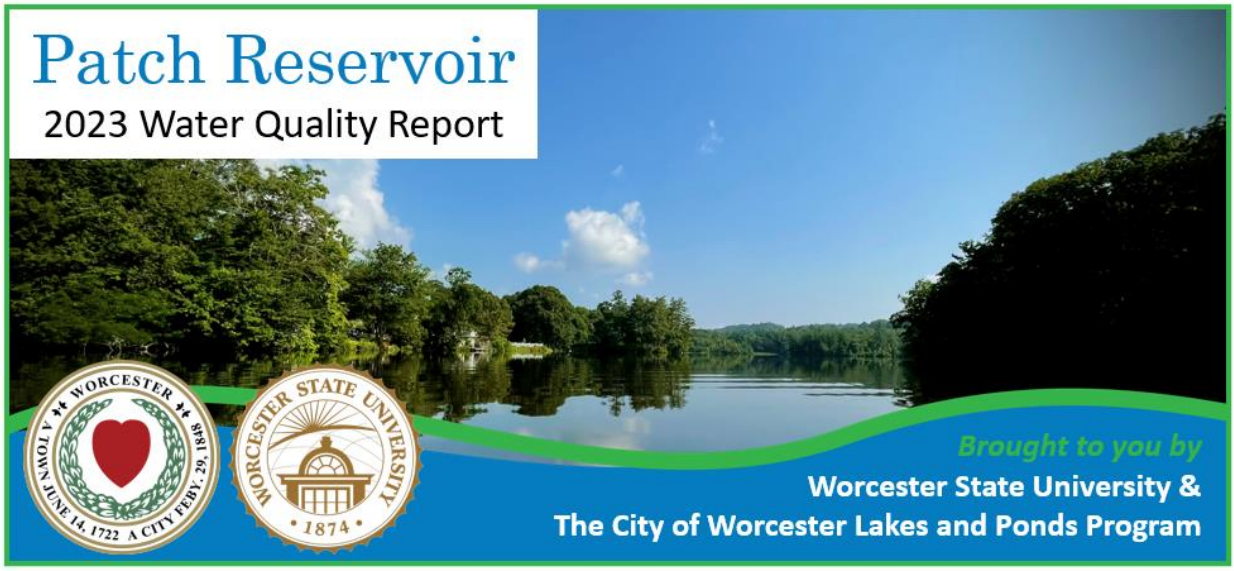

Summary

The following report is presented by the City of Worcester Department of Sustainability and Resilience (DSR), Lakes and Ponds Program (L&P), in collaboration with Worcester State University (WSU). It details water quality monitoring results, management activities and outreach efforts on Patch Reservoir in 2023. This report is the product of a collaboration between L&P and WSU called the "Tatnuck Brook Project" in which researchers and students from WSU utilized L&P methodologies to monitor parts of the Tatnuck Brook Watershed in which L&P has not had resources to fully examine. This allows us to directly compare results between waterbodies and better understand dynamics throughout the watershed to create more informed management plans in future years. The "State of the Lake" will be rated "Excellent", "Good", "Fair", or "Poor" based on the results' implications on water quality and recreational value.

Patch Reservoir feels many of the pressures of the city facing challenges including lake closures due to cyanobacteria, invasive aquatic plants, and low water clarity. However, management by community groups has led to water quality that supports a healthy ecosystem and a wide variety of recreational opportunities. ***In 2023, Patch Reservoir received a score of "Fair/Good".*** Continue reading to learn more about this rating and water quality monitoring results.

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 an excellent recreational resource, serving as a venue for fishing, paddling, 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. Since 2022, researchers at WSU have 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.

Figure 1 *– WSU Students, faculty, and staff collected and analyzed data for the Tatnuck Brook water quality project.*

As an urban waterbody, 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 Patch 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.

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 (WCMC) indicated an elevated risk of cyanobacteria blooms, prompting two treatments of algaecide (copper sulfate) to Patch Reservoir in July 2023. These treatments kept cyanobacteria densities safe for recreation and wildlife. To address the invasive water chestnut and milfoil, contractors applied two rounds of the herbicides Clearcast, Flumigard SC, and Tribune, as well as copper sulfate to treat the cyanobacteria, on 12-Jul and 27-Jul. A post treatment survey took place on 22-Aug which showed that 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 is completely managed.

Sampling Analysis and Overview

Sampling from multiple locations within a waterbody and its watershed leads to better understanding of the water that enters the reservoir, how it is transformed within, and the water leaving the reservoir. To account for these changes over space and time, samples are taken at sites located in tributaries, at the surface and bottom of mid-lake sites, and the outlet.

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 insight into where certain impairments in the lake originate. Outlets are the major exits for water in the lake. Most L&P program water quality parameters are measured at the major natural tributaries and outlets of the lakes.

In 2023, Patch Reservoir was generally 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), conductivity, and total

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

phosphorus (TP). Altogether, there were 15 total sampling events, and 9 of these events sampled the Patch Reservoir in-lake site. For all 9 lake sampling events, there was no rainfall 24 hours prior to data collection.

In addition to monitoring by WSU, volunteers from the Worcester Cyanobacteria Monitoring Collaborative took samples for phycocyanin and cyanobacteria abundance on 29-April, 15-May, 27-May, 12-June, 24-June, 10-July, 22-July, 7-Aug, 19-Aug, 5-Sept, 16-Sept, 2-Oct, 14-Oct, and 30-Oct.

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, flagged data should be treated with caution. For more information on WSU's data quality, please contact Laura Reynolds, lreynolds2@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. Turbidity is a measurement of how much suspended particles in water interfere with light penetration. Turbid water 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 using a turbidimeter. 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 were collected on each lake visit by WSU. A turbidimeter was used to measure the turbidity at the surface. Turbidity is measured in Nephelometric Turbidity Units (NTUs). To measure turbidity, a small sample of water was collected in a vial and placed in the turbidimeter to be measured.

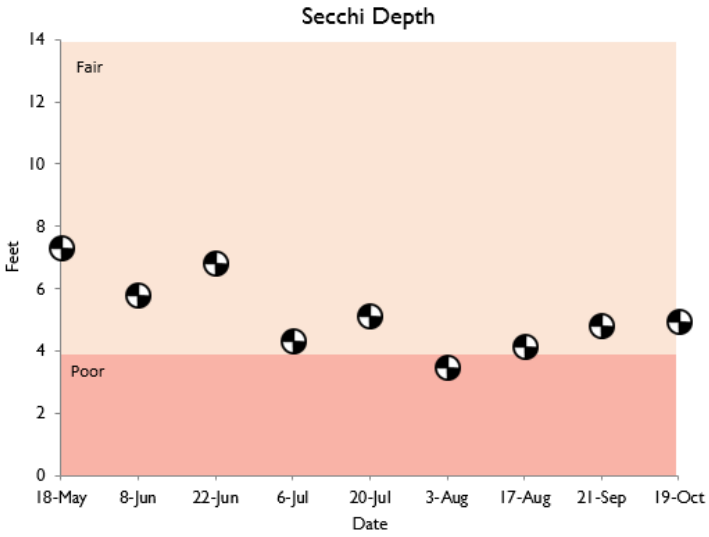

Figure 3 – *Secchi depth oscillated between about three and seven feet throughout the sampling season. Secchi depth began in the "Fair" category in May, dipped into the "Poor" category in late summer, and then rose again into the "Fair" category in the fall.*

Water Clarity at Patch Reservoir. At Patch Reservoir, Secchi depth was considered "Poor" and "Fair" throughout the season, with a maximum clarity of 7.3 feet in mid-May, and a minimum of 3.4 feet on 13-Aug (see *Figure 3)*. Secchi depth readings generally stayed in the range considered "Fair" except for one day in August where clarity was at a minimum. The lowest turbidity was 1.2 NTU and the highest was 5.3 NTU (see *Figure 4)*. Based on Secchi depths, water clarity at Patch Reservoir was given an overall rating of "Fair" in 2023.

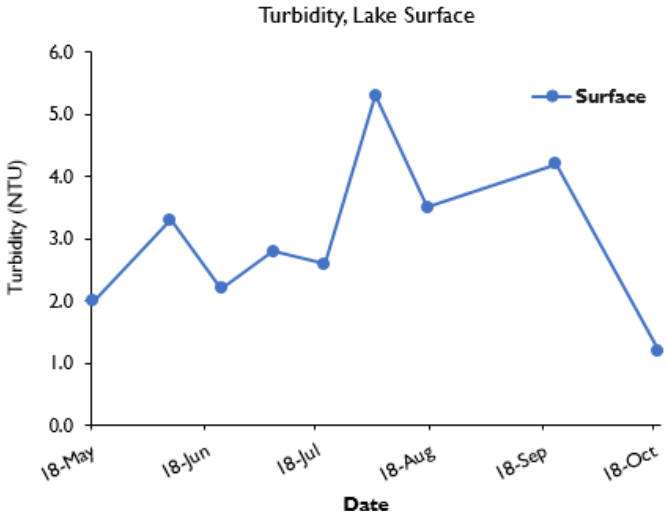

Figure 4 – *Turbidity at the lake's surface ranged between 1.2 and 5.3 NTU when measured in 2023.*

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 13.3°C and 26.2°C with the maximum recorded on 20-Jul (*see Figure 5)*. Most readings were in the range considered "Excellent", although the highest recorded temperatures were considered "Good". Bottom temperatures ranged between 13.0°C and 17.1°C with the maximum recorded on 21-Sept. 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. Temperature at Patch Reservoir was rated "Excellent" in 2023.

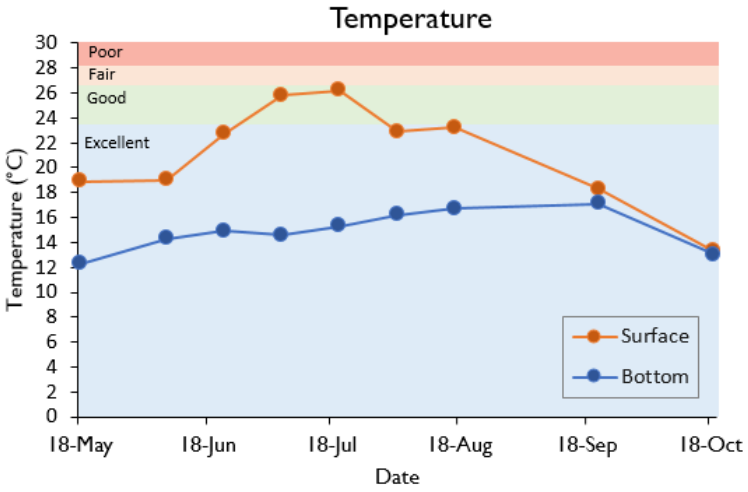

Figure 5– *Temperature stayed in the "Excellent" category for the majority of the season at the surface and bottom of Patch Reservoir, although at the surface it increased into the "Good" category during the hottest part of the summer.*

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 2023 sampling season, the brook had a maximum temperature of 24.7°C degrees on 20-Jul at the spillway of Patch Reservoir, falling within the "Poor" temperature range. Temperature in the Tatnuck Brook inflow was considered "Fair" during 4 of 8 sampling events and was considered "Good" or "Excellent" otherwise.

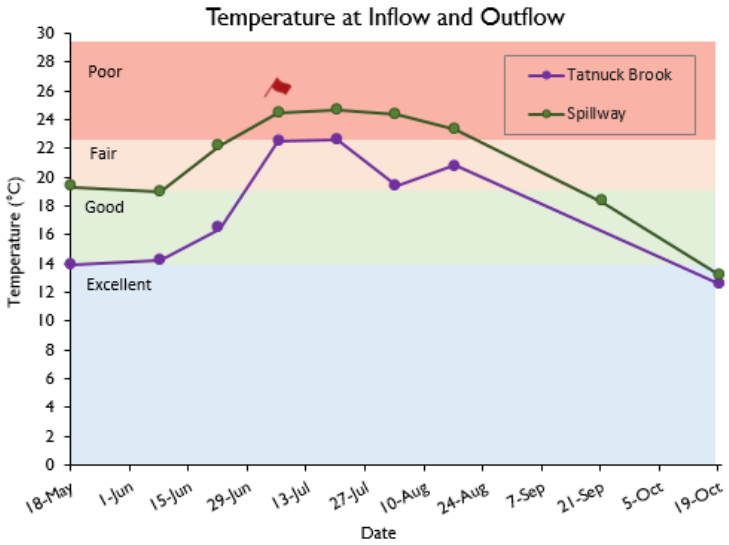

Figure 6– *Water temperature at the Patch Reservoir spillway was on average 5.8 degrees higher than when it entered the lake.*

Temperature results from 6 of the 9 sampling events at the Patch Reservoir spillway were considered "Fair" or "Poor" (see *Figure 6)*. 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 5.8 degrees higher than the water that enters the reservoir. This resulted in 3 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.

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.

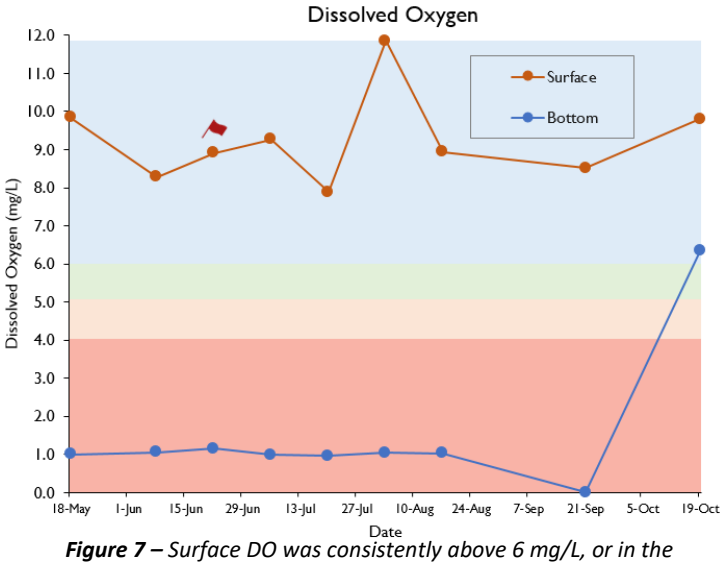

Figure 7 – *Surface DO was consistently above 6 mg/L, or in the range considered "Excellent". All but one bottom reading was in the range considered "Poor"*

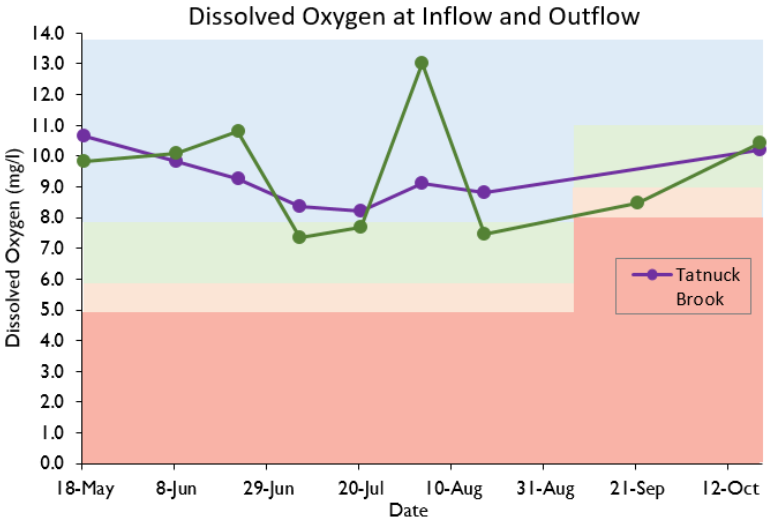

Figure 8 – *In Tatnuck Brook, 5 of 8 DO readings were in the range considered "Excellent" for a CFR.*

Dissolved Oxygen at Patch Reservoir.

Surface DO at Patch Reservoir ranged between 7.89 mg/L and 11.85 mg/L (*see Figure 7*) and was rated as "Excellent". DO stayed fairly constant throughout the season except for the spike on 3-Aug. Bottom DO remained below 4 mg/L until 19-Oct, 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 2023 was rated "Fair".

In the Tatnuck Brook inflow, 5 of 8 DO readings were in the range considered "Excellent" for a CFR. (see *Figure 8*). DO at the spillway was often lower than the tributary for most of the season and was generally considered "Excellent" and "Good".

Nutrients

Nutrients, primarily 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 P, samples were collected for total phosphorus (TP) twice a month at a subset of the sampled sites (the main tributary, the surface and deep lake sites, and the spillway site).

Nutrients at Patch Reservoir. TP at the surface of Patch Reservoir was fairly constant, ranging between 0.023 mg/L and 0.046 mg/L (see *Figure 9*). Concentrations generally had a slight increase 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 or very close to 0.075 mg/L, in the category considered "Poor".

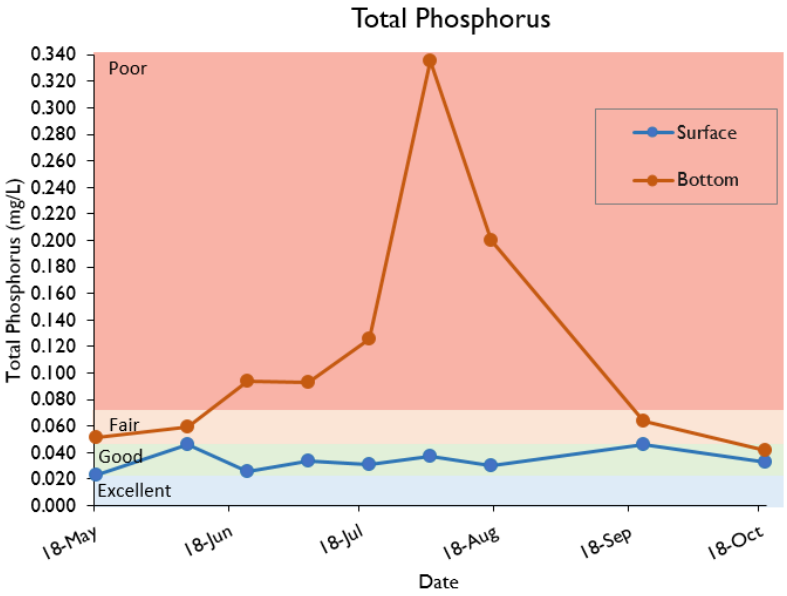

Figure 9 – *Total phosphorous was generally considered "Good" at the surface site but ranged from "Good" to "Poor" at the bottom. The highest results from the bottom occurred between late June and late August, with the maximum reading of 0.335 mg/L on 3-Aug.*

TP concentrations in the inflow and outflow of the reservoir were widely variable, ranging between 0.014 and 0.051 mg/L, although most results were in the range considered "Good" and "Excellent" (see *Figure 10*). When comparing seasonal averages between sites, the spillway was only 0.013 mg/L higher than the inflow. All but one TP result from the Tatnuck Brook Inflow was in the range considered excellent. Concentrations at the spillway were less predictable and generally higher, ranging between 0.026 mg/L and 0.051 mg/L, with most results in the categories considered "Fair" and "Poor".

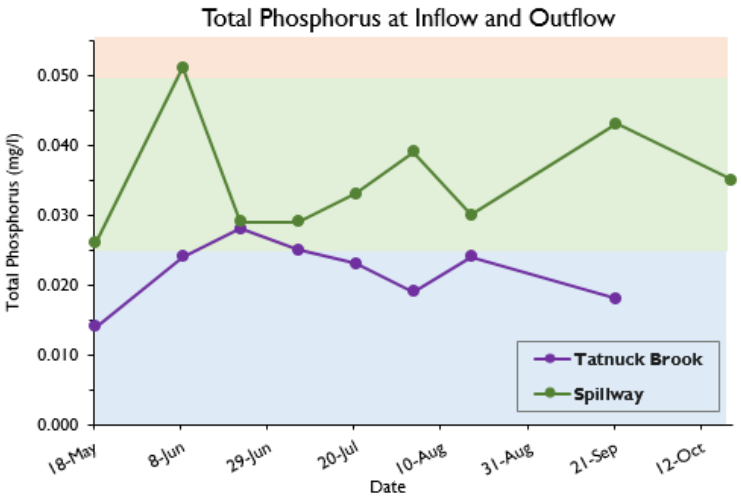

Figure 10 – *Total phosphorus was consistently lower in Tatnuck Brook than at the spillway and often considered "Excellent". TP at the spillway was generally in the range considered "Good".*

Overall, nutrients at Patch Reservoir in 2023 were rated "Fair".

Cyanobacteria

Cyanobacteria are naturally occurring microorganisms in lakes and ponds. Using sunlight and nutrients such as phosphorus, 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 detected during all but two WCMC sampling events, but all levels indicated relatively small cyanobacteria population and none were above the 50 ug/L threshold indicating potential bloom conditions (see *Figure 9*). Observed cyanobacteria genera include, *Aphanizomenon*, *Oscillatoria*, *Dolichospermum*, and *Woronichinia*. In general, these results indicate improved conditions relative to 2022, when phycocyanin concentrations in the range indicative of bloom conditions were observed twice during the sampling season.

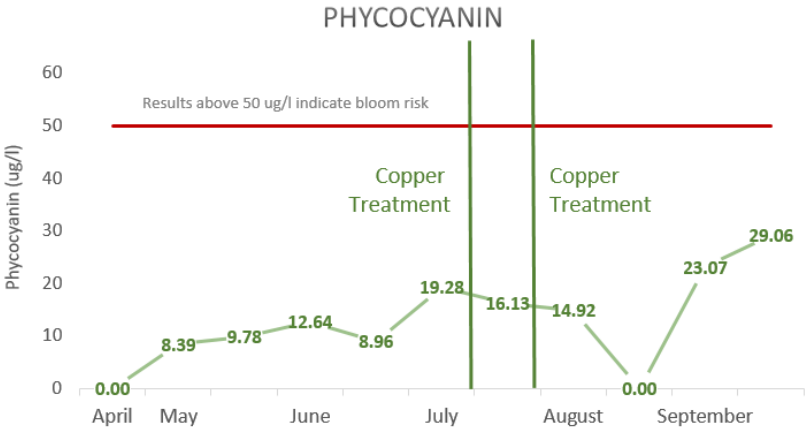

Figure 9 – *Phycocyanin measured in samples collected by the WCMC was consistently below 50 ug/L, the level associated with cyanobacteria bloom risk.*

Invasive Aquatic Plants and Animals

An invasive plant or animal is an organism that is not native to the region and outcompetes local flora and fauna. 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 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 *Figures 12 and 13*). All treatments are approved by the Worcester Conservation Commission and applied by licensed professionals.

Figure 12 – *Invasive Water Chestnut in the northern portion of Patch Reservoir.*

In the past, 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. In 2023, a combination of herbicides, Clearcast, Flumigard SC, and Tribune, were used and effectively treated the water chestnut population of this summer, which extended over a smaller area than that of the previous summer.

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.

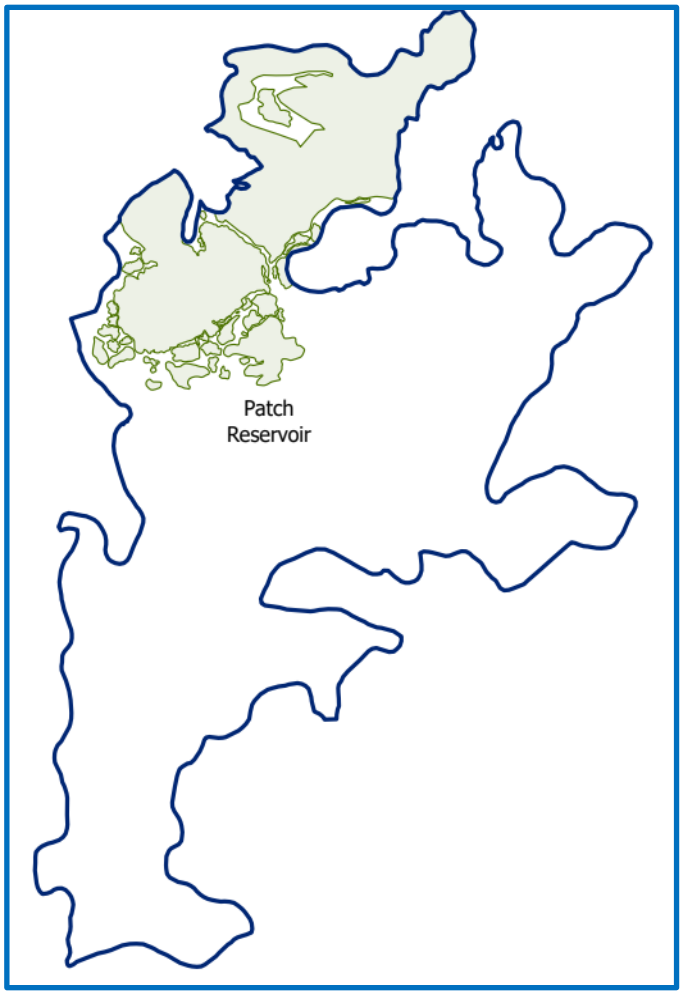

Figure 13 – *Invasive aquatic plant coverage at Patch Reservoir in 2021, mapped by Lauren Vigneault and Dr. William Hansen.*

State of the Lake

In 2022, the State of the Lake for Patch Reservoir was “Fair”; in 2023, however, Patch Reservoir is considered “Fair/Good”. 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 become far more proactive, and blooms were suppressed this summer. Monitoring by WSU indicated moderately elevated nutrient concentrations, 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. However, all water quality measurements except bottom oxygen improved between 2022 and 2023.

Ongoing Projects and Plan for 2024

Water Quality Monitoring

Tatnuck Brook Project. Since 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?" This summer, students and faculty continued to measure water quality around Patch Reservoir and Cooks Pond in collaboration with concurrent sampling by the City of Worcester downstream. Major contributors to the project in 2023 included: Cailey Ryan, Klarissa Johnson, Casey Mullaly, Austin Salvadore, and Dr. Laura Reynolds.

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.

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.

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. In 2024 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 2023.

Figure 14 *- Contractors applying the herbicide Clearcast to Invasive Water Chestnut at Patch Reservoir.*

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 24-Apr 2024 (which is open to the public), and to the Tatnuck Brook Watershed Association.

Family Aquatic Science Day. In June 2023, Tatnuck Brook Watershed Association (TBWA) hosted an event at Coes Reservoir called the Aquatic Science Day (*see Figure 15*). In this event local school children 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.

The Lakes and Ponds Program and WSU plans on supporting the TBWA in holding the event again in 2024 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.

Many thanks to the Friends of Patch Reservoir, and to Cailey Ryan, Klarissa Johnson, Casey Mullaly, Austin Salvadore, and Dr. Laura Reynolds.

Figure 15 – *Students and volunteers at the 2023 Aquatic Science Day collect fish and other aquatic organisms in a seine net.*