Harmful Algal Bloom Monitoring and Research Project: Octoraro Reservoir, 2022 Technical Summary

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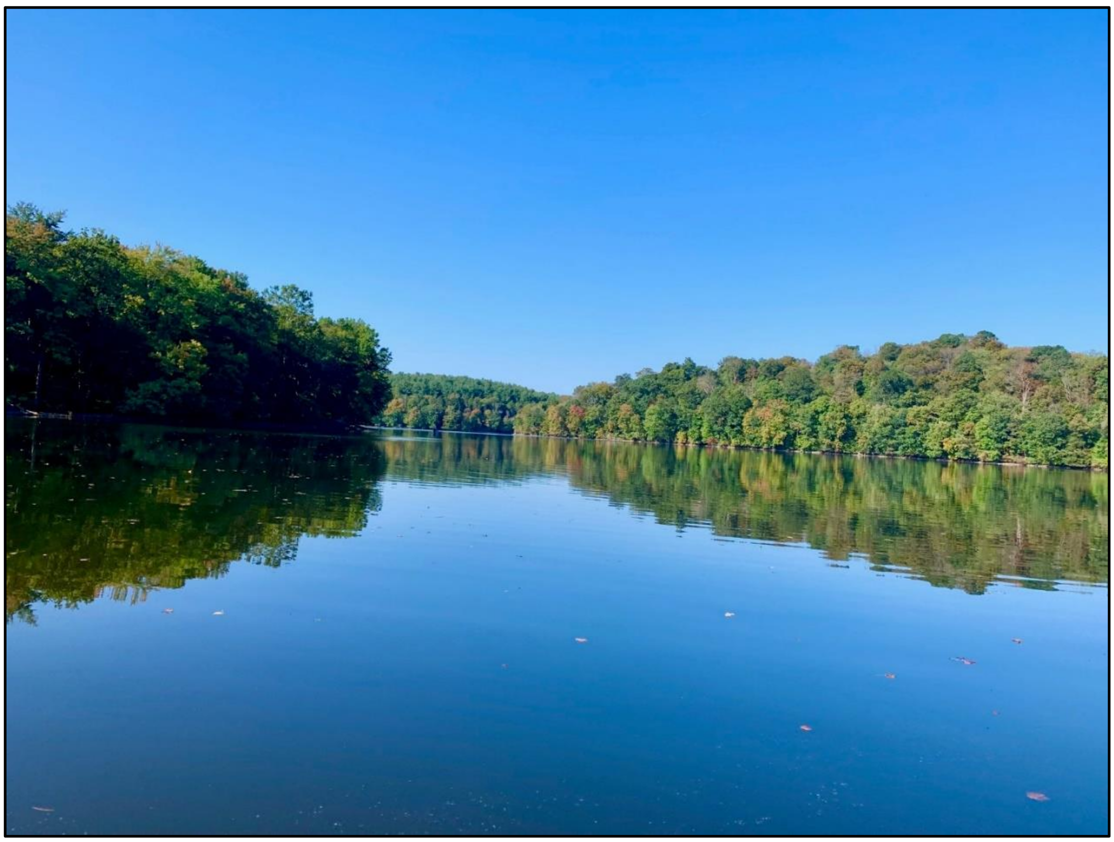

SUSQUEHANNA RIVER BASIN COMMISSION

NY ▪ PA ▪ MD ▪ USA

INTRODUCTION AND BACKGROUND

Harmful algal blooms (HABs) are a topic of increasing interest to aquatic scientists, particularly as they are related to a changing climate. Monitoring for current HABs outbreaks is a critical part of recreational water quality monitoring, as it is important to know when to limit or ban recreational water contact (swimming, wading, fishing) in a given waterbody to prevent harm to human health. This type of monitoring has been underway by a variety of regulatory groups such as state health departments and environmental agencies.

Susquehanna River Basin Commission (Commission) staff continue to work with the Pennsylvania Department of Environmental Protection (PADEP) and the Pennsylvania Department of Conservation and Natural Resources (PADCNR) through the PA HABS Task Force to assist in gathering data and sharing research and monitoring strategies. Because of the lag time between sampling and results and how rapidly HABs can materialize, warnings can be delayed and people exposed unknowingly. More recently, Commission staff have also been working with Chester Water Authority (CWA) to monitor for HABS in Octoraro Reservoir in Lancaster County, PA. This lake is used as a drinking water source by CWA as well as being heavily used for secondary contact recreation (i.e., fishing, kayaking, boating).

In recent years, scientists have been evaluating potential methods of predicting HABs. The objective of this study in Octoraro Reservoir is to use some lessons learned during the Lackawanna Lake pilot study in 2021 (Steffy, 2022) to continue refining use of continuous monitoring techniques for algal pigments, compare results to more traditional discrete water samples, and assess the use of remote satellite imagery to evaluate the potential of these methods to predict the occurrence of HABs. For this study, the Sentinel-2 satellite will be the primary satellite from which multispectral imagery data will be obtained. Octoraro Reservoir covers 650 acres in eastern Lancaster County and is manmade and formed at the confluence of East Branch Octoraro Creek and West Branch Octoraro Creek (Figure 1).

This research will inform Commission staff and other interested scientists on the potential for using continuously monitored chlorophyll-a paired with other parameters as way to build a predictive model for HABs within the Susquehanna River Basin (basin). The HABs monitoring efforts started in 2021, and have been the first of its kind undertaken by the Commission in the pursuit of growing awareness of the impact of HABs within the basin.

With recognition that findings from this study will not answer every question or apply to every lake in the basin, the unique and innovative aspects of this ongoing research include: (i) the Commission’s commitment to explore new technologies and monitoring techniques to better assess water resource issues in the basin; (ii) the Commission’s commitment to filling in research gaps and supporting our member states’ agencies; and (iii) the Commission’s long-standing leadership in continuous monitoring applications.

The objective of this summary report is to document the findings from the first year of monitoring in Octoraro Reservoir in 2022.

Figure 1. Map of Octoraro Reservoir with Sampling Locations and Buoy Location

METHODS

A YSI EXO sonde was deployed within a buoy in June 2022 on the southern part of Octoraro Reservoir near the dam. Data were collected continuously every 30 minutes through the end of October 2022. The buoy was set so the sonde was collecting data about 1 meter below the water surface.

One in-lake monitoring site was co-located with the monitoring buoy, and additional in-lake sampling will be done at Station 1 and Station 2 to capture in-lake variability and evaluate the water quality coming in from the West and East Branches of Octoraro Creek, respectively.

Temperature, pH, dissolved oxygen, conductivity, turbidity, chlorophyll-a, phycocyanin, light intensity, and air temperature will be collected continuously at 30-minute intervals at the in-lake monitoring buoy site. Water samples collected from all three in-lake sites will be analyzed for total nitrate, phosphorus, and lab-measured chlorophyll-a. Additionally, continuous monitoring data sondes have been deployed in both the East and West Branches of Octoraro Creek upstream of any backflow influences of the reservoir.

While not included in the scope of this project, Commission staff also collected additional samples at PADEP's request. Algal samples and associated algal toxin analysis (as warranted) were collected by Commission staff and analyzed by PADEP Bureau of Labs. These data will compliment study data particularly as staff look to relate algal colony counts with chlorophyll and phycocyanin data as well as toxin data as that dynamic is multi-faceted and often inconsistent across time and space.

RESULTS AND DISCUSSION

Data were aggregated to daily and monthly means for general assessment of water chemistry. Monthly box plots for temperature, dissolved oxygen, pH, specific conductivity and turbidity were created (Figure 2). Temperature patterns were predictable, responding to increases and decreases in air temperature across seasons. Conductivity showed very little variation across the study period and pH, while often approaching 9.0, was fairly consistent. The biggest and most obvious difference in this basic water chemistry was seen in September when dissolved oxygen declined, pH was more variable, and turbidity increased. Precipitation patterns did not line up with turbidity values so chlorophyll and phycocyanin data were evaluated for the potential of a localized algal bloom.

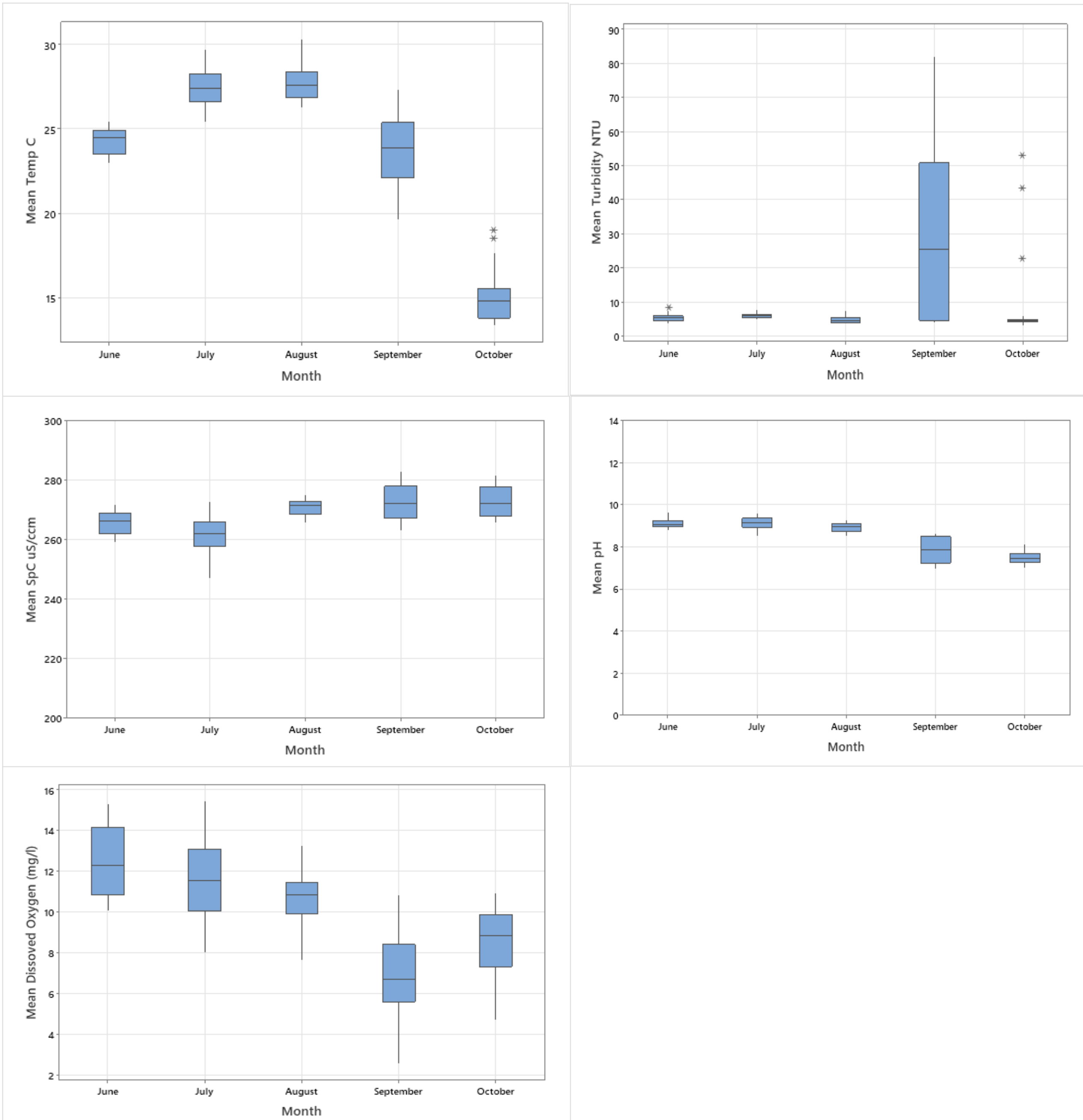

Figure 2. Summary of Monthly Basic Water Chemisty Data Collected at Octoraro Monitoring Buoy, June-October 2022

Chlorophyll-a and phycocyanin are measured with a total algal sensor on the YSI EXO and function by converting a relative fluorescence unit (RFU) into an algal concentration. The concentrations shown in Figure 3 are relative as we were unable to successfully correlate concurrently sampled lab-measured chlorophyll with sonde-derived chlorophyll due to issues in accuracy of lab analysis. Improvements were made to this process in 2023. However, even the relative concentrations spikes in September point to a different water chemistry. Looking at time series data, it is clear that in late September, chlorophyll and phycocyanin both spiked and corresponded with rapidly declining oxygen and increased turbidity (Figure 4). Rainfall patterns showed a large rainfall event about two weeks prior to the phycocyanin spike: this suggests that turbidity was not from the rain but from runoff inputs that may have impacted the conditions for increased cyanobacteria (Figure 5). Additionally, light intensity during this same time period showed a temporary decline, implying lower water visibility with more algal cells. All these data point to at least a localized algal bloom although no lake-wide bloom was reported nor was the drinking water source impacted. Drinking water supply was already being mixed with Susquehanna River water during this time due to nitrate concentrations and lake level.

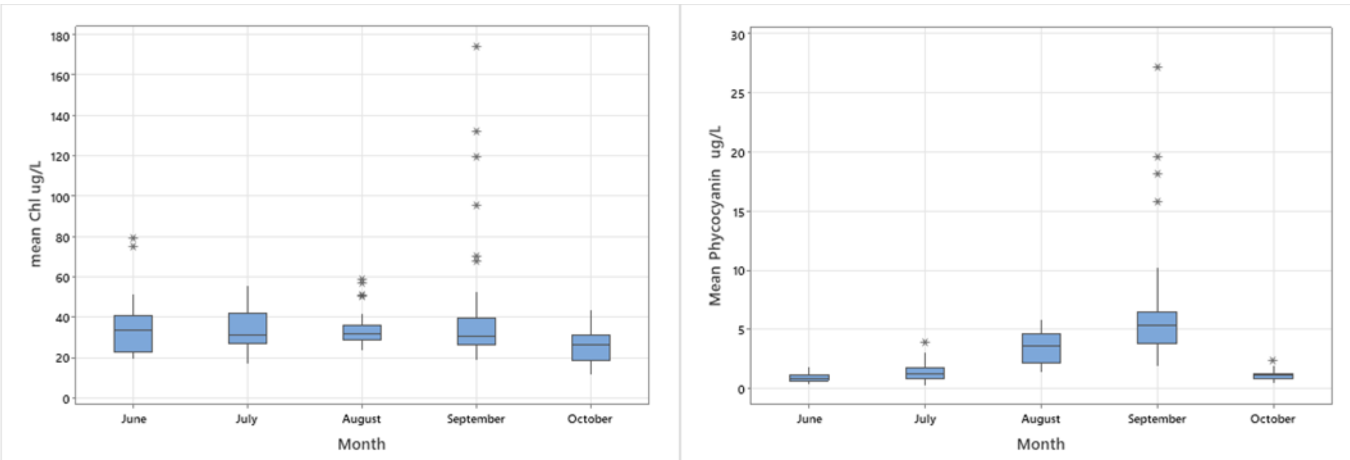

Figure 3. Monthly Algal Water Chemistry from EXO Total Algal Sensor

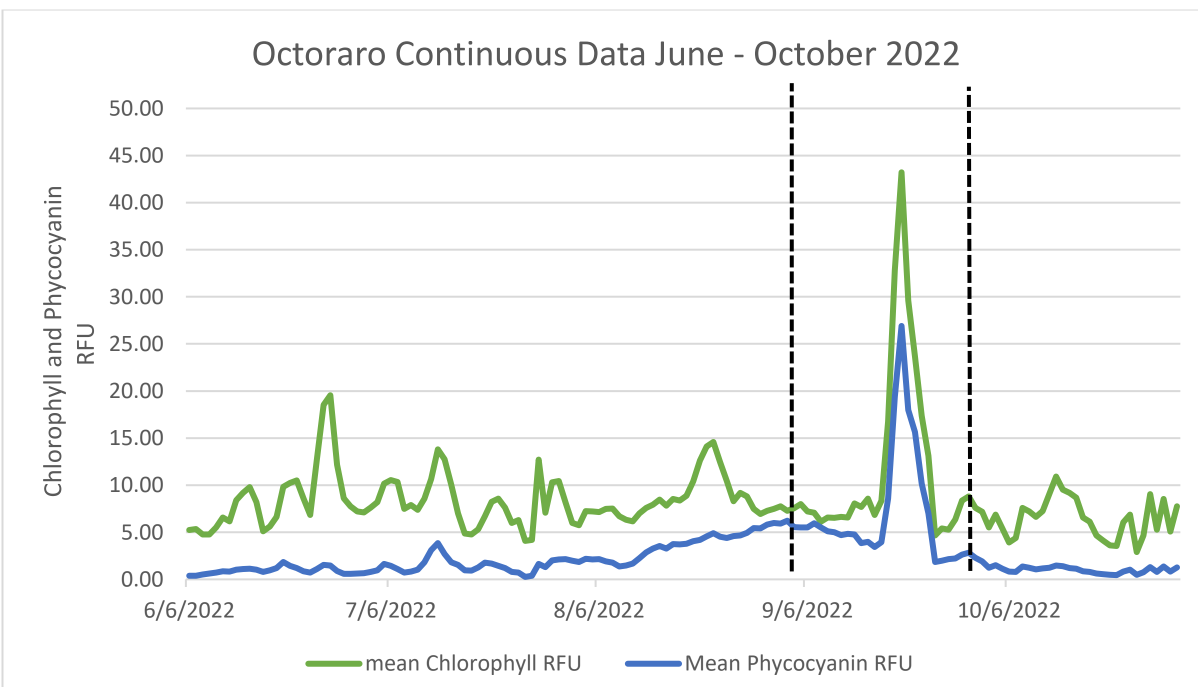

Figure 4. Time Series of Mean Daily Chlorophyll and Phycocyanin RFU Values

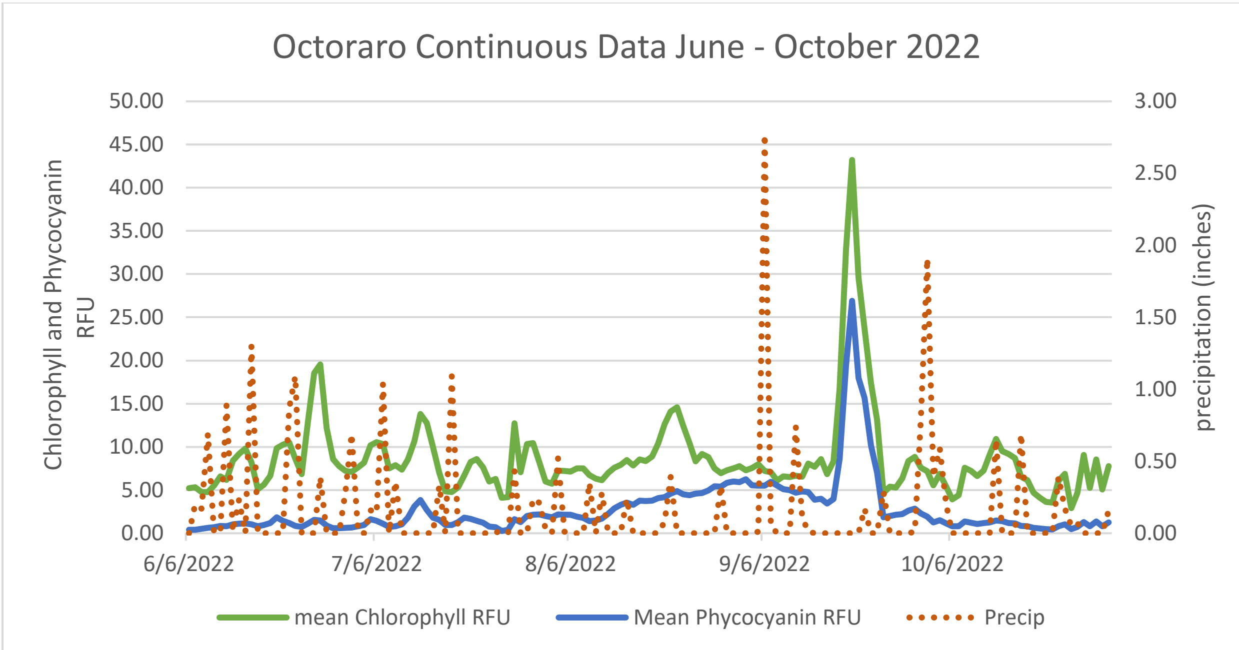

Figure 5. Time Series of Mean Daily Chlorophyll and Phycocyanin RFU Values and Precipitation

During each monthly visit, depth profiles were completed at the buoy site to examine water chemistry throughout the water column. After July, temperature was relatively stable over the whole 9 meter depth; dissolved oxygen, however, showed a consistent steep decline between 2-3 meters depth and was generally below 5 mg/L by 4 meters in depth (Figure 6). Conductivity and turbidity were consistent. pH was typically at or above 9.0 at the surface and 1 meter where the majority of the algae would be and then leveled off to neutral below 1 meter. Additionally, max chlorophyll and phycocyanin were always observed in the top 2 meters of the water column as well.

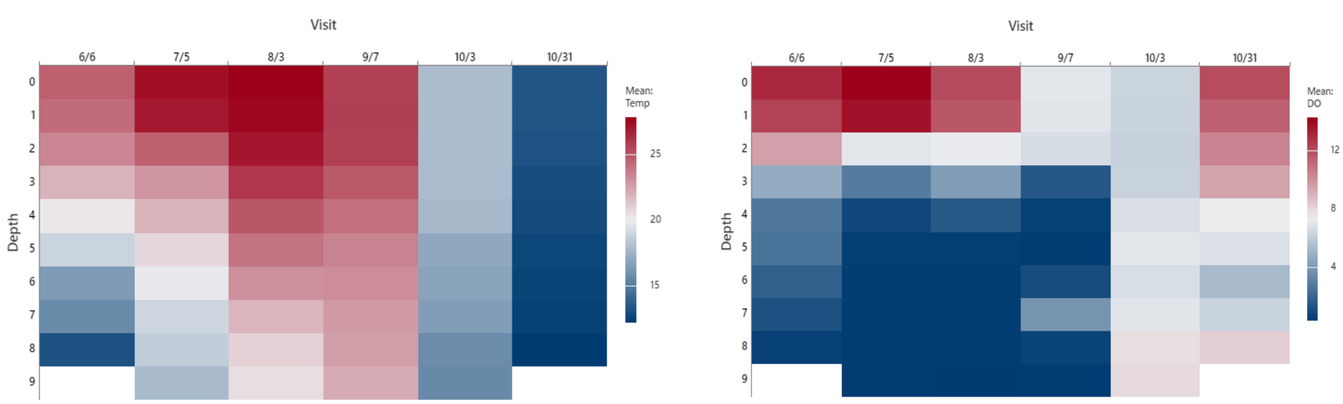

Figure 6. Depth Profiles for Temperature and Dissolved Oxygen

Algal blooms are often associated with high levels of nutrients such as nitrate and phosphorus. Monthly samples of both were taken at three locations in the lake to assess variability. Station 1 represented inputs from West Branch Octoraro Creek, Station 2 represented inputs from the East Branch Octoraro Creek, and the site at the buoy reflected what was near the drinking water intake pipe in the lower portion of the lake near the dam (Figure 1). High concentrations of nitrate are nothing new in Octoraro Reservoir or the surrounding drainage area. Octoraro Watershed is largely agricultural with over 1,200 farms in its nearly 200 mi^2 drainage area. So it was no surprise to routinely see nitrate concentrations in the lake exceeding 6 mg/L at all three sites (Figure 7).

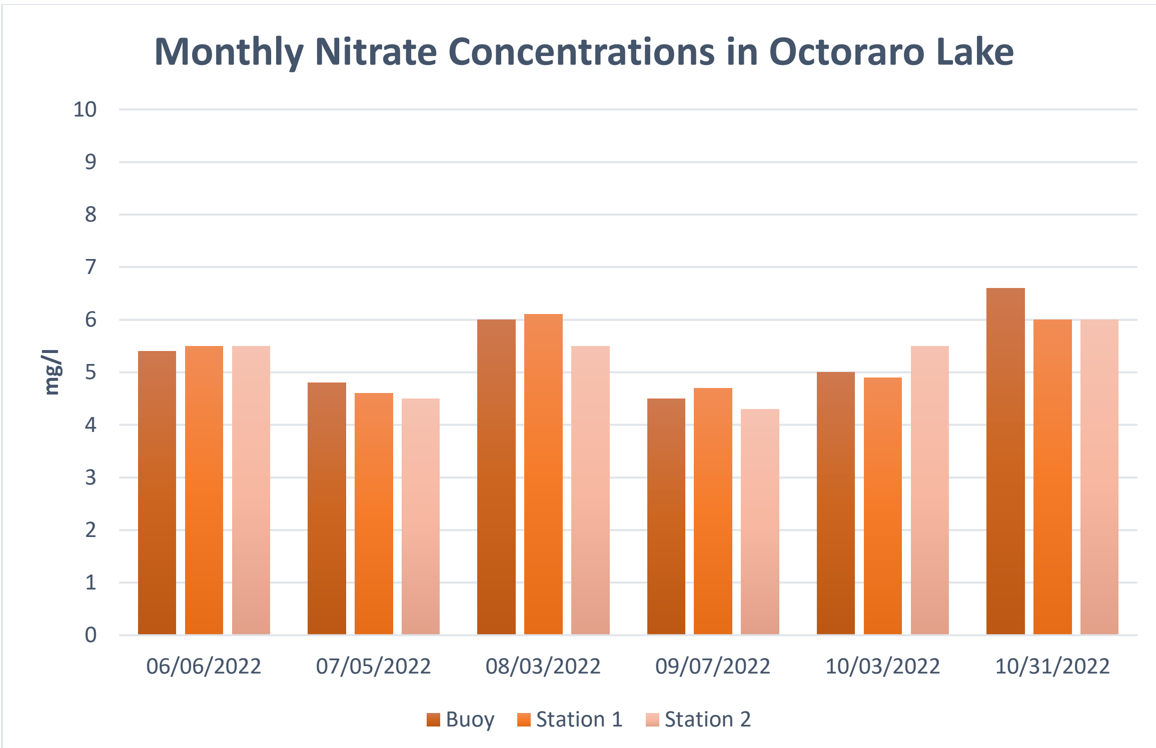

Figure 7. Monthly Nitrate Concentrations at Three Locations in Octoraro Reservoir, 2022

Total phosphorus (TP) concentrations in Octoraro Reservoir hover around 0.1 mg/L but early in the season, Station 1 (West Branch influence) had higher TP concentrations, while later in the summer, Station 2 (East Branch influence) was higher (Figure 8). The buoy site, which is near the outflow, typically had the lowest concentrations of TP.

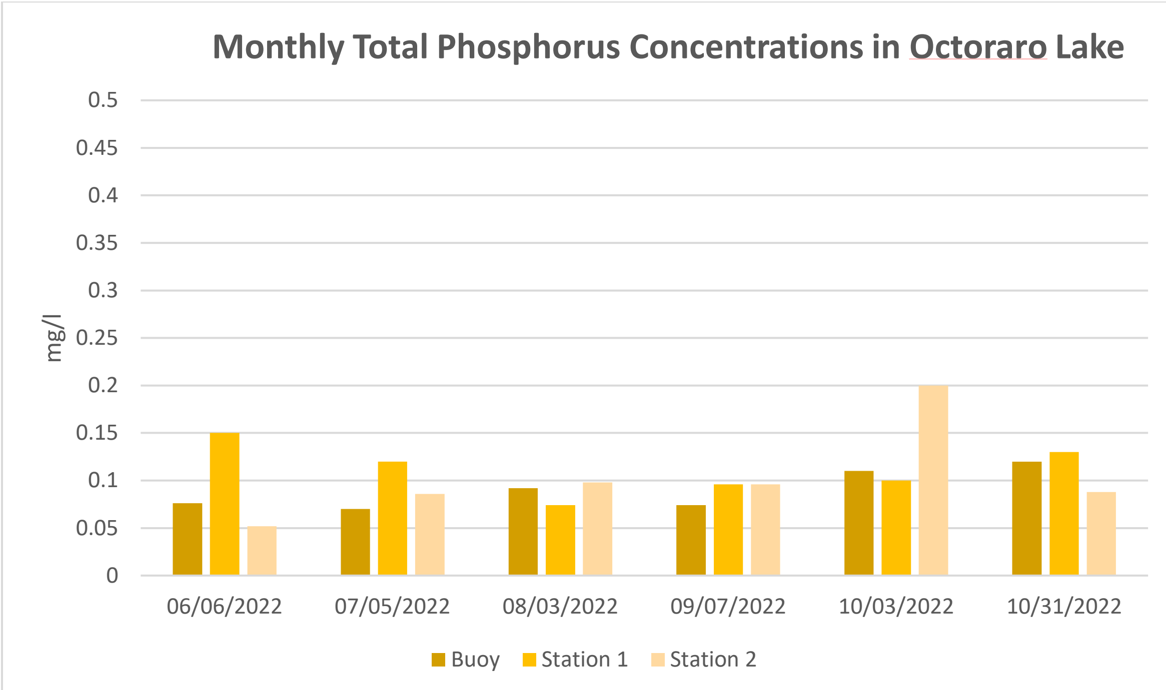

Figure 8. Monthly Total Phosphorus Concentrations at Three Locations in Octoraro Reservoir, 2022

Concurrently with above sampling, algal samples were taken monthly for PADEP which were analyzed for presence of potentially toxin-producing algae, and toxin tests if algal cell thresholds were exceeded. This work was completed for PADEP and overall results are beyond the scope of this project but it was helpful to look at the sample taken closest to the time of the assumed algal boom. High cell counts of Raphidiopsis were seen at all four of the sampling locations as well as very low but measurable amounts of anatoxin (0.58-0.72 ppb). However, when the high counts of Raphidiopsis were seen in the sample, no spike in chlorophyll-a or phycocyanin was observed. It was not until two weeks later when those indicators spiked but no discrete samples were taken during the suspected bloom period: by the next monthly sampling event, all indicators were back to baseline conditions. This points to the importance of real-time monitoring or alternatively, the potential of using remote satellite imagery to detect changes in chlorophyll and provide some predictive power on conditions being suitable for an algal bloom.

In 2021 and 2022, we sampled concurrently when possible or within two days of a Sentinel-2 satellite crossing with the intention to correlate one point in the lake over multiple satellite passes over the 6-month sampling season. Multispectral imagery returns from remote satellite imagery has been used in numerous applications regarding HABs. Larger, more advanced satellite technology is used in large lakes where specific algal values can be remotely measured but the spatial resolution is such that it precludes use in small lakes. The Sentinel-2 satellite is more low-tech, but has a 5-day return time and a 10-meter spatial resolution, so it is a good candidate to explore for small lakes.

Established indices are available in the literature for using multispectral data like what are collected by the Sentinel-2 (Table 2). These include Blue Green Index (BGI), Normalized

Difference Chlorophyll Index (NDCI), and 2BDA and 3BDA which are a combination of red wavelength bands.

Algorithm	Index	Reference	Sample Size	Chlorophyll-*a* Range (ug/l)
BGI	B(2)/B(3)	Nguyen et al., 2020	39	42.00 - 258.00
NDCI	(B(5)-B(4))/(B(5)+B(4))	Mishra & Mishra, 2012	35	0.90 - 16.06
2BDA	B(5)/B(4)	Duan & Bastiaanssen, 2013	75	0.99 - 42.44
3BDA	$(B(4)^{-1}-B(5)^{-1})*B(6)$	Gitelson et al., 2008	8	19.67 - 93.14

Table 2. Sources of the Four Band Combinations Previously Found to Correctly Predict Field-measured Chlorophyll-a Concentrations (Each of the four sources had sample sizes and concentration ranges similar to Octoraro Reservoir (2022) locations (n = 18, 14.3 – 72.67 ug/l).)

Despite having similar datasets to what was used in the literature, we did not have very good correlation with our chlorophyll data collected in lake and predicted chlorophyll from any of the indices (Figure 9). It is likely that two factors were likely responsible for this. In the studies where the indices were developed, multiple samples were taken within a lake on the same day and compared to one satellite image. In both years of our study, we were attempting to compare one point in the lake with satellite images across time. With only having one point on the lake, the spectral return values did not vary widely, so as our chlorophyll values fluctuated, the metrics, BGI, NDCI, and 2BDA and 3BDA remained pretty much the same.

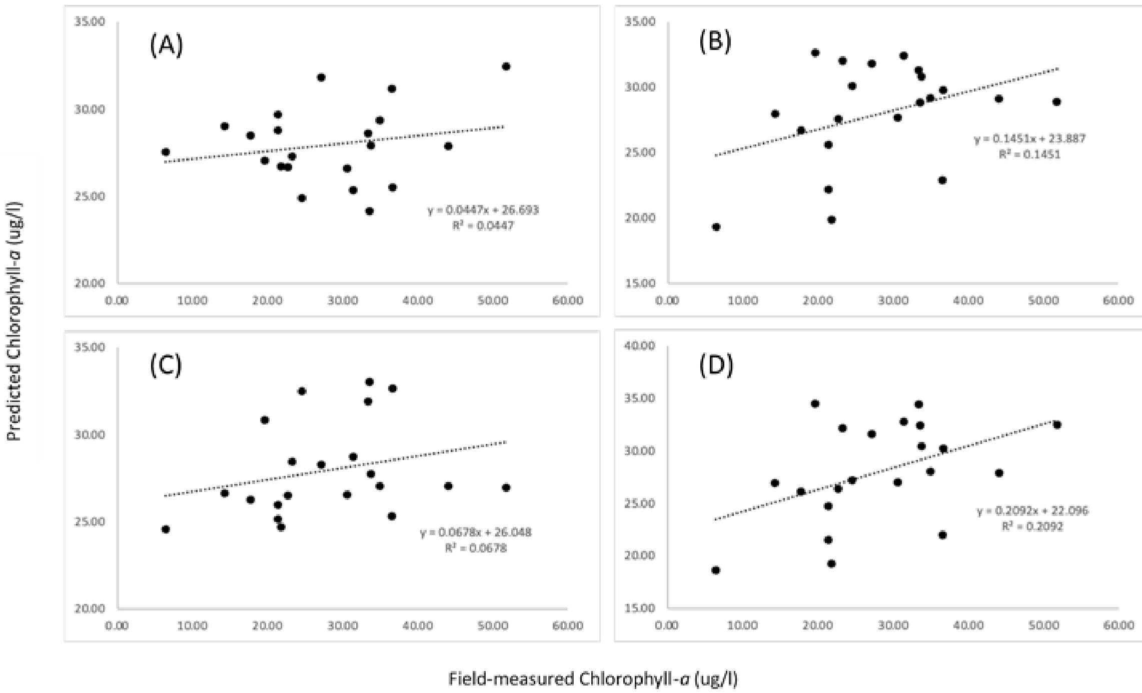

Figure 9. Validation Plots Comparing Field-measured Chlorophyll-a to Predicted Chlorophyll-a Using (A) BGI, (B) NDCI, (C) 2BDA, and (D) 3BDA Indexes Calculated Using Sentinel-2 Imagery for Octoraro Reservoir

The second issue that likely impacted the results was inconsistency with lab chlorophyll results. When using the YSI EXO total algae sensor, lab samples for chlorophyll must be collected to provide a lake-specific correction factor for the chlorophyll-a concentrations derived from RFU values using internal regression equations programmed in the sonde. However, when lab chlorophyll results were not at all consistent and did not even correspond to higher or lower RFU values, the actual chlorophyll concentrations that were compared to predicted concentrations were very suspect.

NEXT STEPS

In 2023, the monitoring buoy with an EXO data sonde and total algae sensor was once again deployed in Octoraro Reservoir. We did an earlier deployment in May 2023, hoping to capture more variabilty in water quality and the buoy will be pulled out at the end of October again. In order to address some of the issues from the first two years, in addition to monthly samples concurrent with the Sentinel-2 satellite, we also did a sampling blitz in early Septmeber 2023 on a day where the satellite was crossing. We sampled 15 locations within Octoraro Reservoir for chlorophyll a and hope that results will be more meaningful in comparing predicted to actual chlorophyll. Additionally, we changed labs for chlorophyll analysis and sampled in triplicate to increase reliability and get a handle on variability. Initial results with the new lab are very promising with much better correlation between sonde data and lab data.

Also in 2023, we have been working more closely with CWA to validate data from new continuous water quality monitoring technology they recently deployed in Octoraro Reservoir. CWA staff also flew their drone over parts of the lake during our sampling blitz in an effort to compare drone multispectral data with similar data collected by Sentinel-2.

These results were shared with the PA HABS Task Force in March 2023 and have been incorporated into the wider PADEP Statewide HABS database. Partners in the PA HABS Task Force include PADEP, PA DCNR, PA Department of Health, PA Fish and Boat Commission, and PA Bureau of Labs. Results were also presented at the poster session of the National Monitoring Conference in April 2023. Staff are in early conversations with NYSDEC staff for data exchange and information sharing about the NY HABs program.

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