Beach 3.6 m contour	46.68592	-91.929726
2	10052502	Lake Superior – W. of Amnicon	46.69601	-91.849785
3	101	Lake Superior – N.E. Poplar River	46.7	-91.78334
4	10052503	Lake Superior – W. of Bardon Cr	46.71865	-91.72388
5	10052504	Lake Superior – E. of Pearson Cr. Station	46.73117	-91.67240
6	103	Lake Superior – W. of Brule R.	46.7486	-91.618065
7	10052505	Lake Superior – W. of Douglas Co Line	46.75911	-91.571304
8	10052587	Lake Superior – E. Iron River	46.77119	-91.48382
9	10052510	Lake Superior – E. of Flag River Station	46.79663	-91.37061
10	10052511	Lake Superior – Block 11	46.83277	-91.29428
11	10052514	Lake Superior – Cranberry River	46.8377	-91.2646
12	10038057	Lake Superior – Bark Bay Point Clay Bluffs	46.8675	-91.22806
13	10052512	Lake Superior – Bark Bay W. of Bark R	46.85046	-91.1902
14	10052513	Lake Superior – Siskiwit Bay	46.85905	-91.115295
15	10054863	Lake Superior – Miwaukuie Bay	46.88067	-91.0615

Sample Collection

Sample collection on Lake Superior is highly subject to weather conditions. During sampling weeks, the crew monitored weather conditions, and in the interest of crew safety, sampled on days where waves were less than 2 feet. Therefore, some weeks contained gaps in site data due to unsafe weather conditions. Wind magnitude and direction can vary rapidly over the course of a day, which made it necessary to amend sampling plans in the field, leading to some sites not being sampled. To try to keep our timing consistent throughout the season, we only sampled the weeks determined at the beginning of the season. Throughout those weeks, samples were collected on Mondays, Tuesdays, or Wednesdays. There was a shipping delay the second day of the late June sampling that impacted hold times and temperatures of parameters. The dates sampled are shown in Table 2.

Time of arrival, weather conditions, latitude/longitude, and depth were recorded at each site. Secchi depth was collected on the shaded side of the vessel. The depth at which the disk disappeared and reappeared was recorded. This measurement was completed by the same researcher in each sampling round to ensure consistency throughout the dataset.

Sonde profiles were collected using a YSI ProDSS of dissolved oxygen (concentration and percent), temperature, specific conductance, pH, and turbidity at each site during each event. The sonde was calibrated to the standards of the manual. pH and conductivity were calibrated daily using standard solutions purchased from YSI. The pH probe did not pass its calibration checks at the beginning of the season and new probe was purchased and installed, but this did not occur till the end of the field season due to back log, more details are provided in results.

Surface water samples were collected for chlorophyll a (chla), total suspended sediment (TSS), orthophosphate (OrthoP), total phosphorus (TP), total nitrogen (TN), and nitrate-nitrite (NO_3-NO_2). TP was run as low-level phosphorus (LLTP) with a lower detection method (Table 3 and 4). Algal ID and enumeration samples were collected at sites 1, 3, 6, 8, 9 and 14 throughout the sampling season to gain a better understanding of how the algal community shifts within the nearshore.

Prior to collecting water samples, sampling bottles and lids were triple rinsed with site water to minimize contamination. All samples were taken approximately 6 inches below the surface of the water. Sampling containers were filled to the shoulder of the bottle unless stated below. 1 mL of 25% H2SO4 sulfuric acid was added to the sample for nutrients that contain TP, TN, and NO3/NO2, to preserve until analysis. When LLTP was sampled, a separate sampling bottle that was acid washed was filled and preserved. Algal ID samples were preserved with 2.5ml of Glutaraldehyde before shipment.

OrthoP and chla were field filtered. OrthoP filtrate was collected through 0.45 µm mixed cellulose ester (MCE) filters. Chla filtrate was collected through 5.0 µm MCE filters and then both were stored on ice in the dark. The volume of water that passed through each Chla filter was recorded for each site and sampling event.

Samples were collected into appropriate sampling containers (Table 3) and placed on ice. After returning to the dock, samples were shipped to the Wisconsin State Lab of Hygiene for analysis. OrthoP was analyzed at PACE Analytical in Duluth, MN to avoid issues with hold times. Samples were driven on ice after sampling event to lab for analysis.

Table 3: Methods for algal sample handling. NA stands for "Not Applicable".

Parameter	Lab Code	Collection Bottle	Field Filter?	Preservation/Shipping	Hold time	LOD
Chlorophyll-*a* (Chl-*a*)	ICC25120	500 mL plastic quart bottle	Yes 47 mm, 5 um pore, no more than 6 inches of mercury (20kPa)	If filtered 15 mL polypropylene centrifuge tube wrapped in foil on ice. If not packed with ice in a dark cooler	48 hours (unfiltered); 3.5 weeks (filtered)	0.0578 µg/L
Microcystin	ETC47500	Glass of PETG 125 to 1000 mL	No	Half-filled bottles frozen< -20 C if not to be analyzed within 24-48 hrs	5 days	0.10 µg/L
Saxitoxin	ETC47520	40 or 60 mL Amber glass with Teflon caps	No	Add preservative at a rate of 1 mL of 10X Concentrated Sample Diluent per 9 mL of Sample. Store sample in a dark & cool location at all times. Ship overnight on Ice.	5 days or frozen	0.022 µg/L
Algal ID/ Enumeration	ETC47001	250 mL plastic bottle	No	Glutaraldehyde 1 mL of 25% glutaraldehyde for every 100 mL	Several years	NA

Table 4: Methods for nutrient sample handling. NA stands for "Not Applicable".

Parameter	Lab Code	Collection Bottle	Field Filter?	Preservation/Shipping	Hold Time	LOD
Total Suspended Solids (TSS)	ICC65000	500mL plastic quart	No	Less than 6C	7 days	2
Orthophosphate (ORTHOP)	EPA 365.3	125mL polyethylene	Yes, 0.5 µm	Less than 6C, but not frozen	48 hours	0.0014
Low Level Total Phosphorus (TP)	ICC52010	250 mL plastic bottle	No	1mL of 25% H2SO4, Less than 6C, but not frozen	28 days	0.00190
Total Nitrogen (TN)	ICC46601	250mL plastic bottle	No	1mL of 25% H2SO4, Less than 6C, but not frozen	28 days	0.058
Nitrate/Nitrite (NO3/NO2)	ICC46000	250mL plastic bottle	No	1mL of 25% H2SO4, Less than 6C, but not frozen	28 days	0.055 mg NO3+NO2-N/L

For the summary statistics tables, non-detect values were replaced with half of the limit of detection. This provides a conservative estimate of average concentrations of parameters in the nearshore. For graphic visualization ND were not displayed.

For graphics and analysis of hydrologic information the depth of 0.5 m was used. This was done to pair values with surface water grabs for nutrients. For full profile of water column view Appendix.

Results/Discussion

Lake Superior is an oligotrophic system; thus, it has low concentrations of nutrients. The values observed are at the lower limit of some of the methods used by the Wisconsin State Lab of Hygiene and PACE Analytical. There were many non-detects for TSS and OrthoP. LLTP dataset had values that were between the limit of quantification and the limit of detection. We acknowledge that we have a low degree of certainty for these values, but they are used in the analysis.

Gaps in the data are most likely due to sites not being sampled during a round of sampling. This was either caused by weather creating unsafe sampling conditions, or slow boating conditions such that a site had to be skipped to make it back in time to ship samples to the lab for analysis.

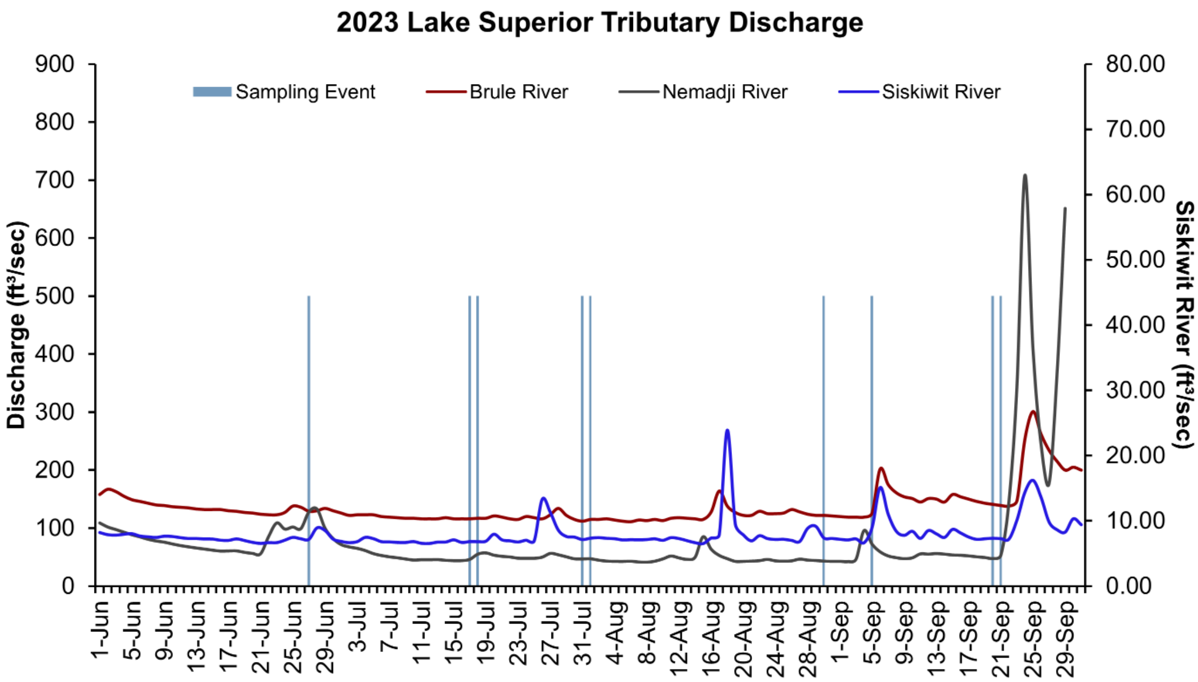

Figure 2: Tributary discharge (ft3/sec) for three Lake Superior tributaries located near the sampled sites. Sampling events are depicted in grey vertical lines. Discharge values are depicted in red, black, and blue for Brule, Nemadji, and Siskiwit respectively. Siskiwit River had a much lower discharge, thus it is on its own axis.

Hydrodynamic Data

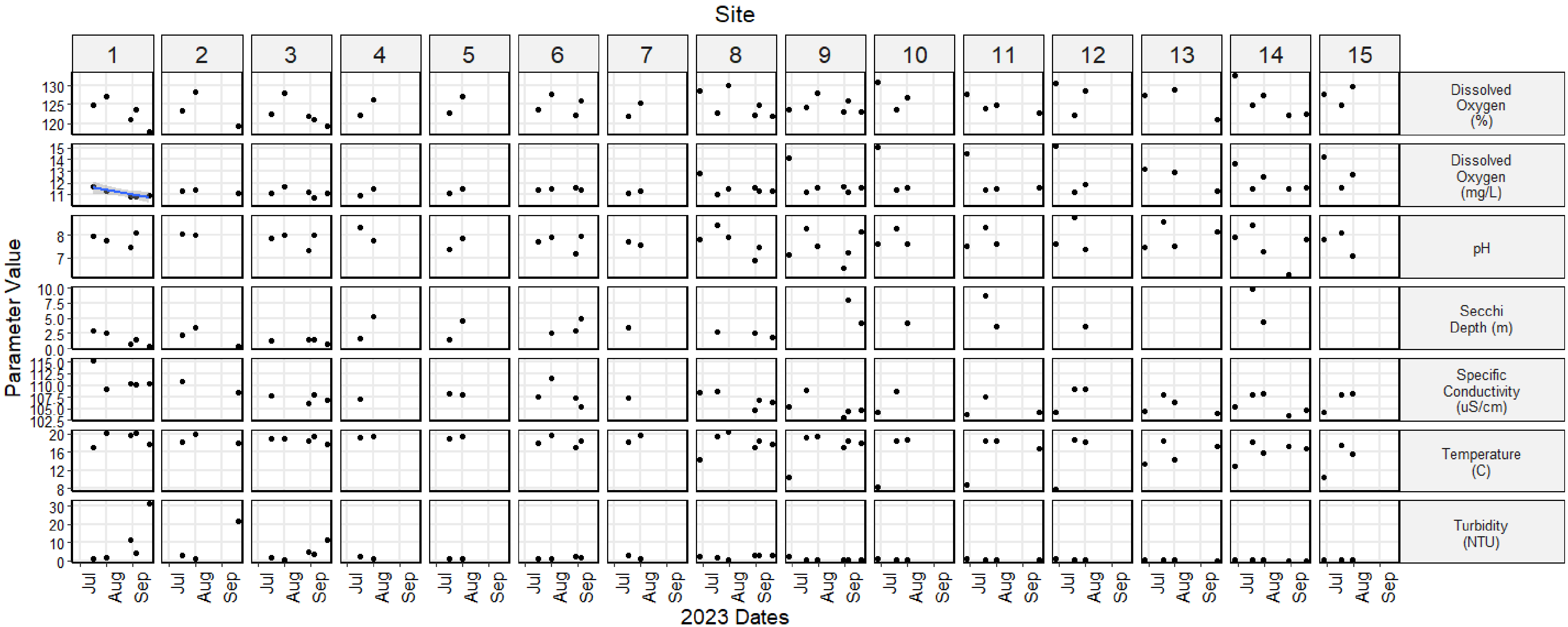

Figure 3: Trends in hydrodynamic parameters measured through time and by site. Numbers on top represent the site number. For each column, the cell moves through the sampling season from June to September. Parameters are arranged in alphabetical order. Black dots are data points. The blue line is linear regression depicting rends when slope was significant (unadjusted $p<0.05$). Grey shading depicts the standard error for the linear regression model. Data displayed is from 0.5 m water depth for all sites and times.

Table 5: Summary statistics for hydrodynamic measurements using Sonde surface values (0.5m). count is the number of samples in our dataset. Mean is the value of parameter. Min is the minimum values. Max is the maximum value. Stdev is the standard deviation of values.

Hydrodynamic Parameters summaries averaged over sites and sampling rounds.

Parameter	Count	Mean	Min	Max	Stdev
Dissolved Oxygen (%)	57	126	117	132	3
Dissolved Oxygen (mg/L)	57	12	11	15	1
Secchi Depth (m)	57	4	0	10	2
Specific Conductivity (uS/cm)	57	108	104	116	2
Temperature (°C)	57	18	9	21	3
Turbidity (NTU)	57	5	0	30	5
pH	57	7.5	6	9	0.5

Temperature

Water temperature is a driving factor for if and when an algal bloom may occur (Calieri et al., 2014). Temperatures greater than 10°C are considered to stimulate the growth of algal blooms (Sterner et al., 2020). The average surface temperature recorded for this field season was 18°C. While surface temperatures were warm enough to promote the growth of a bloom, there was no long- lasting or widespread bloom event during this sampling season. This indicates that factors other than water temperature are necessary to have algal bloom formation in Lake Superior's nearshore environment.

Similar temperature trends were observed in sites 1-15, where the maximum temperatures occurred in mid-July to early August (Figure 3). The sites located further to the east experienced more variability in surface temperatures than sites located further to the west.

The first sampling round, which occurred in late June, showed the coldest water temperatures for the season in site 12 (Bark Bay) at 7.9°C. Early season eastern sites were cooler than western ones. Western sites surface temperatures remained similar throughout the sampling season

When examining the water column profile data there is not a large variation in temperatures from surface to depth at most times and locations. Sites 8, 12-15 experienced a large variation of temperatures between surface and depth measurements when compared to the other sites early season profiles. These sites profile data (**Appendix**) shows minimal thermocline development, with a slight thermocline shown at sites in late June, this is most likely due to the shallowness of the sampling sites.

Turbidity

Recorded turbidity for the area consisted of low values overall (average 5 NTUs), especially at sites 9-15 (Figure 3). Earlier in the season, turbidity was generally higher (average 10 NTUs),but observe plume action after a rain event in September. Site off of Wisconsin Point (site1) showed a peak during the late September sampling, which was driven by surface values.

pH

pH Probe was not calibrated properly for the beginning portion of the season. It did not register the correct standard pH during calibration. After multiple efforts of trouble shooting, the probe was not responding correctly and a new probe was ordered but did not arrive in time for use over season, thus pH was not interpreted for this report.

Dissolved Oxygen (DO)

DO probe was experiencing sporadic technical glitches in the field, not displaying data. Thus, not all sites have DO data for all sampling events. September showed lowest DO values for sites. Typically, eastern sites experienced highest DO values in late June. Percent DO were typically, over 100%, throughout the season.

Nutrients

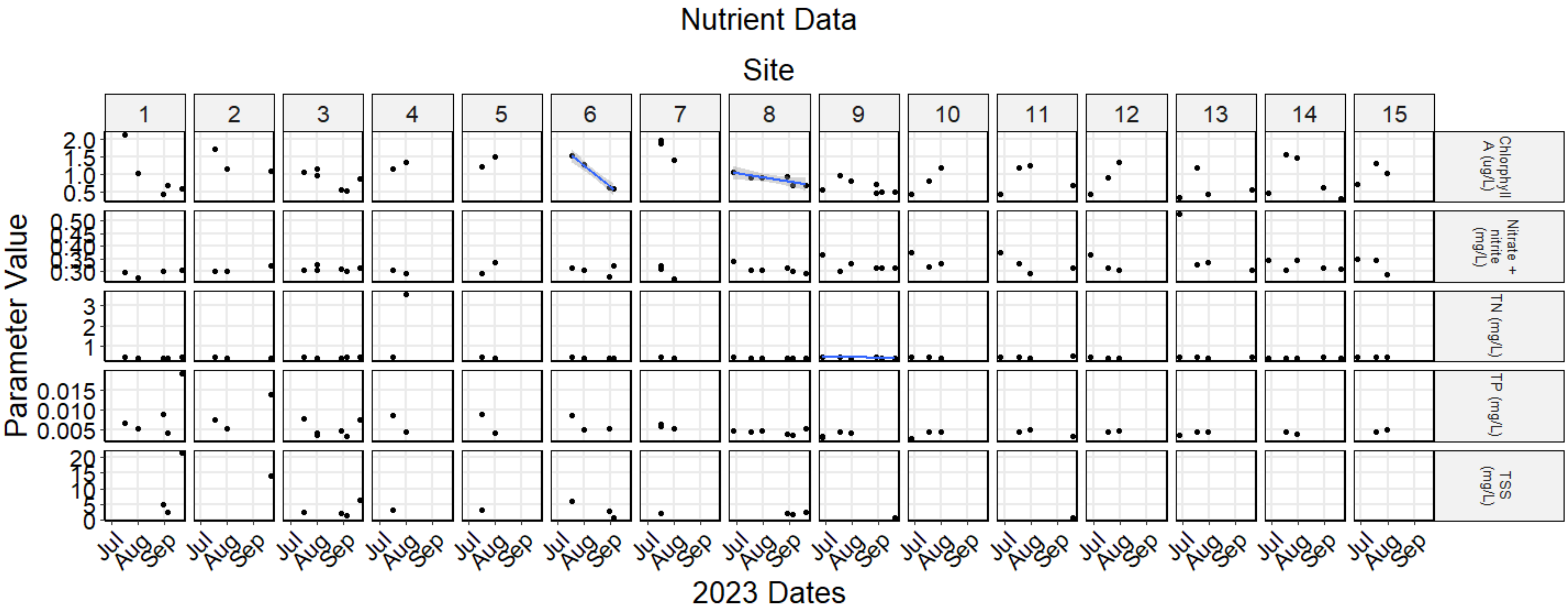

Figure 4: Trends in nutrient parameters measured through time and by site. Numbers on top represent the site number. For each column, the cell moves through the sampling season from June to September. Parameters are arranged in alphabetical order. Black dots are data points. Blue lines are linear regression depicting trends for each site and parameters through time. Grey shading depicts the standard error for the linear regression model.

Table 6: Summary statistics for nutrient measurements. N is the number of samples in our dataset. Min is the minimum values. Mean is the average value. Max is the maximum value. SD is standard deviation of values, NDs are number of non-detects in dataset.

Nutrient summaries averaged over sites and sampling rounds.

Parameter	Count	Mean	Min	Max	Stdev	NDs
Chlorphyll A (µg/L)	55	0.8	0.4	2	0.4	0
Nitrate + nitrite (mg/L)	55	0.3	0	0.54	0.06	1
OrthoP (mg/L)	55	NaN	NaN	NaN	0	55
TN (mg/L)	55	0.4	0.4	3.6	0.4	0
TP (mg/L)	55	0.006	0.003	0.018	0.003	9
TSS (mg/L)	55	3	0	21	3	36

Chlorophyll-*a* (Chla)

Chlorophyll-*a* can be used as a proxy to estimate the overall algal biomass in aquatic ecosystems. It is also a metric that details primary productivity within an aquatic ecosystem.

Most samples were below 2 µg/L of Chlorophyll *a*. Generally speaking, chla values tend to be higher during the summer season, with an observed decrease towards the end of the season. The chla minimum occurred during the September sampling events for sites 12-15. The chla maximum occurred during the July sampling events for sites 4-7. The maximum chla concentration, 2.13 µg/L, for the sampling season occurred at site 1 (Wisconsin Point) in late June (Table 4 of Appendix).

Lake Winnipeg, a large freshwater lake in Manitoba Canada, uses 10 µg/L as an indicator of potential bloom conditions (Binding et al., 2018). From this sampling endeavor, none of the samples reached this concentration.

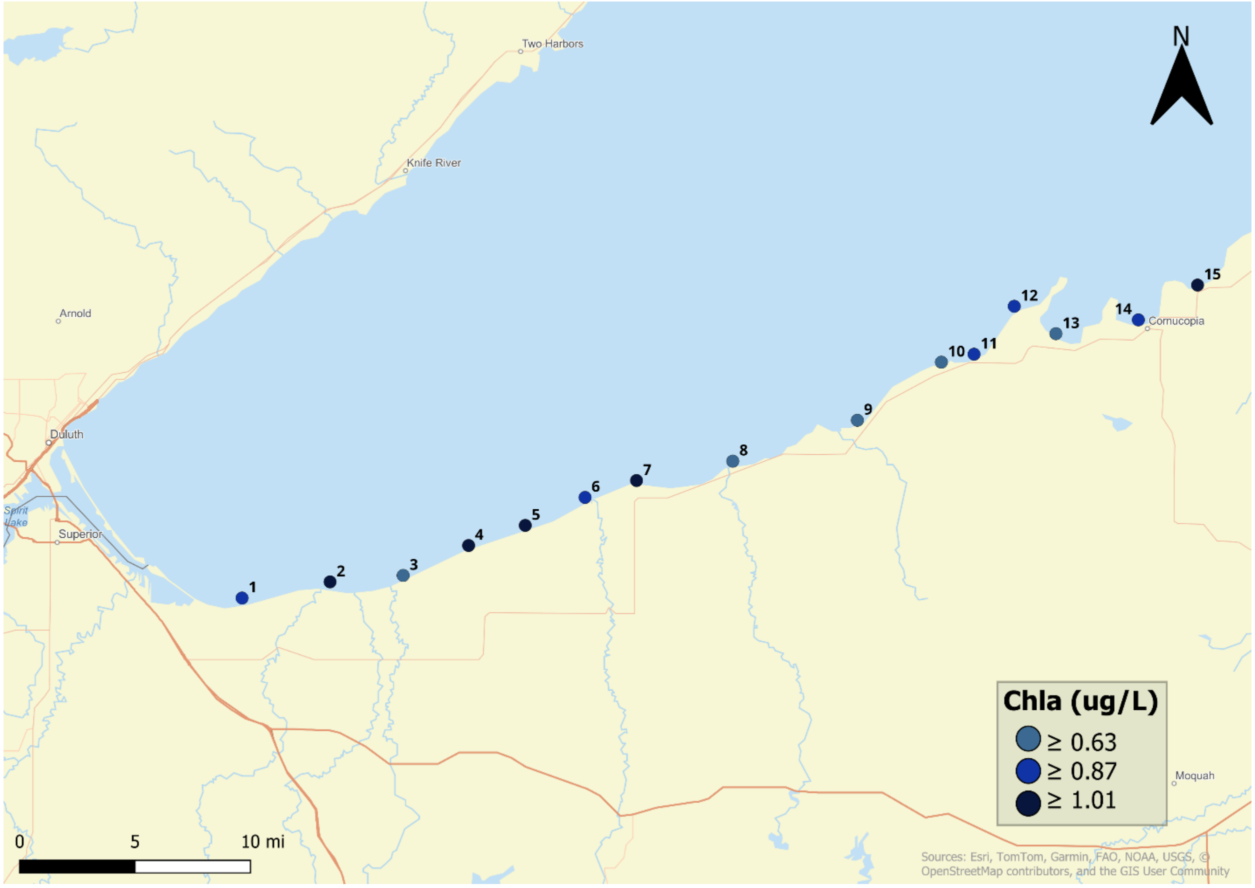

Figure 5: Average chlorophyll-a nutrient sample values per site collected in 2023. Color groupings based off of data distribution.

Nitrate/Nitrite (NO3/NO2)

Sites 9-15 have higher nitrate/nitrite concentrations than those further west. Site further east have more variability in concentrations when compared to western sites.

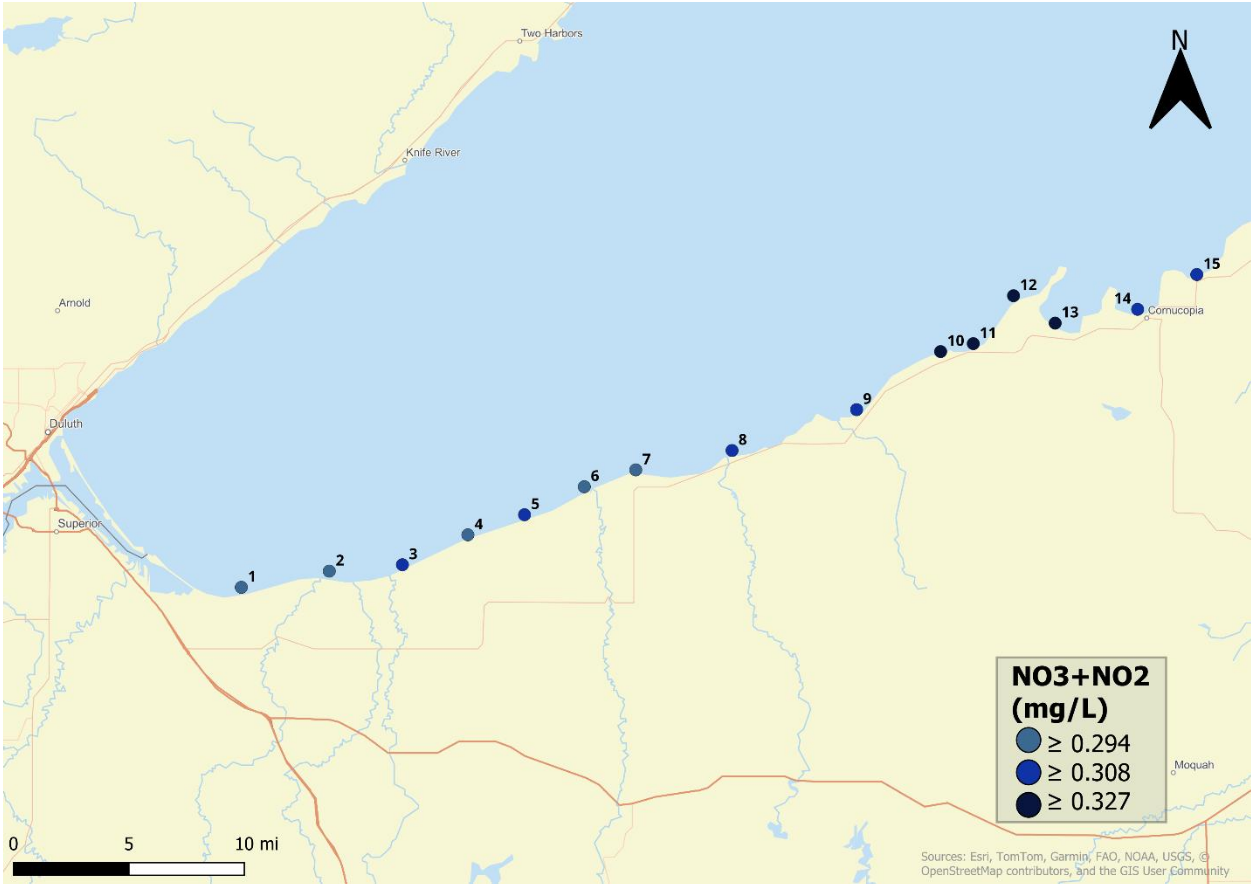

Figure 6: Average nitrate and nitrite nutrient sample values per site collected in 2023. Color groupings based off of data distribution.

Ortho Phosphorus (OrthoP)

All data is below the LOD, therefore there are no trends to discuss.

Total Nitrogen (TN)

The majority of sites show similar values throughout the season, ranging from 0.40 to 0.45 mg/L. The sites experienced similar dynamics through space and time. There is a large spike in concentration site 4 in early August, that doesn't seem to align with any other nutrient or hydrological parameters and is thought to be an outlier, not indicative of any large changes in the system.

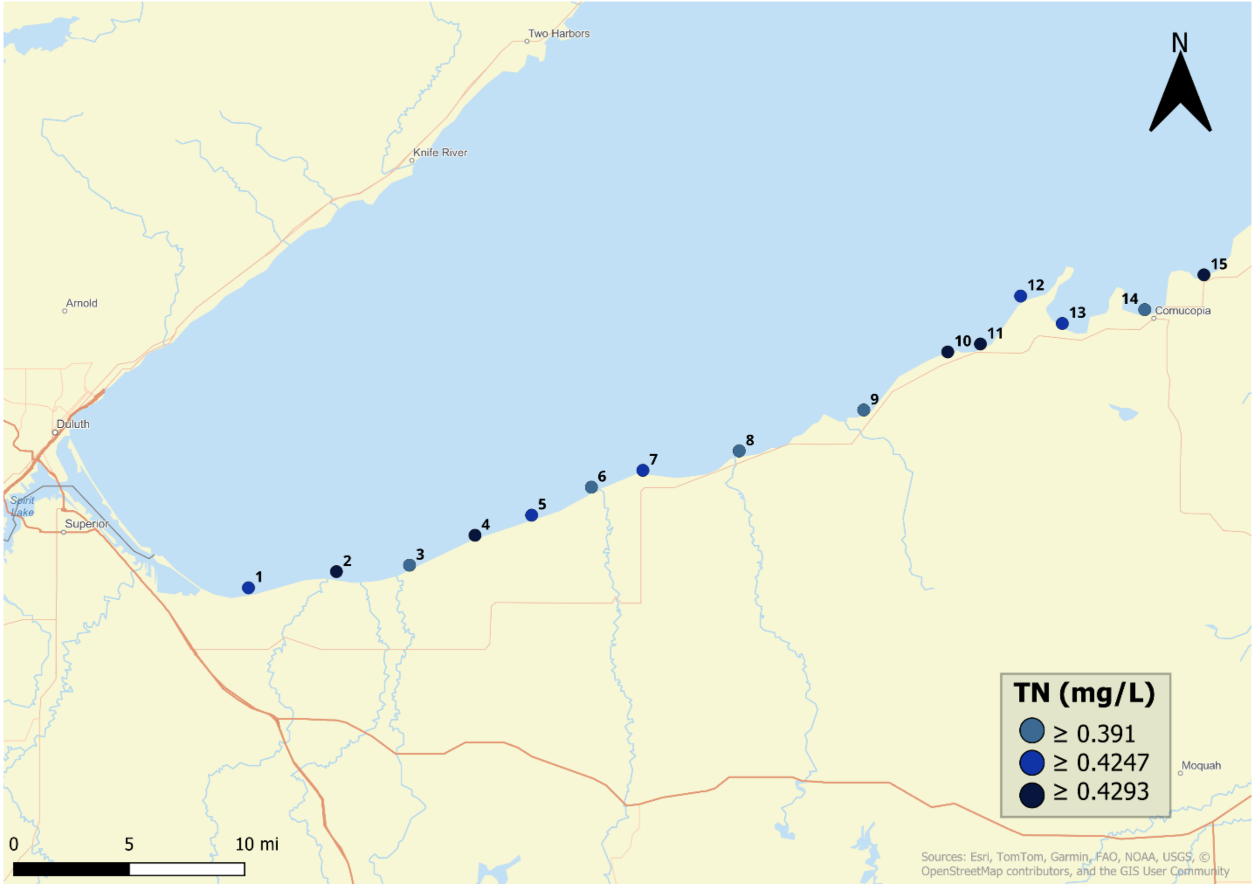

Figure 7: Average total nitrogen nutrient sample values per site collected in 2023. Color groupings based off of data distribution.

Total Phosphorus (TP)

Phosphorus is an influential macronutrient that regulates the growth of algae within an aquatic ecosystem in a P limited system. Phosphorus in the nearshore could be from a variety of sources such as agricultural runoff, nearby wetlands, and the resuspension of sediments. Inputs from local tributaries with varying biological conditions may factor in as well. Phosphorus can bind to varying sediment types, such as iron (Fe) and rich clay, and when storm events occur, resuspension and redistribution of phosphorus in an aquatic system may occur (Bennington et al., 2010). The source of phosphorus in this area is not known, but it is important to think of what sources are potentially contributing when interpreting data.

Inland lakes and impoundments of Wisconsin typically experience algal blooms when concentrations of TP were 20 µg/L and 30 µg/L, respectively, or higher although blooms at lower concentrations have been observed (WDNR Lakes). These concentrations were not reached in this monitoring project. Low concentrations of phosphorus in the nearshore likely limit growth of algal communities.
The National Coastal Condition Assessment (NCCA) established that concentrations of less than 5 µg/L TP are considered good water quality, and concentrations greater than 10 µg/L

are considered poor. On average, sites from this field season had a concentration of 6 µg/L, indicating that these criteria for water quality might not be the best metric for these very nearshore waters. The monitoring design for this Nearshore monitoring project is different than the sampling design of the NCCA, which may lead to the discrepancy. To achieve the comparison values, concentrations from each site were averaged over the sampling season, rather than a snapshot view that NCCA uses. Additionally, NCCA typically has a wider range of depths for their sampling locations (2-30m), where this project was focused on the 5 m contour. Likely showing a higher proportion of site with direct tributary influence.

The Low-Level Total phosphorus method was implemented for all rounds of sampling, yet there were still non-detects especially for eastern sites. Maximum values of 18 µg/L for TP for the season were reached during September at sites 1 and 2.

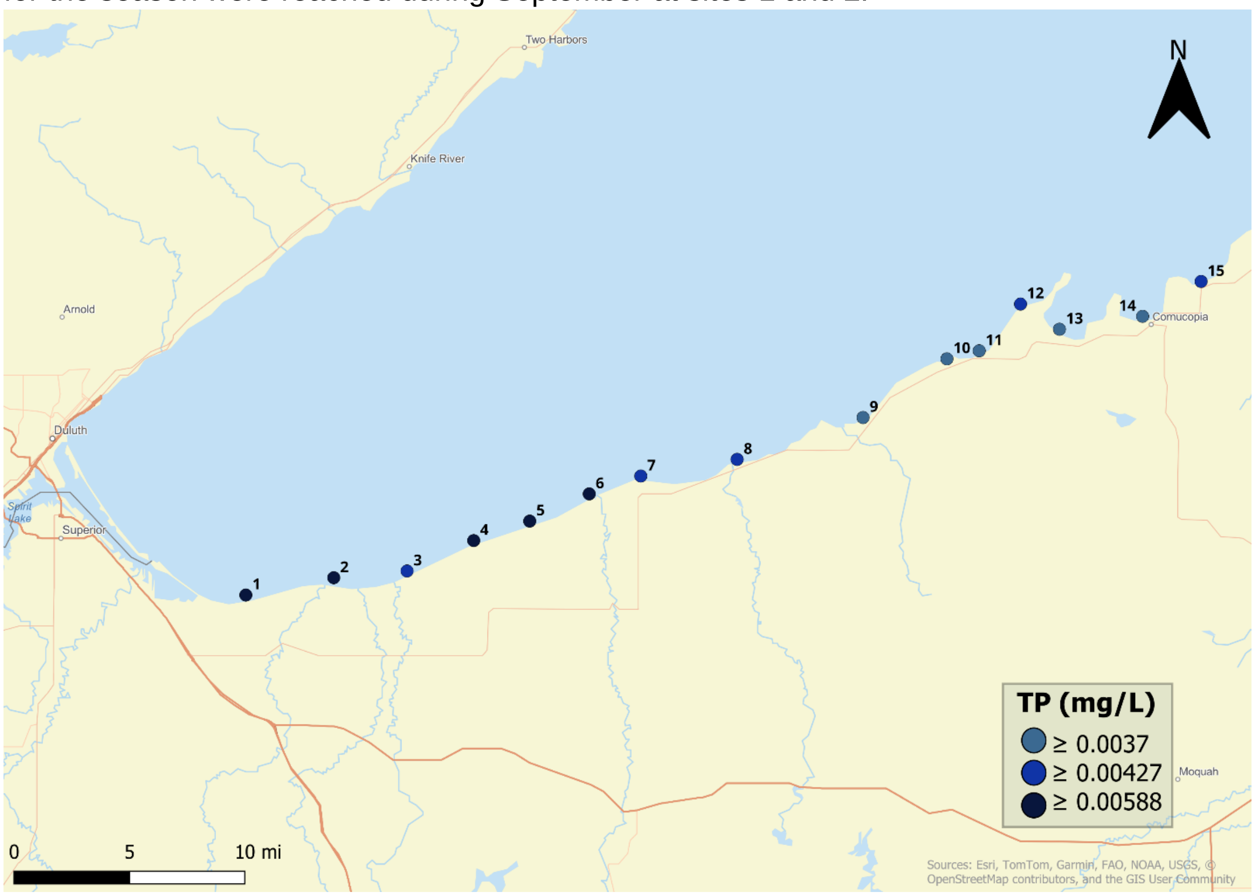

Figure 8: Average total phosphorus nutrient sample values per site collected in 2023. Color groupings based off of data distribution.

Table 7: *National Coastal Condition Assessment (NCCA) Eutrophication Indicators.*

Indicator	Good	Fair	Poor
TP (ug/L)	< 5	> 5 to < 10	> 10
Chl-a (ug/L)	< 1.3	>1.3 to < 2.6	> 2.6
DO (mg/L)	> 5	< 5 to > 2	< 2
Secchi (m)	> 8	< 8 to > 5.3	< 5.3

Total Suspended Solids (TSS)

Most TSS samples came back as non-detects, thus we were unable to establish trends in data. Concentrations above the LOD were most consistently observed at site 1, 3 and 6. This is most likely due to proximity to river inputs. Maximum TSS values of 21 mg/L occurred during late September at near Wisconsin point (site 1).

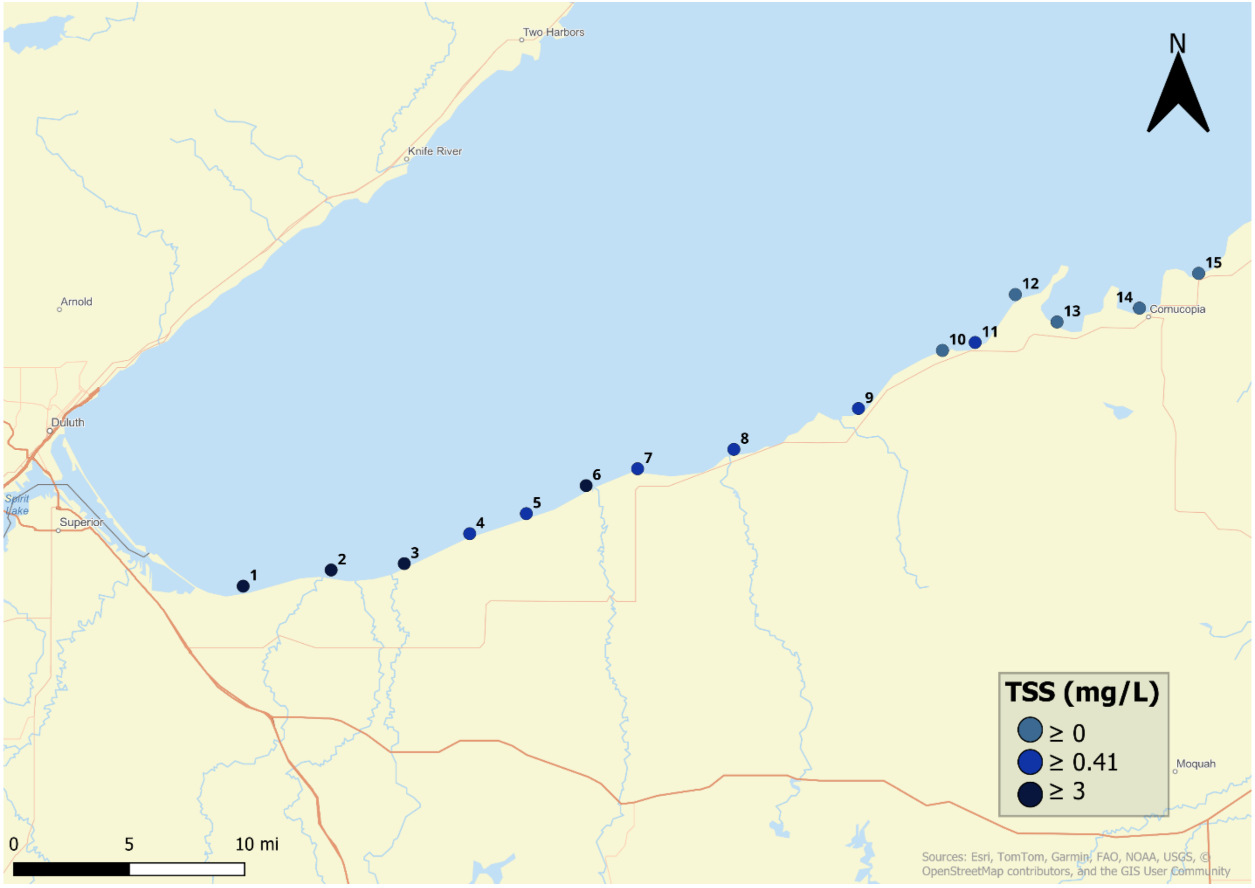

Figure 9: Average total suspended solids sample values per site collected in 2023. Color groupings based off of data distribution.

Algal ID Enumeration

Algal ID and Enumeration was conducted throughout the field season for 6 sites (1,3,6,8,9 and 14). We selected these sites to capture a wide distribution of geographical locations, with focus on tributary inputs or bay areas. There was also a preference for areas where partners were collecting data upstream to capitalize on synergies. This allowed us to track how the community shifted throughout the season. We captured the presence of cyanobacteria through this analysis that was not detected by any of our water quality data. Cyanobacteria or cyanophyta were detected at all sites analyzed and were seen to be a large part (>50%) of the population at sites 6,8,9, and 14, especially later in the season (late August-September). In late September, at site 14 approximately 90% of the community composition was Cyanophyta. See Appendix for counts of phyla for each site.

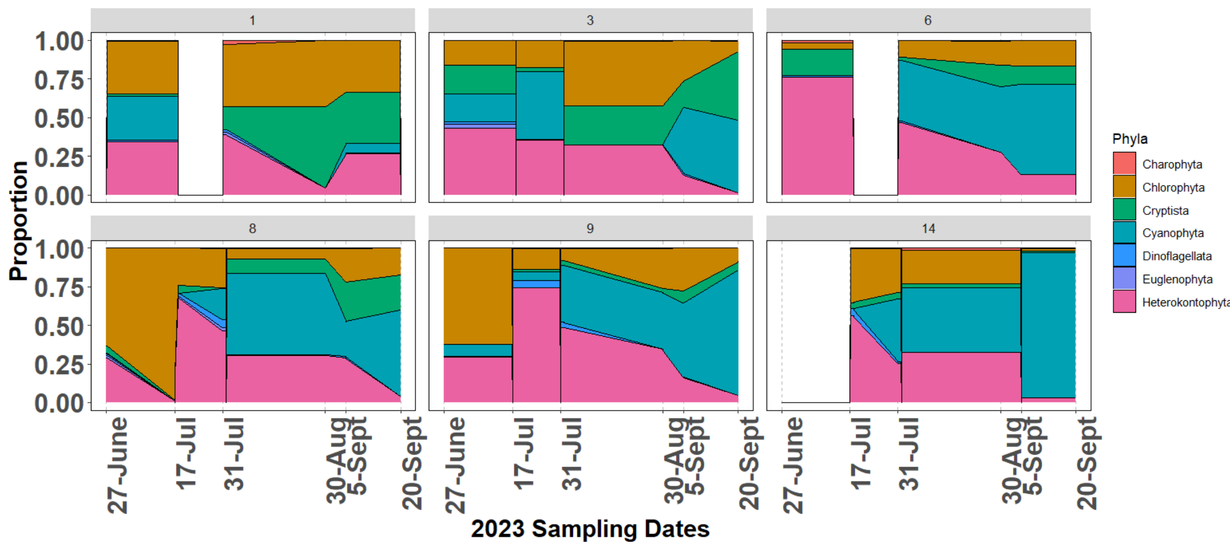

Figure 10: Algal ID and enumeration by phylum from 6 of the 15 sites (1, 3, 6, 8, 9, and 14). Colors represent phyla groups. X axis is date of sampling. Y axis represents the % number of cells of phyla per total cells collected.

Carlson analysis

The trophic state index (TSI) can be calculated using chla and TP and the simplified equations derived from Carlson (1977). The output of the equation determines which category the water falls into: Oligotrophic (0-40), Mesotrophic (40-50), and Eutrophic (50+). TSI can help assess the biological condition of a lake. Oligotrophic systems typically have fewer available nutrients, less algal growth, and tend to have increased water clarity, mesotrophic systems have moderate water clarity and a moderate amount of available nutrients, and eutrophic systems have a high amount of available nutrients, decreased water clarity, and increased algal growth (Chapra and Dobson, 1981).

$$TSI\ (Chla) = 9.8 * \ln\ (Chla) + 30.6$$

$$TSI\ (TP) = 14.42 * \ln(TP) + 4.15$$

$$TSI = (TSI\ (Chla) + TSI\ (TP))/2$$

Equation 1: Trophic State Index calculations. WisCALM 2018, Units for chlorphyll-a and TP are µg/L.

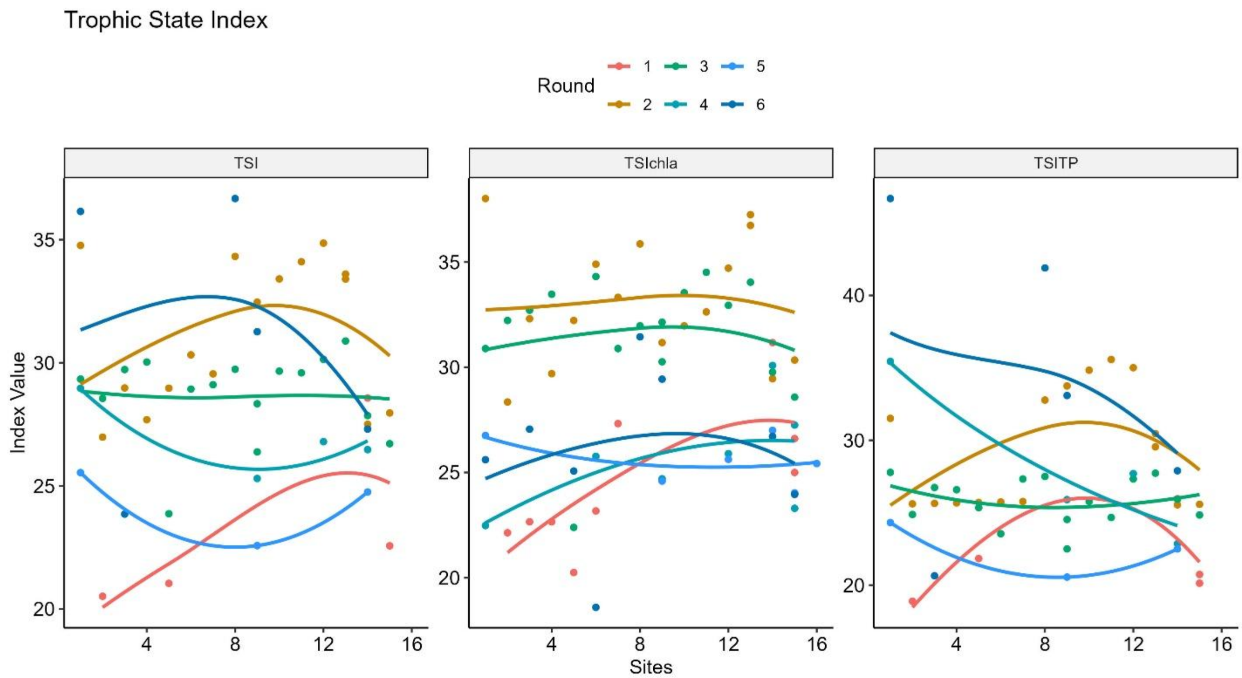

Figure 11: Trophic state index summary. Graph A shows the overall index. Graph B shows the chlorophyll-a contribution. Graph C shows the TP contribution. LOESS smoothing shows trends for each round of sampling.

All sites and timepoints were below the value of 40, which designates that they were oligotrophic. Rounds 2 and 6 (Early July and Late September) experienced the closest to mesotrophic conditions, especially for the western sites. This was driven by chla for round 2 and TP for round 6. Mid-season chla TSI (July) were seen to be greater than other timeframes. TP TSI tends to decrease as we move from west to east, with sites off the Brule River having larger TP values. This transition seems to occur around east of site 9 (Table 7). Sites further east had multiple non-detects for TP values, thus a total TSI score was not able to be calculated (decreasing N for Table 7).

Table 8: Average TSI by site. "N" represents count of TSI used to average.

Site	Average TSI	N
1	30.9	5
2	33.6	3
3	27.7	6
4	31.5	2
5	31.8	2
6	30.6	3
7	32.6	3
8	37.1	6
9	25.7	3
10	25.3	3
11	27.5	3
12	28.9	2
13	24.6	3
14	29.6	2
15	29.3	2

Climate Influence

According to data collected from 2023, with the exception of September, air temperatures were lower in 2023 relative to the past 5 years, leading to cooler lake temperatures (Figure 7). 2019 and 2021 were considered low flow years for precipitation and river flow, and 2023 experienced similar conditions, with the exception of September. In 2023, September was an outlier due to remaining warmer and experiencing more monthly precipitation than previous years. Correlating with this, the highest tributary discharges occurred during late September in 2023. The current thought regarding algal bloom formation is that they tend to occur in warmer and higher flow years. While this may be true, we have also observed them in these lower flow and cooler temperature years. It is anticipated that climate change will increase the precipitation the area of study will receive, regarding total amount and frequency of rain events, thus we anticipate that blooms will become more prevalent (Walsh et al., 2014).

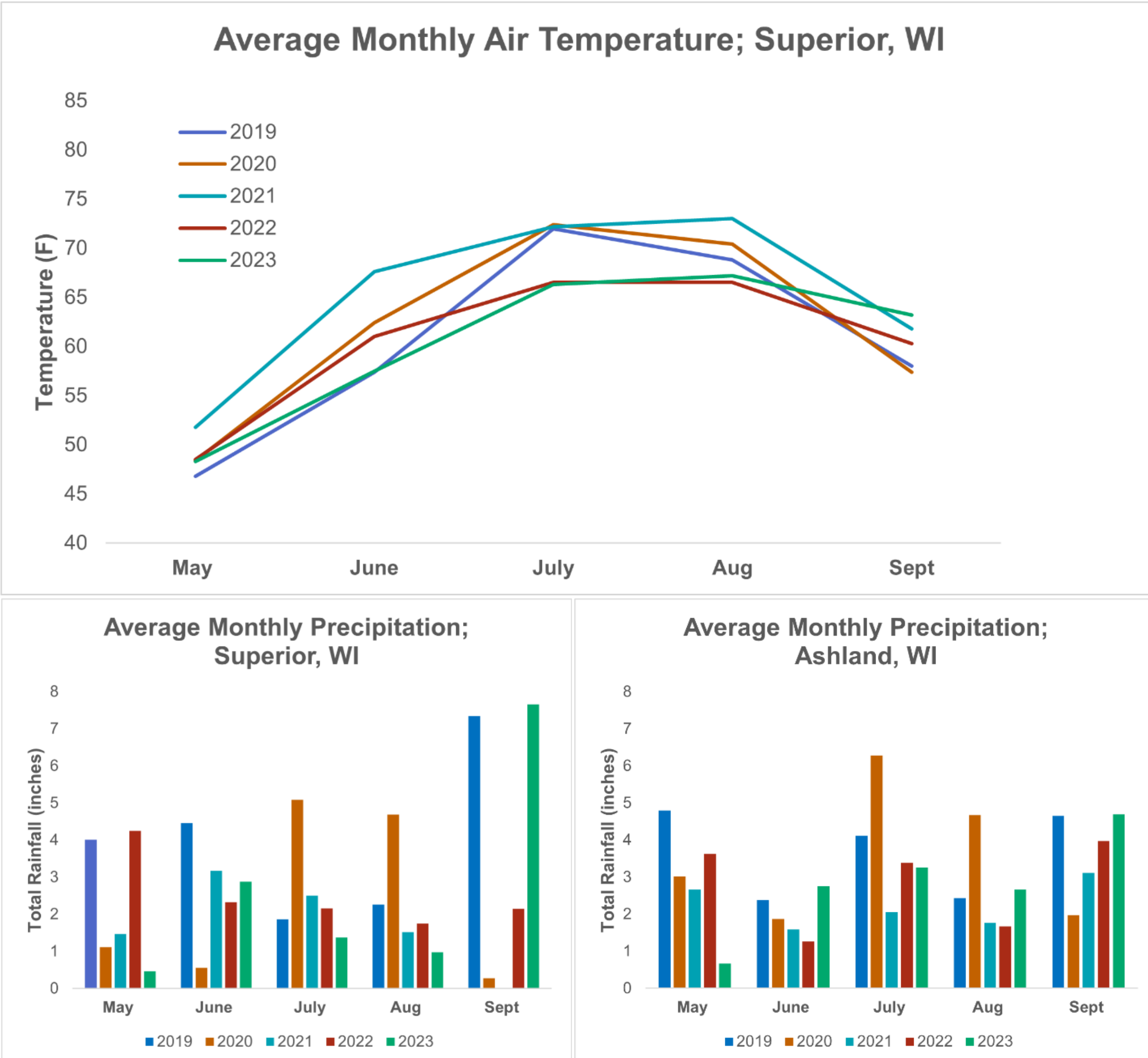

Figure 12: Summer 2023 climatology for Superior, WI and Ashland, WI. The top panel is the average monthly air temperature in Superior, WI for the 2023 summer season, which was comparable to the monthly air temperature in Superior. The bottom panel is the average monthly precipitation for Superior, WI (left) and Ashland, WI (right) in the 2023 summer season.

Conclusion

Over the past four years, this monitoring effort has worked to improve understanding of nearshore water-quality conditions associated with cyanobacterial bloom development along the Wisconsin Lake Superior shoreline. While no active harmful algal blooms were captured at the monitoring sites during this period, the program has successfully met its broader objective of characterizing nearshore physical, chemical, and biological conditions relevant to bloom formation.

Cyanobacteria were observed at all six algal sampling locations, demonstrating that bloom-forming taxa are a frequent presence within the nearshore phytoplankton community during the sampling period. These observations provide valuable baseline information and confirm that the absence of blooms does not equate to an absence of cyanobacteria. Notably, while these taxa were found throughout the season, they often represented a larger proportion of the total algal population later in the summer, suggesting a seasonal shift in community composition even in years without a major bloom event. Further investigation indicates that *Dolichospermum* spp.—the genus primarily responsible for blooms in Lake Superior proper—is a common occurrence within the nearshore zone of the Wisconsin shoreline (Wood et al., 2025). This finding suggests that factors other than simple presence, such as environmental thresholds or interacting drivers, are likely responsible for bloom initiation.

The dataset also provides insight into how nearshore conditions vary spatially across sites. Nearshore waters reached surface temperatures that are generally considered favorable for bloom development, indicating that thermal conditions alone are not sufficient to trigger blooms in this system. Initial examination of nutrient data did not reveal a direct relationship between nutrient concentrations and observed cyanobacterial populations, underscoring the complexity of nearshore dynamics and the likely role of hydrodynamics, nutrient form, timing, and transport processes in influencing bloom potential. Collectively, these results suggest that bloom development in Lake Superior's nearshore is governed by a combination of factors, rather than a single controlling variable.

With four years of data, this monitoring program has begun to establish a baseline understanding of nearshore water-quality conditions at the sampled sites. However, the data also indicate that these environments are highly dynamic, exhibiting substantial spatial and temporal variability. While the dataset is sufficient to characterize typical ranges and patterns in temperature, nutrients, and phytoplankton communities, continued monitoring is necessary to distinguish these baseline conditions from episodic or threshold-driven changes that likely precede bloom events.

Moving forward, sampling will continue at the same locations on a biweekly basis to expand the dataset and better capture variability across a wider range of environmental conditions. This temporal resolution will improve interpretation of nutrient dynamics and their interactions with physical drivers. The use of a low-level total phosphorus method is critical for this region, particularly for detecting trends at eastern sites, and will be implemented in the 2024 sampling season. Ortho-phosphorus analysis will return to the Wisconsin State Laboratory of Hygiene to improve detection limits and ensure consistency with other nutrient measurements. Finally, algal identification will continue at the six established sites to further refine the understanding of spatial variability in nearshore phytoplankton communities.

This work is being strengthened through collaboration with basin partners, including the Wisconsin Department of Natural Resources, National Park Service, Burke Center for Freshwater Innovation, and the Lake Superior National Estuarine Research Reserve. Together, these partners are developing a long-term nearshore monitoring framework for Wisconsin's Lake Superior waters. A recently awarded grant will support a post-doctoral researcher to analyze a combined nearshore dataset and provide recommendations to optimize sampling design for the 2025 monitoring strategy. Additional collaborative efforts are extending monitoring further east along the Wisconsin shoreline, improving the understanding of how nutrient dynamics evolve as water moves around the Apostle Islands and mixes with Chequamegon Bay. Continued partnership will be essential for developing a comprehensive picture of nearshore processes and refining the capacity to detect and understand harmful algal bloom risk in Lake Superior.

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Appendix

Sonde Profile Data 2023

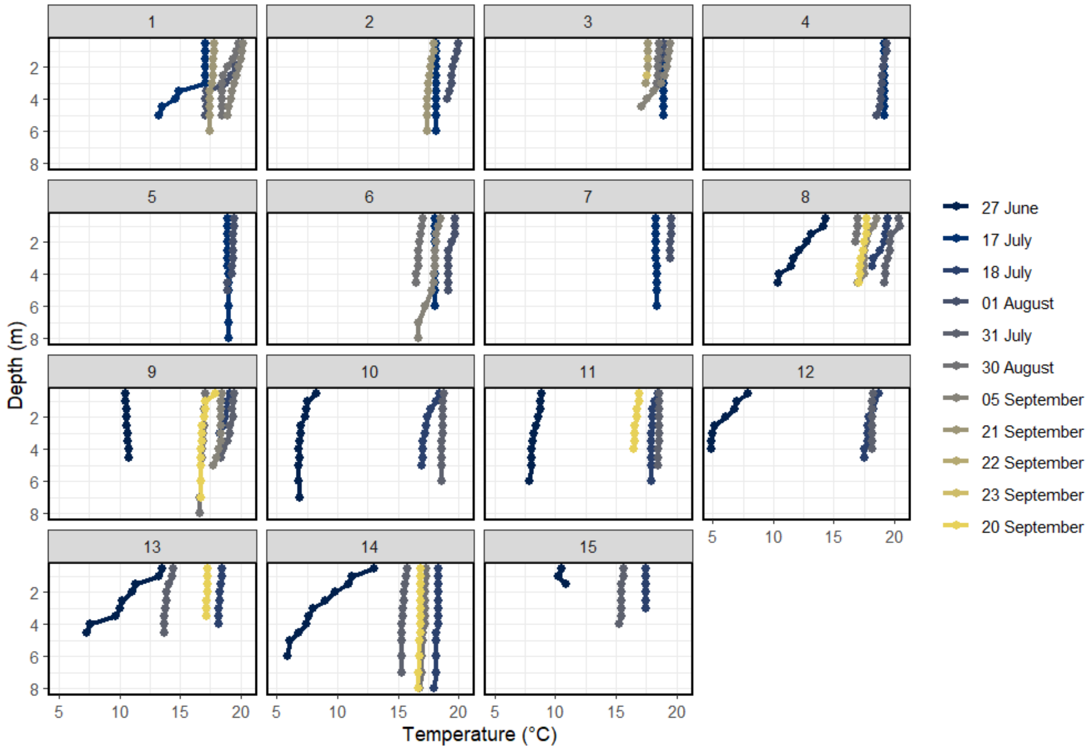

Figure A1: Temperature data (°C) from YSI ProDSS measurements collected in 2023.

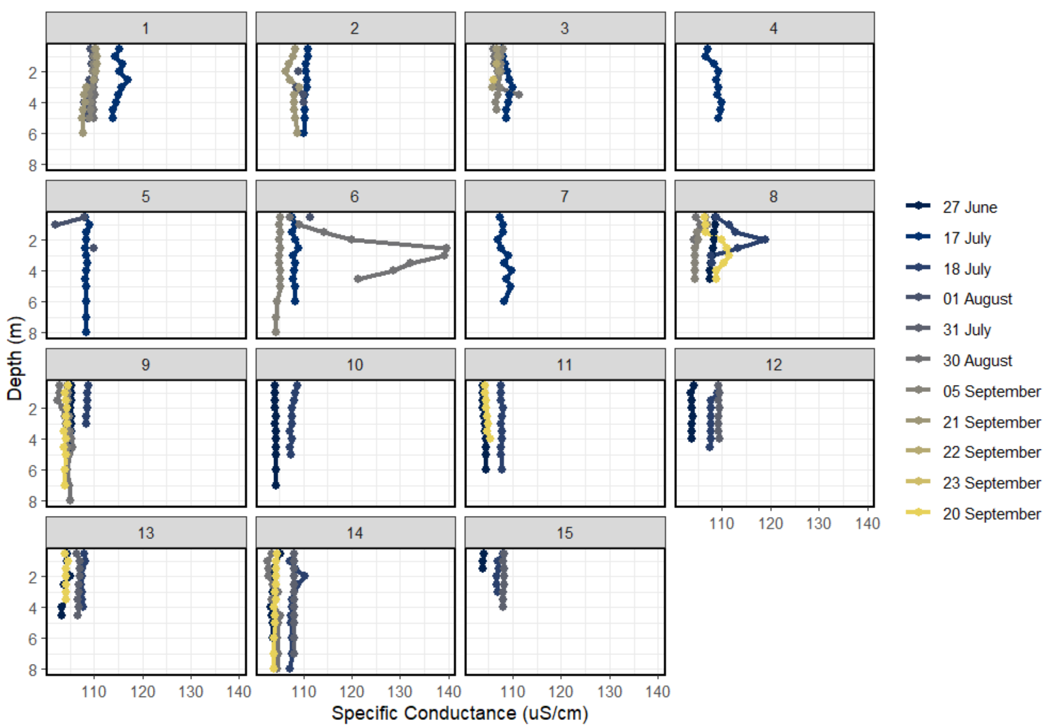

Figure A2: Specific conductance data (uS/cm) from YSI ProDSS measurements collected in 2023.

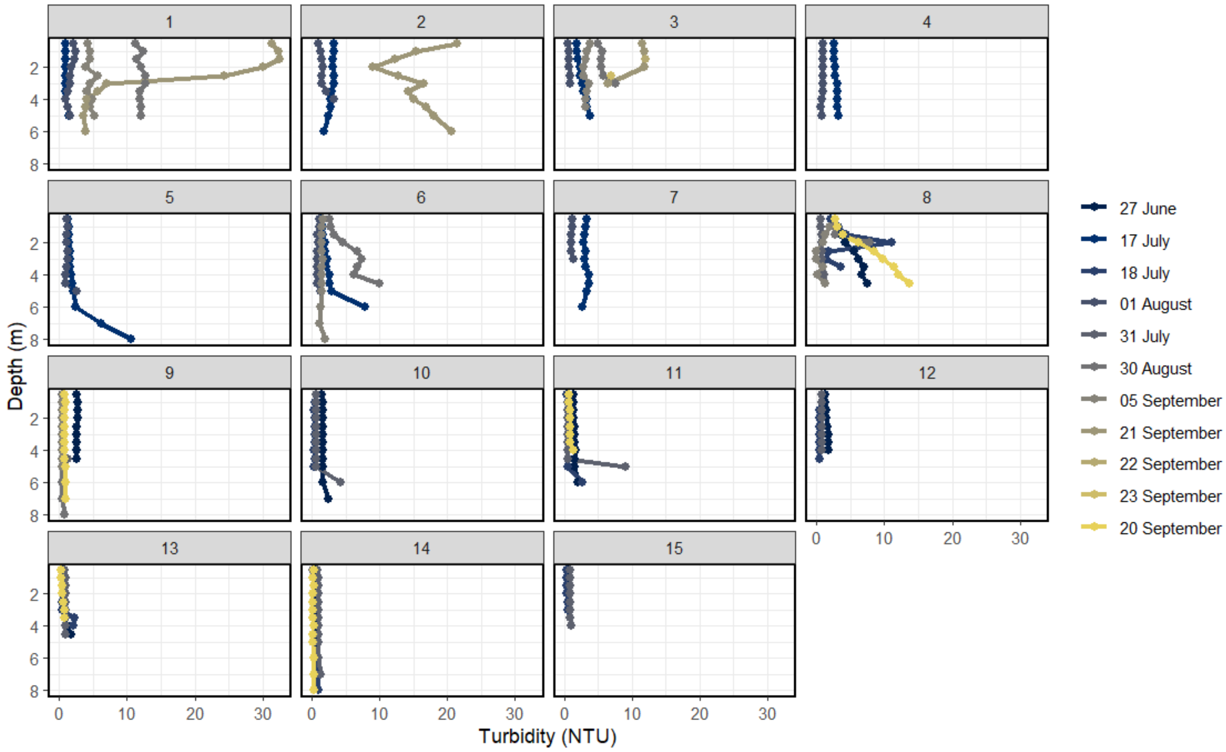

Figure A3: Turbidity data (NTU) from YSI ProDSS measurements collected in 2023.

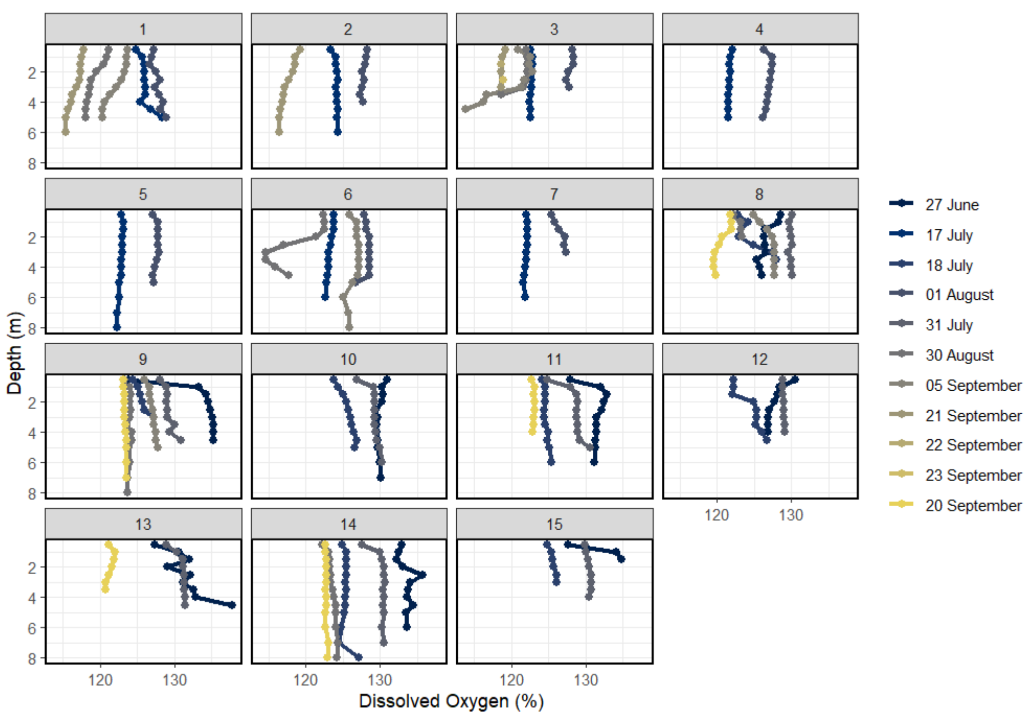

Figure A4: Dissolved oxygen data (%) from YSI ProDSS measurements collected in 2023.

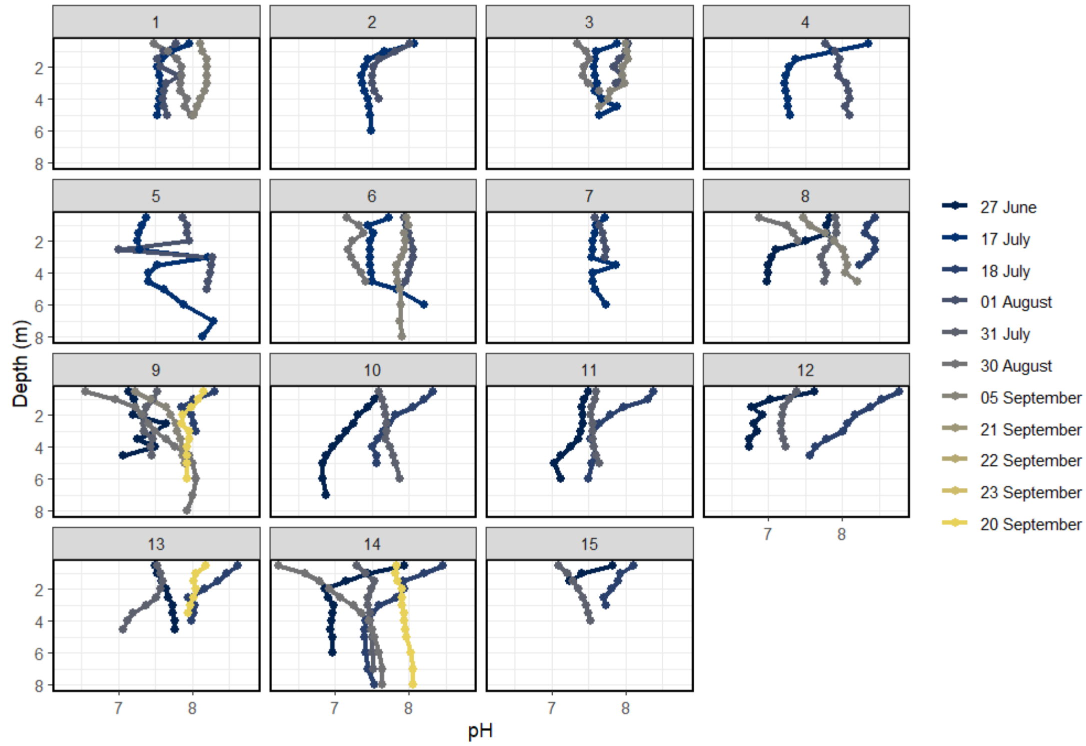

Figure A5: pH data from YSI ProDSS measurements collected in 2023.

Maps of Nutrient Data

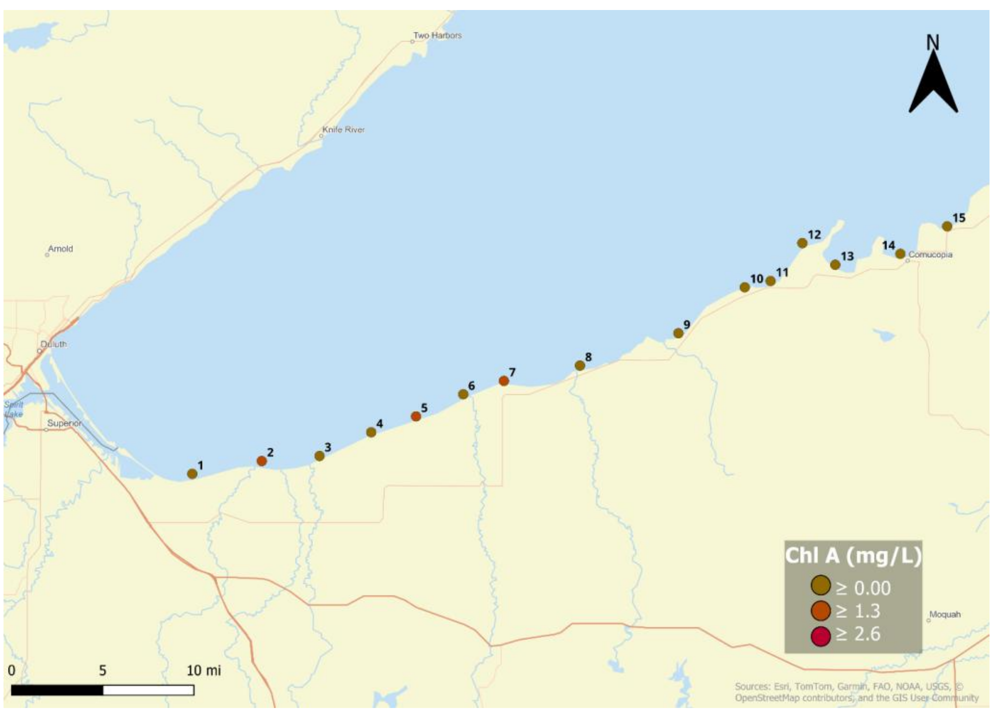

Figure A6: Average chlorophyll-a nutrient sample values per site collected in 2023. Color groupings based off of data distribution.

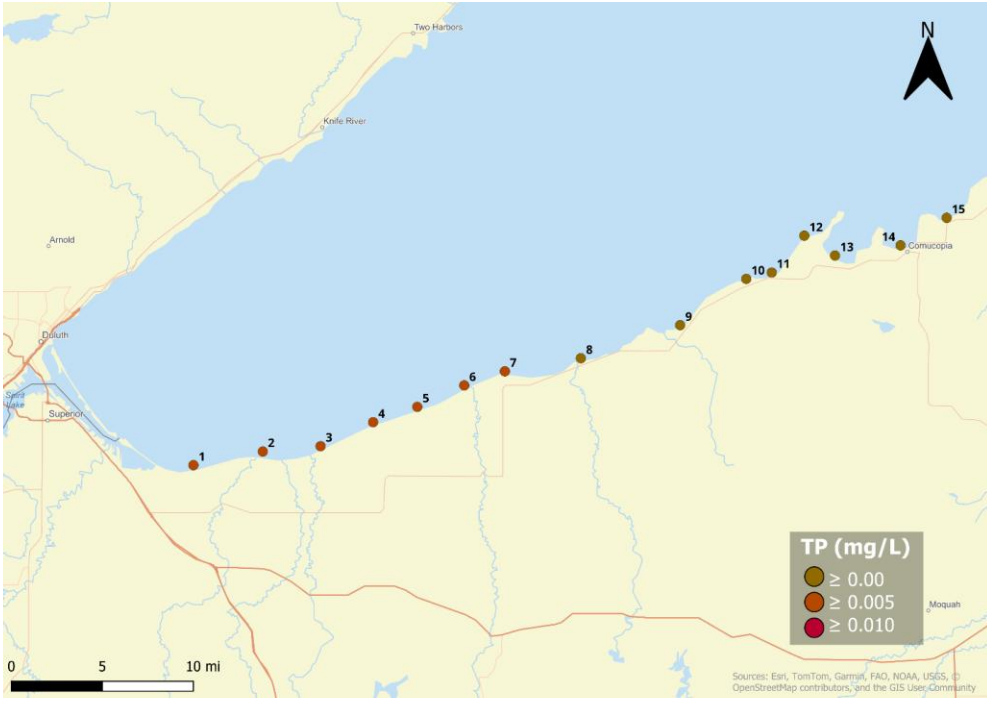

Figure A7: Average total phosphorus nutrient sample values per site collected in 2023. Color groupings based off of data distribution.

Summary Table Data

Table A1: Summaries of 2023 nutrient data grouped by sampling round.

Hydrodynamic Parameter summaries grouped by sampling round.

Round	Parameter	Count	Mean	Min	Max	Stdev	NDs
1	Dissolved Oxygen (%)	2	105	102	105	3	0
1	Dissolved Oxygen (mg/L)	2	10.8	10.4	10.8	0.4	0
1	pH	7	8.1	7.5	8.1	0.3	0
1	Secchi Depth (m)	13	1.4	0	2.8	0.7	0
1	Specific Conductivity (µS/cm)	13	111	105	117	3	0
1	Temperature (°C)	13	13.8	12.6	15	0.6	0
1	Turbidity (NTU)	13	10	0	50	10	0
2	Dissolved Oxygen (%)	14	115	110	120	5	0
2	Dissolved Oxygen (mg/L)	12	11.6	11.2	12	0.2	0
2	Secchi Depth (m)	14	2	0	4	1	0
2	Specific Conductivity (µS/cm)	14	108	104	116	4	0
2	Temperature (°C)	14	14	12	16	2	0
2	Turbidity (NTU)	14	3	0	12	3	0
3	Dissolved Oxygen (%)	15	114	110	116	2	0
3	Dissolved Oxygen (mg/L)	15	10.4	10	10.8	0.2	0
3	pH	15	8	7	10	1	0
3	Secchi Depth (m)	15	2.4	0.8	3.2	0.8	0
3	Specific Conductivity (µS/cm)	15	111	105	117	3	0
3	Temperature (°C)	15	18	17.4	18.6	0.3	0
3	Turbidity (NTU)	15	4	0	16	4	0
4	Dissolved Oxygen (%)	15	110.4	108.8	111.2	0.8	0
4	Dissolved Oxygen (mg/L)	15	11.4	10.2	12	0.6	0
4	pH	7	8.28	8.19	8.46	0.09	0
4	Secchi Depth (m)	13	2	1	6	1	0
4	Specific Conductivity (µS/cm)	15	108	102	111	3	0
4	Temperature (°C)	15	14	10	18	2	0
4	Turbidity (NTU)	15	3	0	12	3	0
5	Dissolved Oxygen (%)	7	108	106	110	2	0
5	Dissolved Oxygen (mg/L)	7	9.8	9.6	10.2	0.2	0
5	pH	15	8.4	7.8	8.4	0.2	0
5	Secchi Depth (m)	11	4	2	6	2	0
5	Specific Conductivity (µS/cm)	15	108	104	116	4	0
5	Temperature (°C)	15	18	16	19	1	0
5	Turbidity (NTU)	15	1	0	5	1	0
6	Dissolved Oxygen (%)	12	104	102	108	2	0
6	Dissolved Oxygen (mg/L)	12	10.5	9.8	12.6	0.7	0
6	pH	12	8	7	8.5	0.5	0
6	Secchi Depth (m)	9	3	1	6	1	0
6	Specific Conductivity (µS/cm)	12	106	104	108	2	0
6	Temperature (°C)	12	15	6	18	3	0
6	Turbidity (NTU)	12	2	0	8	2	0

Table A2: Hydrodynamic parameter 2023 data summaries grouped by site.

Nutrient summaries grouped by sampling round.

Round	Parameter	Count	Mean	Min	Max	Stdev	NDs
1	Chlorphyll A (µg/L)	13	2	0	4	1	0
1	Nitrate + nitrite (mg/L)	13	0.34	0.32	0.36	0.02	0
1	Ortho-P (mg/L)	3	0.0048	0.0042	0.0048	6e-04	0
1	TN (mg/L)	13	0.55	0.5	0.65	0.05	0
1	TP (mg/L)	11	0.015	0.012	0.018	0.003	0
1	TSS (mg/L)	3	6	4	8	2	0
2	Chlorphyll A (µg/L)	14	1.6	0.8	3.2	0.8	0
2	Nitrate + nitrite (mg/L)	14	0.34	0.3	0.36	0.02	0
2	Ortho-P (mg/L)	3	0.006	0.004	0.008	0.002	0
2	TN (mg/L)	14	0.52	0.44	0.56	0.04	0
2	TP (mg/L)	9	0.012	0.009	0.018	0.003	0
2	TSS (mg/L)	4	4	2	8	2	0
3	Chlorphyll A (µg/L)	15	2	1.2	2.4	0.4	0
3	Nitrate + nitrite (mg/L)	15	0.31	0.28	0.32	0.01	0
3	Ortho-P (mg/L)	2	NaN	NaN	NaN	0	0
3	TN (mg/L)	14	0.5	0.48	0.52	0.01	0
3	TP (mg/L)	8	0.009	0.009	0.018	0.003	0
3	TSS (mg/L)	1	NA	NA	NA	NA	0
4	Chlorphyll A (µg/L)	12	0.8	0	2.4	0.8	0
4	Nitrate + nitrite (mg/L)	12	0.34	0.33	0.36	0.01	0
4	TN (mg/L)	12	0.48	0.46	0.52	0.02	0
4	TP (mg/L)	12	0.006	0.003	0.012	0.003	0
4	TSS (mg/L)	4	2.5	2	3	0.5	0
5	Chlorphyll A (µg/L)	15	0.6	0	1	0.2	0
5	Nitrate + nitrite (mg/L)	15	0.329	0.308	0.343	0.007	0
5	Ortho-P (mg/L)	9	0.0045	0.004	0.005	5e-04	0
5	TN (mg/L)	15	0.44	0.4	0.5	0.02	0
5	TP (mg/L)	14	0.006	0.003	0.009	0.003	0
5	TSS (mg/L)	1	NA	NA	NA	NA	0
6	Chlorphyll A (µg/L)	12	0.6	0.3	1.2	0.3	0
6	Nitrate + nitrite (mg/L)	12	0.34	0.32	0.4	0.02	0
6	Ortho-P (mg/L)	3	0.0048	0.0042	0.0048	6e-04	0
6	TN (mg/L)	12	0.45	0.3	0.5	0.05	0
6	TP (mg/L)	12	0.003	0.003	0.012	0.003	0
6	TSS (mg/L)	3	4	2	6	2	0

Hydrodynamic Parameter summaries grouped by site.

Parameter	Site	Count	Mean	Min	Max	Stdev	NDs
Dissolved Oxygen (%)	1	3	112	108	116	4	0
Dissolved Oxygen (%)	2	3	114	108	120	6	0
Dissolved Oxygen (%)	3	4	110	105	120	5	0
Dissolved Oxygen (%)	4	3	110	110	115	5	0
Dissolved Oxygen (%)	5	4	112	104	116	4	0
Dissolved Oxygen (%)	6	4	114	108	120	6	0
Dissolved Oxygen (%)	7	4	110	105	115	5	0
Dissolved Oxygen (%)	8	5	112	105	119	7	0
Dissolved Oxygen (%)	9	5	108	104	116	4	0
Dissolved Oxygen (%)	10	5	108	106	112	2	0
Dissolved Oxygen (%)	11	5	110	105	115	5	0
Dissolved Oxygen (%)	12	5	110	105	115	5	0
Dissolved Oxygen (%)	13	4	112	108	114	2	0
Dissolved Oxygen (%)	14	6	108	104	116	4	0
Dissolved Oxygen (%)	15	5	108	104	116	4	0
Dissolved Oxygen (mg/L)	1	3	11.2	10.4	12	0.8	0
Dissolved Oxygen (mg/L)	2	3	11.2	10.5	11.9	0.7	0
Dissolved Oxygen (mg/L)	3	4	10.5	10	11.5	0.5	0
Dissolved Oxygen (mg/L)	4	3	10.5	10.5	11.2	0.7	0
Dissolved Oxygen (mg/L)	5	4	10.8	10.2	11.4	0.6	0
Dissolved Oxygen (mg/L)	6	4	11.2	10.4	12	0.8	0
Dissolved Oxygen (mg/L)	7	3	10.8	10.2	11.4	0.6	0
Dissolved Oxygen (mg/L)	8	4	10.5	9.8	11.9	0.7	0
Dissolved Oxygen (mg/L)	9	5	11	10	11.5	0.5	0
Dissolved Oxygen (mg/L)	10	5	10.5	9.8	11.2	0.7	0
Dissolved Oxygen (mg/L)	11	5	10.8	9.9	11.7	0.9	0
Dissolved Oxygen (mg/L)	12	5	11	10	13	1	0
Dissolved Oxygen (mg/L)	13	4	11.2	9.6	12	0.8	0
Dissolved Oxygen (mg/L)	14	6	10.5	9.8	11.2	0.7	0
Dissolved Oxygen (mg/L)	15	5	10.5	9.8	11.9	0.7	0
pH	1	3	8	7.5	8.5	0.5	0
pH	2	3	8.2	8	8.4	0.2	0
pH	3	4	8.1	7.8	8.4	0.3	0
pH	4	3	9	8	10	1	0
pH	5	4	8.5	7.5	9	0.5	0
pH	6	4	8.5	8	9	0.5	0
pH	7	4	8	7.2	8.8	0.8	0
pH	8	3	7.6	7.2	8	0.4	0
pH	9	4	7.8	7.2	8.4	0.6	0
pH	10	4	7.7	7	8.4	0.7	0
pH	11	4	7.8	7.2	8.4	0.6	0
pH	12	4	7.8	7.2	8.4	0.6	0
pH	13	4	7.7	7	8.4	0.7	0
pH	14	4	8.4	7	8.4	0.7	0
pH	15	4	7.7	7	8.4	0.7	0
Secchi Depth (m)	1	5	2	1	4	1	0
Secchi Depth (m)	2	5	2	0	3	1	0
Secchi Depth (m)	3	6	1.8	0.9	3.6	0.9	0
Secchi Depth (m)	4	5	1.6	1.2	2.4	0.4	0
Secchi Depth (m)	5	6	2	1	4	1	0
Secchi Depth (m)	6	6	2	1	5	1	0
Secchi Depth (m)	7	5	0.8	0.4	1.2	0.4	0
Secchi Depth (m)	8	6	1.6	0.8	3.2	0.8	0
Secchi Depth (m)	9	6	3	2	5	1	0
Secchi Depth (m)	10	5	3	2	6	1	0
Secchi Depth (m)	11	6	4	2	6	2	0
Secchi Depth (m)	12	4	2.1	1.4	3.5	0.7	0
Secchi Depth (m)	13	2	3.2	2.8	3.2	0.4	0
Secchi Depth (m)	14	6	5	2	6	1	0
Secchi Depth (m)	15	2	3.2	2.8	3.6	0.4	0
Specific Conductivity (µS/cm)	1	5	114	112	116	2	0
Specific Conductivity (µS/cm)	2	5	111	111	117	3	0
Specific Conductivity (µS/cm)	3	6	111	108	114	3	0
Specific Conductivity (µS/cm)	4	5	110	108	112	2	0
Specific Conductivity (µS/cm)	5	6	110	106	112	2	0
Specific Conductivity (µS/cm)	6	6	108	104	110	2	0
Specific Conductivity (µS/cm)	7	6	110	105	115	5	0
Specific Conductivity (µS/cm)	8	6	108	106	110	2	0
Specific Conductivity (µS/cm)	9	6	108	106	110	2	0
Specific Conductivity (µS/cm)	10	5	106	105	108	1	0
Specific Conductivity (µS/cm)	11	6	106	104	108	1	0
Specific Conductivity (µS/cm)	12	6	106	104	108	2	0
Specific Conductivity (µS/cm)	13	5	106	102	106	2	0
Specific Conductivity (µS/cm)	14	6	106	104	108	1	0
Specific Conductivity (µS/cm)	15	5	106	104	108	2	0
Temperature (°C)	1	5	16	14	18	2	0
Temperature (°C)	2	5	16	16	18	2	0
Temperature (°C)	3	6	17	14	18	1	0
Temperature (°C)	4	5	16	14	18	2	0
Temperature (°C)	5	6	16	14	18	2	0
Temperature (°C)	6	6	16	14	18	2	0
Temperature (°C)	7	6	14	14	18	2	0
Temperature (°C)	8	6	15	12	18	3	0
Temperature (°C)	9	6	16	14	18	2	0
Temperature (°C)	10	5	15	12	18	3	0
Temperature (°C)	11	6	15	12	18	3	0
Temperature (°C)	12	6	12	8	20	4	0
Temperature (°C)	13	5	16	12	20	4	0
Temperature (°C)	14	6	15	12	18	3	0
Temperature (°C)	15	5	16	12	18	2	0
Turbidity (NTU)	1	5	4	0	12	4	0
Turbidity (NTU)	2	5	4	0	12	4	0
Turbidity (NTU)	3	6	4	2	8	2	0
Turbidity (NTU)	4	5	4	2	8	2	0
Turbidity (NTU)	5	6	5	0	15	5	0
Turbidity (NTU)	6	6	4	0	12	4	0
Turbidity (NTU)	7	6	20	0	60	20	0
Turbidity (NTU)	8	6	6	3	9	3	0
Turbidity (NTU)	9	6	3	1	4	1	0
Turbidity (NTU)	10	5	2	0	4	1	0
Turbidity (NTU)	11	6	3	0	4	1	0
Turbidity (NTU)	12	6	2	0	4	1	0
Turbidity (NTU)	13	5	0.7	0.7	2.1	0.7	0
Turbidity (NTU)	14	6	0.8	0	2.4	0.8	0
Turbidity (NTU)	15	5	0.8	0	1.6	0.8	0

Table A3: Nutrient summaries grouped by site and parameter.

Nutrient summaries grouped by site.

Parameter	Site	Count	Mean	Min	Max	Stdev	NDs
Chlorophyll A (µg/L)	1	4	1	0	2	1	0
Chlorophyll A (µg/L)	2	5	2	1	3	1	0
Chlorophyll A (µg/L)	3	5	1	0	3	1	0
Chlorophyll A (µg/L)	4	5	1.8	0.9	2.7	0.9	0
Chlorophyll A (µg/L)	5	6	2	1	4	1	0
Chlorophyll A (µg/L)	6	5	1.8	0.9	2.7	0.9	0
Chlorophyll A (µg/L)	7	6	2	1	4	1	0
Chlorophyll A (µg/L)	8	6	1.6	0.8	2.4	0.8	0
Chlorophyll A (µg/L)	9	6	1.2	0.6	1.8	0.6	0
Chlorophyll A (µg/L)	10	5	0.7	0	2.1	0.7	0
Chlorophyll A (µg/L)	11	6	1.4	0.7	2.1	0.7	0
Chlorophyll A (µg/L)	12	6	0.7	0	2.1	0.7	0
Chlorophyll A (µg/L)	13	5	0.4	0.4	1.2	0.4	0
Chlorophyll A (µg/L)	14	6	0.9	0.6	1.2	0.3	0
Chlorophyll A (µg/L)	15	5	1	0.5	1.5	0.5	0
Nitrate + nitrite (mg/L)	1	4	0.32	0.31	0.33	0.01	0
Nitrate + nitrite (mg/L)	2	5	0.325	0.32	0.33	0.005	0
Nitrate + nitrite (mg/L)	3	5	0.32	0.31	0.33	0.01	0
Nitrate + nitrite (mg/L)	4	5	0.325	0.32	0.33	0.005	0
Nitrate + nitrite (mg/L)	5	6	0.328	0.312	0.328	0.008	0
Nitrate + nitrite (mg/L)	6	5	0.33	0.31	0.34	0.01	0
Nitrate + nitrite (mg/L)	7	6	0.33	0.27	0.36	0.03	0
Nitrate + nitrite (mg/L)	8	6	0.32	0.28	0.36	0.02	0
Nitrate + nitrite (mg/L)	9	6	0.34	0.32	0.35	0.01	0
Nitrate + nitrite (mg/L)	10	5	0.34	0.32	0.36	0.02	0
Nitrate + nitrite (mg/L)	11	6	0.34	0.32	0.36	0.02	0
Nitrate + nitrite (mg/L)	12	6	0.36	0.33	0.39	0.03	0
Nitrate + nitrite (mg/L)	13	5	0.34	0.32	0.36	0.02	0
Nitrate + nitrite (mg/L)	14	6	0.34	0.32	0.36	0.01	0
Nitrate + nitrite (mg/L)	15	5	0.34	0.32	0.36	0.02	0
Ortho-P (mg/L)	1	1	NA	NA	NA	NA	0
Ortho-P (mg/L)	2	3	0.005	0.004	0.006	0.001	0
Ortho-P (mg/L)	3	1	NA	NA	NA	NA	0
Ortho-P (mg/L)	4	2	0.006	0.003	0.009	0.003	0
Ortho-P (mg/L)	5	2	0.0042	0.0042	0.0049	7e-04	0
Ortho-P (mg/L)	6	2	NaN	NaN	NaN	0	0
Ortho-P (mg/L)	7	2	NaN	NaN	NaN	0	0
Ortho-P (mg/L)	8	1	NA	NA	NA	NA	0
Ortho-P (mg/L)	9	2	0.0042	0.0042	0.0049	7e-04	0
Ortho-P (mg/L)	10	1	NA	NA	NA	NA	0
Ortho-P (mg/L)	11	1	NA	NA	NA	NA	0
Ortho-P (mg/L)	12	2	0.0042	0.0042	0.0049	7e-04	0
TN (mg/L)	1	4	0.56	0.49	0.63	0.07	0
TN (mg/L)	2	5	0.52	0.48	0.6	0.04	0
TN (mg/L)	3	5	0.49	0.42	0.63	0.07	0
TN (mg/L)	4	5	0.55	0.45	0.6	0.05	0
TN (mg/L)	5	6	0.54	0.48	0.6	0.06	0
TN (mg/L)	6	5	0.49	0.42	0.63	0.07	0
TN (mg/L)	7	6	0.48	0.42	0.6	0.06	0
TN (mg/L)	8	6	0.48	0.42	0.6	0.06	0
TN (mg/L)	9	6	0.5	0.4	0.55	0.05	0
TN (mg/L)	10	5	0.48	0.42	0.51	0.03	0
TN (mg/L)	11	6	0.48	0.4	0.56	0.04	0
TN (mg/L)	12	6	0.48	0.4	0.56	0.04	0
TN (mg/L)	13	5	0.45	0.42	0.48	0.03	0
TN (mg/L)	14	6	0.4	0.32	0.48	0.08	0
TN (mg/L)	15	4	0.44	0.4	0.46	0.02	0
TP (mg/L)	1	3	0.012	0.008	0.016	0.004	0
TP (mg/L)	2	4	0.01	0.005	0.02	0.005	0
TP (mg/L)	3	5	0.009	0.006	0.012	0.003	0
TP (mg/L)	4	4	0.01	0.008	0.012	0.002	0
TP (mg/L)	5	6	0.01	0.005	0.02	0.005	0
TP (mg/L)	6	4	0.006	0	0.018	0.006	0
TP (mg/L)	7	6	0.012	0	0.018	0.006	0
TP (mg/L)	8	6	0.012	0.004	0.016	0.004	0
TP (mg/L)	9	5	0.008	0.004	0.012	0.004	0
TP (mg/L)	10	5	0.008	0.004	0.008	0.002	0
TP (mg/L)	11	5	0.008	0.004	0.012	0.004	0
TP (mg/L)	12	4	0.004	0	0.012	0.004	0
TP (mg/L)	13	3	0.0024	0.0018	0.003	6e-04	0
TP (mg/L)	14	3	0.003	0.002	0.004	0.001	0
TP (mg/L)	15	3	0.004	0	0.008	0.004	0
TSS (mg/L)	2	2	4	0	8	4	0
TSS (mg/L)	3	1	NA	NA	NA	NA	0
TSS (mg/L)	4	2	2.8	2.4	3.2	0.4	0
TSS (mg/L)	5	2	4	2	4	2	0
TSS (mg/L)	6	1	NA	NA	NA	NA	0
TSS (mg/L)	7	5	6	3	9	3	0
TSS (mg/L)	8	2	2.4	2	2.4	0.4	0
TSS (mg/L)	11	1	NA	NA	NA	NA	0

Table A4: Algal ID/enumeration of Schaffer Beach (site 1).

Date	Phyla	Count	Percent Population
7/17	**Cyanophyta**	**1097**	**28.3**
	Chlorophyta	1319	34.0
	Heterokontophyta	1326	34.2
	Charophyta	18	0.5
	Cryptista	73	1.9
	Dinoflagellata	48	1.2
8/1	Heterokontophyta	411	38.8
	Chlorophyta	428	40.4
	Charophyta	27	2.5
	Cryptista	156	14.7
	Euglenophyta	20	1.9
	Dinoflagellata	17	1.6
8/30	Chlorophyta	1555	43.1
	Heterokontophyta	167	4.6
	Cryptista	1888	52.3
9/5	Heterokontophyta	484	26.7
	Chlorophyta	609	33.5
	Cryptista	599	33.0
	Dinoflagellata	5	0.3
	Cyanophyta	**119**	**6.6**

Table A5: Algal ID/enumeration of Poplar River (site 3).

Date	Phyla	Count	Percent Population
7/17	**Cyanophyta**	**363**	**18.0**
	Heterokontophyta	873	43.3
	Chlorophyta	328	16.3
	Cryptista	368	18.3
	Dinoflagellata	32	1.6
	Euglenophyta	50	2.5
8/1	**Cyanophyta**	**1555**	**44.1**
	Heterokontophyta	1255	35.6
	Chlorophyta	607	17.2
	Charophyta	6	0.2
	Cryptista	96	2.7
	Dinoflagellata	6	0.2
8/30	Chlorophyta	1665	42.3
	Heterokontophyta	1262	32.1
	Charophyta	13	0.3
	Cryptista	984	25.0
	Dinoflagellata	13	0.3
9/5	**Cyanophyta**	**1096**	**42.6**
	Heterokontophyta	329	12.8
	Chlorophyta	686	26.7
	Dinoflagellata	34	1.3
	Cryptista	425	16.5
9/21	**Cyanophyta**	**4363**	**46.7**
	Heterokontophyta	129	1.4
	Chlorophyta	649	6.9
	Charophyta	32	0.3
	Cryptista	4169	44.6

Table A6: Algal ID/enumeration of Brule River (site 6).

Date	Phyla	Count	Percent Population
7/17	Heterokontophyta	1831	76.1
	Cryptista	405	16.8
	Charophyta	39	1.6
	Chlorophyta	101	4.2
	Dinoflagellata	31	1.3
8/1	Chlorophyta	266	11.1
	Cyanophyta	**945**	**39.4**
	Heterokontophyta	1120	46.7
	Dinoflagellata	26	1.1
	Cryptista	43	1.8
8/30	**Cyanophyta**	**1678**	**42.2**
	Heterokontophyta	1100	27.6
	Chlorophyta	623	15.7
	Charophyta	15	0.4
	Cryptista	556	14.0
	Euglenophyta	7	0.2
9/5	**Cyanophyta**	**2320**	**58.5**
	Heterokontophyta	513	12.9
	Chlorophyta	646	16.3
	Charophyta	5	0.1
	Cryptista	479	12.1
	Dinoflagellata	5	0.1

Table A7: Algal ID/enumeration of Iron River (site 8).

Date	Phyla	Count	Percent Population
6/27	Chlorophyta	1241	63.2
	Heterokontophyta	564	28.7
	Cryptista	91	4.6
	Cyanophyta	**18**	**0.9**
	Dinoflagellata	18	0.9
	Euglenophyta	33	1.7
7/18	Chlorophyta	218	21.7
	Heterokontophyta	537	53.4
	Chlorophyta	189	18.8
	Euglenophyta	5	0.5
	Cryptista	41	4.1
	Dinoflagellata	16	1.6
7/31	Chlorophyta	399	25.1
	Cyanophyta	**324**	**20.4**
	Heterokontophyta	739	46.5
	Charophyta	7	0.4
	Dinoflagellata	78	4.9
	Cryptista	7	0.4
	Euglenophyta	34	2.1
8/30	**Cyanophyta**	**2749**	**52.6**
	Heterokontophyta	1590	30.4
	Chlorophyta	351	6.7
	Charophyta	31	0.6
	Cryptista	486	9.3
	Dinoflagellata	8	0.2
	Euglenophyta	8	0.2
9/5	**Cyanophyta**	**727**	**22.5**
	Heterokontophyta	939	29.1
	Chlorophyta	705	21.8
	Charophyta	15	0.5
	Cryptista	818	25.3
	Dinoflagellata	23	0.7
9/21	**Cyanophyta**	**7324**	**56.2**
	Heterokontophyta	511	3.9
	Chlorophyta	2252	17.3
	Cryptista	2952	22.6

Table A8: Algal ID/enumeration of Flag River (site 9).

Date	Phyla	Count	Percent Population
6/27	Chlorophyta	2578	62.5
	Heterokontophyta	1211	29.3
	Cyanophyta	**317**	**7.7**
	Dinoflagellata	21	0.5
7/18	Chlorophyta	98	13.6
	Heterokontophyta	537	74.6
	Charophyta	3	0.4
	Cryptista	11	1.5
	Dinoflagellata	33	4.6
	Cyanophyta	**38**	**5.3**
7/31	Chlorophyta	182	7.6
	Cyanophyta	**886**	**37.0**
	Heterokontophyta	1159	48.4
	Charophyta	9	0.4
	Cryptista	75	3.1
	Dinoflagellata	84	3.5
8/30	**Cyanophyta**	**740**	**36.5**
	Heterokontophyta	698	34.5
	Chlorophyta	519	25.6
	Charophyta	10	0.5
	Cryptista	59	2.9
9/5	**Cyanophyta**	**3121**	**48.3**
	Heterokontophyta	1048	16.2
	Chlorophyta	1801	27.9
	Cryptista	483	7.5
	Dinoflagellata	7	0.1
9/21	**Cyanophyta**	**3747**	**81.1**
	Heterokontophyta	215	4.7
	Chlorophyta	404	8.7
	Charophyta	3	0.1
	Cryptista	254	5.5

Table A9: Algal ID/enumeration of Siskiwit Bay (site 14).

Date	Phyla	Count	Percent Population
7/18	Chlorophyta	204	34.9
	Heterokontophyta	329	56.2
	Charophyta	3	0.5
	Cryptista	22	3.8
	Dinoflagellata	27	4.6
7/31	**Cyanophyta**	**1201**	**40.7**
	Heterokontophyta	740	25.1
	Chlorophyta	841	28.5
	Charophyta	16	0.5
	Cryptista	112	3.8
	Dinoflagellata	44	1.5
8/30	**Cyanophyta**	**720**	**41.9**
	Heterokontophyta	555	32.3
	Chlorophyta	376	21.9
	Charophyta	24	1.4
	Cryptista	45	2.6
9/21	**Cyanophyta**	**12329**	**94.2**
	Heterokontophyta	396	3.0
	Chlorophyta	225	1.7
	Charophyta	44	0.3
	Cryptista	85	0.6
	Dinoflagellata	7	0.1