A year of sampling on Lake Wawasee

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Executive Summary

The Lilly Center for Lakes & Streams routinely samples Lake Wawasee weekly in the summer for clarity, oxygen, pH, nutrients/sediments, algae populations, microcystin toxin, and more. While this provides key information on lake water quality during the peak recreational season, processes that occur during other times of the year are not observed. This study, funded by the Herdrich and Griffith families, involved monthly sampling of Lake Wawasee for all of these parameters in the "off season," including during ice coverage. The results showed anoxic conditions both in summer and late winter at the bottom of the lake, highest nutrient content and lowest water clarity in the summer, and a lack of microcystin in the off seasons in 2020 and early 2021. Cooler months are important "reset times" for lakes, and this year-long study showed some previously unseen aspects of the lake's ecology and chemistry.

Methods

Lake Wawasee ("Wawasee" onward) is a 3,006-acre glacial lake in the northeast corner of Kosciusko County, IN. It is the largest natural inland lake in Indiana. We sampled the lake at its deepest point off Waco Point (41.40449, -85.70878), collecting monthly samples of the lake's profile (temperature, pH, oxygen, and conductivity at every meter), water clarity, nutrient/sediments (at 1 meter below surface and 1 m above bottom), and microcystin toxin (integrated sample of top 6 ft of the water column). Algae populations were also sampled and preserved. These populations were made into permanent microscope slides and are in the process of being identified and enumerated. All water samples were collected, stored, and analyzed according to our quality assurance protocol (QAPP) approved by the Indiana Department of Environmental Management (IDEM; Lilly Center 2021).

The sampling dates were 01/07/2020, 02/20/2020, 03/11/2020, 04/20/2020, 05/20/2020, 09/23/2020, 10/13/2020, 11/12/2020, 12/15/2020, 02/05/2021, and 03/05/2021. The 2021 days were included in order to sample during ice coverage conditions, as only the February sample of 2020 had ice cover. Weekly summer samples from 06/02/2020 to 08/11/2020 were a part of the Lilly Center's regular sampling program and were included here as well. Nutrient samples were not analyzed on samples from 03/11 through 06/02 due to COVID-19-related lab closures.

Results and Discussion

Wawasee's overall average water temperatures were 55 °F at the surface, 49 °F in the middle of the water column, and 46 °F near the bottom. In months with ice cover, the surface is colder than the water below it because it is near freezing and not under pressure. The surface

reached 33 °F at its coldest, while the middle and bottom of the water column reached 34 and 35 °F, respectively. In the warmer months, the surface warmed up the most, reaching 82 °F on 7/14/20, while 30 ft down hit over 65 °F and the bottom peaked at 55 °F.

Vertical temperature profiles of the lake during each month of sampling show important changes throughout the seasons (Figure 1). Entirely straight lines, such as in the colder months, indicate the lake is the same temperature from top to bottom. Conditions began to cool in September, and two layers of water could be distinguished: a warm layer from 0 to 35 ft, called the epilimnion, and another about 10 degrees cooler under 35 ft, called the hypolimnion. Periods where the lake has two temperature layers (when the line curves heavily warm to cold) are also times that water does not mix and oxygen can run out at the bottom of the lake. The time when the lake reaches the same temperature top to bottom for the first time and the lake water mixes in full is called “turnover.” This likely occurred in late April and late November 2020.

Lake temperature and oxygen are closely related, illustrated by graphing them in the same profile manner (Figure 2). Left and right movement of the lines in an oxygen profile figure represents lower and higher oxygen content. Many of the lines switched positions compared to the temperature graph; colder months had higher oxygen content in the water than warmer months. Profiles from the summer months curve dramatically to the left at about 15-20 ft in the water column, the same spot the water got cooler (Figure 1). This indicates that oxygen is low where the warm and cold layers meet. In fact, the water ran out of oxygen entirely at about 35 ft in July, August, and September. Water lacking oxygen is called "anoxic." Low-to-no oxygen means limited summer habitat for fish, especially species that prefer deep, cool water.

Oxygen can also run low in the winter as depicted in Feb. 2020 and Feb. 2021 profiles at 60 ft and below (Figure 2). While the water was the same temperature and should be able to mix, ice cover prevented wind from refreshing oxygen supplies and moving water around. The lake was still and sealed, leading to low oxygen at the end of winter.

Monthly pH profiles from this study showed similar seasonal changes (Figure 3). pH remained slightly basic, from 7-9 pH for the duration of the summer and increased in the epilimnion (top, warm layer). Algae are the most likely culprits; their photosynthesis uses carbon dioxide, an acidifying agent. Lower CO_2 leads to more basic (higher pH) water. Lake pH can also be influenced by local geology, rainfall, and snowmelt.

Water clarity is a basic but important measure of water quality. Like many lakes, Wawasee’s clarity fluctuates over the course of the year, with the lowest clarity occurring when particulate is abundant in the water (Figure 4). That time is summer, when algae is most prevalent. We measured visibility down to a murky 3.3 ft on June 30, 2020, but down to a notably deep 18.5 ft under the ice on March 5, 2021. The black bar in the figure represents what the EPA determines would be the water clarity of a high quality lake in our region. Lake Wawasee exceeded this guideline in 8 of 22 (36%) samplings in this study.

Due to their impact of algae populations, nutrients have a large influence on water clarity. Phosphorus is the most significant nutrient in most lakes. Microscopic plant and microbe life compete fiercely for it, and an excess of phosphorus leads to an abundance of these primary producers in the food chain. Lake Wawasee had high phosphorus readings, particularly in the summer and early fall (Figure 5). In 12 of 17 epilimnion measurements, the total phosphorus measured above EPA’s guideline of 0.01 mg P/L for high quality lakes in this area (EPA 2012).

For the hypolimnion, 6 of 9 results were above the guideline. One epilimnion phosphorus result of 1.55 mg P/L on 7/28/2020 was deemed an outlier and removed (as outlined in the Lilly Center QAPP) as a result so high is more likely a piece of organic matter in the sample and not representative of the lake at that time.

Total nitrogen is also a necessary nutrient for lake life, but tends to be more naturally abundant. Too much nitrogen can still encourage excess plant and algae growth. Like phosphorus, Wawasee had higher-than-recommended amounts of nitrogen at both the top and bottom of the lake (Figure 6), peaking in September for both layers.

Suspended sediment (Figure 7) is relevant to lakes for its ability to choke out aquatic life, reduce clarity, and carry in additional nitrogen and phosphorus. Rainfall and shallow boating can influence sediment levels too. No suspended sediment was detected in September in either layer, while the most was found in the epilimnion in August at 8.5 mg/L.

Microcystin toxin, produced by blue-green algae, was detected in Wawasee at some points during 2020 (Figure 8). While not directly correlated to the amount of algae in the water, microcystin is most common when blue-green algae is highly active: the summer. No microcystin was detected outside of the summer (indicated by the small blue squares and listed as 0.075 ppb, which is half of the detection limit for this toxin analysis). This finding supports the regular sampling practice of the Lilly Center for sampling local lakes in only the summer months for algae toxins. The highest microcystin reading was 0.73 ppb, just below IDEM's threshold for dog/pet recreation. People are advised by IDEM to stay out of the water at 8.0 ppb, and are prohibited from recreating in state waters with 20.0 or more ppb (IDEM 2021). While past data shows Lake Wawasee can have microcystin levels at or above these guidelines, it is also capable of healthy recreational levels even in peak blue-green algae season.

Conclusion

With one year of monthly sampling on Wawasee, we were able to observe a full annual cycle of the lake including mixing periods in April and November, showing that the lake is dimictic, or mixes twice a year. The lake suffers anoxia at the bottom in summer and during ice coverage in the winter. Water clarity and nutrient levels show that Lake Wawasee's water quality fluctuates throughout the year, dancing around and below EPA guidelines for high lake quality for this area. Lake many lakes, nutrients, especially phosphorus, are the main parameter of concern. Reduction of Lake Wawasee's phosphorus and nitrogen inputs would assist water clarity issues, reduce algae blooms, and may reduce risk of high microcystin levels.

Literature Cited

Indiana Department of Environmental Management (IDEM). 2021. "Indiana Reservoir and Lake Sampling Update." Available at: https://www.in.gov/idem/algae/indiana-reservoir-and lake-sampling-update/ . Accessed 2/1/2021.

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United States Environmental Protection Agency (EPA). 2012. Recreational Water Quality Criteria. Available at: https://www.epa.gov/sites/production/files/201510/documents/rwqc2012.pdf . Accessed 1/14/2021.

Appendix

Figures and tables begin on the next page.

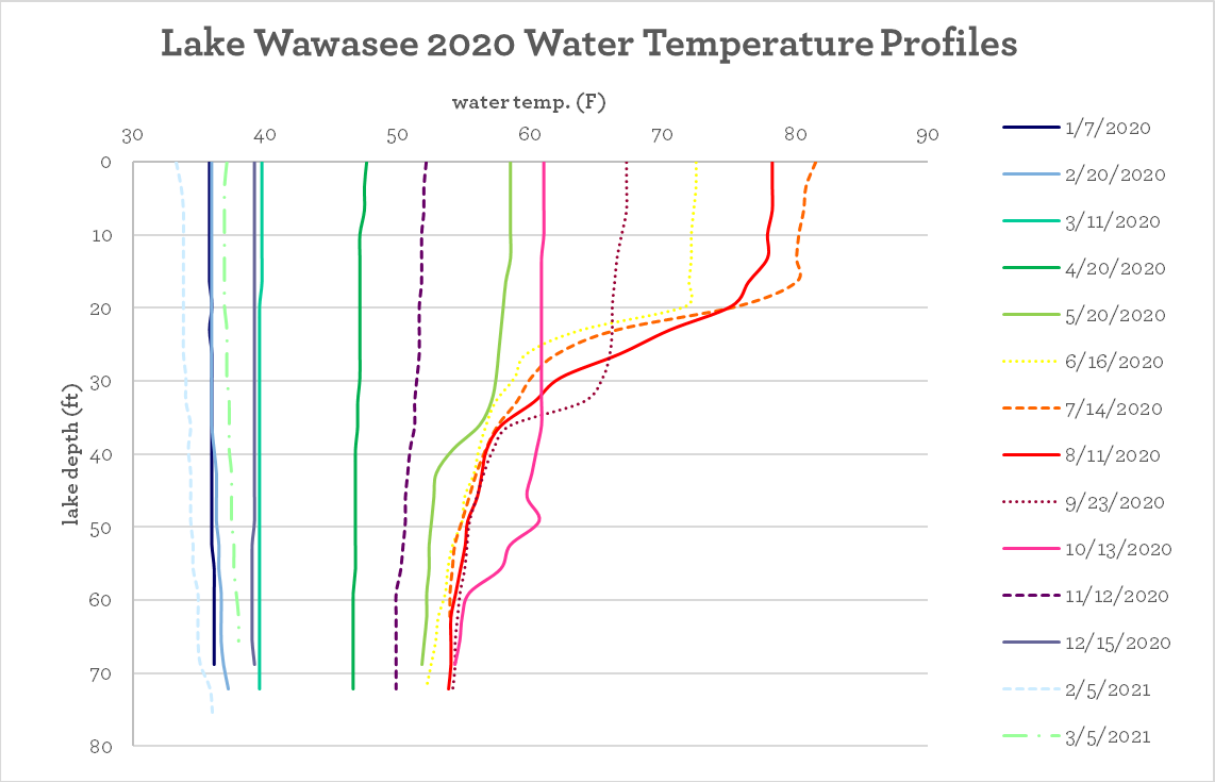

Figure 1: Lake Wawasee's temperature profiles for each monthly sampling event. A bend in the line indicates the water is warmer (to the right) or cooler (to the left) at that depth (on the left axis). Entirely straight lines, such as in the colder months, indicate the lake is the same temperature from top to bottom.

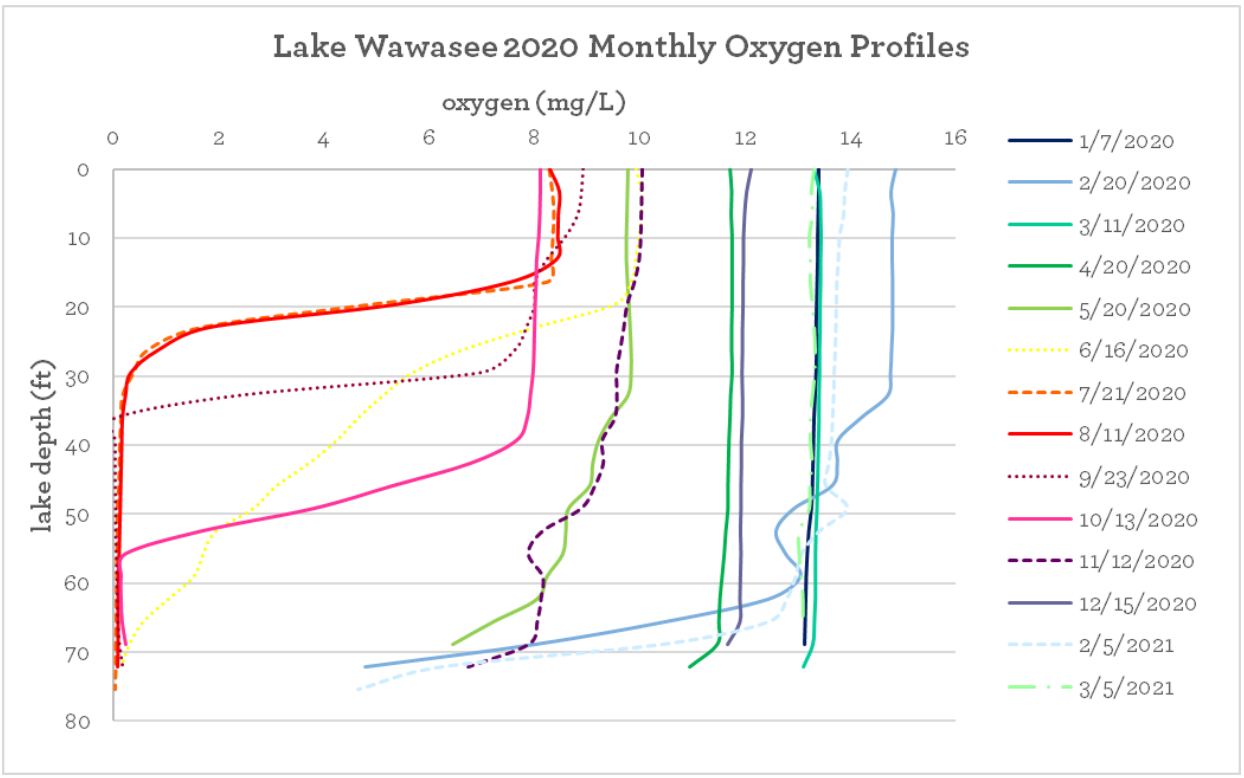

Figure 2: Lake Wawasee's oxygen profiles for each monthly sampling event. The line indicates the water is higher in oxygen (to the right) or lower (to the left) at that depth (on the left axis). Entirely straight lines, such as in the early spring, indicate the lake contains the same amount of oxygen top-to-bottom.

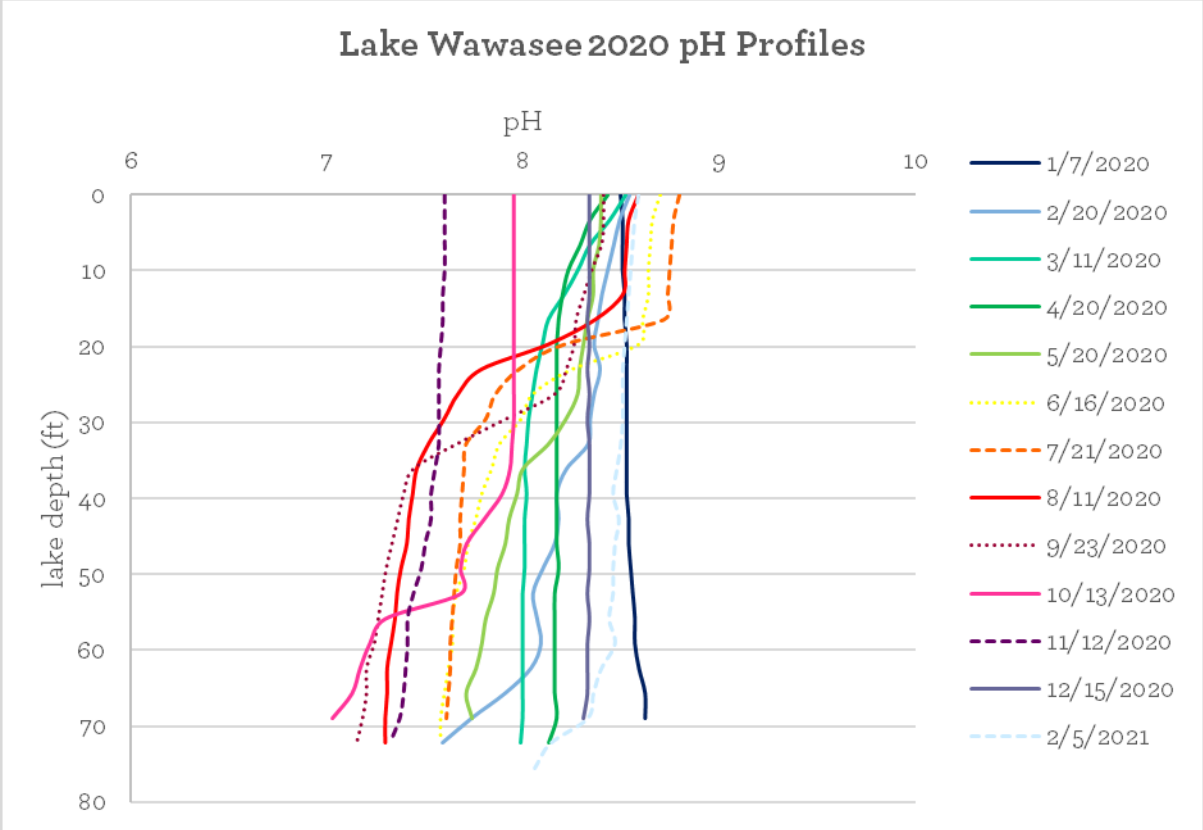

Figure 3: Lake Wawasee's pH profiles for each monthly sampling event. Like the other graphs, higher pH (basic) portions of the water column trail to the right, and low pH (more acidic) is to the left. pH 7 is neutral, so Lake Wawasee's water was slightly basic throughout the year.

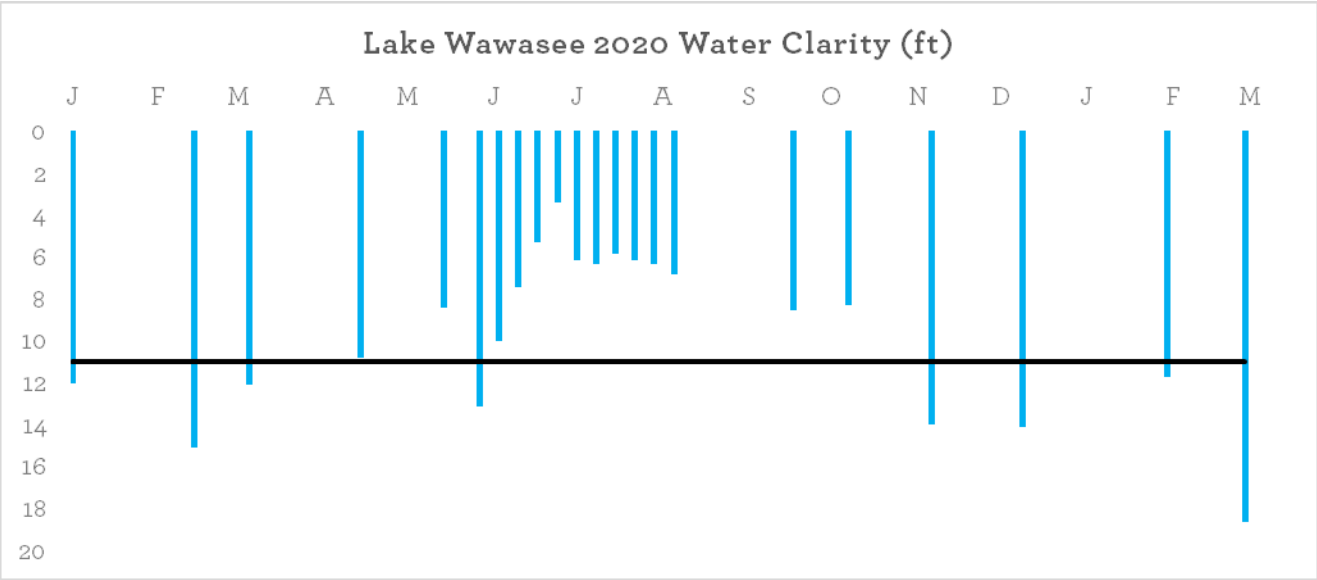

Figure 4: Lake Wawasee's water clarity in ft each month, measured by Secchi disk. The Y axis is oriented with zero at the top and descending, to represent the water's depth. The black bar in the figure represents what the EPA determines would be the water clarity of a high quality lake in our region.

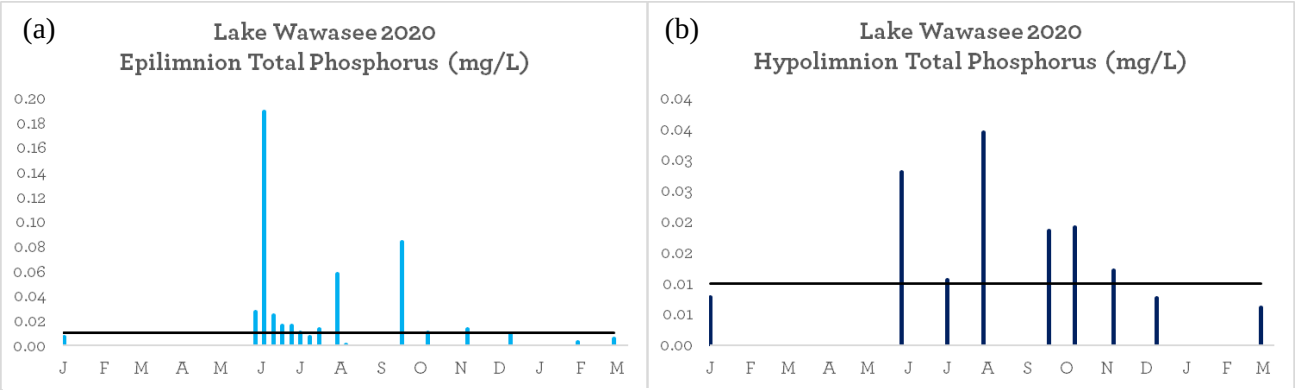

Figure 5: Total phosphorus measurements from Lake Wawasee's epilimnion (a; taken from 3.3 ft) and hypolimnion (b; taken from 66-76 ft). The black horizontal line represents the EPA high water quality guideline for the region at 0.010 mg P/L.

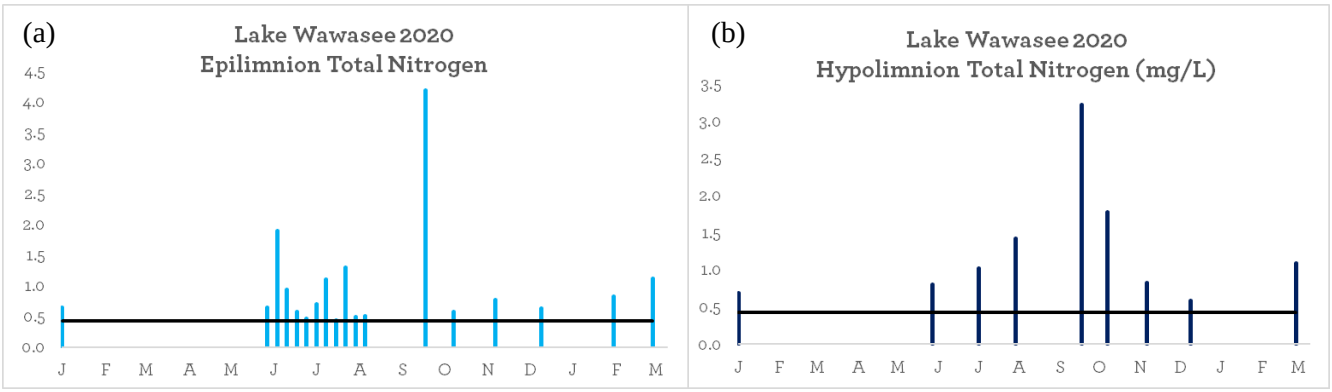

Figure 6: Total nitrogen measurements from Lake Wawasee epilimnion (a; taken from 3.3 ft) and hypolimnion (b; taken from 66-76 ft). The black horizontal line represents the EPA high water quality guideline for the region at 0.43 mg N/L.

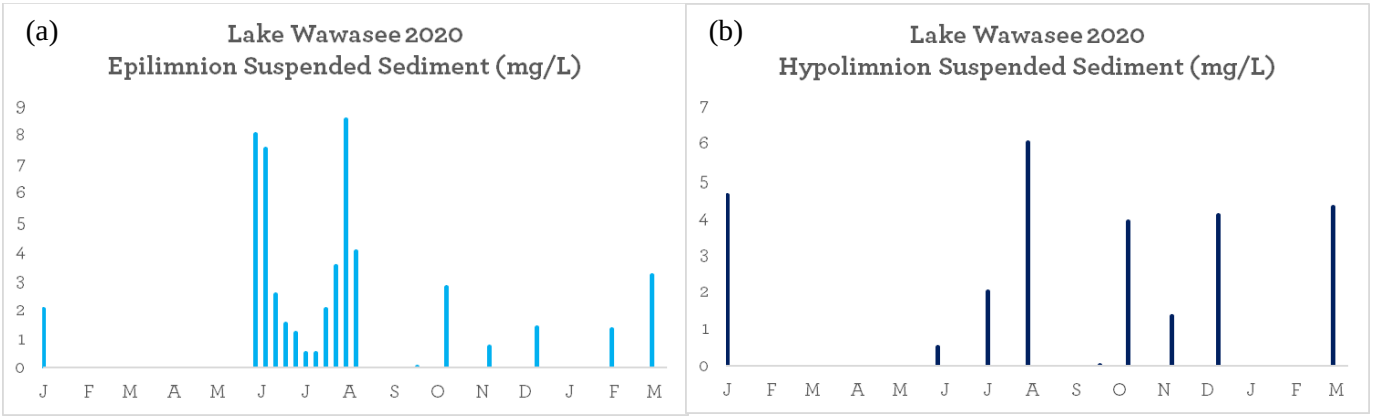

Figure 7: Suspended sediment measurements from Lake Wawasee epilimnion (a; taken from 3.3 ft) and hypolimnion (b; taken from 66-76 ft).

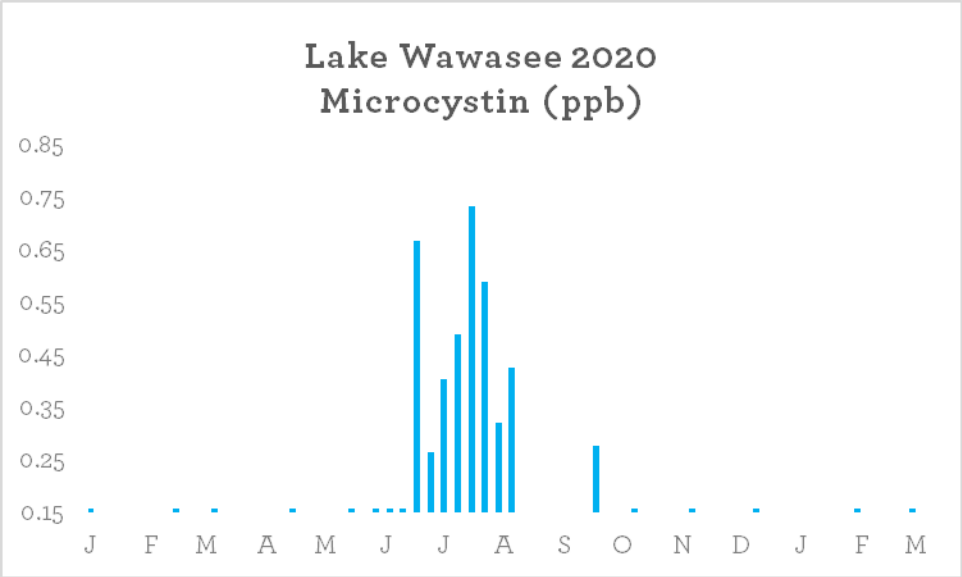

Figure 8: Microcystin toxin from the top 6 ft of Lake Wawasee in (ppb). The bottom of the scale is 0.15 ppb, the lowest toxin level that can be detected by this analytical method. The top of the scale is near 0.8 ppb, IDEM's dog recreation threshold. Tiny bars at 0.15 indicate toxin was not detected in the sample, though amounts smaller than 0.15 may be present.

Table 1: Air temperature and wind speed data for each sampling day.

Sample Date	Air Temp (F)	Max Wind Speed (knt)	Average Wind Speed (knt)
1/7/2020	38.1	7.2	5.1
2/20/2020	27.1	10.0	7.0
3/11/2020	38.1	7.2	5.1
4/20/2020	61.3	8.5	7.5
5/20/2020	56.3	11.0	10.5
6/2/2020	74.5	11.2	7.0
6/9/2020	77.7	7.6	6.7
6/16/2020	69.8	6.3	4.9
6/23/2020	67.8	20.5	7.3
6/30/2020	80.6	5.1	3.7
7/7/2020	100.8	0	0
7/14/2020	84.6	4.2	3
7/21/2020	81.9	4.3	2.9
7/28/2020	81.5	7.4	4.5
8/4/2020	69.6	6.9	4.8
8/11/2020	82.9	8.4	7.4
9/23/2020	69.8	3.7	3.5
10/13/2020	65.5	15.1	4
11/12/2020	53.8	5	2
12/15/2020	29.3	9.9	9.5
2/5/2021	20.5	24.3	16.2
3/5/2021	44.4	7.2	5.9

Table 2: Wawasee specific conductivity (SPC) by depth (Z) for each sampling date.

Sample Date	Z (ft)	SPC (mS/cm)	Sample Date	Z (ft)	SPC (mS/cm)
	3.3	0.362		3.3	0.331
1/7/2020	36.1	0.362	7/14/2020	36.1	0.38
	62.3	0.362		62.3	0.388
	3.3	0.367		3.3	0.327
2/20/2020	36.1	0.371	7/21/2020	36.1	0.381
	62.3	0.379		62.3	0.386
	3.3	0.367		3.3	0.327
3/11/2020	36.1	0.368	7/28/2020	36.1	0.381
	62.3	0.368		52.5	0.391
	3.3	0.370		3.3	0.329
4/20/2020	36.1	0.372	8/4/2020	36.1	0.382
	62.3	0.373		62.3	0.389
	3.3	0.369		3.3	0.33
5/20/2020	36.1	0.373	8/11/2020	36.1	0.386
	62.3	0.378		62.3	0.393
	3.3	0.367		3.3	0.344
6/2/2020	36.1	0.377	9/23/2020	36.1	0.389
	62.3	0.382		62.3	0.404
	3.3	0.369		3.3	0.359
6/9/2020	36.1	0.378	10/13/2020	36.1	0.359
	62.3	0.383		62.3	0.413
	3.3	0.356		3.3	0.363
6/16/2020	36.1	0.376	11/12/2020	36.1	0.364
	62.3	0.379		62.3	0.365
	3.3	0.341		3.3	0.363
6/23/2020	36.1	3.79	12/15/2020	36.1	0.364
	62.3	0.384		62.3	0.364
	3.3	0.377		3.3	0.374
6/30/2020	36.1	0.381	2/5/2021	36.1	0.376
	62.3	0.385		62.3	0.377
	3.3	0.331		3.3	0.371
7/7/2020	36.1	0.379	3/5/2021	36.1	0.371
	62.3	0.383		65.6	0.371