Lake Oscawana 2023 Water Quality & Aquatic Plant Monitoring Report

Prepared for the Lake Oscawana Management Advisory Committee,
Town of Putnam Valley, NY

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Northeast Aquatic Research, LLC
northeastaquaticresearch@gmail.com

Executive Summary: Key Points from the 2023 Monitoring Report

- Water quality is in significantly decline in Lake Oscawana. The data show that in 2023, most metrics used to define lake condition showed serious deterioration. Evidence from the data suggests that the decline started in 2021 and intensified in 2022.
- Water clarity was possibly the worst on record in 2023, when most of the summer had Secchi disk transparency values of near or less than 2 meters. Poor clarity began in late 2021 when the lake experienced a severe fall-winter cyanobacteria bloom and continued through 2022 when the lake again had poor clarity (<2m) throughout the months of September and October.
- Water temperature profiles showed that the lake was stratified in April, the first seasonal visit. Lake monitoring is designed to have the first visit collect data from an isothermal water column. This indicates that monitoring needs to begin in March. The lake appeared to lose its epilimnion and hypolimnion between June and July, when profile data showed the water column was a metalimnion from top the bottom, characterized by a lack of isothermal conditions at the top and bottom of the lake. Instead, the profiles showed a gradual decline in temperature at each meter depth. Water temperature profiles also showed that the lake was not isothermal on the last day of monitoring in October, indicating that the lake needs to be visited in November.
- The seasonal maximum ascent depth of the anoxic boundary in 2023 was 4.8m below the surface in mid-September. This is the highest value recorded in Oscawana and represents a huge increase in the volume of anoxic water in the lake. The anoxic boundary has slightly worsened over the last several years, reaching 5.81m in 2020, 5.77m in 2021, and 5.35m in 2022. These values exceed the target threshold of 6.0m from the surface.
- The total phosphorus concentrations are perhaps the most concerning of the declining water quality parameters. Surface water TP has been between 20-30ppb in the later months of 2019, 2021, and 2022. Surface water TP was nearly 40ppb in late 2023. In the spring of 2022, TP was between 20ppb and 40ppb. However, in spring 2023, surface water TP remained low in April, May, and June, indicating serious watershed instability. Later 2023 TP concentrations were between 20 and 40 ppb, with only one exception.
- Bottom water TP concentrations were higher than the historical average across all stations in September 2023. The highest bottom water TP was 740ppb, 50% higher than the long-term average highest concentration. In 2022, the highest bottom water TP concentration was 1150ppb, roughly 130% higher than the average highest concentration. These data show that internal loading, although always a source of N and P, is now a serious source of phosphorus to the water column.
- Surface TN concentrations have typically ranged between 200 and 400ppb, with very rare occurrences of concentrations higher than 400ppb. TN spiked to nearly 600ppb at the end of 2022 and again in 2023. These extremely high total nitrogen values are from anthropogenic organic nitrogen originating from septic systems around the lake. Without the buffer of aquatic plants in the littoral zone to intercept nutrient-rich groundwater, expect the TN value in the surface water of the lake to continue to increase in the near future, probably reaching 1000ppb to 1200ppb by late summer in the years to come.

- Bottom water TN continues to show signs of significant internal loading, mainly in the form of ammonia. Bottom water TN now reaches 2500ppb to nearly 4000ppb each summer.
- Aquatic plant survey results showed a continued dramatic decrease in abundance and distribution of previously dominant species; Eurasian Milfoil, Large-leaf Pondweed, and Tapegrass. Robbins Pondweed may have been exterpated from the lake, as it was not found in 2023. The remaining dominant aquatic plants, White Water Lily, Coontail, and Tape Grass, are likely to be eliminated from the lake either this year (2024) or next year (2025). The loss of aquatic plants thoughout the lake will likely result in a crash of the fish community in future years.
- *Lyngbya sp.*, a filimentous cyanobacteria that forms benthic mats, was more abundant than any of the aquatic plants typically found in the lake. Grass carp are likely to remove all the aquatic plants in the lake, shifting the vegetation to complete dominance by Lyngbya. Lyngbya is known to produce at least two different cyano-toxins.

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Description of Monitoring Parameters

All measurements should be taken at the deepest open-water location in a lake.
Large or irregularly shaped lakes often require more than one testing site.

Secchi Disk Clarity

Water clarity measurements use an 8-inch circular **Secchi disk** attached to a measuring tape. The disk should be lowered into the water on the shady side of the boat. Using a view scope to shade out light in one's peripheral vision, the Secchi disk is lowered until it disappears from view in the water column. The depth at which the Secchi disk disappears from view is considered the water clarity measurement. Secchi clarity is dependent on light penetration. Light penetration is affected by phytoplankton, suspended sediments, and microscopic organic matter in the water column. Clearer waterbodies have greater Secchi transparency values. Lakes and ponds experience fluctuations in Secchi clarity throughout the season, typically driven by increases or decreases in nutrients that stimulate phytoplankton growth. Ideally, water clarity should be tracked at least monthly from April to October.

Lake Profile Measurements

Temperature in lakes and ponds in the northeast follows a seasonal pattern of warming and cooling. Following ice-melt in early spring, lakes and ponds will be more or less uniform in temperature from top to bottom. Temperature measurements should be made at one-meter increments from the lake surface to the bottom on a monthly basis. Combined, measurements at all 1-meter depth increments are referred to as a lake profile. Profile measurements change as the sun's rays penetrate into the water column. Clearer water allows for greater sunlight penetration and deeper warming during the summer months. The depth and development of a **thermocline**, or the zone of rapid temperature change, is dependent on water depth, surface area of the lake, climatic conditions, and water clarity. A thermocline effectively isolates top and bottom waters during summer months because warm water at the surface is less dense than the cold water at the bottom of the lake. In the fall, the lake cools off as air temperatures drop, resulting in a weakening thermocline and eventually water "turn-over." Lake turnover simply means that the temperature becomes uniform from top to bottom and that there is no longer a thermocline. In lakes deeper than 20ft in the northeast, this turnover traditionally occurs in the spring and the fall. Shallower lakes are more dependent on weather and may experience multiple thermal mixing events in a season. Very large and deep lakes often have more complicated temperature dynamics that require multiple monitoring sites.

Dissolved oxygen in a lake is essential to aquatic organisms. At the surface of a lake, the water is in direct contact with the air, and atmospheric oxygen is dissolved into the water as a result of diffusion. Water mixing, driven by wind and temperature currents, circulates this oxygen throughout the water column during spring and fall mixing periods. Yet because lakes warm non-uniformly, the thermocline that develops in summer months will temporarily cut off the bottom waters from surface water circulation of oxygen. In lakes with very little decomposing plant material at the bottom, this is not usually a problem because there is enough oxygen to sustain the lake through the summer months. More nutrient-rich lakes, however, can be depleted of oxygen in the bottom waters below the thermocline. This phenomenon results in **anoxic** (<1mg/L) conditions in deeper waters of many lakes. An absence of oxygen changes the bottom chemistry for multiple months. It is critical to track oxygen loss beneath the thermocline and/or the level of the **anoxic boundary**. The anoxic boundary is defined as the depth of water at which dissolved oxygen is depleted in the summer. Anoxia worsens towards the end of summer, just before fall 'turn-over,' which will eventually replenish oxygen to the bottom, even in polluted lakes. Anoxia also tends to worsen over time, increasing incrementally for years and years. Organisms like fish and invertebrates that need oxygen to survive are not able to inhabit deeper waters in many lakes during the summer. Lakes and ponds with severe oxygen problems during summer months also experience increased nutrient levels at the lake bottom. This is the result of changing chemistry between the presence or absence of oxygen.

Lake Nutrients Samples

Water samples should be collected monthly from April to October in at least the deepest part of the lake. The most critical times for sampling are early spring, mid to late summer, and the fall. Sampling depths usually incorporate top, middle, and bottom depths. Deeper lakes may need more samples, and shallower lakes may only need top and bottom samples. Water samples are typically analyzed for total phosphorus, total nitrogen, ammonia nitrogen, and nitrate nitrogen. In baseline assessments, a number of additional parameters are also needed. ***Phosphorus*** and ***Nitrogen*** are the two principal plant nutrients that drive aquatic plant and algae growth. Due to lake temperature stratification, these nutrients are not usually present in the same quantities throughout the lake. Typically, the bottom of the lake has more phosphorus and nitrogen as the summer progresses because bottom-sediments release nutrients when oxygen is depleted. Just as anoxia increases over time, phosphorus and nitrogen also tend to increase over time as a waterbody becomes more eutrophic, or dominated by plants and algae.

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Description of Monitoring Parameters Continued…

Calculated Values

Relative Thermal Resistance to Mixing (RTRM) is a unit-less ratio that describes the difference in water density between each meter. Higher numbers indicate stronger thermal **stratification**. Stratification is the result of density differences as warming surface waters become less dense than cold deeper water. The RTRM is a relative number that distinguishes the intensity and depth of the thermocline. RTRMs describe how the lake is or is not mixing with respect to layers of water at specific depths. RTRMs also show when the lake becomes de-stratified as the result of temperature changes or excessive wind energy that can overcome thermal density boundaries.

Percent Oxygen Saturation is the percentage of dissolved oxygen at a given depth, relative to the water's capacity to hold oxygen, which is based on its temperature. For instance, 50% O_2 saturation means that the water contains only half of the dissolved oxygen that it is able to hold at its current temperature. In essence, anything less than 100% means that the biological oxygen demand, or rate at which oxygen is used up, is depleting the water of oxygen at a rate faster than it can be replenished. A percentage greater than100% is frequently a result of excessive phytoplankton production of oxygen that causes the water to be supersaturated.

Additional Important Profile Measurements

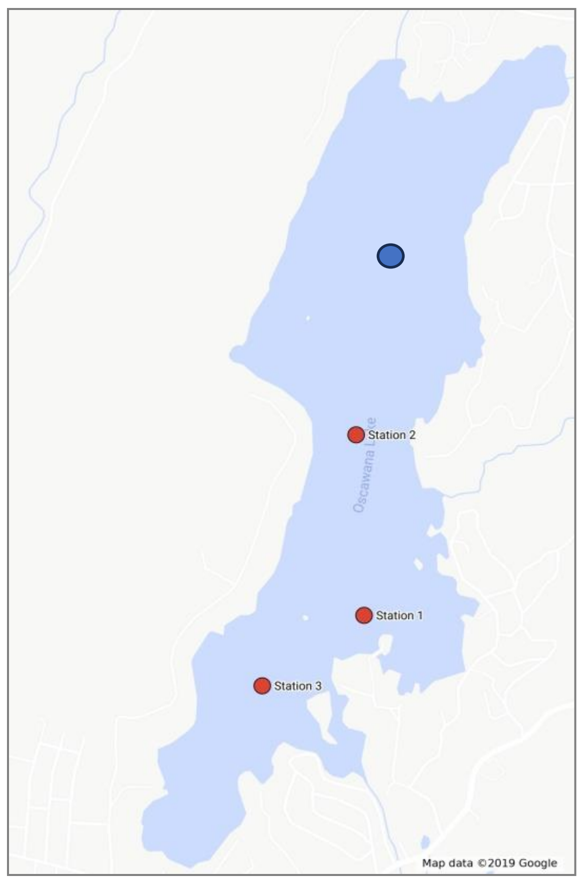
Specific Conductance, also referred to as conductivity, measures the quantity of dissolved ions in water that conduct electricity. Conductivity measurements can also be taken at one-meter increments from surface to lake bottom with calibrated probes. Alternatively only surface samples may also be collected and tested in the lab. Conductivity generally increases with dissolved salt content in the lake, which can be traced to either natural mineral sources or to human inputs from road salting and septic systems.

Station 1: The "Deep Hole" is approximately 35-ft deep and is the primary water quality monitoring site.
(41.39063, -73.84836)

Station 2: The northern monitoring station is located in approximately 27-ft of water.
(41.39553, -73.84824)

Station 3: The southern station is also located in roughly 27-ft of water and represents water quality near some of the most populated and disturbed areas of the lake.
(41.38817, -73.85275)

All water quality monitoring stations are too deep to support aquatic plant growth. All stations lose oxygen from late spring to late summer. The three sites differ substantially depending variable lake conditions.



Water Clarity

The Lake Oscawana Management Plan, published in 2020, set the minimum target water clarity value to be 2-meters, and identified that water clarity greater than 4-meters was considered particularly good based on the lake's historical data. These thresholds are shown as horizontal dashed lines in **Figure 1** below.

The seasonal trends in water clarity at Lake Oscawana for the years 2017-2023 are shown in **Figure 1**. The typical seasonal variability in water clarity is shown in the trends for 2017 and 2018, and to some extent in 2019-2021. This trend is exemplified by moderate-to poor clarity in spring months, followed by an increase to the best clarities of the season during the May-July timeframe, followed by an abrupt decline typically in early August, and then moderate to poor conditions in August, September, and October. The decline in clarity was associated with timing of when the anoxic boundary ascended into the bottom layer of the thermocline. However, the trends shown in 2022 and 2023 are significantly different. In these years, clarity began declining much earlier in the season. In 2023, clarity rapidly declined after June 1st. In both years, water clarity was less than 2 meters for extended periods of time during the August – October timeframe. Some poor water clarity in 2023 could be attributed to heavy rain fall during summer months.

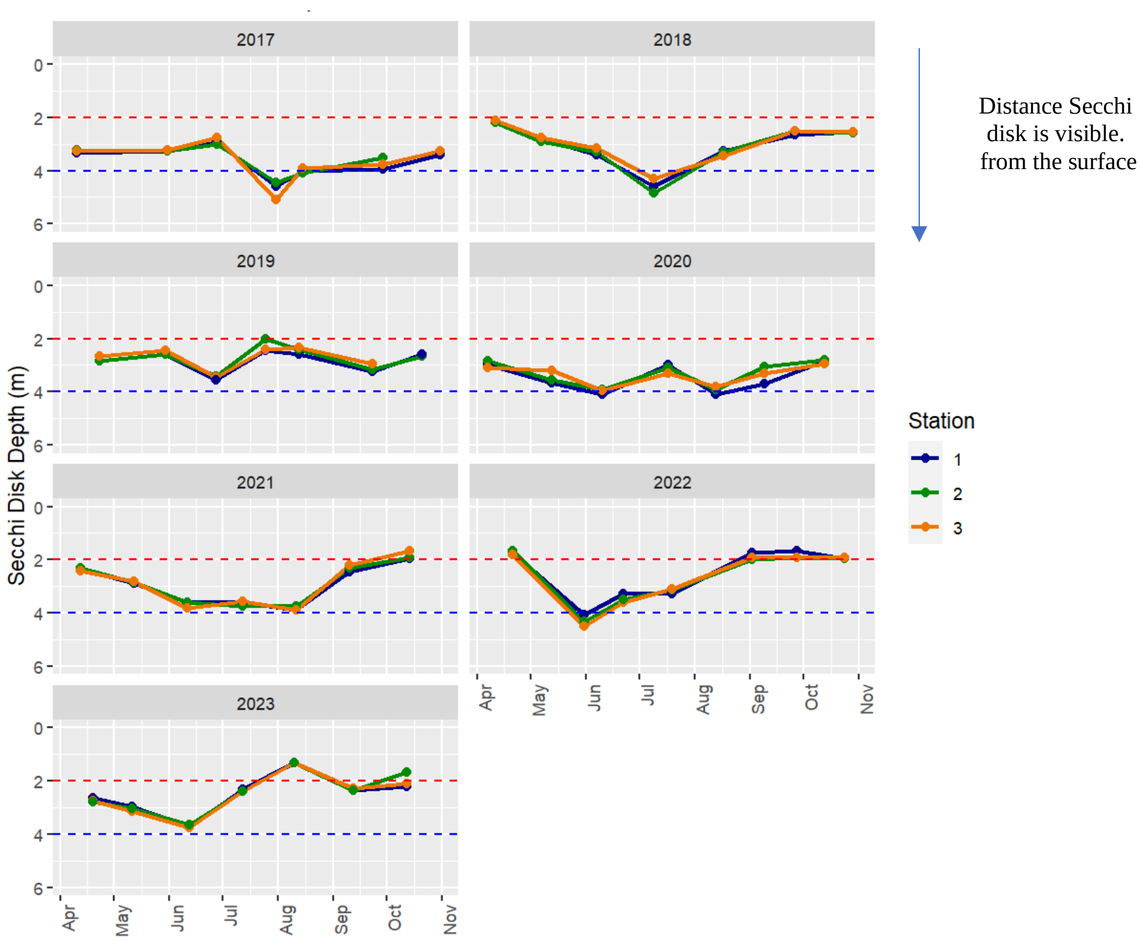


Figure 1. Water clarity 2017-2023 seasonal pattern, St 1-3. Red dashed line shows minimal acceptable clarity, blue dashed line is target clarity.

Water Temperature

The 2023 water temperature profiles measured at Station 1 are shown in **Figure 2**. Profiles collected from Stations 2 and 3 are shown in **Figure 3**. Profiles show the lake was thermally stratified at the time of our first sampling visit in April. Summer warming reached maximum temperature in July, when surface water was 28°C. A warm fall allowed the lake to remain stratified down to 4 meters through September. Water below 4 meters during July, August, and September was metalimnetic in nature to the bottom. That is, water continued getting colder with depth instead of reaching a point below which water had uniform temperature despite decreasing depth. The lake cooled down by October to have uniform temperature between the surface and 9 meters, but water below 9 meters remained unmixed, and as shown in **Figure 6**, was anoxic at the time of our last visit.

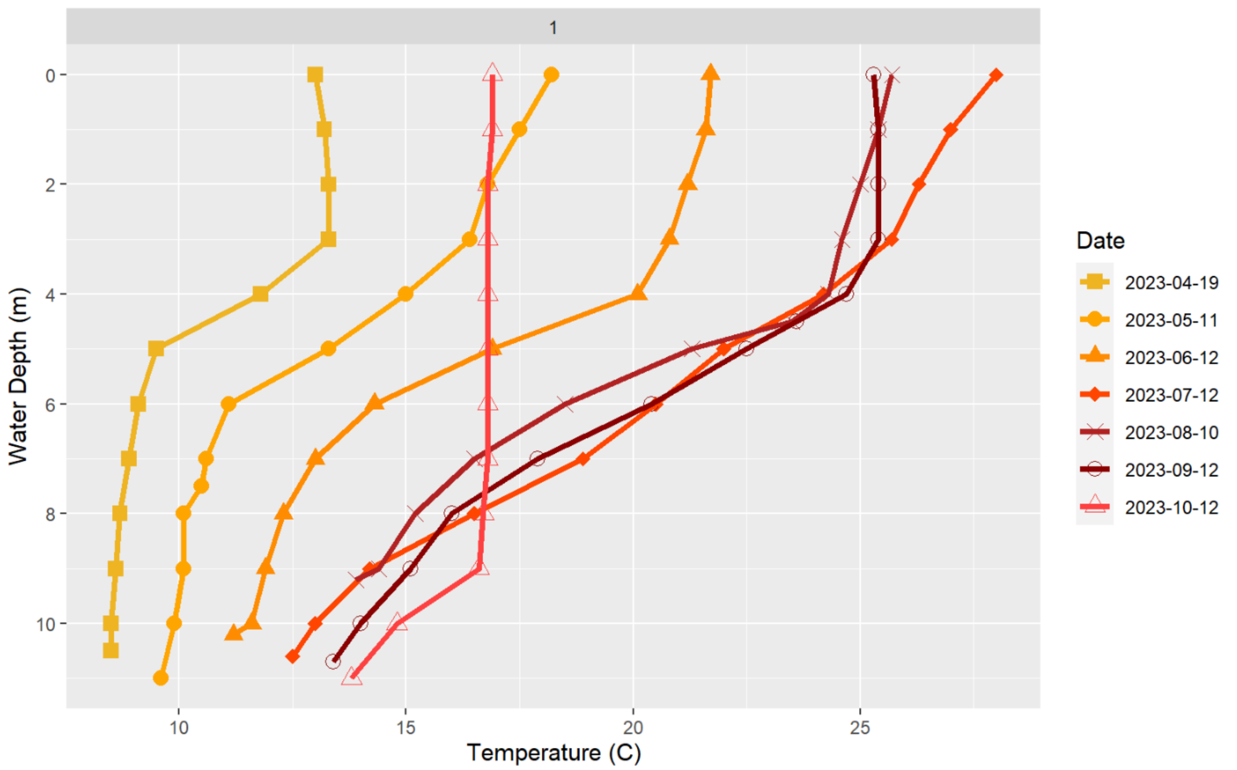


Figure 2. Station 1 water temperature (°C) 2023.

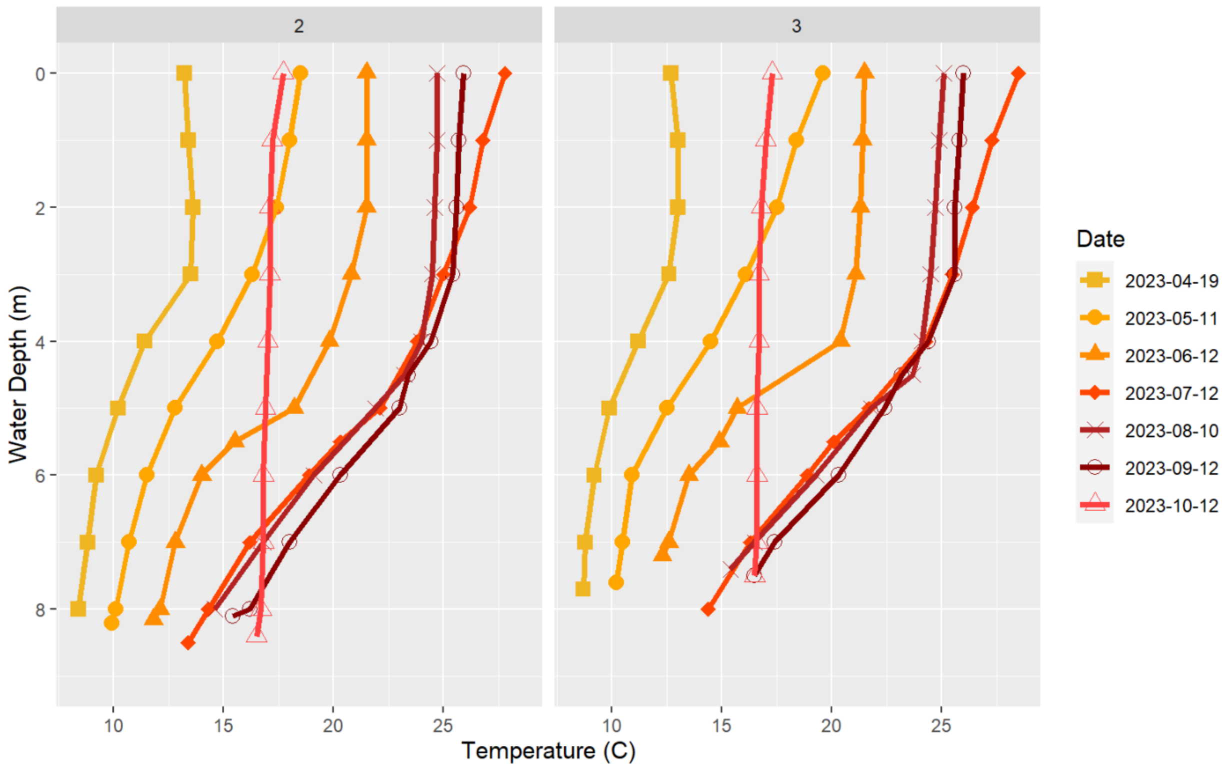


Figure 3. Station 2 & 3 water temperature (°C) 2023.

Data Loggers

In spring 2023, the Town of Putnam Valley and LOMAC purchased HOBO temperature data loggers. On May 11th, NEAR deployed the eleven data loggers at the deepest location in the lake (Station 1). Two loggers were deployed at 1 meter below the surface of the water for QA/QC. One logger was deployed at each meter (2 meters, 3 meters, etc) to the bottom of the lake at 10 meters. The loggers recorded temperature (°C) every 30 minutes. On July 12th, NEAR staff downloaded the logger data using the HOBOconnect app, which is Bluetooth-enabled, and redeployed the loggers. Downloading the data at least once during the season ensures that the loggers are operating smoothly and provides lake users with up-to-date information regarding the water temperature. On October 12th, NEAR staff downloaded the logger data for the final time and removed the logger and buoy system from the lake.

To effectively display the continuous logger data over the course of the sampling period, NEAR staff created a temperature isopleth, shown in **Figure 4**. Isopleths are a great method for visualizing continuous data. The surface temperature was warmest from early to late July, and briefly in early September. The zone of rapid temperature change (thermocline) typically occurred between 4 meters and 6 meters. Water deeper than 6 meters remained below approximately 20°C during the sampling period. By late September, the lake began to mix, though a warm spell in early October briefly warmed the upper waters.

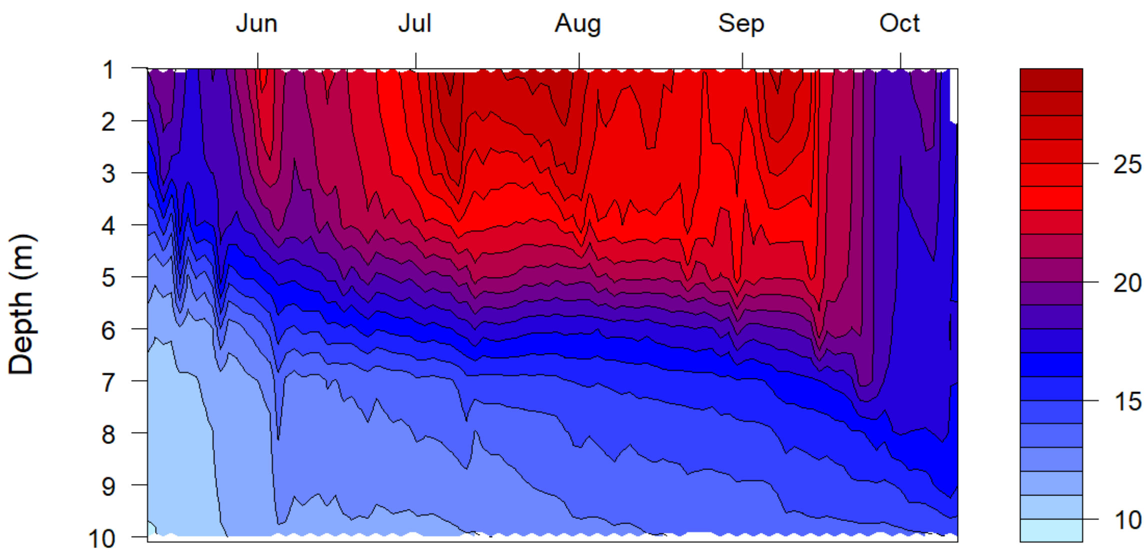


Figure 4. Daily water temperatures from the data loggers at the deep station in 2023.

The intensity of thermal stratification is quantified using Relative Thermal Resistance to Mixing (RTRM), a dimensionless value calculated using the density differences between 1-meter-thick layers of water in the lake. Mixing is defined as taking water from two adjacent meters each with different temperatures and blending them together to create a two-meter-thick layer of the same temperature.

The 2023 RTRM values from Station 1 are shown as horizontal bars in **Figure 5**. RTRM values near zero indicate no mixing resistance. RTRM values between 5 and 30 indicate weak resistance to mixing, values between 30 and 60 indicate strong resistance to mixing, and values above 60 indicate very strong resistance to mixing. Tracking the change in RTRM each season allows for understanding of the duration and strength of thermal barriers in the lake, and it defines the location and thickness of the three lake layers during stratification (epilimnion, metalimnion, and hypolimnion).

RTRM was relatively weak in April and October, shown in Figure 5 by shorter bars. In May and June, RTRM generally increased with depth until approximately 5 meters or 6 meters. In July, there were high RTRM values between depths (longest bars), indicating strong resistance to mixing between depths. The RTRM values in August and September were higher with greater depth, indicating the upper waters were relatively mixed.

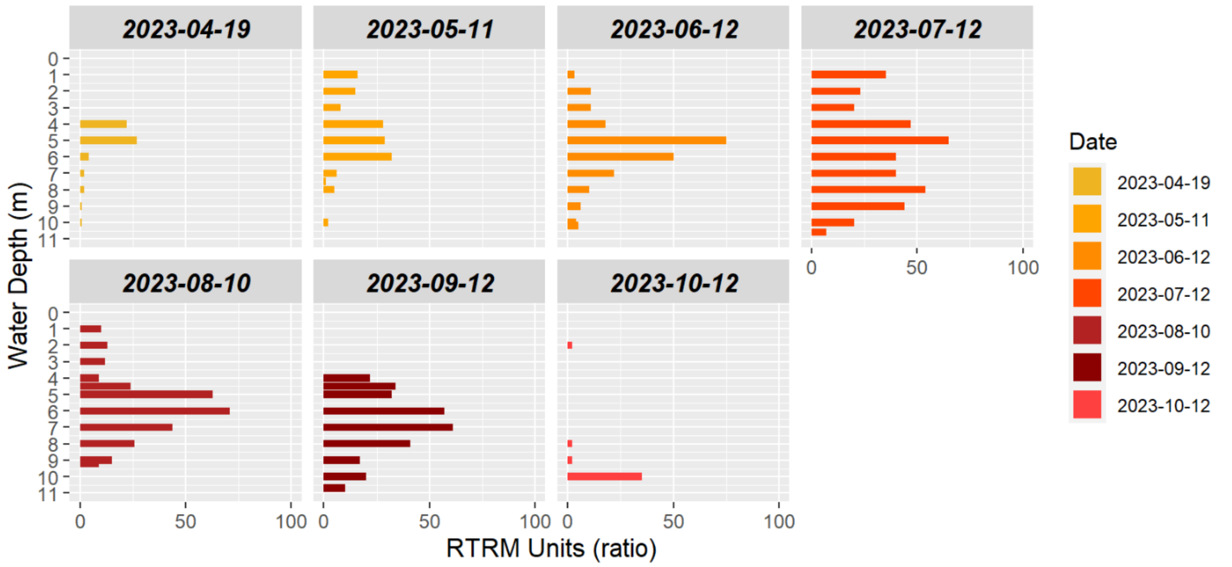


Figure 5. Relative thermal resistance to mixing (RTRM) at station 1 in 2023.

Dissolved Oxygen

The 2023 dissolved oxygen profiles from Station 1 in Lake Oscawana are shown in **Figure 6**, while Stations 2 and 3 are shown in **Figure 7** Dissolved oxygen concentrations recorded in April were above 10 mg/L in upper waters. However, below a depth of 4 meters, dissolved oxygen sharply declined with depth, dropping to 5.58 mg/L at the very bottom. In May, dissolved oxygen concentration was further reduced, and water below 10 meters was devoid of dissolved oxygen (termed anoxic). The bottom waters remained anoxic through October. The anoxic boundary occurred at 5 meters during all of August and September.

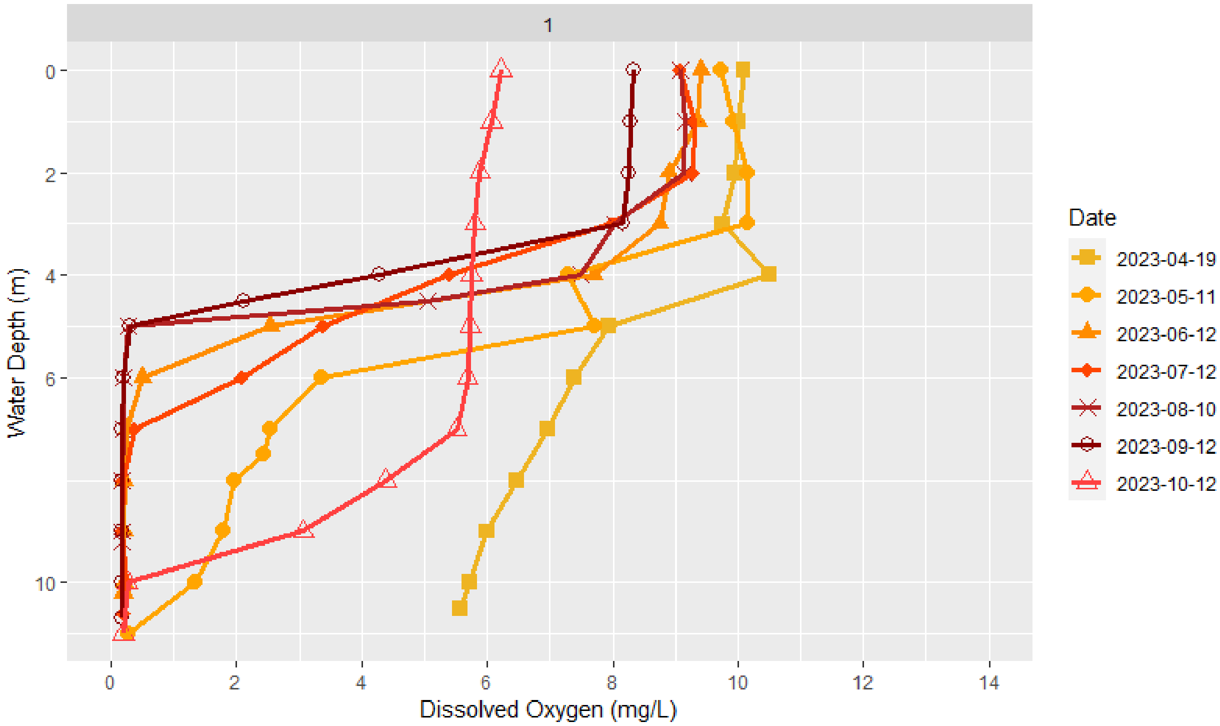


Figure 6. 2023 dissolved oxygen profiles from station 1.

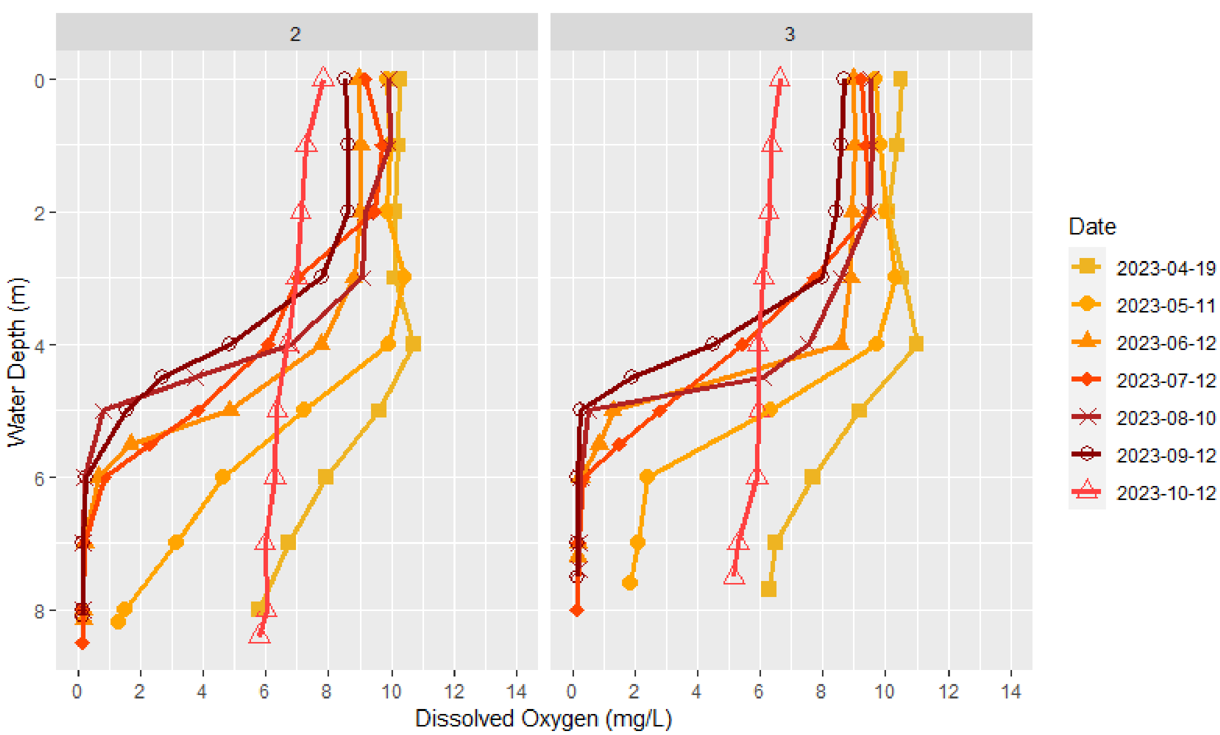


Figure 7. 2023 dissolved oxygen profiles from stations 2 & 3.

The anoxic boundary trends between 2017 and 2023 (**Figure 7**) show the maximum height in 2023 was higher than the prior 6 years. The maximum ascent depth of the anoxic boundary in 2023 was 4.8 meters, occurring in mid-September. This represents a considerable increase in the dissolved oxygen demand in the bottom lake water. For many years, 1998 to 2018, the anoxic boundary would barely ascend up to the 6-meter depth. In the years 2019 to 2022, the anoxic boundary was shallower than 6 meters on at least two occasions during the season. In 2023, the anoxic boundary was startingly shallower than any year prior, reaching the top layer of the thermocline.

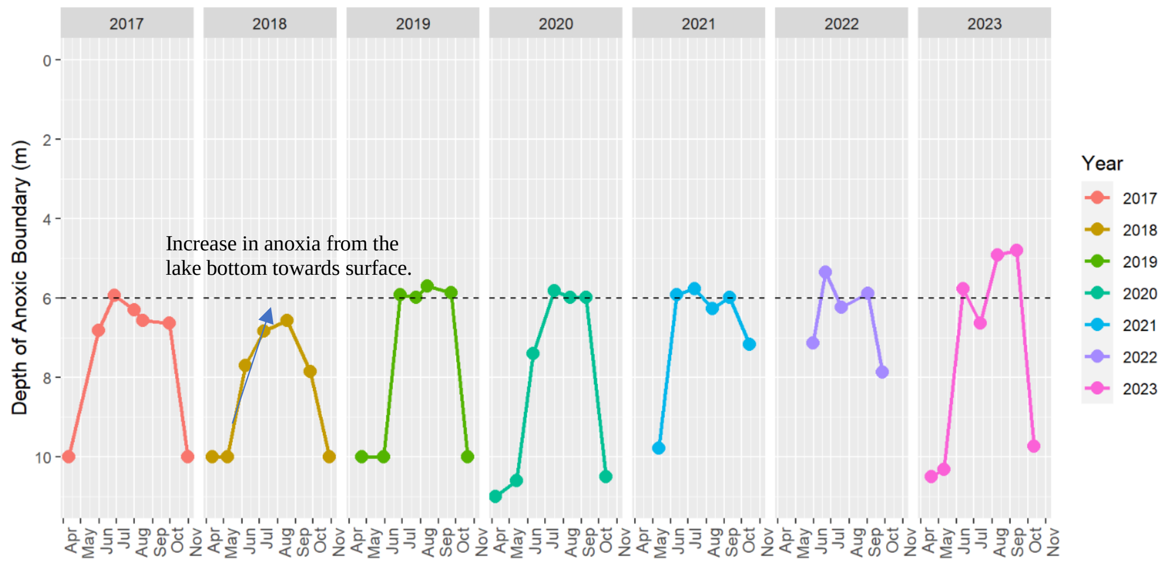


Figure 8. Seasonal anoxic boundary pattern at station 1 2017-2023.

Nutrients

Phosphorus

The total phosphorus (TP) concentration in Lake Oscawana should remain below 20 µg/L in the surface waters for the entire season to minimize the likelihood of harmful cyanobacteria (blue-green algae) blooms. TP in the surface waters remained low in April, May, and June. By July, TP concentrations across all three sampling stations had increased to nearly 30ppb. Concentrations remained moderate to high through October, with Station 2 exhibiting the highest value of 39 µg/L on October 12th (**Figure 9**). This is the third highest surface water TP concentration on record (**Figure 10**).

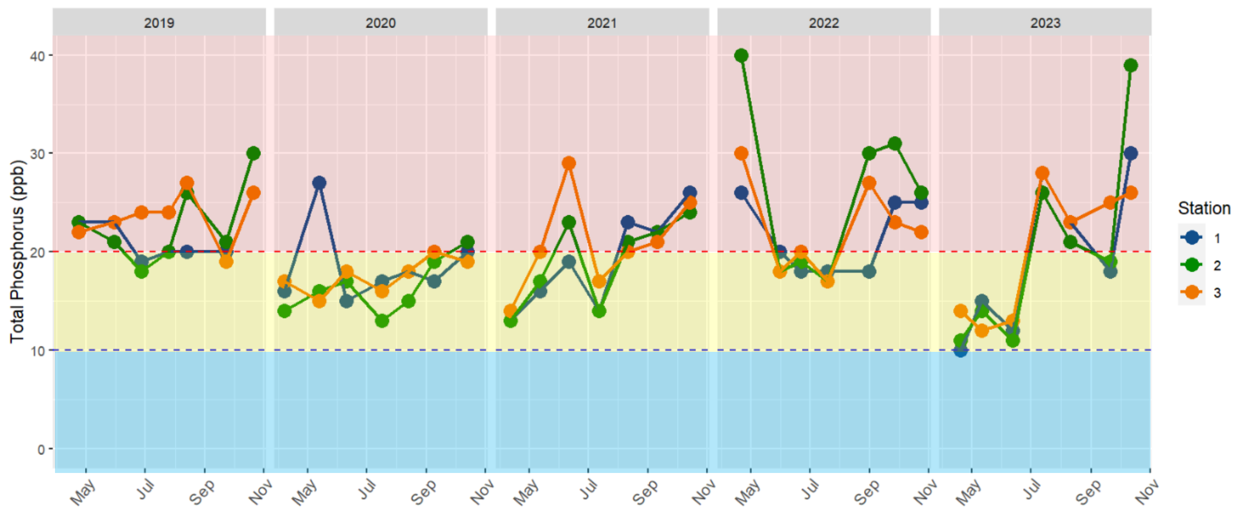


Figure 9. Surface (1m) total phosphorus 2019-2023 at all stations.

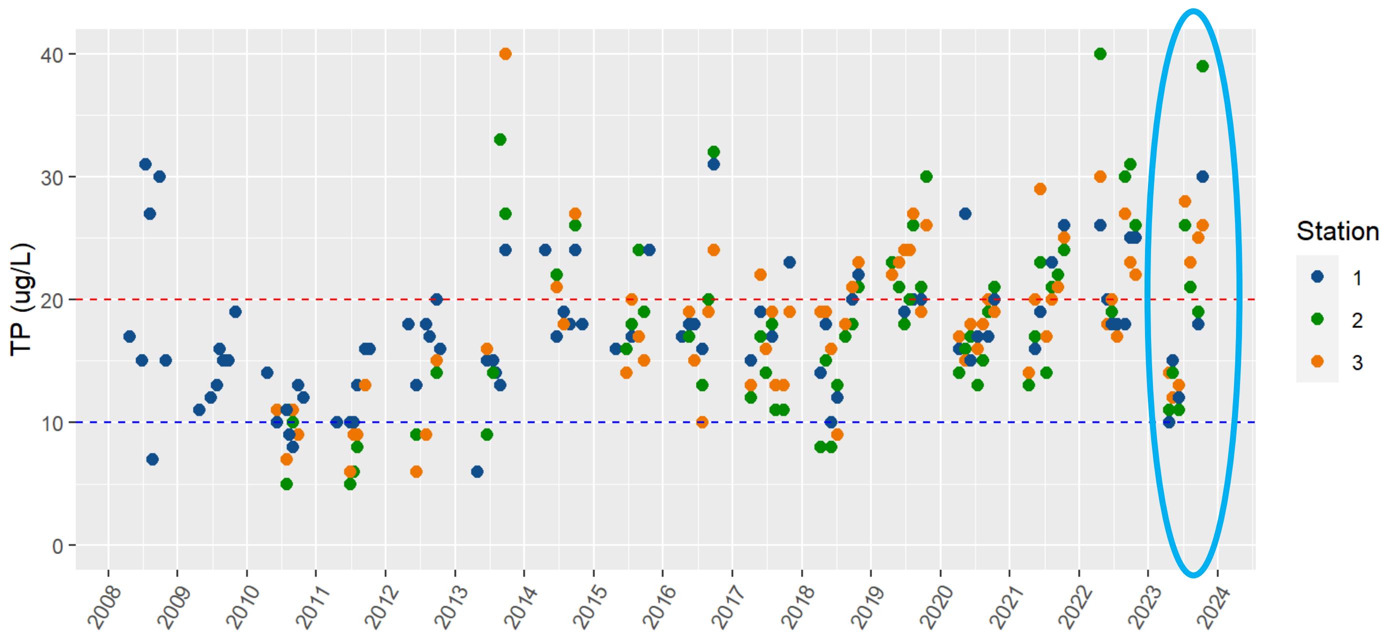


Figure 10. Long-term surface water total phosphorus concentrations (St.1, 2, & 3)

In **Figure 11** below, the dotted line shows the monthly average bottom-water phosphorus concentrations between 2016 and 2021 compared to 2022 and 2023 bottom water values.

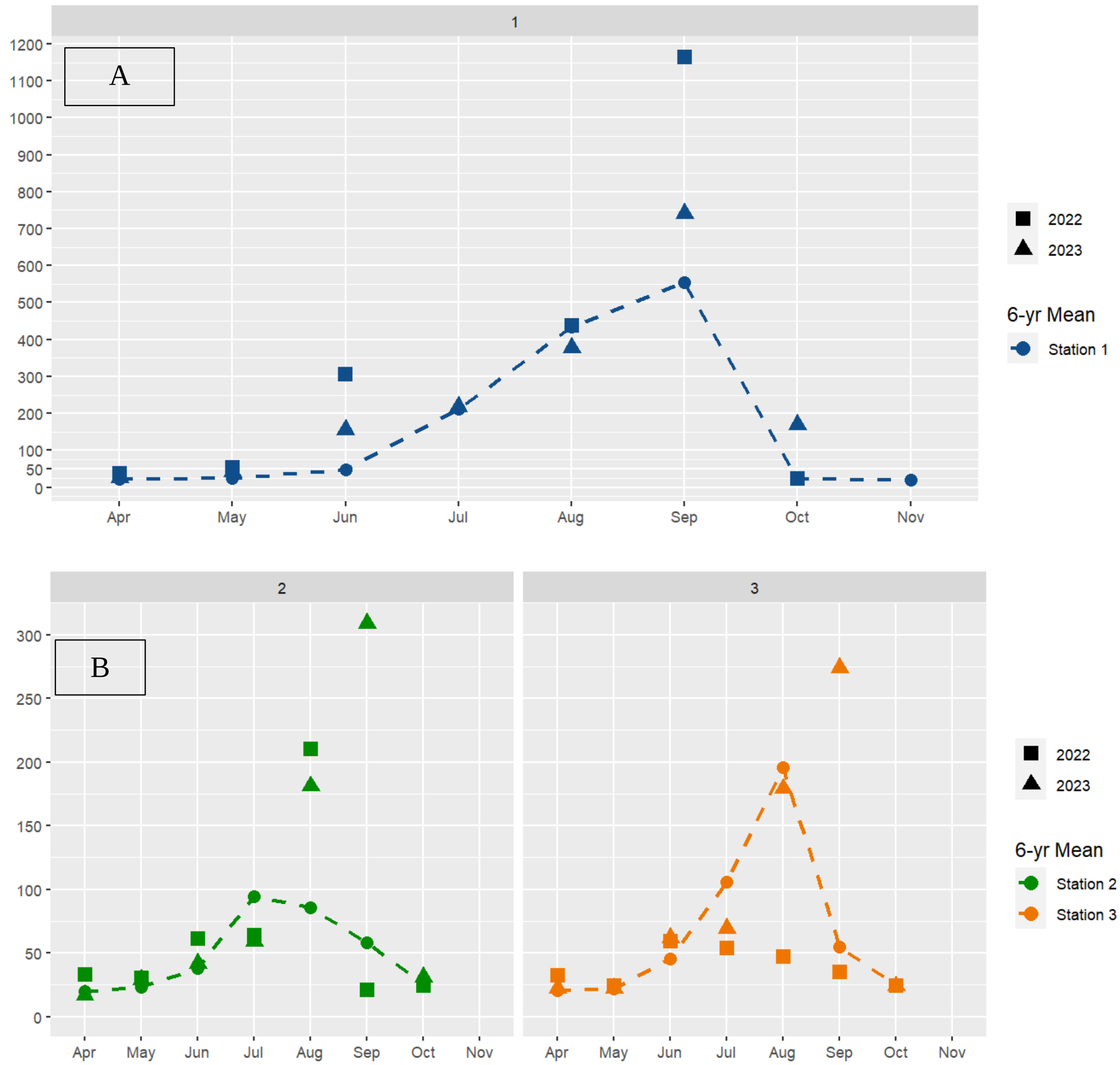


Figure 11. Station 1 (A) & station 2 & 3 (B) bottom total phosphorus (2016-2021 mean vs. 2022 & 2023)

Nitrogen

The average surface total nitrogen (TN) concentration in 2023 was similar between the three stations. Surface TN varied between 250 and 400 ppb from April through July but spiked at all three stations to a maximum seasonal concentration of 582 ppb in August (**Figure 12**). **Figure 13** shows the highest surface water concentration recorded in 2022 was 572 ppb in October.

The bottom water nutrients total phosphorus, total nitrogen, and ammonia nitrogen are compared in **Figure 14.** The total nitrogen can be seen to consist mostly of ammonia. Anoxic conditions in the hypolimnion allow for the release of nutrients such as ammonia from the sediment into overlying water. In September, the bottom TN level reached a peak of 2,697 ppb, marking a moderate decrease from the peaks observed in 2021 (3785 ppb) and 2022 (3,744 ppb).

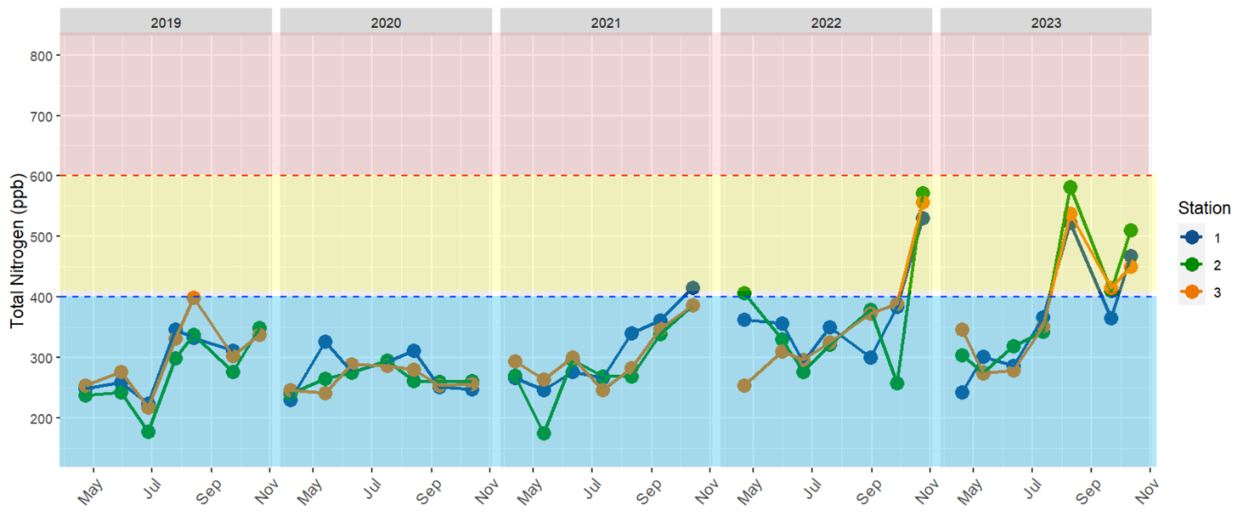


Figure 12. Surface total nitrogen 2019-2023 at all stations.

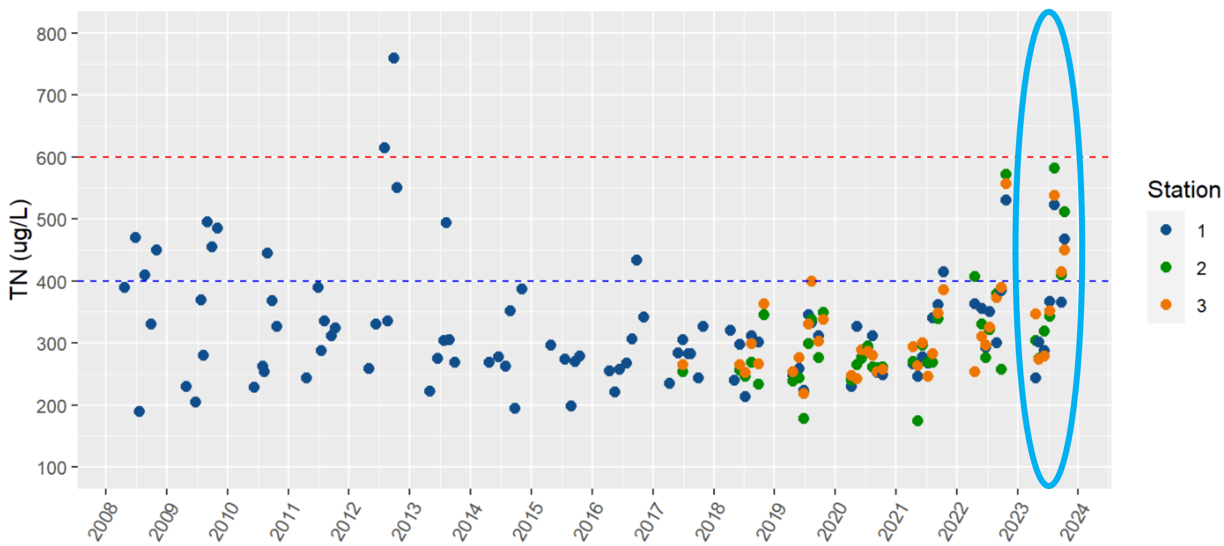


Figure 13. Long-term surface water total nitrogen at all stations.

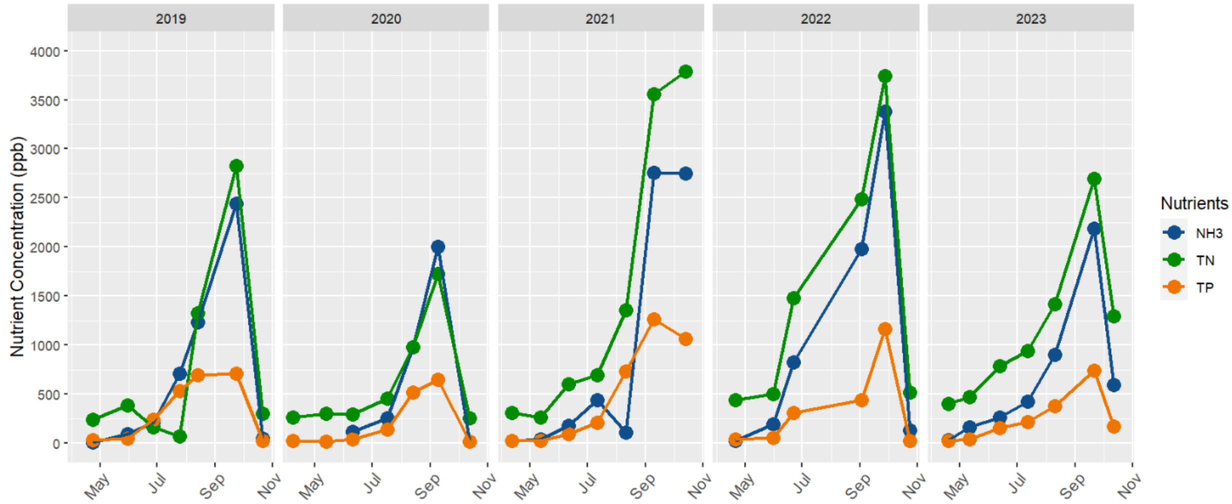


Figure 14. Station 1: 2019-2023 bottom-water (~9-10m) nutrients: ammonia nitrogen (NH_3), total nitrogen (TN), & total phosphorus (TP).

Inlet Nutrients & Bacteria

The 2022 and 2023 seasonal inlet nutrient concentrations are displayed for TP in **Table 1** and TN in **Table 2**. All inlets except for Upstream Inlet 4 had elevated levels of phosphorus (20 ppb) at least once in 2023. Inlets 4 and 7 consistently had excessively high TP concentrations.

Nitrogen concentrations of lower than about 200 ppb are acceptable for lake inlet water; higher values indicate loading of either particulate organic nitrogen, nitrate, or possible ammonia. In 2023, the average TN concentrations at inlet 7 were higher compared to those in 2022.

In **Table 1** and **Table 2**, blank cells indicate that no sample was collected.

*Table 1. Inlet **total phosphorus (TP)** concentrations (ppb) in 2023 (compared to 2022).*

Date	Weather	Inlet 1	Inlet 2	Inlet 3	Inlet 4	Upstream Inlet 4	Inlet 5	Inlet 6	Inlet 7
4/19/23	Baseflow	10	8	10	36	14	8		26
5/11/23	Baseflow	12	21	23	41		11		25
6/12/23	Baseflow	10	18		84				31
9/21/23	Baseflow	21	39	67	105		28		367
10/12/23	Baseflow		24	56	56			29	93
4/21/22	Baseflow			30	39	3214		NA	880
5/31/22	Baseflow	12	26	73	50	116	16		37
6/22/22	Baseflow			33	46	272			31
7/19/22	Baseflow								
10/24/22	Baseflow	11	39						65

*Table 2. Inlets **total nitrogen (TN)** concentrations (ppb) in 2023 (compared to 2022)*

Date	**Weather**	**Inlet 1**	**Inlet 2**	**Inlet 3**	**Inlet 4**	**Upstream Inlet 4**	**Inlet 5**	**Inlet 6**	**Inlet 7**
4/19/23	Baseflow	500	226	657	2823	2940	123		877
5/11/23	Baseflow	308	214	625	3180		108		1060
6/12/23	Baseflow	359	367		1331				449
9/21/23	Baseflow	515	330	715	1385		243		1011
10/12/23	Baseflow			611	1694			55	689
4/21/22	Baseflow			538	2998	100			22
5/31/22	Baseflow	262	285	855	2137	1911	138		501
6/22/22	Baseflow			767	1868	3302			533
7/19/22	Baseflow								
10/24/22	Baseflow	475	149						207

In addition to the nutrient sampling, *Escherichia coli* (*E. coli*) bacteria testing was conducted at the inlets. Samples were collected in-situ by NEAR staff in sterile bottles (provided by the lab) and were delivered to EnviroTest Laboratories, Inc. All *E. coli* bacteria test results are displayed in (**Table 3**) below. *E. coli* counts in 2023 were generally much lower than 2022 counts (**Table 4**). The highest count in 2023, 130 cfu/100mL was observed at inlet 4 on June 13th. The highest count in 2022, 87,000 cfu/100mL was observed at inlet 4 upper on April 21st. In 2023, inlet 4 upper was sampled once and the results were below the detection limit (1 cfu/100mL).

Photo 1. Sampling Location Upstream of Inlet 4

Map 1. Sampling Location Upstream of Inlet 4

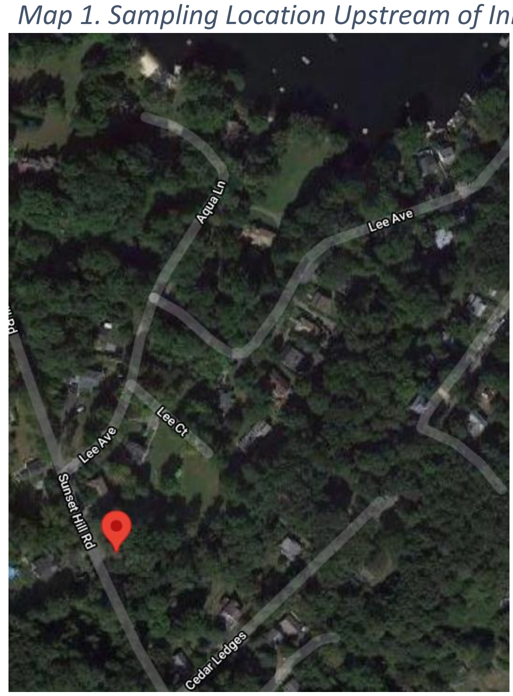


Table 3. All 2023 E. coli samples (colony forming units/100mL)

All baseflow samples	Inlet 3 (41.395986, -73.842008)	Inlet 4 (41.38173, -73.8564)	Inlet 4 Upstream (41.389485, -73.840989)	Inlet 7 (41.38962, -73.84326)
4/19/23	16	29	ND	6.3
5/11/23	15	18	NS	54
6/12/23	NS	130	NS	27

ND = Not detected
NS = Not sampled

Table 4. All 2022 E. coli samples (colony forming units/100mL).

All baseflow samples	Inlet 3 (41.395986, -73.842008)	Inlet 4 (41.38173, -73.8564)	Inlet 4 Upstream (41.389485, -73.840989)	Inlet 7 (41.38962, -73.84326)
4/21/22	10	20	87,000	20
5/31/22	52	8,700	74	86
6/22/22	95	240	3,300	200
7/19/22	270	88	1,700	440
10/24/22	NS	NS	NS	NS

Zooplankton

The most abundant group of zooplankton were rotifers, whose population was very high from April to June and again in October (**Figure 15**).

Calanoids were present in large numbers in May, with high numbers of small-bodied forms, <0.4mm (**Figure 16**).

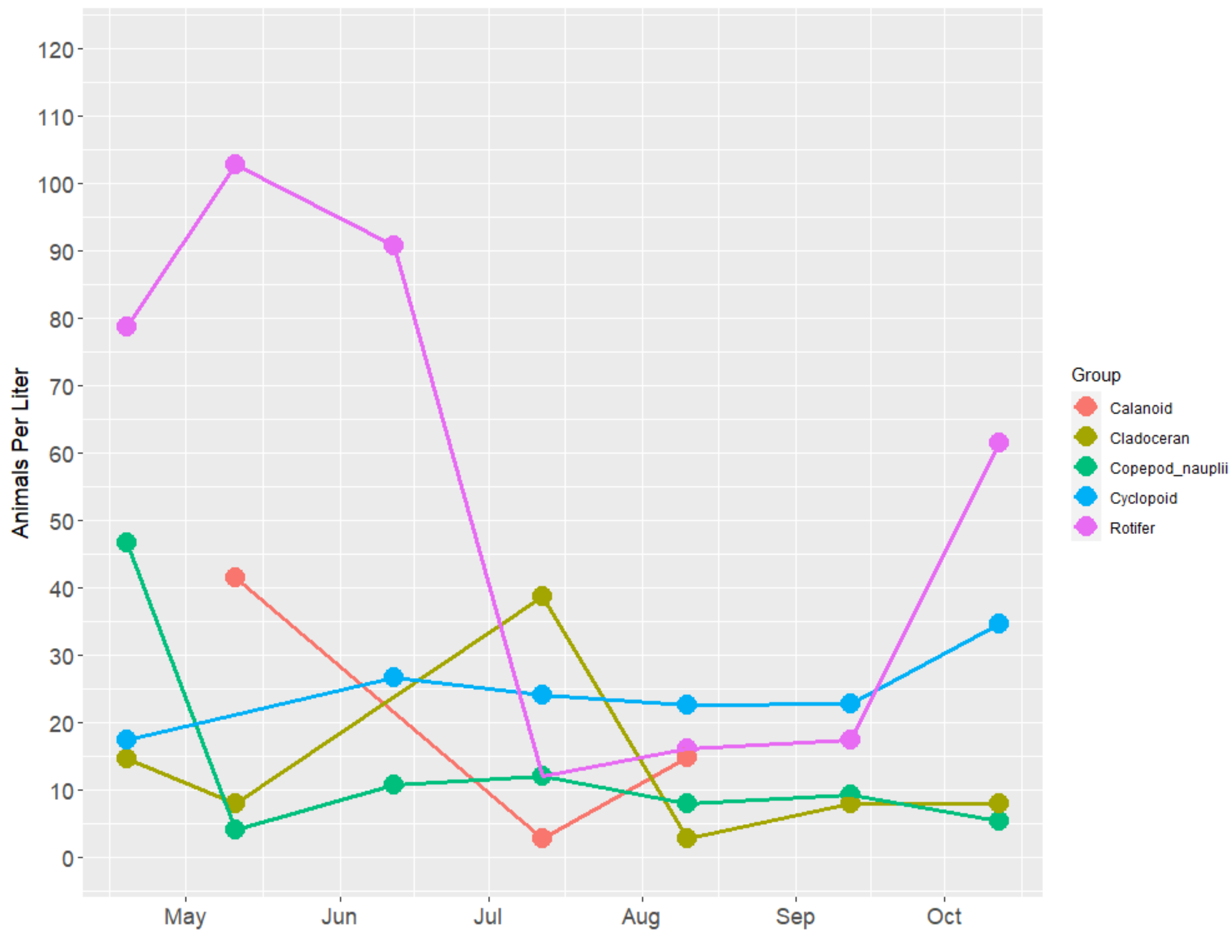


Figure 15. Station 1 zooplankton groups in 2023.

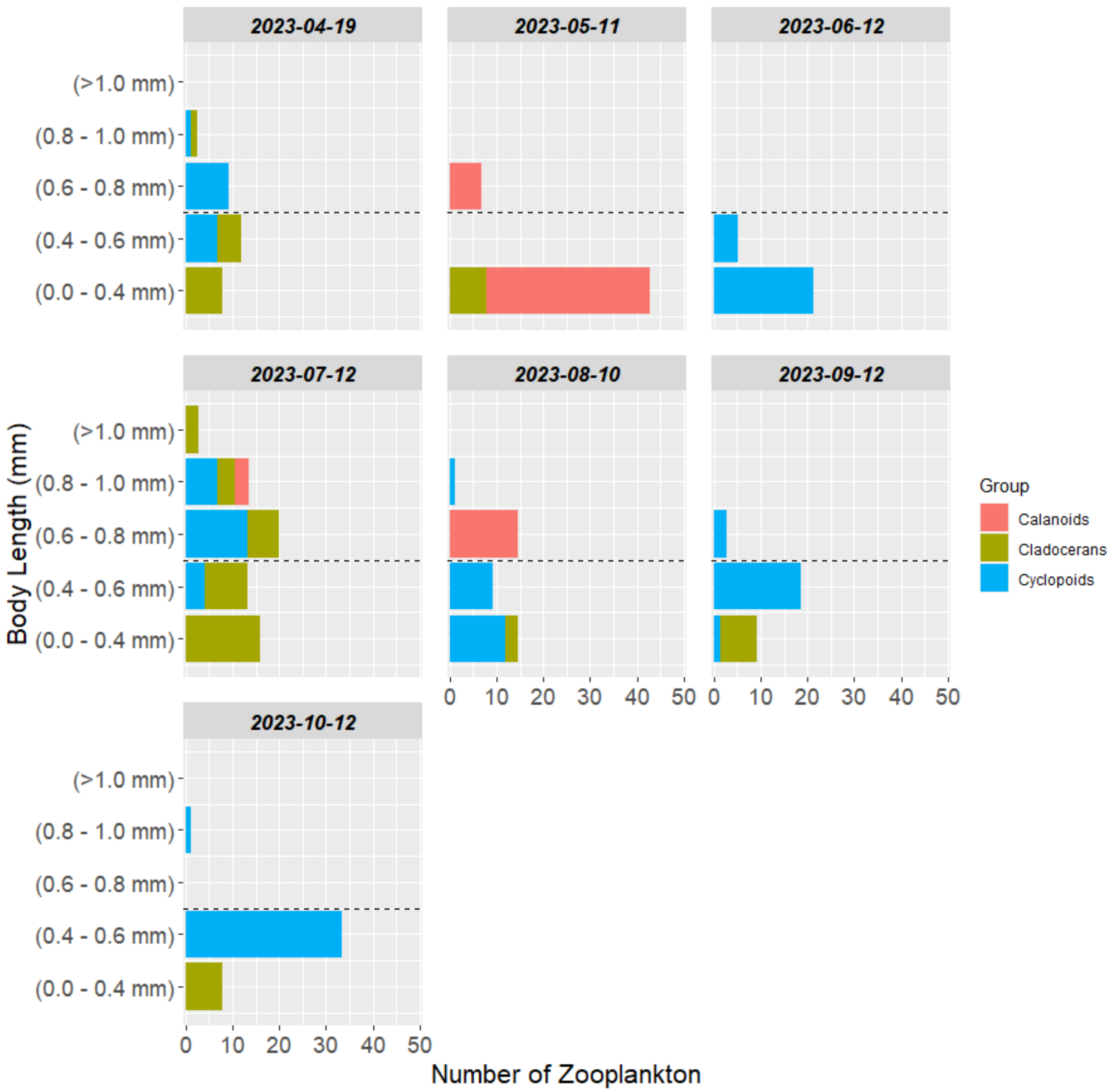


Figure 16. Zooplankton body length by group at station 1 in 2023.

Phytoplankton

Total phytoplankton counts (cells/mL) by group for 2023, 2022, 2021, and 2020 are displayed in **Table 5**. The lake was once again dominated by diatoms and cyanobacteria in 2023. In September, *Planktolyngbya*, a known toxin producer, dominated at 134,694 cells/mL (**Table 6**).

The World Health Organization (WHO) and the Environmental Protection Agency (EPA) provide guidance on the probability of health effects from cyanobacteria exposure based on cell counts (**Figure 16**). The August count puts the lake in the Moderate Risk category, while the September count falls within the category of High Risk.

High cyanobacteria cell counts from August to October coincided with poor water clarity readings.

Table 5. A) Phytoplankton in cells/mL by group in 2023, B) compared to 2022, C) 2021 and D) 2020.

A) 2023	**4/19/2023**	**5/11/2023**	**6/12/2023**	**7/12/2023**	**8/10/2023**	**9/12/2023**	**10/12/2023**
Cyanobacteria	0	0	2,886	5,248	37,026	159,389	19,766
Green algae	0	0	160	466	292	0	0
Diatoms	4,548	2,828	467	991	1,866	350	2,362
Chrysophytes/Golden	0	0	4,374	1,020	0	0	0
Dinoflagellates	0	0	15	0	0	0	0
Euglenophytes	0	0	0	29	0	0	0

B) 2022	**4/21/2022**	**5/31/2022**	**6/22/2022**	**7/19/2022**	**9/2/2022**	**9/27/2022**	**10/24/2022**
Cyanobacteria	33,820	350	875	6,706	30,321	34,054	27,988
Green algae	0	0	0	2,274	0	0	0
Diatoms	9,504	9,330	19,825	2,128	7,697	0	321
Chrysophytes/Golden	292	0	0	0	0	0	0
Dinoflagellates	0	0	0	0	0	0	0
Euglenophytes	0	0	0	0	0	0	0

C) 2021	**4/12/2021**	**4/28/2021**	**5/12/2021**	**6/11/2021**	**7/12/2021**	**8/11/2021**	**9/10/2021**	**10/14/2021**
Cyanobacteria	4,927	6,531	466	379	3,557	10,262	56,647	77,114
Green algae	0	933	146	321	175	0	87	0
Diatoms	4,344	379	4,315	1,720	583	525	525	2,478
Chrysophytes	641	3,061	233	321	0	0	0	0
Dinoflagellates	0	0	0	29	0	0	0	0
Euglenophytes	0	0	0	0	0	0	0	0

D) 2020	**4/7/20**	**5/13/20**	**6/10/20**	**7/17/20**	**8/13/20**	**9/9/20**	**10/13/20**
Cyanobacteria	8,455	612	0	6,560	2,187	136,565	40,408
Green algae	175	1,224	1,691	1,341	437	4,932	1,224
Diatoms	5,248	6,472	1,895	408	29	2,891	7,755
Chrysophytes	437	204	437	233	15	4,252	204
Dinoflagellates	0	0	0	58	0	0	0
Euglenophytes	0	0	0	0	0	340	0

Table 6. A) Cyanobacteria genus counts monthly in 2023, B) 2022, C) 2021, D) 2020.

A) 2023	**4/19/2023**	**5/11/2023**	**6/12/2023**	**7/12/2023**	**8/10/2023**	**9/12/2023**	**10/12/2023**
Dolichospermum	0	0	0	4,082	19,825	12,741	0
Chrysosporum	0	0	554	1,166	17,201	0	15,160
Aphanothece	0	0	0	0	0	875	0
Planktothrix	0	0	2,332	0	0	0	4,606
Microcystis	0	0	0	0	0	11,079	0
Planktolyngbya	0	0	0	0	0	134,694	0

Chroococcus	0	0	0	0	0	0	0
Totals	**0**	**0**	**2,886**	**5,248**	**37,026**	**159,389**	**19,766**

B) 2022	**4/21/2022**	**5/31/2022**	**6/22/2022**	**7/19/2022**	**9/2/2022**	**9/27/2022**	**10/24/2022**
Dolichospermum	0	350	875	0	875	3,499	2,332
Chrysosporum	0	0	0	0	4,956	11,079	22,741
Planktothrix	23,324	0	0	0	4,956	3,499	2,332
Planktolyngbya	10,496	0	0	6,706	19,534	13,994	583
Chroococcus	0	0	0	0	0	0	0
Totals	**33,820**	**350**	**875**	**6,706**	**30,321**	**32,071**	**27,988**

C) 2021	**4/12/2021**	**4/28/2021**	**5/12/2021**	**6/11/2021**	**7/12/2021**	**8/11/2021**	**9/10/2021**	**10/14/2021**
Dolichospermum	0	117	0	0	1,953	1,749	1,020	0
Chrysosporum	262	3,499	350	0	1,458	0	36,968	43,294
Planktothrix	4,665	0	0	0	0	0	0	9,329
Planktolyngbya	0	2,915	0	0	0	7,464	18,659	24,490
Chroococcus	0	0	117	379	146	1,050	0	0
Totals	**4,927**	**6,531**	**466**	**379**	**3,557**	**10,262**	**56,647**	**77,114**

D) 2020	**4/7/20**	**5/13/20**	**7/17/20**	**8/13/20**	**9/9/20**	**10/13/20**
Dolichospermum	0	0	6,414	875	3,061	0
Chrysosporum	3,499	612	87	0	0	5,714
Planktothrix	3,790	0	0	0	133,503	22,449
Planktolyngbya	1,166	0	0	1,312	0	12,245
Chroococcus	0	0	58	0	0	0
Totals	**8,455**	**612**	**6,501**	**2,187**	**136,564**	**40,408**

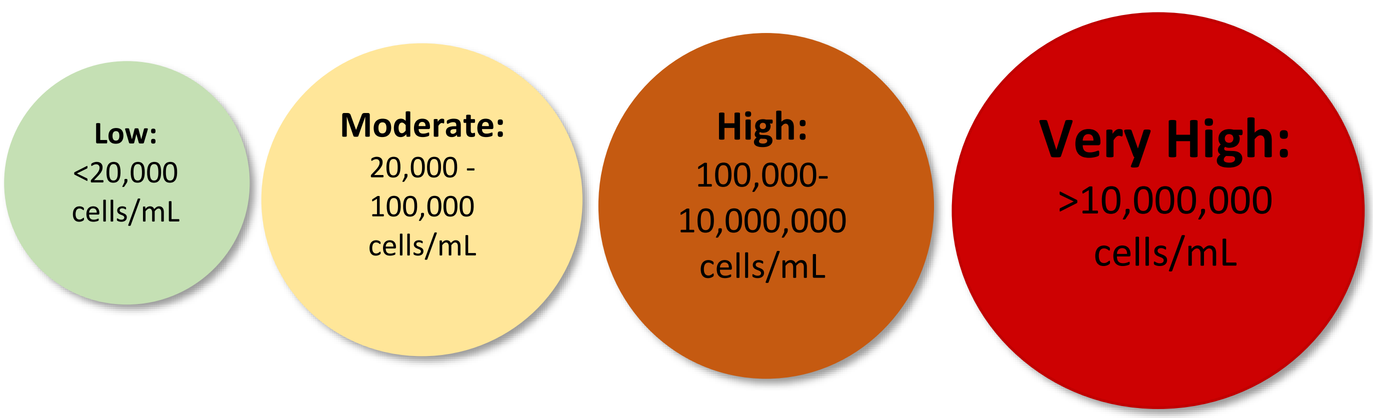


Figure 17. World Health Organization (WHO) probability of health effects based on the number of cyanobacteria present in a water sample.

Aquatic Plant Management

Lake Oscawana was surveyed for aquatic plants over two days, on July 12th and July 13th, 2023. The following maps provide species density data at all observation points throughout the littoral zone.

Lyngbya sp., a benthic cyanobacteria genus, was dominant during the July comprehensive survey, documented at 48% of the survey waypoints (**Table 7**). There has been a steady increase in *Lyngbya sp.* in the lake since 2019, especially in densely populated areas along the eastern and northern shorelines (**Map 1**). In 2023, *Lyngbya sp.* was documented more along the northwestern shoreline, which is rocky and forested. The increase in *Lyngbya sp.* is concerning and may be due to a combination of decreased macrophyte growth and increased nutrient input into the lake.

White Water Lily (*Nymphaea odorata*) was the most dominant aquatic plant species documented in 2023 (**Map 2**). The species was found at 29% frequency and an average density of 27%. Grass carp do not prefer Lilies, so this species is managed primarily via harvesting efforts, though the population has remained steady since 2019.

Coontail (*Ceratophyllum demersum*) was less abundant in 2023 than in 2022 but was still present at 26% frequency with an average density of 11% (**Map 3**).

The abundance of Tapegrass (*Vallisneria americana*) decreased approximately 40% compared to 2022 (**Map 8**). Tapegrass is decreasing in density, but is still abundant in the lake.

Eurasian Watermilfoil (*Myriophyllum spicatum*) was found less frequently in 2023 than in 2022 (**Map 4**). A significant decline in the abundance and density of Eurasian Watermilfoil was initially noted in 2022.

Green Filamentous Algae has fluctuated annually since 2019, as shown in **Map 6**. Filamentous Algae has historically not been dominant in the lake. In 2023, Filamentous Algae was documented at 5% frequency and an average density of 7%.

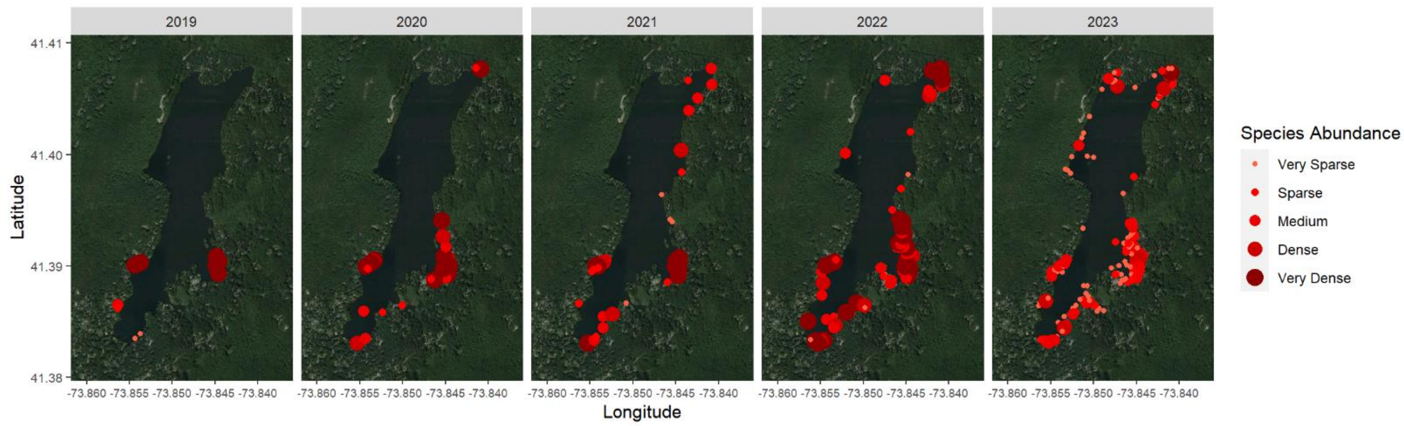
The declining frequency of Large-Leaf Pondweed (*Potamogeton amplifolius*) recorded in 2021 and 2022 continued in 2023 (49% in 2021, 35% in 2022, 5% in 2023) (**Map 7**).

Robbin's Pondweed (*Potamogeton robbinsii*) was not located in the lake in 2023. The frequency and density of Robbin's Pondweed was observed to be shrinking over the last few years (**Map 8**).

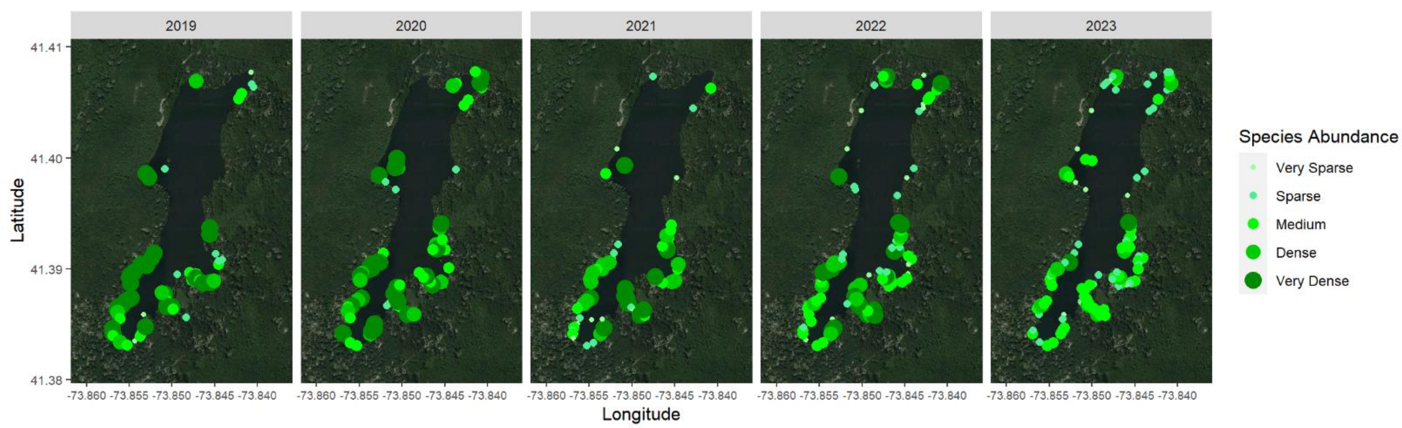
Table 7. Aquatic plant species present during July 2023 survey.

Scientific Name	Common Name	Frequency %	Avg. Density %
Lyngbya sp.	Cyanobacteria Mats	48	15
Nymphaea odorata	White Water Lily	39	27
Ceratophyllum demersum	Coontail	26	11
Vallisneria americana	Eel Grass / Tapegrass	16	18
Myriophyllum spicatum	Eurasian Watermilfoil	6	5
Spirogyra sp.	Filamentous Green Algae	5	7
Pontederia cordata	Pickerelweed	5	10
Potamogeton amplifolius	Large-Leaf Pondweed	5	6
Nuphar variegata	Yellow Water Lily	2	7
Brasenia schreberi	Watershield	2	9

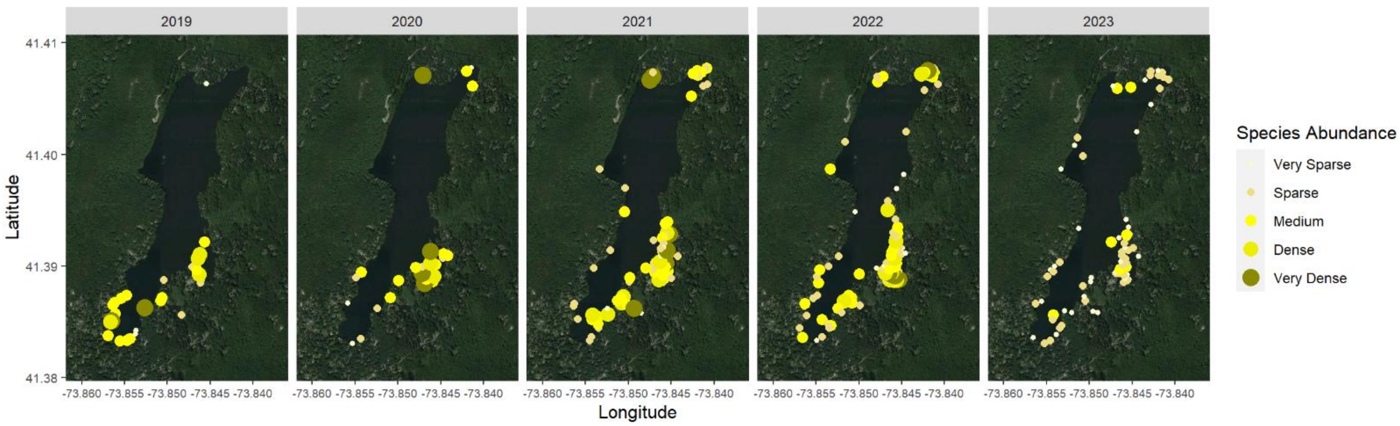
Phragmites sp.	Common Reed	2	15
Typha latifolia	Cattail	1	13
Lemna minor	Common Duckweed	1	7
Chara sp.	Muskgrass	<1	5
Najas flexilis	Common Naiad	<1	5
Potamogeton pusillus	Small Pondweed	<1	5



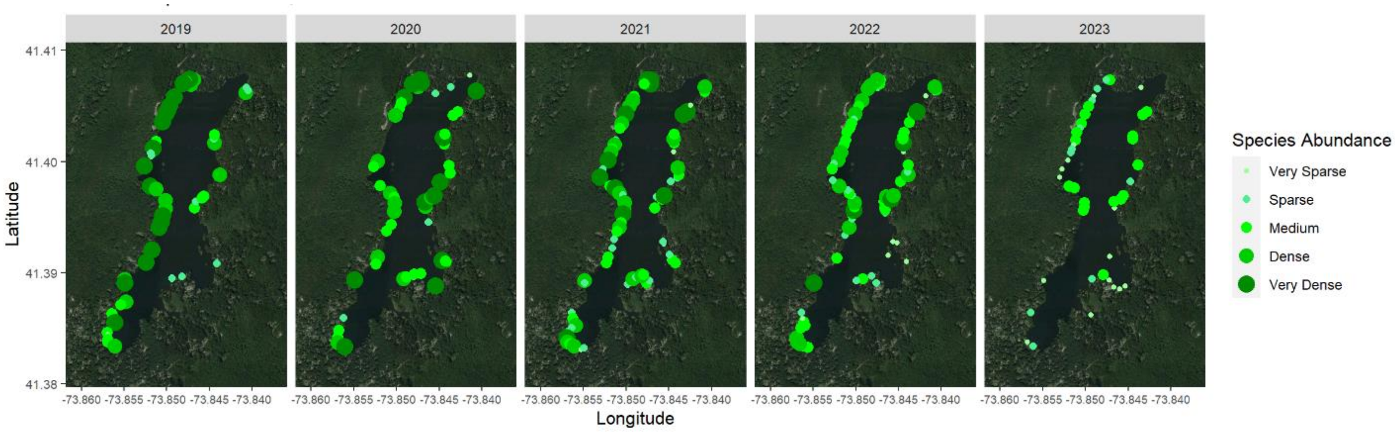
Map 1. Cyanobacteria Mat (Lyngbya sp.) 2019-2023 comparison.



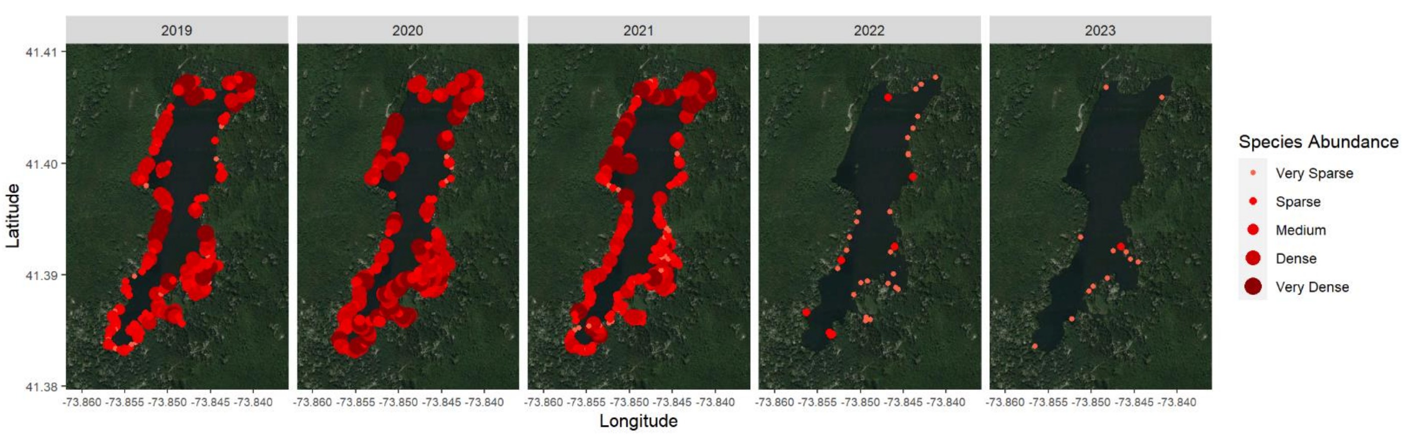
Map 2. White Water Lily (Nymphaea odorata) 2019-2023 comparison.



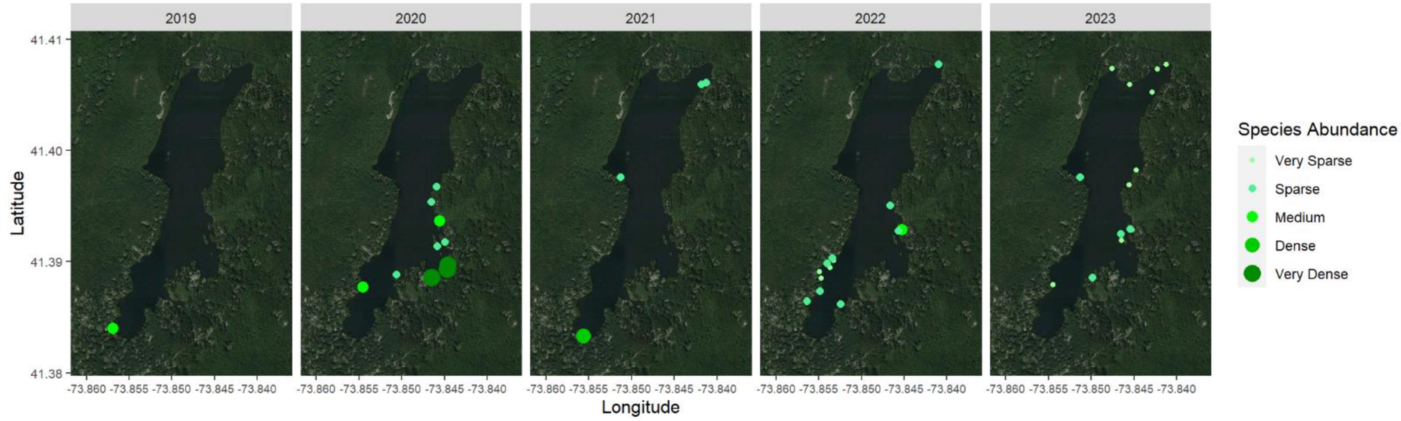
Map 3. Coontail (Ceratophyllum demersum) 2019-2023 comparison.



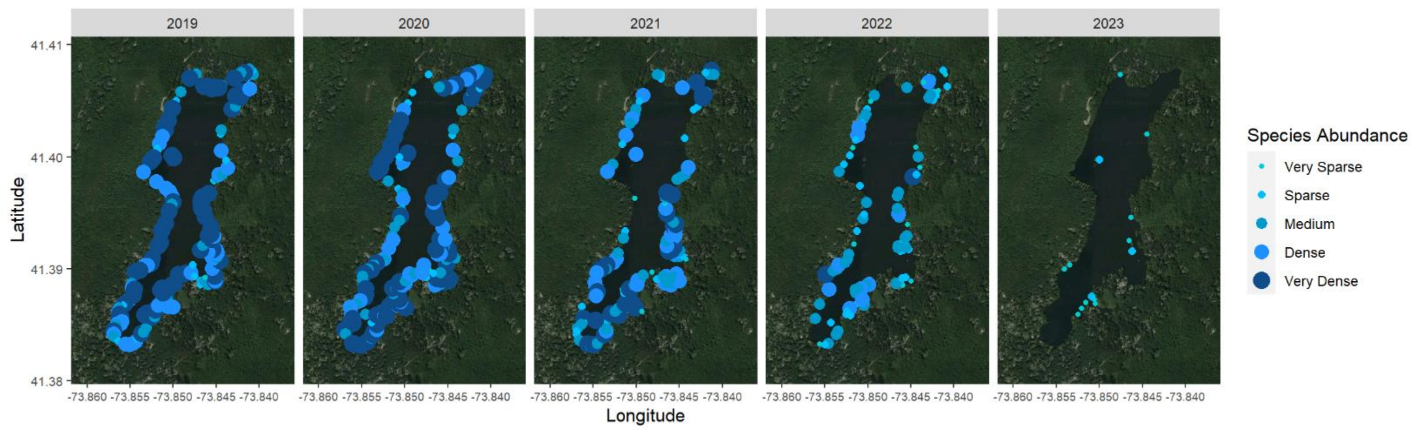
Map 4. Tapegrass (Vallisneria americana) 2019-2023 comparison.



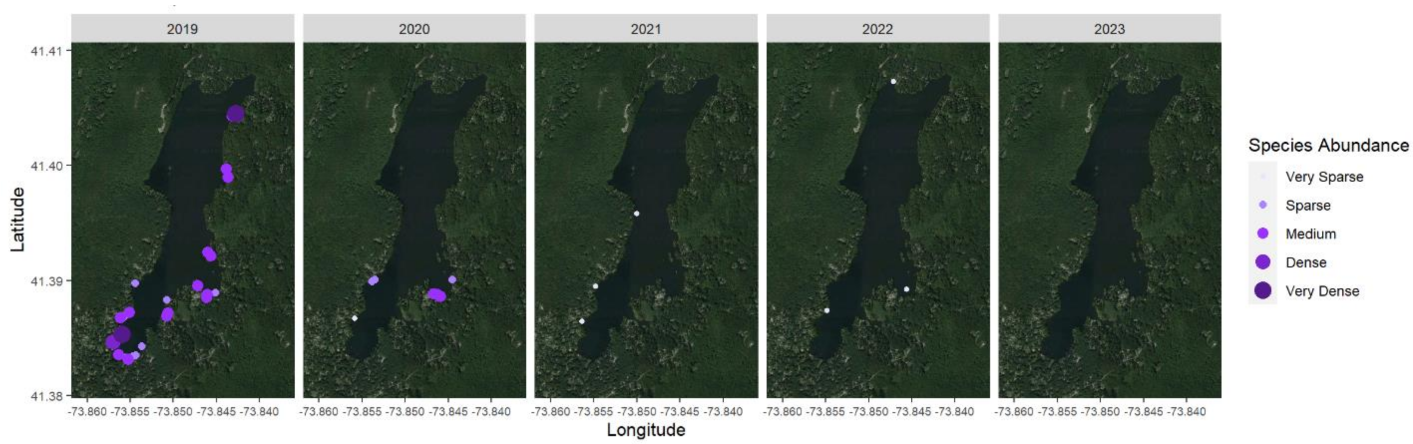
Map 5. Invasive Eurasian Milfoil (Myriophyllum spicatum) 2019-2023 comparison.



Map 6. Filamentous Algae 2019-2023 comparison.



Map 7. Large-Leaf Pondweed (Potamogeton amplifolius) 2019-2023 comparison.



Map 8. Robbins' Pondweed (Potamogeton robbinsii) 2019-2023 comparison.

Conclusions & Recommendations

The 2023 season had the worst water quality of any of the years NEAR has monitored the lake from 1998 to 2023. The Secchi disk depth declined to <2 meters by August 1st and remained around 2 meters for the remainder of the season. Dissolved oxygen loss, as shown by the anoxic boundary, was the most severe on record, with anoxic water recorded at 4.8m from the surface, the highest point ever recorded at the lake. It is important to understand that there is a significant difference between a 4.8m anoxic boundary and a 6m anoxic boundary because this is a full 1.2 meters more anoxic water at a depth in the lake where the volume of water in the 6-meter layer is many times greater that the volume of water in deeper depth layers.

Total phosphorus was moderately good early in the season when TP was near 10ppb, but the concentration climbed rapidly to well above 20ppb in July and remained above 20ppb for the rest of the season, with highest values near 40ppb in October. These erratically high values follow 2022, when late season phosphorus was also very high. Total nitrogen, which has historically been less than 400ppb and often averaging 300ppb, increased to nearly 600ppbin August and remined above 500ppb for the remainder of the season. Bottom water total nitrogen was very high in late summer and early fall in a similar fashion to the last two years. These changes are consistent with grass carp altering the environment by recycling the submersed aquatic community into available phosphorus, nitrogen, and increasing the biological oxygen demand, while also eliminating the macrophytes that used to sequester nutrients in the groundwater as biomass, keeping those nutrients out of the water column until much later in the season.

The aquatic plant abundance has dwindled, with most species now occurring at less than 10% occurrence. Remaining abundant species in 2023, White Water Lily, Coontail, and Tapegrass, will likely decrease in abundance during 2024 and 2025, with other species that are now present at less than 10% frequency probably disappearing.

The increasing abundance of Cyanobacteria mats is worrisome and needs to be monitored closely. Benthic/floating cyanobacteria mats and Filamentous Green Algae will be a constant problem unless septic systems are upgraded.

- Water temperature data loggers were deployed in late spring of 2023. These daily temperature readings will give a more precise seasonal timing of anoxia and potentially provide data that explains why any surface cyanobacteria accumulations may form. Ideally, these loggers should be deployed just after ice-out and removed before ice-on. If the lake does not freeze during the winter, the loggers may be able to remain in the lake.

- Lake monitoring should begin in March and continue into November to track continuing increases of cyanobacteria and the oxygenation of bottom water. We suggest increasing the frequency of lake monitoring to once every two weeks and perhaps every week during the critical months of August to October. One of the goals of the first and last sampling is to catch the lake when there is no stratification, with similar temperatures from top to bottom. Increasingly in the region, we have noticed this occurs in March now instead of April and is occurring later in the season, after October.

Appendix

Raw Water Quality Data 2023

Appendix Table 1. 2023 raw nutrient data

Blank rows indicate samples were not run for that analysis.

Date	Station	Secchi (m)	Depth (m)	TP (ppb)	NH_3 (ppb)	TN (ppb)
4/19/2023	1	2.65	1	10		243
4/19/2023	1		4	12		333
4/19/2023	1		6	15		337
4/19/2023	1		10	26	28	405
4/19/2023	2	2.8	1	11		304
4/19/2023	2		7.5	17		334
4/19/2023	3	2.75	1	14		347
4/19/2023	3		7	22		361
5/11/2023	1	2.95	1	15		302
5/11/2023	1		4	17		319
5/11/2023	1		6	17		296
5/11/2023	1		10.5	42	159	469
5/11/2023	2	3.025	1	14		275
5/11/2023	2		8	29		354
5/11/2023	3	3.125	1	12		274
5/11/2023	3		7.3	22		379
6/12/2023	1	3.7	1	12		287
6/12/2023	1		5	12		263
6/12/2023	1		10	155	265	783
6/12/2023	2	3.65	1	11		319
6/12/2023	2		7.9	42		354
6/12/2023	3	3.75	1	13		279
6/12/2023	3		7	62		461
7/12/2023	1	2.325	1	28		367
7/12/2023	1		5	29		342
7/12/2023	1		10	218	425	941
7/12/2023	2	2.4	1	26		343
7/12/2023	2		8	59		469
7/12/2023	3	2.4	1	28		352
7/12/2023	3		7.7	69		433
8/10/2023	1	1.3	1	23		523
8/10/2023	1		5	18		368

8/10/2023	1		9	377	902	1416
8/10/2023	2	1.3	1	21		582
8/10/2023	2		7.5	181		861
8/10/2023	3	1.3	1	23		538
8/10/2023	3		7	179		861
9/21/2023	1	2.35	1	18		365
9/21/2023	1		5	27		375
9/21/2023	1		10.2	740	2189	2697
9/21/2023	2	2.35	1	19		410
9/21/2023	2		7.5	309		1623
9/21/2023	3	2.275	1	25		415
9/21/2023	3		7	274		1450
10/12/2023	1	2.2	1	30		468
10/12/2023	1		5	25		
10/12/2023	1		10.8	169	594	1297
10/12/2023	2	1.675	1	39		511
10/12/2023	2		8	31		
10/12/2023	3	2.1	1	26		450
10/12/2023	3		7.4	24		461

Appendix Table 2. 2023 raw profile data

Date	**Station**	**Depth (m)**	**Temp (ºC)**	**D.O. mg/L**	**% Sat**
4/19/2023	1	0	13.0	10.09	96.7
4/19/2023	1	1	13.2	10	96.2
4/19/2023	1	2	13.3	9.96	96
4/19/2023	1	3	13.3	9.75	94
4/19/2023	1	4	11.8	10.51	97.9
4/19/2023	1	5	9.5	7.94	70.1
4/19/2023	1	6	9.1	7.38	64.6
4/19/2023	1	7	8.9	6.97	60.7
4/19/2023	1	8	8.7	6.46	56
4/19/2023	1	9	8.6	6	51.9
4/19/2023	1	10	8.5	5.73	49.4
4/19/2023	1	10.5	8.5	5.58	48.1
4/19/2023	2	0	13.2	10.28	98.9
4/19/2023	2	1	13.4	10.21	98.6
4/19/2023	2	2	13.6	10.1	98
4/19/2023	2	3	13.5	10.14	98.1
4/19/2023	2	4	11.4	10.73	98.6

4/19/2023	2	5	10.2	9.62	86.2
4/19/2023	2	6	9.2	7.93	69.5
4/19/2023	2	7	8.8	6.75	58.6
4/19/2023	2	8	8.4	5.79	49.8
4/19/2023	3	0	12.7	10.5	99.7
4/19/2023	3	1	13.0	10.37	99.1
4/19/2023	3	2	13.0	10.09	96.5
4/19/2023	3	3	12.6	10.55	101.1
4/19/2023	3	4	11.2	11	101.1
4/19/2023	3	5	9.9	9.2	81.9
4/19/2023	3	6	9.2	7.68	67.4
4/19/2023	3	7	8.8	6.47	56.1
4/19/2023	3	7.7	8.7	6.31	54.5
5/11/2023	1	0	18.2	9.74	104.2
5/11/2023	1	1	17.5	9.93	104.9
5/11/2023	1	2	16.8	10.16	105.8
5/11/2023	1	3	16.4	10.14	104.4
5/11/2023	1	4	15.0	7.3	73
5/11/2023	1	5	13.3	7.71	74.4
5/11/2023	1	6	11.1	3.37	31
5/11/2023	1	7	10.6	2.54	23.1
5/11/2023	1	7.5	10.5	2.43	22
5/11/2023	1	8	10.1	1.96	17.5
5/11/2023	1	9	10.1	1.79	16.1
5/11/2023	1	10	9.9	1.35	12
5/11/2023	1	11	9.6	0.27	2.4
5/11/2023	2	0	18.5	9.88	106.8
5/11/2023	2	1	18.0	9.96	106.6
5/11/2023	2	2	17.4	9.89	104.6
5/11/2023	2	3	16.3	10.43	107.9
5/11/2023	2	4	14.7	9.94	99.4
5/11/2023	2	5	12.8	7.22	69.2
5/11/2023	2	6	11.5	4.64	43.2
5/11/2023	2	7	10.7	3.13	28.6
5/11/2023	2	8	10.1	1.5	13.6
5/11/2023	2	8.2	9.9	1.29	11.6
5/11/2023	3	0	19.6	9.66	107
5/11/2023	3	1	18.4	9.82	106.2
5/11/2023	3	2	17.5	10.02	106.3
5/11/2023	3	3	16.1	10.31	106.2
5/11/2023	3	4	14.5	9.71	96.6

5/11/2023	3	5	12.5	6.36	60.5
5/11/2023	3	6	10.9	2.39	21.9
5/11/2023	3	7	10.5	2.11	19.2
5/11/2023	3	7.6	10.2	1.86	16.8
6/12/2023	1	0	21.7	9.41	109.3
6/12/2023	1	1	21.6	9.36	108.4
6/12/2023	1	2	21.2	8.9	102.2
6/12/2023	1	3	20.8	8.75	99.9
6/12/2023	1	4	20.1	7.71	86.7
6/12/2023	1	5	16.9	2.55	26.9
6/12/2023	1	6	14.3	0.51	5.1
6/12/2023	1	7	13.0	0.26	2.5
6/12/2023	1	8	12.3	0.22	2.1
6/12/2023	1	9	11.9	0.21	2
6/12/2023	1	10	11.6	0.21	2
6/12/2023	1	10.2	11.2	0.2	1.9
6/12/2023	2	0	21.5	8.98	103.8
6/12/2023	2	1	21.5	9.03	104.4
6/12/2023	2	2	21.5	9	104.1
6/12/2023	2	3	20.8	8.81	100.6
6/12/2023	2	4	19.8	7.77	86.8
6/12/2023	2	5	18.2	4.84	52.4
6/12/2023	2	5.5	15.5	1.69	17.3
6/12/2023	2	6	14.0	0.67	6.6
6/12/2023	2	7	12.8	0.22	2.1
6/12/2023	2	8	12.1	0.18	1.7
6/12/2023	2	8.15	11.8	0.18	1.7
6/12/2023	3	0	21.5	8.98	103.8
6/12/2023	3	1	21.4	9.02	104.1
6/12/2023	3	2	21.3	8.95	103.3
6/12/2023	3	3	21.1	8.9	102.2
6/12/2023	3	4	20.4	8.56	96.9
6/12/2023	3	5	15.7	1.3	13.4
6/12/2023	3	5.5	14.9	0.86	8.7
6/12/2023	3	6	13.5	0.27	2.6
6/12/2023	3	7	12.6	0.2	1.9
6/12/2023	3	7.2	12.3	0.19	1.8
7/12/2023	1	0	28.0	9.07	118.2
7/12/2023	1	1	27.0	9.31	119.3
7/12/2023	1	2	26.3	9.28	117.3

7/12/2023	1	3	25.7	7.98	99.9
7/12/2023	1	4	24.2	5.4	65.7
7/12/2023	1	5	22.0	3.38	39.5
7/12/2023	1	6	20.5	2.08	23.6
7/12/2023	1	7	18.9	0.38	4.2
7/12/2023	1	8	16.5	0.2	2.1
7/12/2023	1	9	14.2	0.17	1.7
7/12/2023	1	10	13.0	0.24	2.3
7/12/2023	1	10.6	12.5	0.21	2
7/12/2023	2	0	27.8	9.19	119.8
7/12/2023	2	1	26.8	9.72	124.3
7/12/2023	2	2	26.2	9.45	119.6
7/12/2023	2	3	25.0	7.01	86.7
7/12/2023	2	4	23.8	6.1	73.8
7/12/2023	2	5	22.1	3.83	44.8
7/12/2023	2	5.5	20.3	2.28	25.8
7/12/2023	2	6	18.9	0.85	9.3
7/12/2023	2	7	16.2	0.23	2.4
7/12/2023	2	8	14.3	0.18	1.8
7/12/2023	2	8.5	13.4	0.17	1.7
7/12/2023	3	0	28.5	9.25	121.6
7/12/2023	3	1	27.3	9.37	120.6
7/12/2023	3	2	26.4	9.47	120
7/12/2023	3	3	25.5	7.74	96.5
7/12/2023	3	4	24.3	5.43	66.2
7/12/2023	3	5	21.7	2.79	32.3
7/12/2023	3	5.5	20.1	1.53	17.2
7/12/2023	3	6	18.9	0.39	4.3
7/12/2023	3	7	16.3	0.2	2.1
7/12/2023	3	8	14.4	0.17	1.7
8/10/2023	1	0	25.7	9.09	114.4
8/10/2023	1	1	25.4	9.16	114.5
8/10/2023	1	2	25.0	9.14	113.6
8/10/2023	1	3	24.6	8.04	99.1
8/10/2023	1	4	24.3	7.48	91.6
8/10/2023	1	4.5	23.5	5.05	61
8/10/2023	1	5	21.3	0.28	3.2
8/10/2023	1	6	18.5	0.2	2.2
8/10/2023	1	7	16.5	0.19	2
8/10/2023	1	8	15.2	0.18	1.9
8/10/2023	1	9	14.4	0.18	1.9

8/10/2023	1	9.2	13.9	0.18	1.8
8/10/2023	2	0	24.7	9.9	122.1
8/10/2023	2	1	24.7	9.96	122.9
8/10/2023	2	2	24.6	9.19	113.2
8/10/2023	2	3	24.5	9.06	111.6
8/10/2023	2	4	24.0	6.79	82.8
8/10/2023	2	4.5	23.2	3.76	45.1
8/10/2023	2	5	21.9	0.81	9.5
8/10/2023	2	6	19.1	0.21	2.3
8/10/2023	2	7	16.8	0.17	1.8
8/10/2023	2	8	14.6	0.17	1.7
8/10/2023	3	0	25.1	9.55	118.6
8/10/2023	3	1	24.9	9.59	118.7
8/10/2023	3	2	24.7	9.47	116.7
8/10/2023	3	3	24.5	8.59	105.4
8/10/2023	3	4	24.1	7.55	92.1
8/10/2023	3	4.5	23.7	6.11	74
8/10/2023	3	5	21.8	0.53	6.1
8/10/2023	3	6	19.3	0.28	3.1
8/10/2023	3	7	16.5	0.21	2.2
8/10/2023	3	7.4	15.4	0.2	2.1
9/12/2023	1	0	25.3	8.33	102.7
9/12/2023	1	1	25.4	8.28	102.3
9/12/2023	1	2	25.4	8.25	102
9/12/2023	1	3	25.4	8.16	100.7
9/12/2023	1	4	24.7	4.27	52.1
9/12/2023	1	4.5	23.6	2.11	25.2
9/12/2023	1	5	22.5	0.29	3.4
9/12/2023	1	6	20.4	0.21	2.4
9/12/2023	1	7	17.9	0.18	2
9/12/2023	1	8	16.0	0.17	1.8
9/12/2023	1	9	15.1	0.17	1.7
9/12/2023	1	10	14.0	0.17	1.7
9/12/2023	1	10.7	13.4	0.17	1.6
9/12/2023	2	0	25.9	8.52	106.4
9/12/2023	2	1	25.7	8.63	107.5
9/12/2023	2	2	25.6	8.62	107
9/12/2023	2	3	25.4	7.76	96.2
9/12/2023	2	4	24.4	4.83	58.6
9/12/2023	2	4.5	23.4	2.71	32.4
9/12/2023	2	5	23.0	1.56	18.4

9/12/2023	2	6	20.3	0.26	3
9/12/2023	2	7	18.0	0.17	1.8
9/12/2023	2	8	16.2	0.17	1.7
9/12/2023	2	8.1	15.4	0.16	1.6
9/12/2023	3	0	26.0	8.69	108.6
9/12/2023	3	1	25.8	8.59	107
9/12/2023	3	2	25.6	8.43	104.8
9/12/2023	3	3	25.6	7.97	98.9
9/12/2023	3	4	24.4	4.49	54.6
9/12/2023	3	4.5	23.2	1.9	22.6
9/12/2023	3	5	22.4	0.28	3.3
9/12/2023	3	6	20.3	0.19	2.2
9/12/2023	3	7	17.4	0.17	1.8
9/12/2023	3	7.5	16.5	0.16	1.7
10/12/2023	1	0	16.9	6.22	65.2
10/12/2023	1	1	16.9	6.07	63.6
10/12/2023	1	2	16.8	5.88	61.6
10/12/2023	1	3	16.8	5.81	60.7
10/12/2023	1	4	16.8	5.75	60.1
10/12/2023	1	5	16.8	5.73	60
10/12/2023	1	6	16.8	5.69	59.5
10/12/2023	1	7	16.8	5.52	57.8
10/12/2023	1	8	16.7	4.38	45.9
10/12/2023	1	9	16.6	3.07	32.1
10/12/2023	1	10	14.8	0.27	2.7
10/12/2023	1	11	13.8	0.2	1.9
10/12/2023	2	0	17.7	7.83	84
10/12/2023	2	1	17.2	7.28	77.3
10/12/2023	2	2	17.1	7.12	75.4
10/12/2023	2	3	17.1	6.98	73.7
10/12/2023	2	4	17.0	6.68	70.5
10/12/2023	2	5	16.9	6.35	66.8
10/12/2023	2	6	16.8	6.28	65.9
10/12/2023	2	7	16.8	5.97	62.5
10/12/2023	2	8	16.7	6.02	62.9
10/12/2023	2	8.4	16.5	5.79	60.3
10/12/2023	3	0	17.3	6.63	70.2
10/12/2023	3	1	17.0	6.36	67
10/12/2023	3	2	16.8	6.27	65.9
10/12/2023	3	3	16.7	6.1	64
10/12/2023	3	4	16.7	5.93	62.1

10/12/2023	3	5	16.6	5.96	62.3
10/12/2023	3	6	16.6	5.89	61.5
10/12/2023	3	7	16.6	5.29	55.2
10/12/2023	3	7.5	16.5	5.16	53.9

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