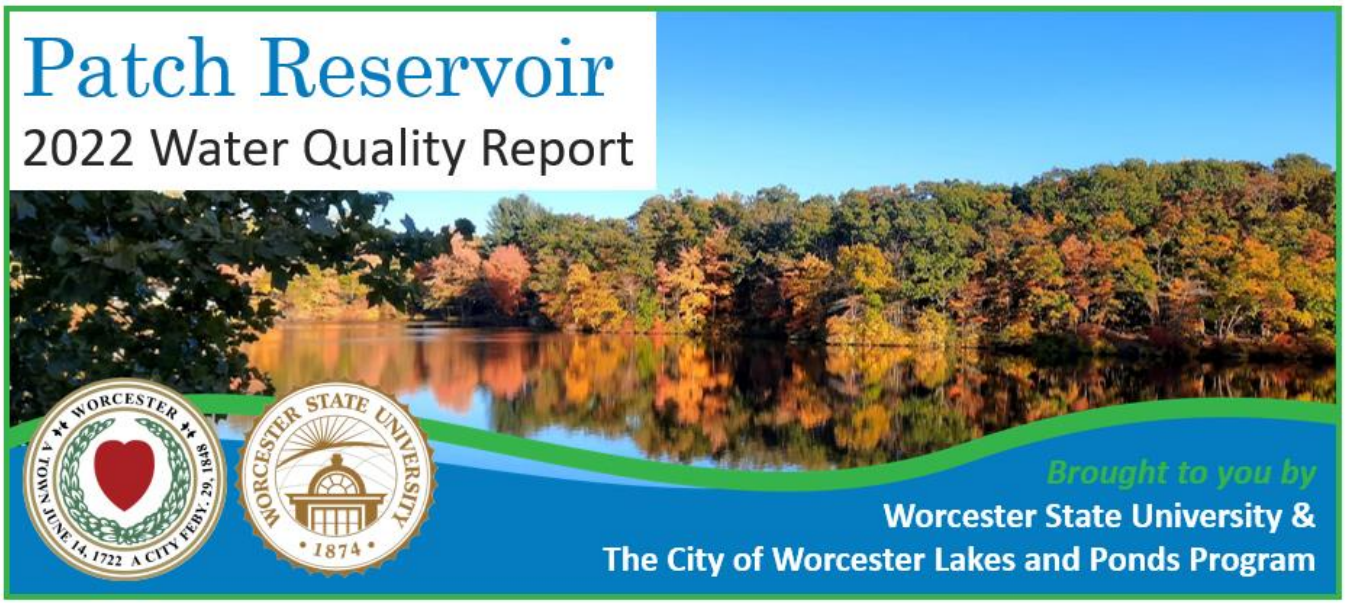


## *Background*

Patch Reservoir is a shallow, 31-acre waterbody located in the Tatnuck neighborhood of western Worcester near Worcester State University (WSU). It is approximately 13 feet deep at the deepest point, which is located in the southern portion of the reservoir. Patch Reservoir was created when Tatnuck Brook was dammed in the late 1800's to supply water to the Patch farm and ice to the city. It is located in the middle of a chain of mill ponds along the Tatnuck Brook, which extends south from Holden. Patch Reservoir is part of the Tatnuck Brook watershed and feeds into Patch Pond and Coes Reservoir.

Patch Reservoir is bordered on the west side by Mill Street, a highly trafficked roadway. Homeowners, the Greater Worcester Land Trust, the City of Worcester, and The Church of Worcester own land around Patch. The public land on the southern and eastern portion of the water body contains walking trails. Patch Reservoir is a recreational resource, serving as a venue for fishing, kayaking or canoeing, and walking. Unlike Coes Reservoir, which is downstream from Patch Reservoir, Patch does not have a public beach or support swimming. However, it does host the new WSU Central Massachusetts Watershed Project, a subdivision of the Aisiku STEM center, and serves as a resource for classes and research for students and faculty at WSU. In 2022, researchers at WSU teamed up with the City of Worcester's Lakes and Ponds Program (L&P) to study Patch Reservoir and Cooks Pond using the Quality Assurance Project Plan (QAPP) developed by L&P to better understand water quality in these locations compared to other waterbodies in the city.

## *Water Quality Summary*

In 2022, overall water Quality in Patch Reservoir was rated "Fair". As an urban lake, Patch Reservoir endures many of the pressures of the city. Prior to monitoring in 2022, the pond was known to have periodic cyanobacteria blooms as well as the invasive aquatic plants Water Chestnut (*Trapa natans)* and Eurasian Milfoil (*Myriophyllum spicatum)*. In 2022, monitoring by WSU confirmed the suspicion that the lake suffers from higher than ideal concentrations of phosphorus as well as high temperatures in the summer months. Combined, these factors may be contributing to increased growth of cyanobacteria and

reduced water clarity. Unfortunately, as 2022 was an unusually warm year and there is no historic cyanobacteria data, it is not possible to know if these results are indicative of typical conditions.

## Management Summary

Patch Reservoir has been formally managed for cyanobacteria and invasive aquatic plants since 2018 by the community group, Friends of Patch Reservoir, with support from the City of Worcester Lakes and Ponds Program. Monitoring data from the Worcester Cyanobacteria Monitoring Collaborative, indicated there was elevated risk of cyanobacteria blooms, prompting two treatments of algaecide (copper sulfate) to Patch Reservoir in July of 2022. These treatments kept cyanobacteria densities safe for recreation and wildlife. To address the invasive plant Water Chestnut, contractors applied two rounds of the herbicide Clearcast on 12-Jul and 28-Jul. The treatment was successful in reducing the density of the invasive plant during the season. Unfortunately, due to its unique reproductive strategy, it may be many more years before the Water Chestnut population will be completely manageable.

***Figure 1 –*** *WSU Students, faculty, and staff involved in the Tatnuck Brook water quality project field and lab analyses.*


***Figure 2*** *- Patch Reservoir map and approximate sampling locations.*

## Sampling Analysis and Overview

In 2022, Patch Reservoir was visited twice monthly from May through October and sampled at three locations: the major aboveground tributary, Tatnuck Brook; the deepest part of the reservoir (the southern end of which is approximately 13 feet deep); and the outlet at the spillway located in the southern part of the reservoir (see *Figure 2*). At the in-lake locations, probe measurements and water samples were collected one 1 foot below the surface of the water ("surface"), and two 2 feet off of the bottom of the lake ("bottom"). Parameters evaluated included: Secchi transparency, temperature, dissolved oxygen (DO), pH, total phosphorus (TP), and total dissolved phosphorus (TDP). Samples analyzed for total suspended solids (TSS), ammonia ($NH_3$), and nitrate ($NO_3$) were collected on a monthly basis. Altogether, there were 12 sampling events. For 5 of these events, there was no rainfall 24 hours prior to data collection. However, on 7-Jul, there were 1.47 inches of rain in the 24 hours prior to sampling, on 23-

Sep there were 0.44 inches of rain, and on 6-Oct there were 0.26 inches of rain. These days are categorized as "wet weather" sampling events and are marked with the symbol on the figures.

In addition to monitoring by WSU, volunteers from the Worcester Cyanobacteria Monitoring Collaborative took samples for phycocyanin and cyanobacteria abundance on 6-Jun, 5-Jul, 1-Aug, 12-Sep, and 12-Sep.

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.

## Quality Assurance/Quality Control

Worcester State University and The Lakes and Ponds Program strive to have a robust data set. WSU therefore used Quality Assurance/Quality Control (QAQC) checks to ensure that the data are representative of local conditions and meet precision and accuracy standards. Review of QAQC check results identifies data that need to be flagged and/or censored before they are shared and can highlight issues that affect data quality. When data failed to meet acceptable criteria for these checks, they were marked with a red flag as approaching the QAQC standard. In this report, we have opted not to censor any data; however, data that fell outside of the range for the QAQC check has been marked with a ⊗ and should be treated with caution. For more information on WSU's data quality, please contact laura.reynolds@worcester.edu.

## Water Clarity

Water clarity is a measure of the transparency of water. Algae, microscopic organisms, eroded particles, and re-suspended bottom sediments are factors that interfere with light penetration and reduce water transparency. Clear water allows sunlight to penetrate the depths of a waterbody, supporting growth of aquatic plants, which provide food, shelter, and oxygen to aquatic organisms. Clear water is also pleasant to the eye and safer for recreational contact. Turbid water, or water filled with particles, absorbs more heat from sunlight. This reduces the water's capacity to hold oxygen, creating favorable conditions for algal and cyanobacteria blooms, which further reduce clarity. 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

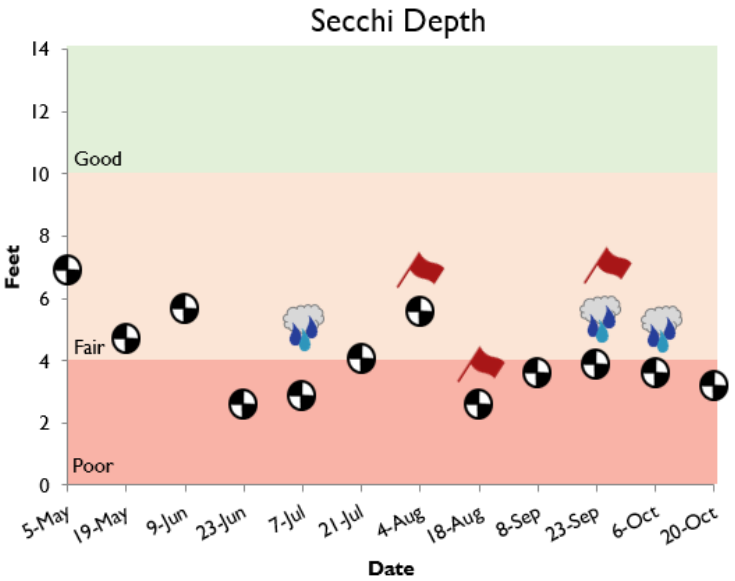


***Figure 3 –*** *Secchi depth oscillated between about three and seven feet throughout the sampling season. Secchi depth began in the "Fair" category in May and ended the season in the "Poor" category.*

visible. Secchi readings were collected on each lake visit by WSU. TSS is a measure of the dry weight of suspended particles in a given amount of water. TSS samples were taken monthly and submitted to a lab for analysis.

***Water Clarity at Patch Reservoir.*** At Patch Reservoir, Secchi depth was considered "Poor" and "Fair" throughout the season, with a maximum clarity of 6.9 feet in early May, and a minimum of 2.6 feet on 23-Jun and 18-Aug (see *Figure 3)*. After May, Secchi depth readings generally stayed in range considered "Poor". Overall, water clarity at Patch Reservoir was rated as "Poor" in 2022.

## *Temperature*

Water temperature is important for understanding both the biology and chemistry of aquatic ecosystems. Because many organisms prefer to live in a narrow temperature range, understanding temperature across the area and depth of a water body is essential. Temperature is also a determining factor in the speed of chemical reactions and the ability of water to hold oxygen. As temperature increases, water can hold less dissolved oxygen. Temperature dynamics in lakes can also determine the level of mixing experienced throughout the water body, affecting the distribution of oxygen, nutrients, and organic matter throughout the lake. Temperature was measured using a temperature sensor on a handheld probe at the water's surface, and two feet from the bottom at the in-lake locations during every sampling event.

***Temperature at Patch Reservoir.*** Surface temperature in Patch Reservoir ranged between 12.7°C and 27.8°C with the maximum recorded on 21-Jul (*see Figure 4)*. Most readings were in the range considered "Excellent", although the highest recorded temperatures were considered "Good" and "Fair". Bottom temperatures ranged between 12.0°C and 23.0°C with the maximum recorded on 18-Aug. Bottom temperatures were consistently below 23.8°C, or in the range considered "Excellent". Overall, temperatures at Patch Reservoir followed expected seasonal variation, increasing in the beginning of the season until reaching a mid-season peak and steadily declining. Due to the high recorded surface temperatures during the summer, temperature at Patch Reservoir was rated "Good" in 2022.

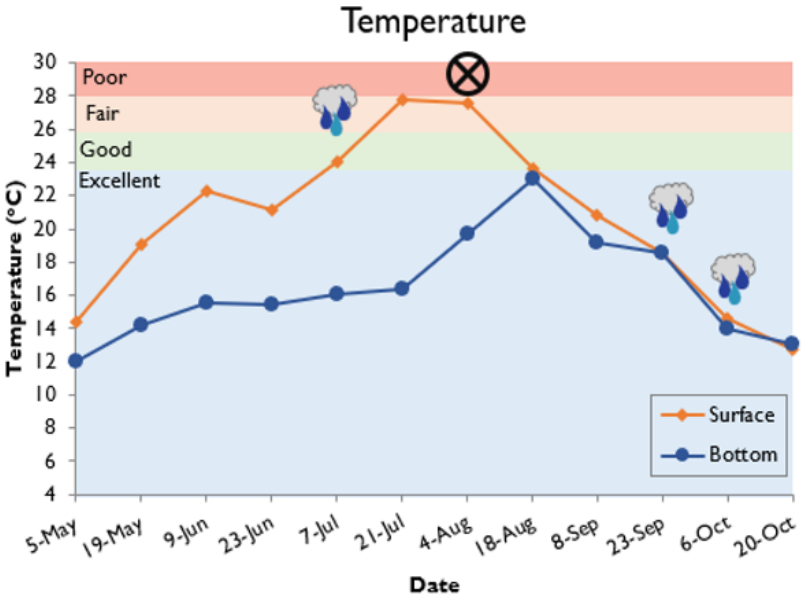


***Figure 4 –*** *Temperature stayed in the "Excellent" category for the majority of the season at the surface and bottom of Patch Reservoir, although at the surface it increased close to the "Poor" category during the hottest part of the summer.*

## Dissolved Oxygen

Oxygen dissolved in water is essential to aquatic life just as it is to life on land. Dissolved oxygen (DO) is a highly variable parameter that is controlled by many factors, including temperature, pressure, aeration, diffusion, rate of photosynthesis, rate of respiration and more. When water temperature rises, water can hold less dissolved oxygen, potentially causing stress to aquatic organisms. Thermal stratification, which is layering in the water column based on temperature, can also create a barrier to waterbody mixing, creating areas with depleted DO in some deeper portions of waterbodies. Increased algal growth followed by excessive decomposition of organic material can also lead to low oxygen conditions, potentially causing fish kills. 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 during every sampling event.

### *Dissolved Oxygen at Patch Reservoir.*

Surface DO at Patch Reservoir ranged between 4.86 mg/l and 11.2 mg/l (*see Figure 5*) and was rated as "Excellent" for most of the season, though it had a steady downward trend. Bottom DO declined throughout early May and remained below 4 mg/l until 23-Sep, indicating hypoxic, or low-oxygen, conditions for much of the sampling season. Due to the shallow nature of the waterbody, hypoxic conditions for this long may represent a situation that is stressful to fish and wildlife. For this reason, DO at Patch Reservoir in 2022 was rated "Fair".

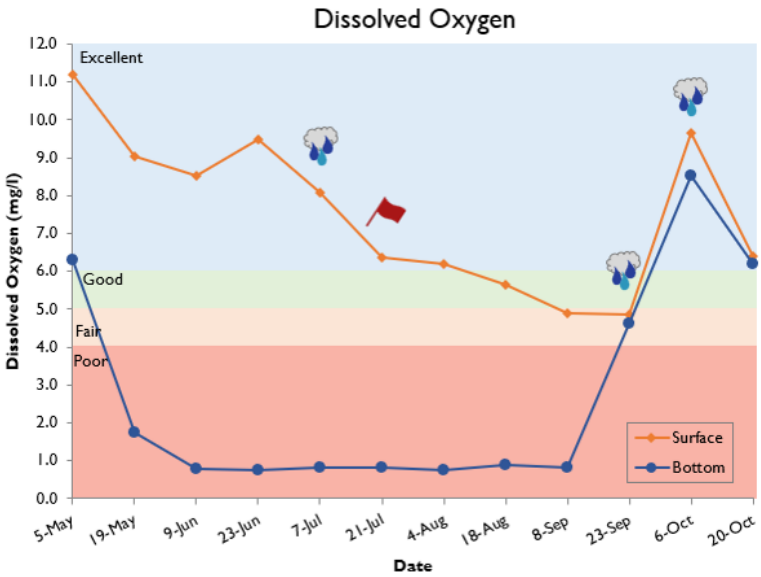


***Figure 5 –*** *Surface DO decreased throughout the season until rebounding in October. Bottom readings were very low between May and September.*

## pH

pH is the concentration of hydrogen ions (H+) in a solution. The more H+ ions that are present, the more acidic the solution. On a scale of 0-14 units, 7 is a neutral pH. As pH increases from 7, the solution is more basic, and as pH decreases from 7, it becomes more acidic. In aquatic ecosystems, pH affects most chemical and biological processes including species distribution, growth rate, reproductive success, and nutrient dynamics in lakes. A high pH can promote chemical reactions that release phosphorus from lake sediments. Healthy lakes in this area have a pH between 6.5 and 8.5. pH was measured 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 Patch Reservoir.*** At Patch Reservoir in 2022, pH ranged between 5.5 and 7.7 with surface readings consistently higher than bottom readings (see *Figure 6*). All but three readings fell within a range considered healthy for lakes in this region. Please note that QAQC flags and missing data were common due to equipment malfunction, and therefore should be treated with caution.

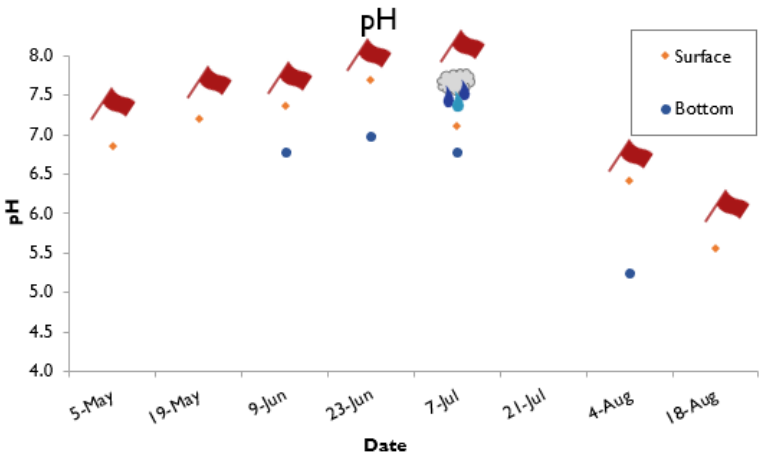


***Figure 6 –*** *As expected, pH was generally lower at the bottom vs surface of the reservoir; however, all results were in the expected range and safe range.*

## Nutrients

Nutrients, primarily nitrogen (N) and phosphorus (P), are food sources for aquatic plants and algae. Although plants and algae are the base of aquatic food chains, and necessary for a healthy lake ecosystem, an overabundance of nutrients can lead to issues such as harmful algal blooms and excessive plant growth. Common nutrient inputs to urban lakes and ponds include fertilizers, pet and goose waste, illicit sewer connections to the stormwater system, and runoff that flows over land into the stormwater 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. To examine the nutrients present in program lakes, WSU collects samples for several compounds and submits them to an external lab for analysis. To measure N, samples are collected for nitrate ($NO_3$) and ammonia ($NH_3$) at all sites monthly. To measure P, samples were collected for total phosphorus (TP) twice a month at all sites, and total dissolved phosphorus (TDP) twice a month at all bottom sites. TDP was analyzed to understand how much P is dissolved in the water and available for use by aquatic organisms.

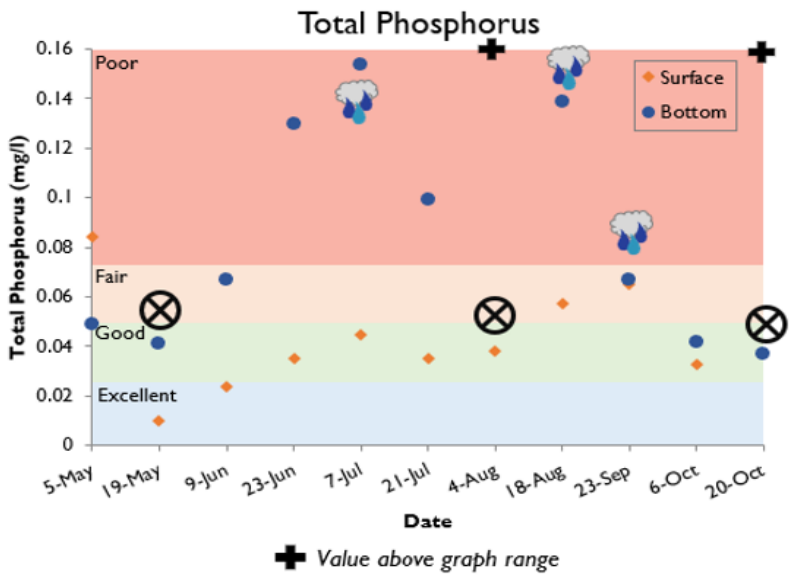


***Figure 7 –*** *Total phosphorous ranged from the "Excellent" to "Poor" categories at the surface site but ranged from "Good" to "Poor" at the bottom. Two outliers occurred in the data set which are indicated by the plus sign. The surface result on 20-Oct was 0.357 mg/l, which is higher than any value captured within the sampling season.*

***Nutrients at Patch Reservoir.*** TP at the surface of Patch Reservoir was widely variable, ranging between 0.010 mg/l and 0.084mg/l (see *Figure 7*). Concentrations generally

increased throughout the season, with most results falling into the range considered "Good". TP concentrations at the bottom of the reservoir were generally much higher, with many above 0.075 mg/l or in the category considered "Poor". The increasing TP concentrations as the season went on may have put Patch Reservoir at higher risk for cyanobacteria blooms. Overall TP at Patch Reservoir in 2022 was rated "Fair".

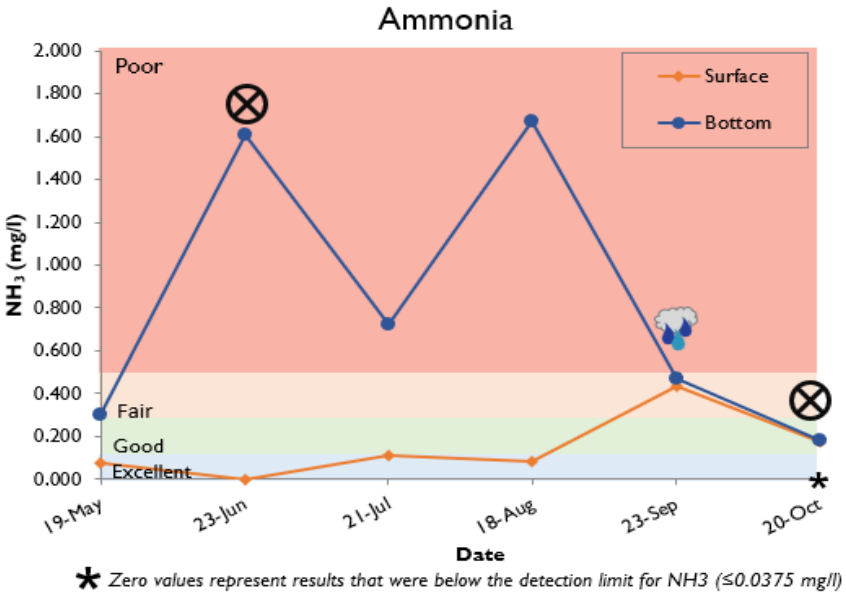


***Figure 8 –*** *Ammonia ($NH_3$) concentrations ranged from the "Excellent" to "Fair" categories at the surface site but ranged from "Good" to "Poor" at the bottom. Several $NH_3$ results were below the detection limit. There were elevated results at the bottom as well as the surface towards the end of the season. Elevated levels on 23-Jun should be reviewed with caution due to external lab errors.*

Generally, $NO_3$ concentrations were low at all sites, with all results below 1 mg/l, which is indicative of an unpolluted waterbody. Surface results for $NH_3$ were also in the "Excellent" category for most of the season and only had one result at the end of the season considered "Fair" (see *Figure 8*). At the bottom of the lake, $NH_3$ was higher, with several results above 0.500 mg/l or in the category considered "Poor". Elevated $NH_3$ concentrations may be the result of previously disturbed sediments contaminating the water samples. Fluctuations between high and low $NH_3$ concentrations from May through September may be evidence of cyanobacteria blooms, as cyanobacteria may be utilizing it to reproduce (decreased concentration periods) and treatments were applied to the lake to combat the blooms (higher concentration periods), however more information is necessary. Overall, $NO_3$ and $NH_3$ at Patch Reservoir were rated "Fair" in 2022.

## *Cyanobacteria*

Cyanobacteria are naturally occurring microorganisms in lakes and ponds. Using sunlight and nutrients such as N and P, cyanobacteria behave similarly to plants and algae. While normal at low densities in healthy ecosystems, under the right conditions, some species of cyanobacteria can reproduce quickly causing potentially harmful blooms. Cyanobacteria blooms, in addition to being unsightly and smelly, can produce toxins that are harmful to humans and pets. Blooms also have the potential to create anoxic conditions that can cause fish kills.

To understand the abundance of cyanobacteria and make decisions regarding lake management and safe access, data collected by the Worcester Cyanobacteria Monitoring Collaborative (WCMC) are utilized to measure cyanobacteria indicators and estimate toxin exposure risk. The WCMC is a group of community science volunteers that collect water quality samples twice monthly between May and October at 24

waterbodies in and around Worcester, including Bell Pond. Parameters examined include phycocyanin and the relative abundance of cyanobacteria taxa. Like chlorophyll, the pigment phycocyanin is used by cyanobacteria to harness the sun's energy, converting carbon dioxide to sugars for growth and reproduction. Because phycocyanin is unique to cyanobacteria, it can be used as an indicator of cyanobacteria's relative abundance in a waterbody. Cyanobacteria taxa and their relative density helps determine what toxins may be present. The WCMC is also able to determine relative density of cyanobacteria genera in samples using a high-powered microscope. Using both phycocyanin and comparative cyanobacteria density the WCMC can begin to assign bloom risk at each participating waterbody. For more information on the WCMC and their results, visit WorcesterMA.gov/WCMC.

***Cyanobacteria at Patch Reservoir.*** Phycocyanin was not detected during the first WCMC sampling of the season, indicating small cyanobacteria population size (see *Figure 9*). However, on 5-Jul, phycocyanin concentration was 353 ug/l, well over the level indicating high bloom risk. Due to these conditions, algaecide treatments (Copper Sulfate) were applied on 12-Jul and 28-Jul. On 1-Aug, Phycocyanin concentration was again below the level indicating boom conditions at 17 ug/l, likely due to the treatments. Phycocyanin results continued to oscillate, increasing from August to September, again indicating high bloom risk. Observed cyanobacteria genera include, *Aphanizomenon*, *Dolichospermum*, and *Microcystis* debris. Cyanobacteria were visually present during all water quality sampling events during the fall. Previously, one treatment was enough to keep densities low at Patch for the rest of the season. However, as the 2022 season progressed, two treatments were applied to try to combat any potential blooms. Even after two treatments, the amount of cyanobacteria continued to rebound. It should be noted that out of the 11 WCMC sampling days, only 4 were carried out for Patch Reservoir.

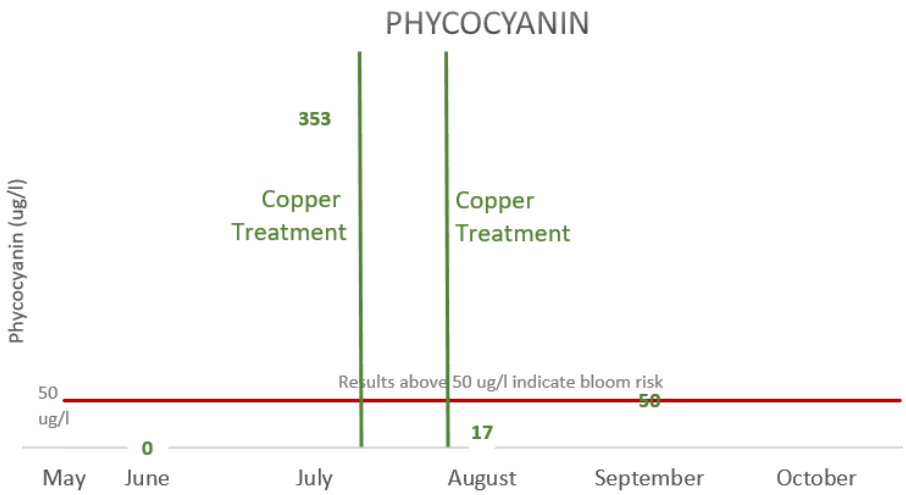


***Figure 9 –*** *Phycocyanin concentration fluctuated throughout the season, rising above the level indicating bloom risk in July, falling after two copper sulfate treatments, and rising again to the level indicating bloom risk.*

## *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 were measured at the major natural tributaries and outlets of the lake.

***Tributaries at Patch Reservoir.*** At Patch Reservoir, the major natural tributary is Tatnuck Brook, which enters the pond from the north. The major outlet of the reservoir is the spillway, located on the southern end of the impoundment. Tatnuck Brook is considered to be a Coldwater Fish Resource (CFR), which means that it is a stream that can hold reproducing cold water fish such as trout. Tatnuck Brook, therefore, has higher standards for temperature than many local urban waterbodies. Over the 2022 sampling season, the brook had a maximum temperature of 22.7°C degrees on 21-Jul and was in what is considered the "Fair" temperature range for 2 of the 12 sampling events though mostly it fell into the "Good" or "Excellent" categories (see *Figure 10*). As water from Tatnuck Brook enters Patch Reservoir, it slows down and is more exposed to the sun and air, warming it up, especially within the small marsh environment where the brook enters the reservoir. On average, the water leaving the Patch Reservoir spillway was 3.9 degrees higher than the water that enters the reservoir. This resulted in four of the sampling events in the summer months to have temperature readings in the "Poor" category for a CFR. These high temperatures may be stressful for cold-water fish species.

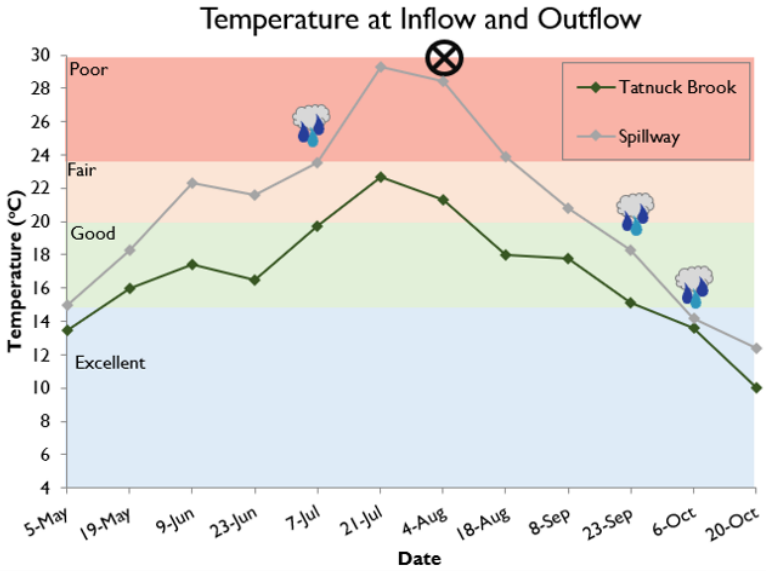


***Figure 10 –*** *Water temperature at the Patch Reservoir spillway was on average 3.9 degrees higher than when it entered the impoundment.*

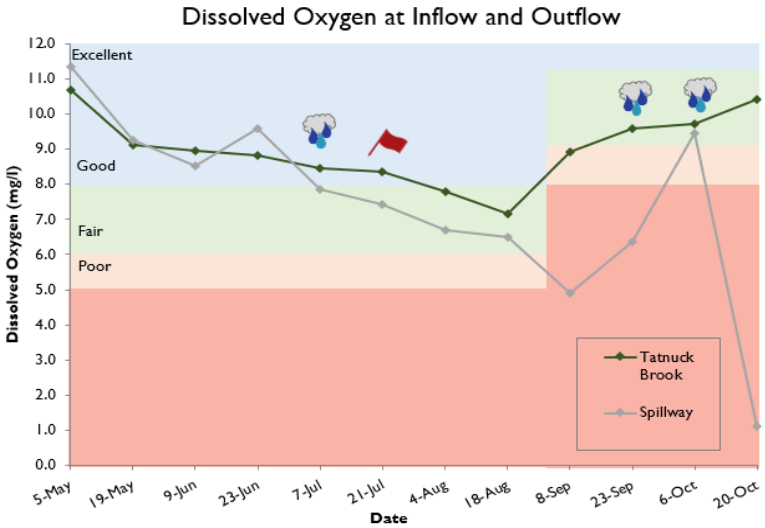


***Figure 11 –*** *DO in Tatnuck Brook and at the Patch Reservoir spillway decreased throughout the season until early fall.*

In Tatnuck Brook, until the end of the sampling season, DO concentrations generally stayed above 6 mg/l, or in the categories considered "Excellent" and "Good" (see *Figure 11*). DO at the spillway was lower than the tributary for most of the season. By the end of the season, concentrations at the spillway decreased into the category considered "Poor" for multiple sampling events.

TP concentrations in Tatnuck Brook were widely variable, ranging between 0.016 and 0.333 although most results were in the range considered "Good" (see *Figure 12*). Two results were considerably higher than the rest, 0.209 mg/l on 9-Jun, and 0.333 mg/l on 23-Sep. Concentrations at the spillway were less predictable and generally higher, ranging between 0.029 mg/l and 0.127 mg/l, with most results in the categories considered "Fair" and "Poor".

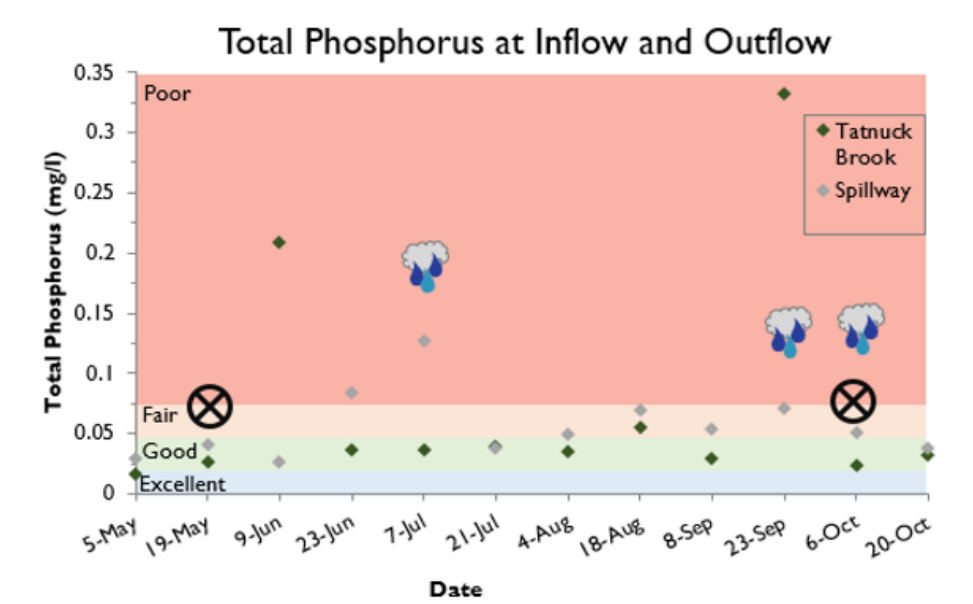


***Figure 12 –*** *Total phosphorus at Tatnuck Brook ranged between the" Excellent" and "Poor" categories between the "Good" and "Poor" categories at the Spillway..*

## *Invasive Aquatic Plants and Animals*

Plants and animals are vital parts of any lake ecosystem. 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. 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 to the region and outcompetes local flora and fauna. The absence of natural constraints, like predators or environmental limitations, allows invasive plants and animals to reproduce at a rapid rate. When invasive aquatic plants and animals become too numerous or dominant, they can overtake all available space, disrupting local ecosystems and making recreation more difficult. Invasive organisms can arrive by hitching a ride on boats, pets, or boots to get to a new location. Some are released with good intentions as a beautiful addition to a landscape or sport fishing opportunity. Professional

***Figure 13 –*** *Invasive Water Chestnut in the northern portion of Patch Reservoir.*

surveys and visual inspections from residents are used to make management decisions regarding invasive species.

***Invasive Aquatic Plants at Patch Reservoir.*** Patch Reservoir is currently managed for several invasive aquatic plants: Water Chestnut (*Trapa natans*), Fanwort (*Cabomba caroliniana*), Eurasian Mifoil (*Myriophyllum spicatum*), and Big Leaved Pondweed (*Potamogeton amplifolius)*. With the support of the City of Worcester, the Friends of Patch Reservoir manages the invasive plant population (see *Figure 13*). All treatments are approved by the Worcester Conservation Commission and applied by licensed professionals.

Previously, the invasive aquatic plant, Water Chestnut, which is found primarily in the northern portion of the reservoir, was managed by volunteer hand-pulls organized by the Friends of Patch Reservoir. Unfortunately, the size of the infestation and geography of the reservoir makes it difficult to eradicate all plants with this method. Since 2019, the contact herbicide Imazomox (trade name Clearcast) has been applied each year to Patch Reservoir. A different spraying technique was utilized in July of 2022 and was found to be the most effective treatment of Patch since 2019. Unfortunately, the reproductive strategy of the Water Chestnut means that it will need to continue to be managed for many years before the infestation is eradicated. In 2018, a chemical was applied to treat the Fanwort and Milfoil. This treatment was effective for several years, but now both plants are starting to re-invade Patch.

In 2022, Flumioxazin (trade name: Clearcast) and Flumiguard SC were applied to Patch 12-Jul and 28-Jul of 2022. The post-treatment survey by Solitude concluded that the treatment was successful in reducing the density of Water Chestnut, but two small patches remained. While invasive aquatic plants have historically been an issue at Patch Reservoir, the adaptable management plan has been effective at controlling species such as Water Chestnut from taking over. Managing the Water Chestnut population at Patch is a long-term project with no potential end date determined.

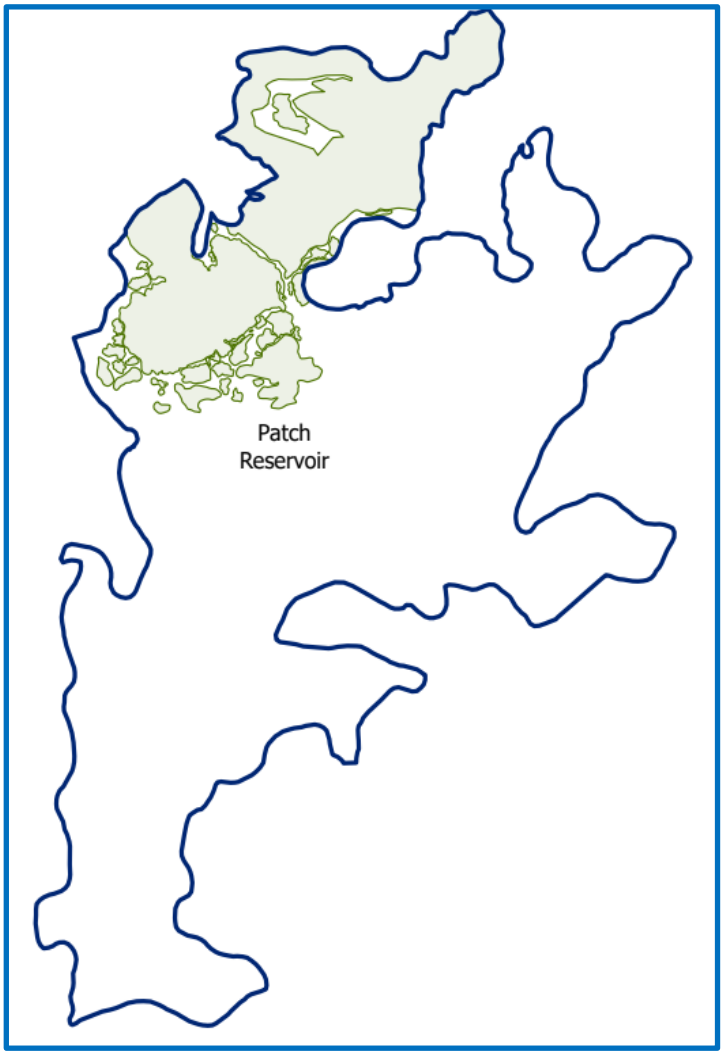


***Figure 14 –*** *Invasive aquatic plant coverage at Patch Reservoir in 2021, mapped by Lauren Vigneault and Dr. William Hansen.*

## *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 lake goers and hikers. Finally, sharp objects like syringes, broken metal, or glass can pose a threat to swimmers and other visitors.

***Figure 15 –*** *Litter collected throughout the sampling season and during the "Zap the Blackstone" clean-up event on 27-Aug 2022.*

***Litter at Patch Reservoir.*** Litter was collected throughout the sampling season whenever it was present during a sampling event. Litter was also collected from the Tatnuck Brook upstream of Patch Reservoir during the Blackstone Zap 50 event on 27-Aug 2022. This clean-up event spanned the Blackstone Watershed and was led around Patch Reservoir by the Friends of Patch Reservoir. Together, at least 10 bags of trash were collected; items included rubber ducks and many golf balls. Several items were too large or heavy to be thrown into a garbage bag, such as a basketball hoop and two cash register boxes.

## *Ongoing Projects*

***Independent Research Projects.*** Since 2021, students and professors at Worcester State University have been utilizing Patch Reservoir as a learning tool. Many students go to the Patch Reservoir Research Facility during science laboratories to learn about different lake properties, aquatic plants, and water quality issues on Patch. Several students have conducted independent research projects on Patch as well. Students have analyzed sediment cores to link different sediment layers to historical events and dates. They have studied sediment grain size in relation to invasive Water Chestnut cover. Students have surveyed fish and macroinvertebrate populations and conducted habitat surveys of Patch Reservoir's shorelines. Students have also utilized GIS to define land use in the watershed and map the historical cover of Water Chestnut.

***Tatnuck Brook Project.*** Over the course of 2022, a team of WSU students, faculty, and staff have worked on the Tatnuck Brook Project, a project funded by the WSU Aisiku Interdisciplinary STEM Research Team Initiative to answer the research question "How does urbanization impact water quality in urban reservoirs?". During the summer months, the team collected water quality data and surveyed

macroinvertebrates in and around Patch Reservoir and Cooks Pond in collaboration with concurrent sampling by the City of Worcester downstream. During the fall, the team split in two so that water quality monitoring and data analysis could be carried out while macroinvertebrate samples were being analyzed. Major contributors to the project included: Stephen Humphrey, Caitlin Dellert, Zachary Trudell, and Kari Mickunas. Additional students are processing the macroinvertebrates, including: Brianna Chang and Katie Steeves; and helping monitor water quality, including Emily Maynard and Alyssa Bishop. WSU faculty members Dr. Allison Dunn, Dr. Laura Reynolds, Dr. William Hansen, Dr. Meghna Dilip, Dr. Diana Sharpe, and Alyssa Hammond helped guide students and oversaw the project.

## *State of the Lake*

In 2022, the State of the Lake of Patch Reservoir is "Fair". Invasive aquatic plants are being managed, but due to the unique reproductive strategy of Water Chestnut, the infestation will continue to return for years to come and will require constant vigilance. Cyanobacteria management has been reactive instead of proactive, and blooms are still occurring throughout the summer. Monitoring by WSU this summer found nutrient concentrations to be "Fair", which, when combined with commonly high-water temperatures, could be contributing to lower water clarity and poor oxygen concentrations on the bottom of the waterbody. Unfortunately, because 2022 was an unusually hot and dry year, it is not possible to know if these conditions are typical or exceptional in Patch Reservoir.

## *Plan for 2023*

### *Water Quality Monitoring*

L&P hopes to continue to collaborate with WSU to support a modified version of the Tatnuck Brook Project as part of The Central Massachusetts Watershed Project, a subdivision of the WSU AIsiku STEM center. The WCMC will also continue to collect samples from Patch Reservoir and aspires to work more collaboratively with Friends of Patch Reservoir so that their data can support more proactive management of cyanobacteria. WSU will continue to collect litter as it is seen when sampling and participate in community clean up events.

### *Lake Management*

Improved management of Patch Reservoir is a priority of the City of Worcester for local residents, but also because of the hydrological connection to Coes Reservoir, which has a public beach.

*Invasive Aquatic Plant Management.* In 2023 the community group, Friends of Patch Reservoir, with help from the Lakes and Ponds Program, will continue to administer the invasive aquatic plant management plan similar to how it was enacted in 2022. Herbicide use will continue, as patches of fanwort and milfoil began to resurface in 2022. As the management goals are currently not being met, they will be updated to better serve the community. Currently, there is no official protocol for alerting the public to the occurrence

***Figure 16** - Contractors applying the herbicide Clearcast to Invasive Water Chestnut at Patch Reservoir.*

of a cyanobacteria bloom in the lake, creating the potential for a public health threat to lake goers. To combat these issue Worcester State University, the Friends of Patch Reservoir, and the Lakes and Ponds Program will hold a meeting to discuss what can be improved going forward.

### *Education and Outreach*

*Presentations of Student Research.* This project has given several opportunities for students to present their research at academic conferences. Students will present at the Massachusetts Undergraduate Research Conference in Late April, the Worcester State Celebration of Scholarship & Creativity on 26-Apr 2023 (which is open to the public), and to the Tatnuck Brook Watershed Association.

*Family Aquatic Science Day.* As part of the 2021 Blue Space Angler Event Series, the Tatnuck Brook Watershed Association (TBWA) hosted an event at Coes Reservoir called the Family Aquatic Science Day (*see Figure 17*). In this event participants of all ages discovered the aquatic environment through a series of booths where they took measurements with water quality meters, learned about aquatic macroinvertebrates, looked at cyanobacteria under a microscope, explored a 3-D replica of a watershed, and collected fish with a large seine net.

***Figure 17–****Attendees and volunteers at the 2021 Family Aquatic Science Day collect fish and other aquatic organisms in a seine net.*

The Lakes and Ponds Program plans on supporting the TBWA in holding the event again in 2023 and increasing participation from local young people. This will serve as an opportunity to continue to raise awareness about factors that lead to cyanobacteria blooms and how community members can support L&P's efforts to mitigate the ecological and public health concerns they create.