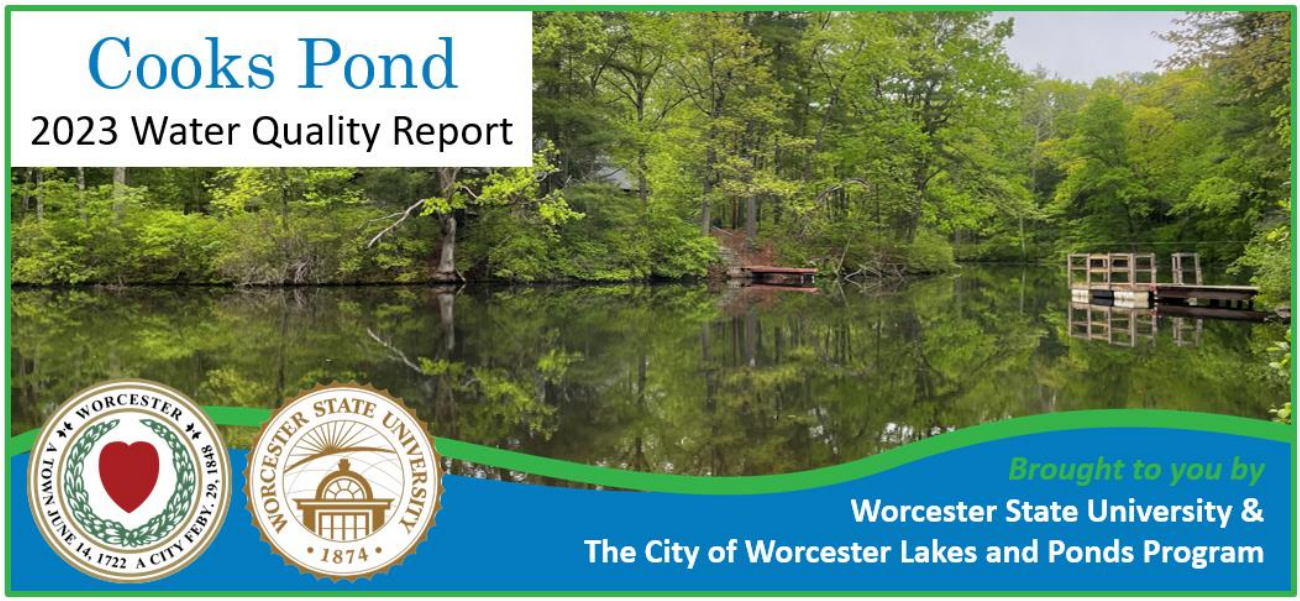

Summary

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 Cooks Pond in 2023. This report is the product of a collaboration between the 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 watershed 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.

Cooks Pond is owned and managed by Smith's Pond Corporation and is the first impoundment of Tatnuck Brook within Worcester's city limits. It exhibits both high quality source water and challenges associated with the built environment. Often exhibiting high water clarity, low nutrient levels, and very low risk of closure due to cyanobacteria and fecal bacteria, Cooks Pond supports a healthy ecosystem and a wide variety of recreational opportunities**.** However, in recent years challenges with invasive aquatic plants have prompted management by the Smith Pond Corporation. ***In 2023, Cooks Pond received a score of "Excellent"***. Continue reading to learn more about this rating and water quality monitoring results.

Background

Cooks Pond is a shallow, 22-acre waterbody located in western Worcester near the Tatnuck neighborhood. It is approximately 11 feet deep at its deepest point, which is in the southeastern portion of the pond near the dam. Cooks Pond is situated in a chain of mill ponds along Tatnuck Brook, which extends south from Holden and was dammed in the 1830s to create a storage pond for a grist mill.

Cooks Pond is bordered on the west by Olean Street, a moderately trafficked roadway. The majority of the shoreline is forested and owned by the Smith's Pond Corporation, whose members collaborated with the Greater Worcester Land Trust and the City of Worcester to preserve the area through a 2007 conservation restriction that has provided public access to much of the land around the pond and protects it from development. The pond itself is owned and managed by Smith's Pond Corporation. Cooks Pond additionally serves as a recreational resource for fishing, paddling, and wildlife viewing. Since 2022, researchers and students from Worcester State University (WSU) have teamed up with the City of Worcester's Lakes and Ponds Program (L&P) to study Cooks Pond and Patch Reservoir, just downstream, 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

As a suburban pond, Cooks Pond endures many of the pressures of the city. However, support of the waterbody by community groups and the City of Worcester has helped Cooks Pond continue to be a fantastic recreational resource. While invasive aquatic plants have been observed in the pond, the adaptable management plan has been effective at keeping invasive aquatic plants in low quantities. The pond generally has low concentrations of phosphorus and "Fair" water clarity for an urban pond. Since beginning participation with the Worcester Cyanobacteria Monitoring Collaborative (WCMC) in 2018, no cyanobacteria blooms have been identified at Cooks Pond.

Management Summary

Since 1912, Cooks Pond and the surrounding property has been managed by recreational and conservation clubs with a mission to preserve and maintain the property. The current Smith's Pond Corporation Board oversees the management and financials associated with the property and pond. A Water Quality Standing Committee was formed in 2017, charged with identifying and coordinating conservation initiatives related to the pond's aquatic resources. Since 2017, the committee and club members have conducted visual inspections and hand removal of invasive Water Chestnut (*Trapa natans*). In 2020, the Committee engaged a lake management company to conduct a Sonar (trade name: Fluridone) treatment throughout the pond. A post-treatment survey by the lake management company indicated a decrease of approximately 90% in invasive aquatic plants such as Milfoil and Water Chestnut, with no Fanwort detected. However, an invasive plant survey done this year by WSU indicated a return of these aquatic invasive plants throughout the pond.

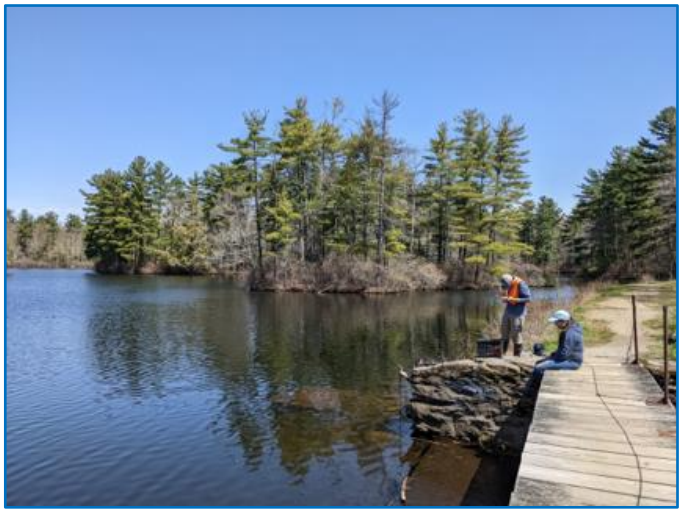

Figure 1 – *WSU students and staff sampling for water quality at the Cooks Pond Dam.*

Sampling Analysis and Overview

Sampling from multiple locations within a waterbody and its watershed leads to better understanding of the water that enters the pond, how it is transformed within, and the water leaving the pond. 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 waterbody originate. Outlets are the major exits for water in the lake. Most of the water quality parameters measured in the lake are also measured at the major natural tributaries and outlets of the lakes.

Cooks Pond was visited once to twice monthly in 2023 from May through October and sampled at five locations: the major aboveground tributary, Tatnuck Brook (upstream of Cooks Pond); two smaller tributaries (Cascades stream and a stream entering near Donkers Farm); an in-lake site at the deepest part of the pond, and the outlet at the spillway located in the southern portion of the pond (see *Figure 2*). At the in-lake location, probe measurements and water samples were collected one foot below the surface of the water ("surface"), and two feet off of the bottom of the lake ("bottom"). Parameters evaluated included: Secchi depth, temperature, dissolved oxygen (DO), conductivity, turbidity, and total phosphorus (TP). Altogether, there were 15 total sampling events, and 9 of these events sampled the Cooks Pond in-lake site. For all 9 of these events, there was no rainfall 24 hours prior to data collection.

In addition to monitoring by WSU, volunteers from the WCMC collected samples for phycocyanin and relative cyanobacteria density analysis to assess bloom risk. Samples were taken approximately twice monthly between late April and October, on 29-Apr, 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. The Worcester Department of Inspectional Services tested the pond 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 Protection's SMART Monitoring Watershed Report Card Criteria.

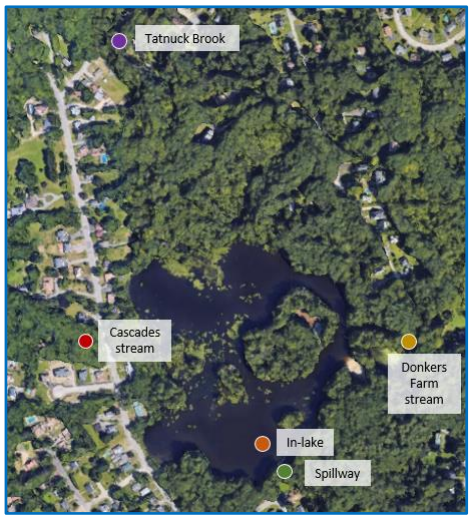

Figure 2 *– Cooks Pond map and approximate sampling locations.*

Quality Assurance/Quality Control

WSU and the L&P strive to have a robust data set. WSU therefore used Quality Assurance/Quality Control (QAQC) checks to ensure that the data were 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 taken at the in-lake site on each visit. A turbidimeter was used to measure the turbidity at the surface of the in-lake site. Turbidity is measured in Nephelometric

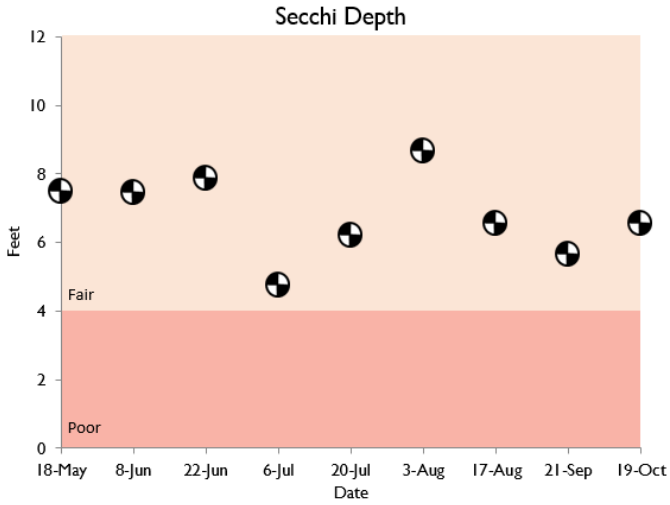

Figure 3 – *Secchi depth was consistently considered "Fair" at Cooks Pond in 2023.*

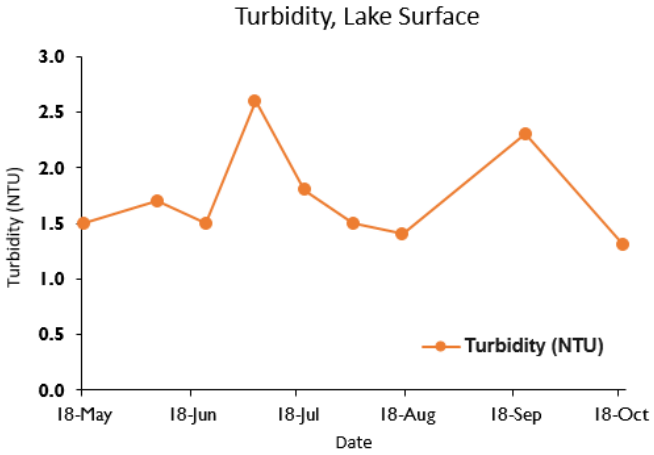

Figure 4 – *Turbidity at Cooks Pond ranged between 1.3 and 2.6 NTU in 2023.*

Turbidity Units (NTUs). To measure turbidity, a small sample of water was collected in a vial and placed in the turbidimeter to be measured.

Water Clarity at Cooks Pond. At Cooks Pond, Secchi depth was rated as "Fair" throughout the season, with a maximum clarity of 8.7 feet in early August (see *Figure 3*). Secchi depth for the season consistently stayed in the category considered "Fair". The minimum recorded clarity of 4.8 feet was recorded on 6-Jul. The turbidity ranged between 1.3 and 2.6 NTU (see *Figure 4*) and was generally negatively correlated with Secchi depth as expected. Based on the Secchi depths, water clarity was categorized as "Fair" 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 (DO). 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.

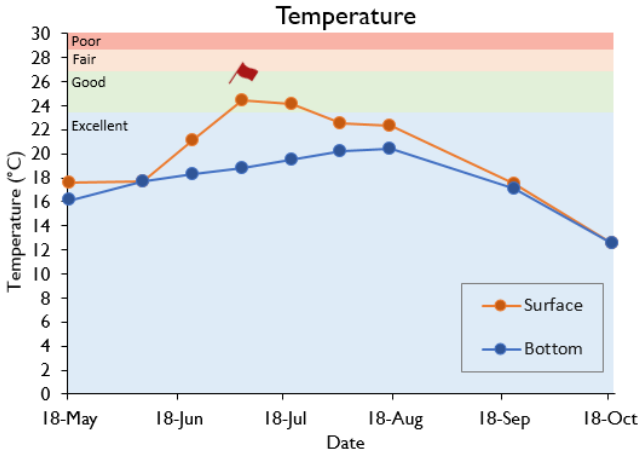

Figure 5 – *Surface temperature readings generally exceeded bottom temperature, following the expected seasonal distribution. Surface temperature ranged between the "Excellent" and "Good" categories, while bottom temperature was consistently considered "Excellent".*

Temperature at Cooks Pond. Surface temperature at Cooks Pond rose throughout the beginning of the season until reaching a maximum recorded temperature of 24.4°C on 6-Jul, which was one of two results considered "Good" (*see Figure 5*). The rest of the season the surface temperature rated as "Excellent." Bottom temperature followed a similar pattern, but it peaked later in the season with the maximum temperature of 20.4°C recorded on 17-Aug. In September and October, temperature readings decreased, with the lowest of the season, 12.5°C recorded at the surface and bottom on 19-Oct.

At Cooks Pond, the major natural tributary is Tatnuck Brook, which enters the pond from the north. The major outlet of the pond 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 sustain cold water fish species such as Trout. CFR tributaries are covered by different and often more stringent SMART Criteria than lakes and non-CFR tributaries. Over the 2023 sampling season, the Tatnuck Brook site had a maximum temperature of 22.2°C on 20-Jul and was in the temperature range considered "Fair" for 4 of the 15 sampling events (see *Figure 6)*. For the most part, the temperature in Tatnuck Brook was in the "Good" or "Excellent" categories. As water from Tatnuck Brook enters Cooks Pond, it slows down and is more exposed to the sun and air, warming it up. On average, the water leaving the Cooks Pond spillway is 3.6°C higher than the water that enters the pond, and spillway water temperatures were considered "Fair" during the middle of the season and "Good" at the beginning and end of the season.

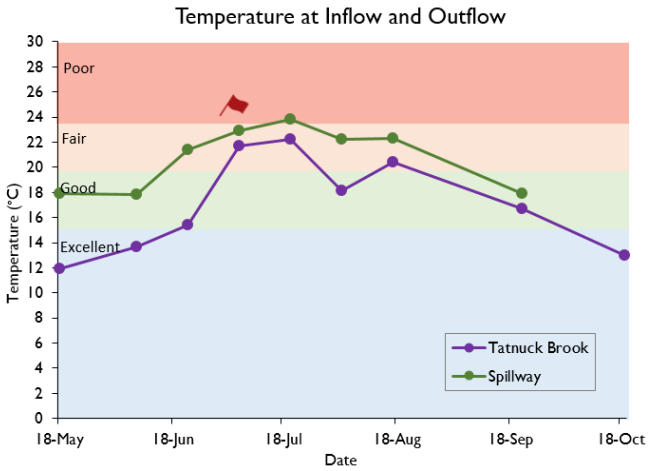

Figure 6 – *Water temperature at the outflow was on average 3.6°C higher than the water that enters the pond from Tatnuck Brook.*

Temperatures at Cooks Pond followed the expected seasonal distribution and was rated overall as "Excellent".

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.

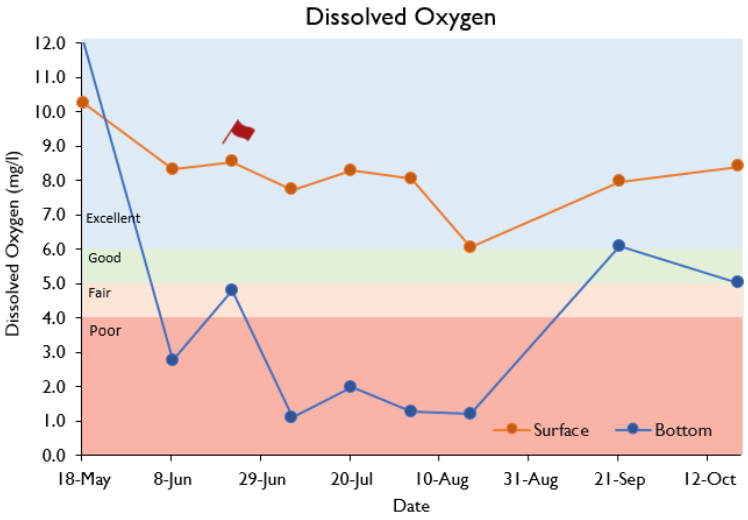

Figure 7 – *Surface DO was considered "Excellent" for the entire season at Cooks Pond. Readings at the bottom of the lake were in the "Excellent" range at the beginning and end of the season but decreased to "Poor" between July and early September.*

Dissolved Oxygen at Cooks Pond. In 2023, DO at the surface of Cooks Pond remained above 6 mg/L, or in the range considered "Excellent" (see *Figure 7*). Surface DO ranged from 6.1 to 10.3 mg/L, starting the season higher and was generally lowest in the early fall. Bottom DO readings indicated that deeper areas of Cooks Pond experienced hypoxic, or low-oxygen, conditions during the middle of the summer. DO ranged between 1.1 mg/L and 12.1 mg/L, with readings falling below 4 mg/L or in the range considered "Poor" between 8-Jun and 17-Aug except for 22-Jun. For the remainder of the season bottom DO readings were higher, in the ranges considered "Good."

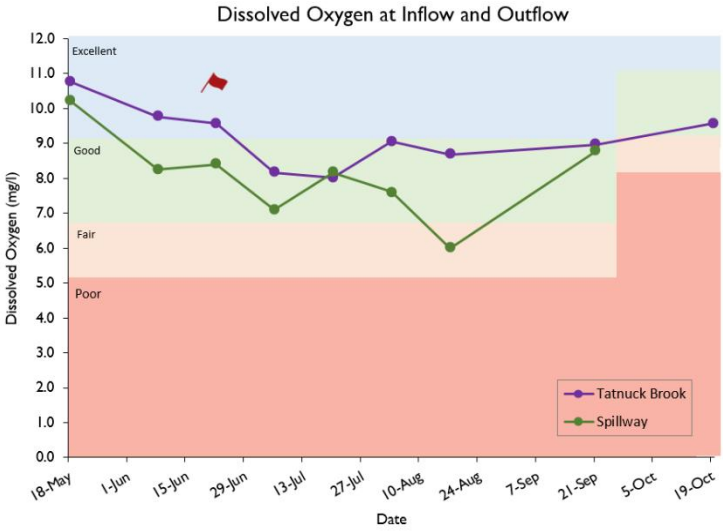

Figure 8 – *DO at Tatnuck Brook and the Cooks Pond spillway generally followed similar seasonal fluctuations. As seen in 2022, DO at the spillway dipped considerably lower than the inflow during late summer.*

In the inflow and outlet of Cooks Pond, DO readings (see *Figure 8*) were generally above 6 mg/L, falling in the ranges considered "Excellent" and "Good" in both. Although DO concentration improved over the fall, stricter standards for DO in CFRs led to the readings being considered "Excellent" and "Good" for the spring and summer season. Given this change in the rating scale, spillway DO values ranges between "Fair" and "Excellent" for the fall readings.

Overall, DO at Cooks Pond in 2023 was rated "Good".

Nutrients

Nutrients such as phosphorus (P) are food sources for aquatic plants and algae. Although plants and algae are the basis 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 Cooks Pond, WSU collected 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 sites (Tatnuck Brook, Donkers Farm Stream, and the surface and bottom in-lake sites).

Nutrients at Cooks Pond. Surface TP results in Cooks Pond ranged between not detected and 0.024 mg/L, with the lowest results at the beginning and end of the season. Surface results were all considered "Excellent" (see *Figure 9*). Bottom TP results followed a similar seasonal distribution but were generally higher than those at the surface, ranging between not detected and 0.038 mg/L, with the highest results in the range considered "Good".

TP in Tatnuck Brook was consistently low, ranging between undetected and 0.012 mg/L. (*see Figure 10)*. In general, TP results were lower at the beginning and end of the season, with several undetected results, and the rest of the season had results that detected some P. TP results in Tatnuck Brook were considered "Excellent". TP results were consistently higher on the surface of the in-lake site than in Tatnuck Brook, although both were consistently in the range considered "Excellent".

In 2023, TP results in Cooks Pond were rated "Excellent".

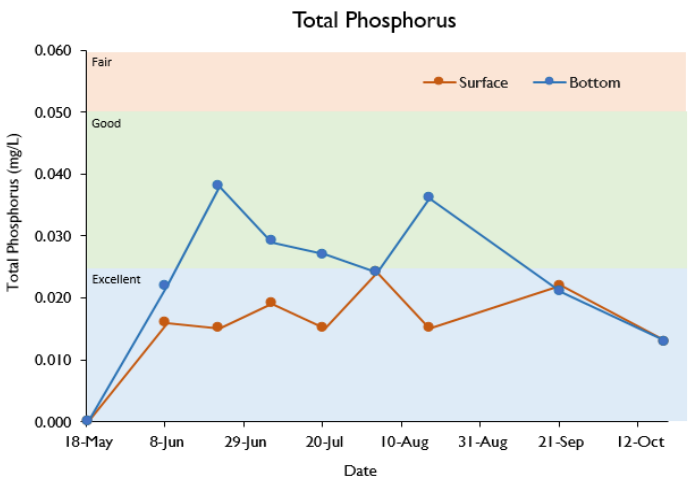

Figure 9 – *Surface TP results in Cooks Pond ranged between not detected and 0.024 mg/L and were considered "Excellent". Bottom TP results were generally higher ranging between not detected and 0.038 mg/L, with the highest results in the range considered "Good".*

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.

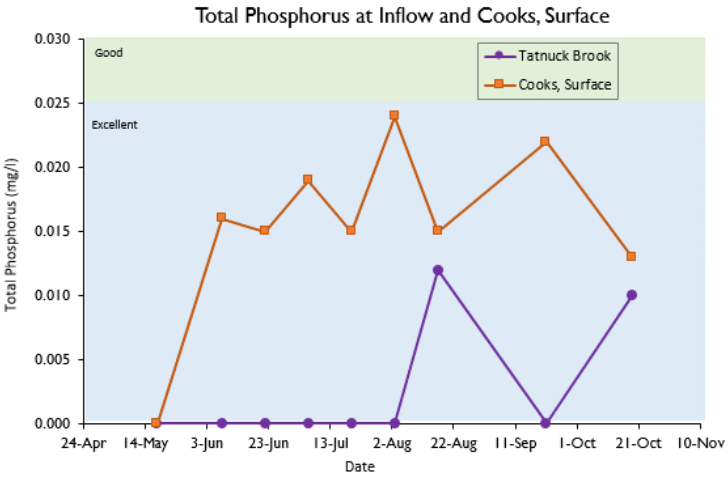

Figure 10 – TP in Tatnuck Brook was generally low, ranging between undetected and 0.012 mg/L and consistently considered "Excellent". TP at the surface of Cooks was consistently higher, though still in the range considered "Excellent".

To understand the abundance of cyanobacteria and make decisions regarding lake management and safe access, the data collected by the Worcester Cyanobacteria Monitoring Collaborative (WCMC) were utilized to measure cyanobacteria indicators and estimate toxin exposure risk. The WCMC is a group of community science volunteers that collected water quality samples twice monthly between May and October at 24 waterbodies in and around Worcester, including Cooks Pond. Parameters examined included 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 help determine what toxins may be present. The WCMC was 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 began to assign bloom risk at each participating waterbody. For more information on the WCMC and their results, visit WorcesterMA.gov/WCMC.

Cyanobacteria at Cooks Pond. – All but one Phycocyanin result from Cooks Pond was low and below the concentration indicating bloom conditions. However, on 22-Jul, results indicated high bloom risk (see Figure 11). As no cyanobacteria were observed and water was clear, the result was suspect, prompting resampling. On 26-Jul phycocyanin concentration was 9 ug/L, well below the level prompting concern. Cyanobacteria did not require any management to avoid bloom conditions. Bloom risk was consistently classified as either "Almost None" or "Low" throughout the 2023 season. Cyanobacteria at Cooks Pond was rated as "Excellent" in 2023.

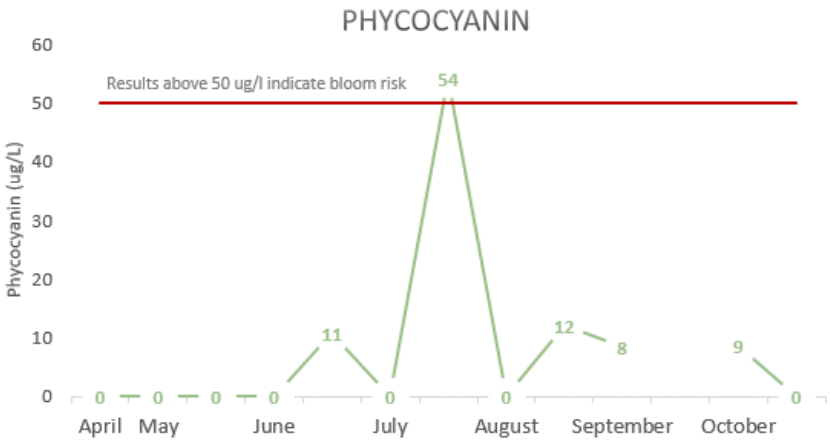

Figure 11 – *All but one Phycocyanin result from Cooks Pond was low and below the concentration indicating bloom conditions. However, on 22-Jul, results indicated high bloom risk. Resampling on 26-Jul indicated phycocyanin well below the level of concern.*

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

Figure 12 – *Invasive aquatic Water Chestnut (*Trapa natans*).*

Invasive Aquatic Plants and Animals at Cooks Pond.

Several invasive species have been observed in Cooks Pond since observations began in 2017, including Water Chestnut (*Trapa natans;* see Figure 12), Fanwort (*Cabomba caroliniana*), and Variable Milfoil (*Myriophyllum heterophyllum*). A 2018 aquatic plant survey conducted by Dr. Robert Bertin showed that Fanwort was abundant in over 90% of the pond, Variable Milfoil was present but sparse in several areas near the dam and beach, and Water Chestnut was rare. Following this survey, a local Order of Conditions was applied for and approved, and the Smith's Pond Corporation hired a lake management company to manage invasive aquatic plants in 2020. The lake management company applied Fluridone (trade name: Sonar) to the pond in May 2020 and the post-treatment survey conducted by the company indicated an approximately 90% reduction in invasive aquatic plants. In 2021, the lake management company applied a contact herbicide in several locations to manage larger patches of Water Chestnut and Variable Milfoil. Since 2021, volunteers have continued to hand pull any Water Chestnut observed and no further treatments have been applied.

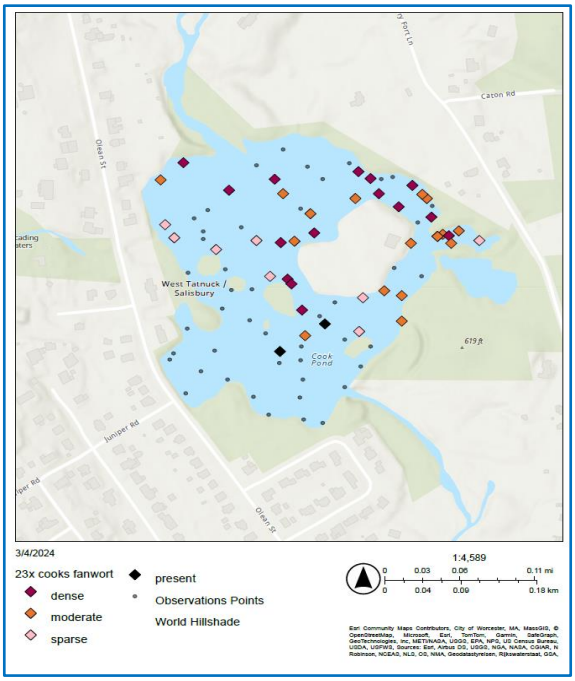

Figure 13 *– In 2023, WSU conducted a survey of invasive Fanwort coverage in Cooks Pond.*

WSU conducted another survey in August 2023. *Figure 13* shows the distribution of the surveyed Fanwort in Cooks Pond. While this figure shows an accurate representation of the distribution of Fanwort, it only shows where the plant was visible from the surface. Additional Fanwort may be present in the deeper parts of the lake where a visual survey of the lake bottom was not possible. Only one Water Chestnut plant was observed in the northwestern part of the pond and pulled during the survey. Milfoil was also abundant throughout Cooks.

State of the Lake

In 2023, Cooks Pond receives an overall score of "Excellent". Though several species of invasive aquatic plants are present, management by the Smith's Pond Corporation has been successful at maintaining access to recreational activity. In-lake water temperature was considered "Excellent". Water clarity was a little lower than expected or desired, but the cause of this was not determined to be cyanobacteria activity. Nutrient concentrations were generally low in the pond as well as its measured tributaries.

Ongoing Projects and Plan for 2024

Water Quality Monitoring

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. WSU will continue to collect litter as it is seen when sampling and participate in community clean up events.

Invasive Aquatic Plant Management

In 2024 the Smith's Pond Corporation will continue to visually inspect and hand pull Water Chestnut and will reevaluate other invasive aquatic plants to determine if additional management is needed. All management decisions will be made by Smith's Pond Corporation as needed.

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.

Coes Aquatic Science Day. In June 2023, Tatnuck Brook Watershed Association (TBWA) hosted an event at Coes Reservoir (downstream of Cooks Pond) called the Aquatic Science Day (*see Figure 14*). 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.

Figure 14 – *Students and volunteers at the 2023 Aquatic Science Day collect fish and other aquatic organisms in a seine net.*

The L&P 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 Smith's Pond Corporation, and to Cailey Ryan, Klarissa Johnson, Casey Mullaly, Austin Salvadore, and Dr. Laura Reynolds.