Background

Indian Lake has a long history in Worcester for industry and recreation. It was originally a 100-acre natural lake called North Pond. It was dammed and expanded to 220 acres in the 1800s to supply water to the Blackstone Canal. After the closure of the canal, the more recent construction of I-190 caused the reduction of the size of the water body to its current acreage of 190. Indian Lake's main tributary is Ararat Brook, which enters from the north. The lake empties over a spillway into a culvert on the eastern side of the lake, and eventually flows into Salisbury Pond to the south. There is a small residential island, called Sears Island, connected by a causeway to the mainland. To the south is a small pond called Little Indian Lake, which is connected to the main lake by a small culvert under Grove Street. Indian Lake has a maximum depth of about 17 feet, with the deepest point being in the north-eastern portion.

Indian Lake is a well-used urban lake, with two city-maintained beaches, Clason Beach and Shore Park, as well as a city-maintained boat ramp at Morgan Park are open all summer long. As such, the lake supports swimming, fishing, motorized and non-motorized boating, and water skiing. The lake is considered a great pond, meaning that it is larger than 10 acres in its natural state, and within the jurisdiction of Chapter 91.

Water Quality Summary

As an urban lake, Indian Lake feels the pressures of the city. It is listed on the Massachusetts Impaired Waters 303d List as Category 4a for low dissolved oxygen and non-native plants and received a TDML, or a nutrient budget, for phosphorus in 2002. Nuisance plants have included European Naiad (*Najas minor*), Eurasian milfoil *(Myriophyllum spicatum*), *Elodea*, pondweed (*Potamogeton pusillus*) and common reed (*Phragmites australis*). Algal blooms have historically been a challenge. However, management by community groups, and more recently, the Lakes and Ponds Program, has meant that the waterbody has enjoyed water quality that has been consistently rated as "good" for recreation and wildlife. In 2020, this continued to be the case.

Previous monitoring did not reveal any industrial or emerging contaminants in concentrations that would concern recreational users. When it comes to cyanobacteria, clarity, and nutrient concerns, Indian Lake performed better than usual in 2020. There were no closures due to cyanobacteria, and in lake clarity and phosphorus concentrations were improved over previous years as well.

However, increased clarity may have contributed to the prevalence of invasive aquatic plants, prompting the Lakes and Ponds Program to take more proactive measures against them in 2021. Monitoring in 2020 also revealed water temperatures were higher than in previous years, and it may have had implications on fish populations. Additionally, there were several beach closures at Shore Park due to exceedances in fecal bacteria indicators. In 2021, steps were taken to remove the cause of these issues including reevaluating our invasive aquatic plant management plan, and keeping an eye on water temperature, in addition to the other indicators mentioned above. Overall, water quality in 2021 continued to be good, with our management plans effective. Following the 2021 water quality results, this report will review some of the exciting projects that are in store for 2022 to continue to improve Indian Lake.

Management Summary

Indian Lake has had management plans for cyanobacteria and invasive aquatic plants for several years now. In addition, in 2021 a plan was implemented to address the increased number of closures due *to E. coli* bacteria indicators that were witnessed in 2020. Following monitoring data indicating rising nutrient or cell densities, the surface of Indian Lake was treated with aluminum sulfate on June 3rd, and with copper sulfate on July 22nd. Together, these treatments kept cyanobacteria concentrations safe for recreation for most of the summer, until an increase in density past the recreational threshold was measured in mid-September, and the lake was closed for recreational use for about 12 days until the density fell on its own. Thankfully, no cyanotoxins were found in the water during this time. Indian Lake was also treated with the herbicide ProcellaCOR on June 24th, the first time an herbicide was used to address the thickly growing invasive aquatic plant, Eurasian milfoil. The herbicide worked very well in reducing the density of the milfoil, so much so that an opportunistic native plant finally had a chance to grow. The plant, thin-leaf pondweed, grew rapidly and overtook the southern portion of the lake. In response the Lakes and Ponds Program treated it with the herbicide diquat dibromide (trade name: Reward) in mid-August to allow the lake to be navigable.

Following high *E. coli* readings in 2020, goose fencing was developed and installed during off-hours at the beach, which reduced goose congregation and may have contributed to the reduced number of beach closures for fecal bacteria in 2021.

Figure A **–** Aerial view of Indian lake and approximate sampling locations.

Sampling Analysis and Overview

Indian Lake was visited semi-monthly from May through November and sampled at four locations: The major aboveground tributary, Ararat Brook; the middle of the two basins of the lake (the northern site, which is about 17 feet deep and the southern site, which is about 5 feet deep); and the outlet at the spillway, located in the eastern part of the lake (see *Figure A*). The in-lake locations were sampled at the surface of the water (1 foot below the surface), and the bottom (2 feet from the lake floor). Parameters evaluated included: Secchi transparency, temperature, dissolved oxygen, pH, total

phosphorus, total dissolved phosphorus, *E. coli*, and litter. Total suspended solids, ammonia, and nitrate were analyzed on a monthly basis. Altogether, there were 14 sampling events. For 9 of these events, there had been no rainfall 24 hours prior to data collection. However, on 5/4, 6/15, 7/6, and 10/5 there were 0.63, 0.34, 0.29, and 0.90 inches of rain that fell within 24 hours of sample collection respectively. These days are categorized as "wet weather" sampling events.

In addition to program sampling, volunteers from the Worcester Cyanobacteria Monitoring Collaborative (WCMC) collected samples from a private dock for phycocyanin and particle counts in preparation for monthly meetings on 5/22, 6/19, 7/17, 8/21, 9/25 and 10/26. Additionally, the Worcester Department of Inspectional Services sampled the beach at Shore Park for *E. coli* as an indicator for harmful bacteria on a weekly basis during the summer months.

Raw data are displayed and explained below. No statistical analysis has been performed. Subsequent ratings of "excellent", "good", "fair", and "poor" for reported values are based on the Massachusetts Department of Environmental Protections SMART Monitoring Watershed Report Card Criteria. While the report will refer to previous data collected by the program, one must be cautious in comparing data sets of this nature over a five year period.

Quality Assurance/Quality Control

To have confidence that the data that were collected are representative of local conditions, Quality Assurance/Quality Control (QAQC) checks were employed along at all steps of the sampling and analysis process to verify the validity of the data. Duplicate samples, or two measurements or samples taken in a row, were compared to ensure precision. Matrix spikes compared results to known benchmarks to ensure they were close to their true value. Blanks were samples of pure water that were submitted as samples to the lab to test the equipment, technique, and the lab analysis. All checks were carried out randomly to ensure that each parameter received robust review. When data failed to meet acceptable criteria for these checks, they were either flagged as being slightly less robust or censored entirely. Flagged data points are marked with a red flag and censored data are not included in this report (see *Figure B*).

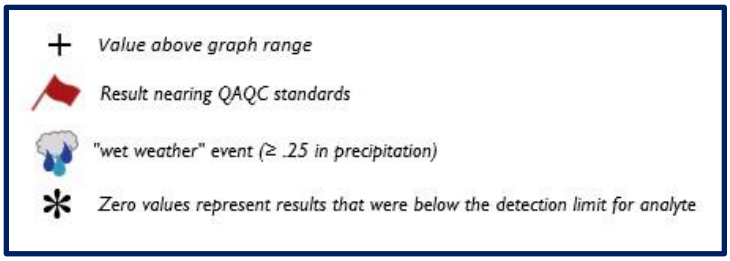

Figure B **-** Data points with QAQC abnormalities or other notable attributes are marked on figures with these symbols.

Fecal Bacteria

Recreational contact with water contaminated by bacteria may make people ill. *Escherichia coli,* or *E. coli*, are a type of bacteria found in the digestive tract of warm-blooded animals, including humans. While most strains are harmless, some can make you very sick. These bacteria can come from pet and goose waste running into the water, from human waste, from illicit sewer connections to the storm water system, from leaking septic tanks, or from the improper application of manure on land. The Commonwealth of Massachusetts has strict water quality standards for public bathing beaches, and the Worcester Department of Inspectional Services tests the water for *E. coli* on a weekly basis during the summer months. If the readings are too high, the city is required to close the beach until readings return to safe concentrations. The Lakes and Ponds Program also samples for *E. coli* semimonthly at one in-lake site to understand it's prevalence outside of the beach area. Samples are collected from the water's surface and sent to an external lab for analysis.

Fecal Bacteria at Indian Lake. This year, there were two days of bacteria-related beach closures at each of the two beaches, Shore Park and Clason Beach. Each of the events occurred during wet weather events. The bacteria counts that triggered these closures all fell in the "fair" range, meaning they were above the recreational threshold but not high enough to be considered "poor" (see *Table 1*). All the rest of the results were "good" or "excellent". For the early closures, it was reported that the goose fencing developed this year was not yet being used at Shore Park Beach. Open water samples for *E. coli* showed lower results, generally falling in the "excellent" range, suggesting that fecal bacteria are not of concern in the middle of the lake (see *Table 2*).

	SHORE PARK BEACH	CLASON BEACH
DATE	RESULT	RESULT
28-Jun	<4	12
6-Jul	28	8
12-Jul	332	100
13-Jul	44	N/A
19-Jul	316	356
20-Jul	188	260
21-Jul	N/A	160
26-Jul	12	24
2-Aug	28	8
9-Aug	8	20
16-Aug	4	16
23-Aug	80	76
30-Aug	4	12

Excellent	*Good*	**Beach closure**
Fair	*Poor*	
Results in colonies/100 ml		

Table 1 **-** There were only two days of beach closures at each Indian Lake beach in 2021.

	OPEN WATER	ARARAT BROOK
DATE	RESULT	RESULT
4-May	2	1120
18-May	1	35
1-Jun	22	145
15-Jun	17	1120
6-Jul	11	261
20-Jul	129	1733
3-Aug	5	102
7-Sep	4	727
21-Sep	13	225
5-Oct	137	1046
2-Nov	24	56
16-Nov	84	29

Table 2 –Open water bacteria results were generally in the "excellent" category. In Ararat Brook, there were 5 results in the "poor" category.

Water Clarity

Water clarity, or the level of transparency of water, is an important measure of water quality. Algae, microscopic organisms, eroded particles, and re-suspended bottom sediments are factors that interfere with light penetration and reduce water transparency. Water clarity is important for a variety of reasons in a lake. Clear water allows light to

penetrate to greater depths and encourages the growth of aquatic plants, which provide food, shelter, and oxygen to aquatic organisms. Turbid water, or water filled with particles, will warm up faster as it absorbs heat from sunlight. This may cause the water's oxygen concentration to fall because warm water can hold less oxygen than cool water. Finally, clear waters are pleasant to the eye, and generally safer for recreational contact. Water clarity can be measured with a Secchi disk or by quantifying total suspended solids (TSS). A Secchi disk is a weighted black and white disk on a calibrated line that is lowered into the water until it is no longer visible. Secchi readings are collected on each lake visit. TSS is a measure of the dry weight of suspended particles in a given amount of water. TSS samples are taken on a monthly basis and submitted to a lab for analysis. This year the Lakes and Ponds Program used samples collected by the Worcester Cyanobacteria Monitoring Collaborative (WCMC) to help assess clarity by conducting particle counts on a tool called the FlowCam Cyano. The FlowCam takes microscopic pictures of the particles in a sample, counts them and allows users to catalog classifications. This aids in understanding what may be impeding clarity and determine next steps for management.

Water clarity at Indian Lake. Indian Lake was sampled for Secchi depth at the northern in-lake site. This year's clarity results ranged between 8.5 and 4.0 feet, (see *Figure C*). Readings were consistently closer to the "poor" category after July. It is notable that the aluminum sulfate treatment on June 3rd was followed by increased clarity in early June, as it has been known to do previously, although this effect was not sustained.

TSS was taken at both in-lake sites at the surface and at the bottom at the northern in-lake site monthly. Surface results were consistent between the northern and southern sites until September, when the southern site began having comparatively higher readings for the rest of the season. TSS at the bottom was generally higher than the surface (which is expected), but it stayed within a healthy range for the whole season.

Of the five dates sampled by the WCMC, particle counts on were highest on 9/25 with a reading of 12,384 particles/ml. This supports the Secchi clarity reading on that week, which was near the "poor" category. A phycocyanin result of 126 units from 9/25 suggests that cyanobacteria were impeding clarity at this point.

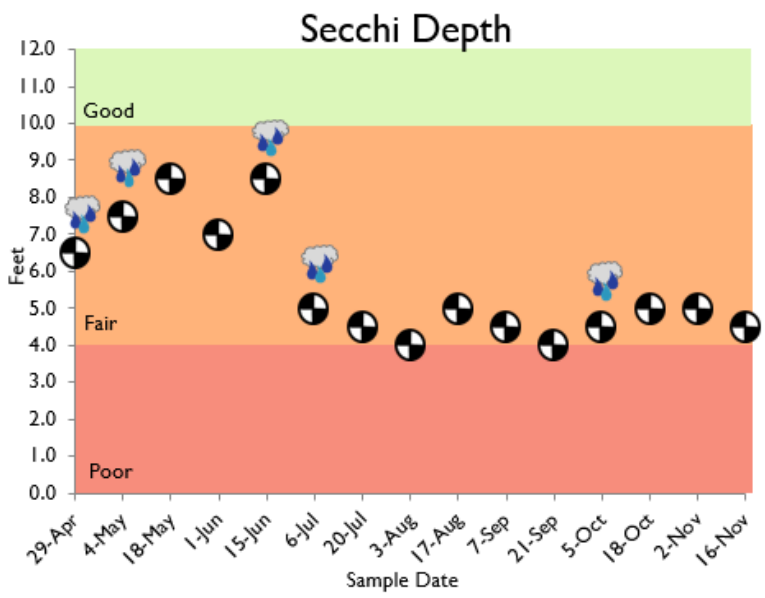

Figure C – Secchi depth results were considered "fair" all season long, ranging from 4 to 8.5 feet.

Temperature/Stratification

Water temperature is important to both the biological activity and water chemistry in a lake. Organisms tend to live in a preferred band of temperatures, and when temperatures are too cold or warm, their populations may experience stress. Water temperature also affects the speed of chemical reactions in addition to how much oxygen can be held in the water. The extent to which water circulates through a lake affects the ability of that water to support aquatic life by mixing oxygen and nutrients up and down the water column. Because the density of water changes with temperature, variations in temperature can cause cold water to settle in a layer on the bottom while warm water stays on top, resulting in stratification. While a natural process, stratification can prevent the replenishing of oxygen on the bottom layers of the lake, and the rise of sediment nutrients to the top, which may be detrimental to lake health. Systems experiencing nutrient loading can suffer from low DO due to increased algal growth and excessive decomposition of organic material. This can lead to fish kills and other ecological issues.

Water temperature at Indian Lake. Water temperature was measured twice monthly at the surface at the two in-lake sites and at the bottom at the northern site. This year, surface temperature was relatively uniform between the northern and southern sites (see *Figure D*). Temperatures fell in the "excellent" or "good" categories for a majority of the sampling season, with one hot day where they approached or entered the "fair" category. Temperature at the bottom of the lake was in the "excellent" range all season. As was observed elsewhere this year, these results are an improvement over the 2020 results, when the temperature of the surface was on average over a degree higher and in the "fair" to "poor" category July through September.

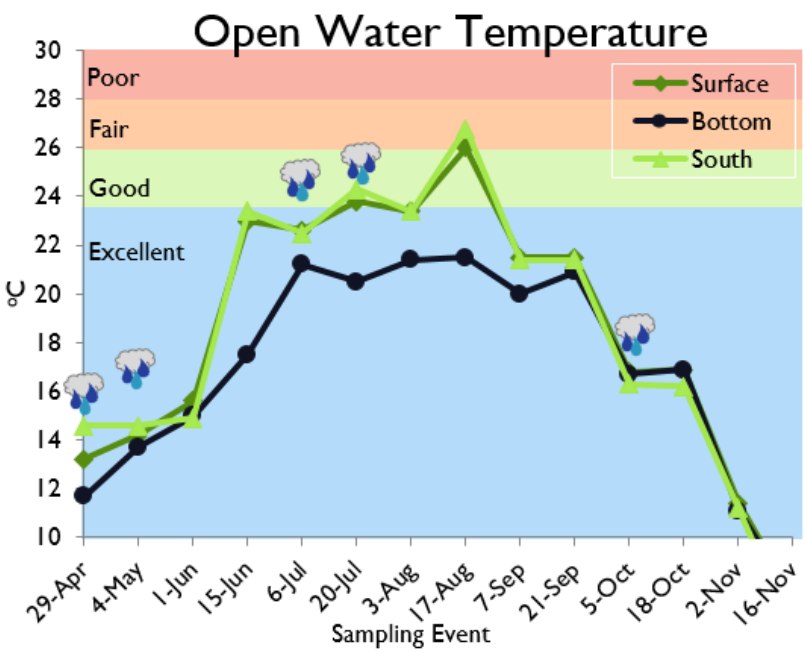

Figure D – Water temperature was in the "excellent" range fir most of the season, and only entered the "fair" category on one sampling event in August.

Dissolved Oxygen

Oxygen in the water is essential to aquatic life, just like it is for life on land. Because algae, plants, fish, and other aquatic organisms require a certain amount of oxygen to survive, dissolved oxygen (DO) is an important indicator of water quality. It is a highly variable parameter with daily and seasonal variation. DO concentration can be affected by temperature, pressure, rate of photosynthesis, decomposition, aeration, diffusion, and respiration by aquatic life. Systems experiencing nutrient loading can suffer from low DO due to increased algal growth and excessive decomposition of organic material. This can lead to fish kills and other ecological issues. DO was measured using a galvanic DO sensor on a handheld probe at the water's surface, and two feet from the bottom at the in-lake locations.

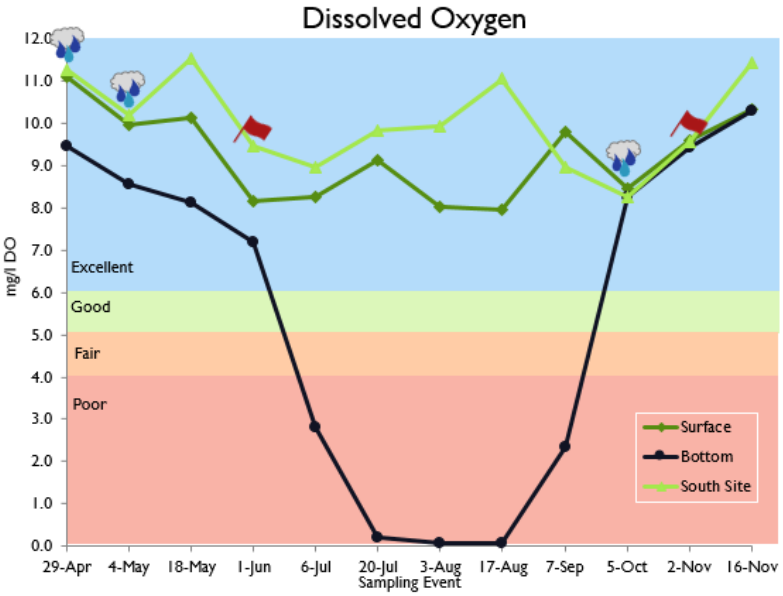

Figure E –Surface DO was in the "excellent" category all season long at the northern and southern sampling sites. Bottom DO was considered "poor" between July and September.

Dissolved Oxygen at Indian Lake. Surface DO was in the excellent range all season at the northern and southern sites (see *Figure E*). DO continues to be higher in the southern site, a pattern that has been observed annually. DO also decreases into the "poor" range between July and September. In past years, when depth profiles were conducted, it was found that oxygen depletion was only observed in the bottom two feet of the water column. Since the water continues to be well mixed and oxygenated above this point, these DO concentrations are not concerning during the daytime hours.

pH

pH is a measure of the number of hydrogen ions (H^+) in a substance. The more H^+ that are present, the more acidic the solution. On a scale of 0-14 units, 7 a neutral pH. As you increase from 7, the solution is more basic, and as you decrease, it becomes more acidic. In waterbodies, pH can change due to respiration and photosynthesis by aquatic organisms. A pH that is too high or low can have implications on the health of aquatic organisms. However, a high pH can also promote chemical reactions that release phosphorus from lake sediments. Like DO, pH can vary throughout the day and season. Healthy lakes in our area have a pH between 6.5 and 8.5. A low pH can be the result of external forces like acid rain. pH is monitored using an ion-selective electrode (ISE) pH sensor on a handheld monitoring probe. Readings are taken at the water's surface and two feet from the bottom.

pH at Indian Lake. This year, pH readings at the surface of Indian Lake continued to be high through most of the sampling season, occasionally increasing quickly in a short period of time (see *Figure F*). This was especially notable in the southern site, which usually read higher than the northern site, peaking at a pH of 10.1 on 8/17. These conditions present challenges to lake health as they favor cyanobacteria and algae growth. pH at the northern deep site was in a more normal range, generally hovering around 7. It is notable that, similar to clarity, the alum treatment in early June seems to have temporarily reduced the high surface pH. It is suspected that the planned installation of an alum dosing station at the mouth of Ararat Brook will help to reduce these wide fluctuations. More on this project will be covered at the end of the report.

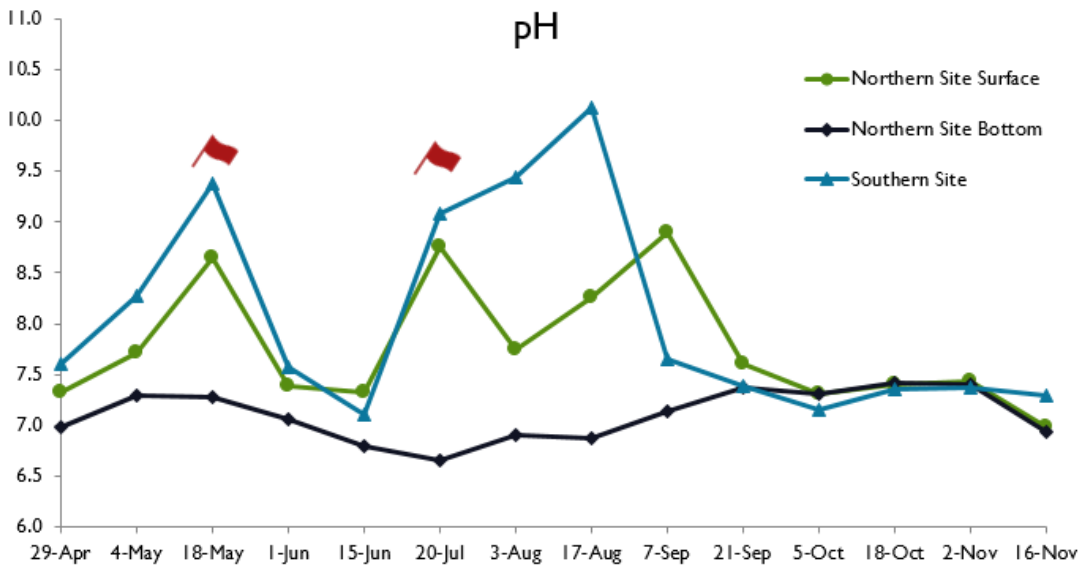

Figure F – Surface pH was higher than any other lake peaking at 10.12 on 8/17. pH on the bottom was in a more normal range, around 7.

Nutrients

Nutrients, primarily nitrogen (N) and phosphorus (P), are food sources for aquatic plants, algae, and cyanobacteria. Although these organisms are the basis of the food chain, and necessary for a healthy lake ecosystem, an overabundance of either N or P can lead to issues such as harmful algal blooms and excessive plant growth. Overgrowth of these organisms can lead to conditions where oxygen is depleted in the water column, potentially causing fish kills. These nutrients have many known sources in urban lakes including fertilizers, pet and goose waste, illicit sewer connections to the stormwater system, and runoff that washes over land and into the storm sewer system. Additionally, under the right conditions, P can be released from the sediments at the bottom of the lake, becoming more available for uptake by organisms. Nutrients are measured in our lakes by collecting water samples and submitting them to an external lab for analysis. N takes several forms in water bodies, including nitrate (NO_3) and ammonia (NH_3). Samples are collected for NO_3 and NH_3 at all sites monthly. Samples are collected bi-weekly for total phosphorus (TP) at all sites and total dissolved phosphorus (TDP) at all deep sites. Measuring TDP allows us to understand how much total phosphorus is in a form that can be easily absorbed by organisms.

Nutrients at Indian Lake. At the surface of the lake, TP was generally in the "excellent" and "good" range all season at the northern and southern site (see *Figure G*). The southern site generally had higher concentrations than the northern site with, with slightly more "good" ranking events as well as one "fair" result. TP at the bottom was generally in the "good" range" with only one "fair" result in August. It should be noted that, while by themselves, these concentrations of TP are not inherently bad, when combined with other factors like warmer temperatures and high pH, they create conditions that are suitable for cyanobacteria blooms. Overall, bloom risk was lower in 2021 than previous years, with a lower average TP concentration at the surface of the lake throughout the season. As with clarity and pH, there was an improvement in TP concentration following the June 3 aluminum sulfate treatment. It is suspected that the planned installation of an alum dosing station at the mouth of Ararat Brook will help to reduce TP even more and further diminish the risk of a cyanobacteria bloom. More on this project will be covered at the end of the report.

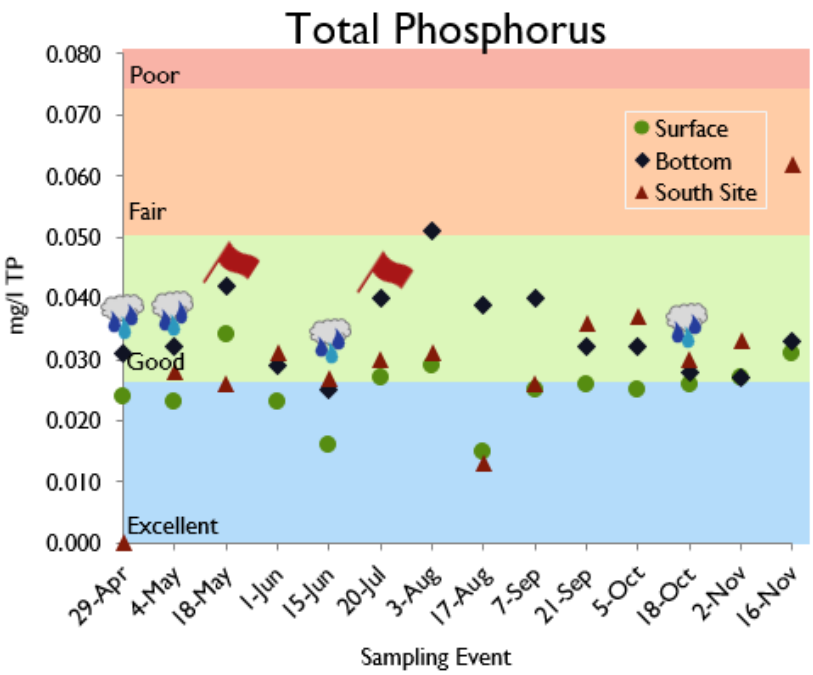

Figure G – TP generally stayed in the "excellent" and "good" categories in 2021. TP concentration was generally higher at the bottom than the surface at the northern site. The southern site raised into the "good" and "fair" categories near the end of the season.

NO_3 concentrations were generally undetectable at the surface until mid-November, when they were still considered low. Results were slightly elevated at the bottom of the lake, but still not considered unhealthy. At the in-lake sites, NH_3 was generally not detected, but when it was, it was in the "excellent" range, below 0.15mg/l

All in all, nutrients at Indian Lake are in the "good" category. Although many of the samples taken this year were rated as "excellent", high water temperatures and pH put the lake at a baseline risk for cyanobacteria blooms, meaning that a lower concentration of nutrients may be necessary to promote a bloom.

Cyanobacteria

Cyanobacteria are commonly occurring microorganisms in aquatic ecosystems. Cyanobacteria are bacteria that use sunlight, N, and P in a similar way to algae. While they are present in small numbers in healthy ecosystems, under warm, high nutrient conditions they can reproduce quickly, causing a bloom. In addition to being unsightly and smelly, blooms can cause low oxygen conditions that are harmful to aquatic life. Cyanobacteria can also produce toxins that are harmful to humans and pets. It is therefore important to understand cyanobacteria dynamics in our lakes and ponds.

During the summer months, as the potential for blooms increases, the City of Worcester contracts an environmental consultant to perform cell counts as needed at Indian Lake. This helps to determine when and if preventative treatments waterbody closures are necessary.

Cyanobacteria and algae use the pigment chlorophyll to harness the sun's energy, converting carbon dioxide to sugars for growth and reproduction. Unlike algae, cyanobacteria also use a pigment called phycocyanin. Because of this, the concentration of phycocyanin as an indicator of cyanobacteria's relative abundance in a waterbody. This concentration can be measured using a tool called a fluorimeter. This year samples collected by the WCMC were used to conduct fluorimetry analysis and measure concentration of phycocyanin, comparing them between waterbodies over the course of the sampling season.

Worcester Cyanobacteria Monitoring Collaborative

Photo Credit: Stephanie Tam

The Worcester Cyanobacteria Monitoring Collaborative (WCMC) is a group of community science volunteers that is working to better understand the diversity and abundance of algae and cyanobacteria in local lakes and ponds. Volunteers collect data monthly between spring and fall at 22 waterbodies in and around Worcester including Indian Lake. Samples are collected for pigment analysis, particle counts and qualitative analysis under a microscope. In the future, this program aims to provide robust quantitative data to local government and community members to assist in making public health and lake management decisions. For more information, check out WorcesterMA.gov/WCMC.

Cyanobacteria at Indian Lake. Indian Lake generally has favorable conditions for cyanobacteria growth, including high water temperatures, elevated pH, and steady nutrient inputs. It has had several documented cyanobacteria blooms over the past years. The Lakes and Ponds Program uses the data collected from the monitoring program to determine the application of preventative treatments. This year, cell counts showed lower concentrations from the beginning of the season through mid-August, most likely with help from the June 3 aluminum sulfate treatment and the July 22 copper sulfate treatment. However, in mid-September, cell counts increased from 14,000 to 105,000 cells/ml in one week, surpassing the recreational threshold of 70,000 cells/ml and therefore causing the need to close the lake (see *Figure H*). While the recreational threshold for cell density is determined by the MA

Department of Public Health to avoid contact with cyanotoxins, subsequent toxin testing showed that there were none present in concerning concentrations. These results demonstrate how quickly cyanobacteria can reproduce, and the need for constant evaluation of these parameter. The Lakes and Ponds Program continued to collect samples for cell counts, and results came back below the recreational threshold on September 17th, allowing for the reopening of the lake after two weeks.

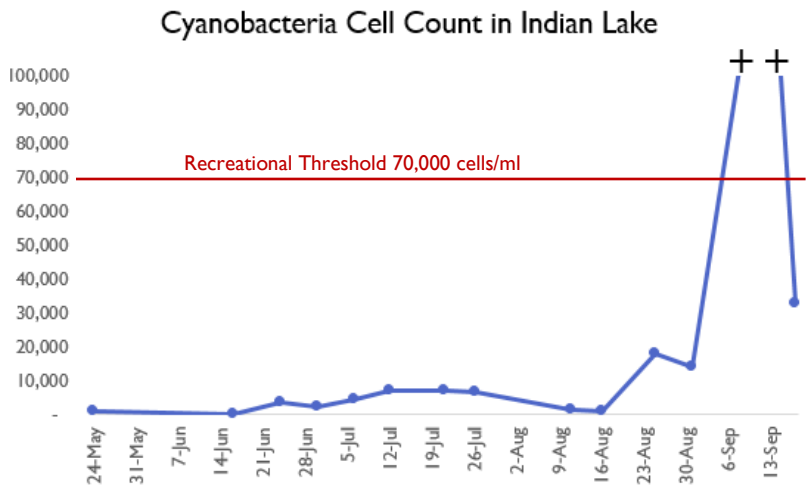

Figure H – Cyanobacteria cell counts sharply rose from 14k to 105k in one week, resulting in a lake-closing cyanobacteria bloom.

Invasive Aquatic Plants and Animals

Native aquatic plants and animals are vital parts of any lake ecosystem. Native plants provide food, shelter and oxygen to other aquatic organisms. Their uptake of nutrients reduces the likelihood of algal blooms, and their root systems stabilize sediments. Native animals play invaluable roles in food webs and their removal can disrupt the ecology of a system. An invasive plant or animal is an organism that is not native, or did not originally come from the area. These plants and animals can become nuisances because their natural constraints, such as predators or environmental limitations, do not exist in their new home, allowing them to multiply at a rapid rate. When aquatic plants and animals become too numerous, they can reduce our ability to enjoy our lakes and ponds, as well as crowd out local species. Invasive organisms can arrive by hitching a ride on boats, pets, or boots to get from place to place. Some are released with good intentions as a beautiful addition to a landscape or sport fishing opportunity. Professional surveys and visual inspections from Lakes and Ponds Program staff are used to make management decisions.

Invasive Aquatic Plants and Animals at Indian Lake. In 2020, Indian Lake experienced uncharacteristically clear waters, which was great for recreation, but also great for invasive aquatic plants. An end of season survey indicated that during that year there was a resurgence of the invasive aquatic plants Eurasian milfoil (*Myriophyllum spicatum*). Previously, nuisance plants were controlled with an entirely chemical-free management plan, combining multiple approaches. This included an annual winter drawdown, in which the water level was reduced by 5-6 feet exposing invasive aquatic plants to the elements, as well as dive teams which aimed to remove the plants by the roots. However, these efforts were not sufficient to keep the plants under control, and in 2021 the herbicide ProcellaCOR was applied for the first time on Indian Lake. As a systemic herbicide, ProcellaCOR kills the milfoil at the root, as opposed to contact

herbicides that only affect the foliage, allowing the plant to reproduce from the root system the following season. The treatment occurred on June 24 and was effective at eradicating the milfoil throughout the lake.

Shortly after the treatment, there was rapid growth of the native plant thin-leafed pondweed in the southern portion of the lake. This phenomenon had not been predicted. The plant is known to be opportunistic, and when it finally has space for it to grow, it grew fast. The Lakes and Ponds Program was able to treat it with the contact herbicide Reward, but not before there were many complaints about how it was impeding recreation. Overall, the invasive aquatic plant management plan was effective at reducing the density of the target plants, and recreational challenges caused by plants were due to an unexpected surge in native ones. However, the Lakes and Ponds Program has again modified its management plan to be prepared for the potential outcome and respond faster in 2022.

Figure I – Thin-leaf pondweed in the southern section of Indian Lake.

Litter

Litter, or inappropriately disposed waste, is harmful to the ecological, aesthetic, and recreational value of lakes and ponds. Improperly discarded plastic and Styrofoam products can be mistaken as food by aquatic organisms and can kill them. Mounds of trash and rotting organic material can cause infestation by disease-carrying vermin. Additionally, they look and can smell unpleasant to beachgoers and hikers. Finally, sharp objects like syringes, broken metal, or glass can pose a threat to swimmers and other beach visitors.

Litter is a difficult parameter to measure in a quantitative way. This year, a new method was employed to quantify litter at lake access points so its accumulation can be better understood. Originally developed by

WPI students, this method records scored observations in five categories so litter can be quantitatively tracked and compared between lake access points throughout the season.

There were five categories that were used for judging "*Overall Conditions*", including cleanup effort, atheistics, safety, litter density, and the impact on the functionality of the site. Each one of these categories receives a score from 1-5. The final score then can be between 5 (the best) and 25 (the worst). The second portion of the classification includes "*Litter Characterization*", which compares the different classes of litter found that day, and includes things like bottles, glass, tobacco products, textiles, and other things commonly found in public spaces.

Overall Litter Conditions

Date	Clean Up Effort	At a glance	Safety	Litter Density	Impact/Functionality	Matrix Score
6/15	3	2	2	2	2	11
7/6	3	3	3	3	2	14
7/20	3	2	2	2	2	11
8/3	3	2	2	2	2	11
8/17	3	2	2	3	2	12
9/7	3	2	2	2	2	11
10/5	2	2	2	2	2	10
10/18	3	3	2	3	2	13
11/2	2	2	2	2	2	10

Table 3 – For the "Overall litter conditions" category, usually scored around 2, indicating that litter was present but conditions were not severe.

Litter at Indian Lake. At Indian Lake, the Litter Tracking Tool was applied to the area surrounding the boat ramp at Morgan Park. For the categories, "Clean-up effort", "At a glance", "Safety", "Litter Density", and "Impact/Functionality" scores ranged between 2 and 3, but were generally higher than other locations surveyed (see *Table 3*). Particularly, the category "Cleanup effort" usually scored 3. The relative abundance of different types of litter were also noted. Similar to sites surveyed at other waterbodies, the litter categories, "small items'', "tobacco products", and "food packaging and containers" generally scored 3 or higher, while the remaining categories often scored 2 or below (see *Table 4*). "Small items" were particularly common with an average score of 3.9. Before September, it was often observed that litter had gathered in the reeds along the shore, but this was not as common later in the season.

Litter Characterization

Date	Bottles	Plastic cups	Glass	Bags	Food packaging	Tobacco products	Recreational/toys	Textiles/clothing	Junk	Small items
6/15	3	2	2	1	3	4	1	2	1	4
7/6	2	1	3	2	3	4	1	1	1	5
7/20	2	1	2	2	3	4	1	3	1	5
8/3	1	2	1	1	3	4	3	2	2	4
8/17	2	3	1	3	3	4	1	1	2	4
9/7	3	1	2	2	3	4	2	1	1	4
10/5	1	3	2	3	3	3	1	1	2	4
10/18	2	3	2	2	3	4	1	1	2	3
11/2	2	1	1	2	3	3	1	2	2	4

Table 4 – Of the litter categories, "small items", "tobacco products", and "food packaging and containers" scored highest, meaning that they were most abundant.

Tributaries

Tributaries are streams that flow into a lake or pond. They collect surface runoff from rain or snowmelt along with some groundwater and carry it through the stream channel to the waterbody. In some cases,

tributaries make up a large portion of the water going into the lake, and the quality of the water in these tributaries can give us hints about where certain impairments in the lake are originating. Outlets are the major exits for water in the lake. Most of the abovementioned water quality parameters are measured at the major natural tributaries and outlets of the lakes in the Worcester Lakes and Ponds Water Quality Monitoring Program.

Tributaries at Indian Lake. Indian Lake has several natural tributaries. As a part of this monitoring program, the parameters described above were measured in the major natural tributary, Ararat Brook, as well as at the spillway on the northeastern end of the lake.

Fecal Bacteria samples taken in Ararat Brook, had a mixture of results in the “good”, “fair”, and “poor” categories. All of the “fair” and “poor” results coincided with wet weather events, suggesting that stormwater inputs may be negatively impacting the brook’s water quality.

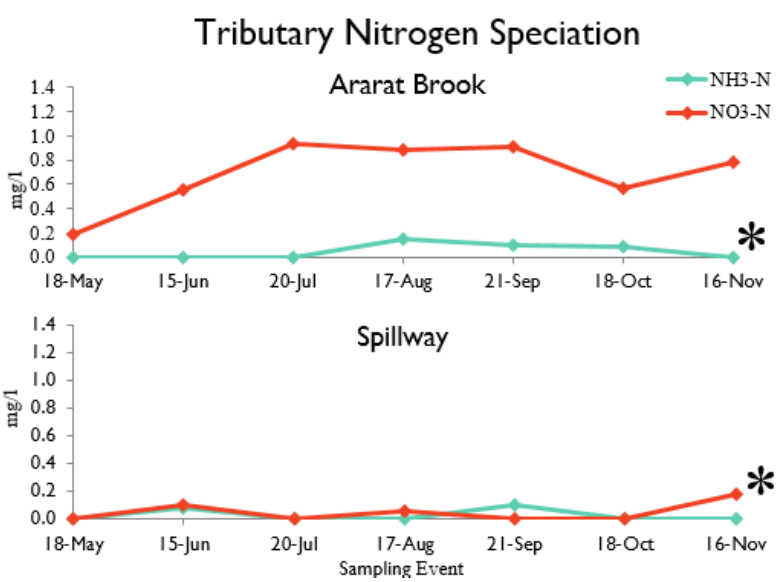

Figure J – *In Ararat Brook, NO_3 concentrations were elevated in comparison to other locations in the city.*

NH_3 concentrations in Ararat Brook were consistently below 0.015 mg/l, and considered to be the "excellent" category (*see Figure J*). NO_3 results, however, were elevated compared to other locations in the city. These nutrients were not found in high concentrations in other locations in the lake nor at the spillway, where all N results are in the "excellent" category.

In Ararat Brook, TP ranged between undetectable and 0.37 mg/l, generally varied between “excellent” and “good”. Ararat Brook has been identified as one of the main sources of phosphorus entering Indian Lake, however, it usually brings the highest concentrations of TP in during short periods of time right after the beginning of storm events. 3 of the 4 highest TP results this year coincided with wet weather events, following this pattern. The Lakes and Ponds Program hopes to address the effects of the increased concentrations of phosphorus entering the lake with the construction of the Alum Dosing Station this spring.

Ongoing Projects

Ararat Brook is the major tributary to Indian Lake, and has many storm drain outfalls that carry stromwater containing phosphorus into Indian Lake. The influx of phosphorus every time it rains is in part why lake-wide aluminum sulfate ("alum") treatments are only temporally effective at reducing lake phosphorus concentration. However, feasibility studies have determined that by applying alum little my little to the mouth of the brook, phosphorus will be immobilized before it enters the lake, effectively reducing the average lake phosphorus concentration while decreasing the total amount of alum used, saving money in the long term. The result would be a reduced likelihood of a cyanobacteria bloom occurring, as well as significantly increased lake water clarity, increasing safety and making the lake more attractive for recreation.

Figure K – Location of proposed alum dosing station off of Shore Drive (left). Geotechnical engineers review the site in September 2021 (right).

In 2021, the project was permitted and the engineering design phase of the project was completed. The property where the station will be constructed was acquired as two separate donations from Bancroft School and the Universalist Church. The project ready to be put out to bid and has a timeline to be constructed by early spring. This summer the Lakes and Ponds Program will calibrate the station and monitor TP in the water, with the goal of eliminating in-lake aluminum sulfate treatments for 2023, while increasing clarity and decreasing the chance of cyanobacteria blooms.

A closer look at Ararat Brook. Ararat Brook is the major tributary to Indian Lake and is also a designated Coldwater Fisheries Resource (CFR), meaning that it is home to several fish species that are known as cold water species, such as certain types of trout. This is special because their presence requires a higher level of water quality than a typical brook. Surveys by MassWildlife have found Ararat Brook to be one of the

most thriving CFRs in the region, which was surprising to many, given the urban environment that it runs through. In 2022, the Lakes and Ponds Program plans on teaming up with MassWildlife and the Greater Worcester Land Trust, which manages land that the brook runs through, to pursue projects that will further promote and protect Ararat Brook, which will ultimately translate into higher quality water for Indian Lake!

Goose Fencing Pilot Project. In 2020, Shore Park Beach was closed for 4 days due to high concentrations of the fecal bacteria indicator, *E. coli*. Further examination of the beach area confirmed that there was an increased presence by geese that were leaving large amounts of droppings on the shore and in the shallow water. In 2021, the Lakes and Ponds Program implemented a pilot project that aimed to reduce the number of beach closures by keeping geese away from the beach in a humane way that was also not inconvenient to beach users. Geese usually enter the beach from the water, and are not good at getting over even low fences. Additionally, they are uncomfortable when there are barriers between the beach and the water, because the water is their escape route from land predators. By erecting a small fence between the shore and water during the evening hours, the use of the beach by the geese was significantly reduced (see *Figure K*). Unfortunately, the use of the fencing was impeded by several factors related to the construction of the fence. In 2022, the Lakes and Ponds Program will improve the construction of the fencing using higher quality materials and make installation easier so as to increase usage during the summer.

Figure L - Goose fencing was developed and installed during off-hours at the Shore Park Beach, inhibiting goose congregation and potentially reducing of the number of closures due to fecal

State of the Lake

In 2021, Indian Lake once again receives an overall rating of “good”, although there have be substantial improvements in several parameters over the previous year. Water temperatures were healthier at the surface and the bottom of the lake, and the goose management plan using fencing appeared to work at reducing bacteria closures at the beaches, although there were still a two days of closures at each beach. Invasive aquatic plants were successfully managed although in reducing the presence of the invasive, habitat was opened to native plants, which then took advantage of the opportunity and increased in

population to nuisance levels. A slow response to this event led to decreased recreational value. Cyanobacteria management had fair results, and although the lake was safe for recreation for all of the swimming season, a late season bloom caused a 14 day closure in mid-late September. 2021 was the first year the lakes and Ponds Program was able to quantify litter in a small portion of the lakefront, and results were good.

Plan for 2022

Water Quality Monitoring at Indian Lake. In 2022, the Lakes and Ponds Program plans to continue to monitor Indian Lake in order to track changes in water quality and implement its cyanobacteria and invasive aquatic plant management plans. In addition to the standard parameters collected every month, one to two rounds of sampling for industrial contaminants will occur, including for parameters which one may expect to find in a post-industrial city, as well as emerging contaminants of concern. These parameters, including heavy metals, PCBs, PFAS, and others, were last sampled at Indian Lake in 2019. At that time, none of the results were of concern. Results will be compared to ensure that there are no new threats to Indian Lake. Additionally, more samples will be taken for cyanobacteria pigment analysis throughout the lake to better understand the formation of cyanobacteria blooms, with the goal of preventing these blooms in the future. This year WCMC data suggested that pigment analysis data may be a high quality indicator of cyanobacteria blooms.

This year, during early August, the Lakes and Ponds Program will carry out another a 24 hour dissolved oxygen study. Previously, results suggested that there have been periods of high lake dissolved oxygen in the hot weeks of the summer, followed by small fish kills. Generally, during the day, there is still a net positive amount of oxygen in the water due to photosynthesis by plants and algae. However, at night, when the sun goes down and photosynthesis stops, oxygen is still required for respiration, though and none is being produced. This leads to a decrease in the amount of oxygen in the water throughout the night, and on really hot nights, when there was less there to begin with, it could deplete it entirely, leading to suffocation of small fish. While current data suggests that this diurnal cycle is occurring in Indian lake on the hottest of days, in the shallowest of water, the Lakes and Ponds Program plans on confirming it next year by taking oxygen readings throughout the night.

An additional sampling plan will be developed and implemented as the Alum Dosing Station comes online. This plan will aim to quantify the concentration of phosphorus before and after the addition of the alum during storm events. The intention is to guide dosing requirements for Ararat Brook to ensure that the project is attaining its intended goal of removing phosphorus before it enters the lake.

Litter Tracking and Management. The Lakes and Ponds Program plans to continue to refine its new Litter Tracking Tool to better understand patterns in litter and trash at Indian Lake. In addition, it will continue to work with its partners, including the Department of Public Works & Parks, and Worcester Green Corps, to use this data to create litter reduction strategies.

Invasive Aquatic Plant Management. Previous to 2021, Indian Lake relied on a 5-6 foot winter water level drawdown to control invasive aquatic plants. Water level drawdowns are a lake management practice used to reduce the density of invasive aquatic plants, specifically Eurasian milfoil, by exposing them to the winter elements. While effective, they are not designed to be annual events, as they cause stress on the entire lake ecosystem. The herbicide treatment of 2021 was highly effective and essentially eradicated this invasive plant, which eliminated the need for the drawdowns to continue. Because eliminating the

drawdown will be a change for residents, in the winter of 2021-2022, a 3 foot drawdown was implemented to allow for this adjustment while reducing stress on the lake ecosystem. During this time, monitoring devices were used to determine the water level throughout the season and compare it to weather events. If there are flood risks above and beyond what would be experienced during spring and summer events, future drawdowns will be adjusted accordingly. However, the current plan is to eliminate the annual drawdown in the winter of 2022-2023.

It is not impossible that the drawdown will occur again in the future. In this case, it will be advertised as soon as possible so that residents can prepare to perform any cleanups that are permitted under the Wetlands Protection Act.

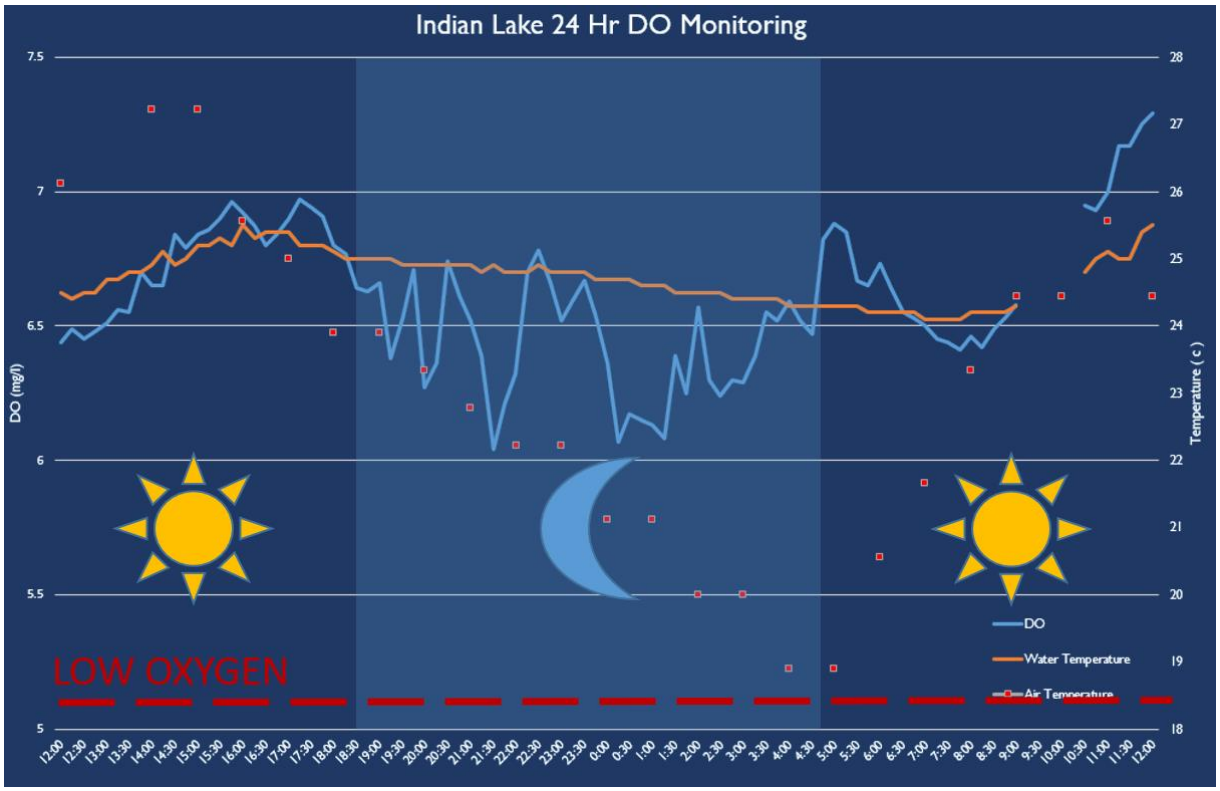

Figure M **–** Results from the 2021 24hr DO study showed a subtle drop during the night but not enough to negatively affect fish populations.