

# **Harmful Algal Bloom Monitoring and Research Project: Octoraro Reservoir, 2024 Technical Summary**

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## 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 continues 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. In recent years, scientists have been evaluating potential methods of better understanding and predicting HABs. The Commission launched a pilot study in 2021 in Lackawanna Lake to test run techniques to monitor and predict HABs (Steffy, 2022).

For the last three years, Commission staff has 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). 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 study in Octoraro Reservoir has two objectives:

1. Continue refining use of continuous monitoring techniques for algal pigments, compare results to more traditional discrete water samples, compare equipment types in continuous monitoring applications, and correlate observed environmental variables with cyanobacteria density and toxins when present (Steffy, 2022; Steffy, 2023; Steffy, 2024).
2. Combine the collected data with Sentinel-2 satellite data to eventually build a predictable HABs model.

This research will inform Commission member states 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. Additional insights are gained each year, and Commission staff continues to build capacity and find new ways to support state and regional monitoring and research efforts.

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 third year of monitoring in Octoraro Reservoir in 2024.



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

## **METHODS**

A YSI EXO sonde was deployed within a buoy in May 2024 on the southern part of Octoraro Reservoir near the dam. Data were collected continuously every 30 minutes through the end of October 2024. The buoy was set so the sonde was collecting data about one meter below the water surface.

One in-lake monitoring site was co-located with the monitoring buoy, and additional in-lake sampling was 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.

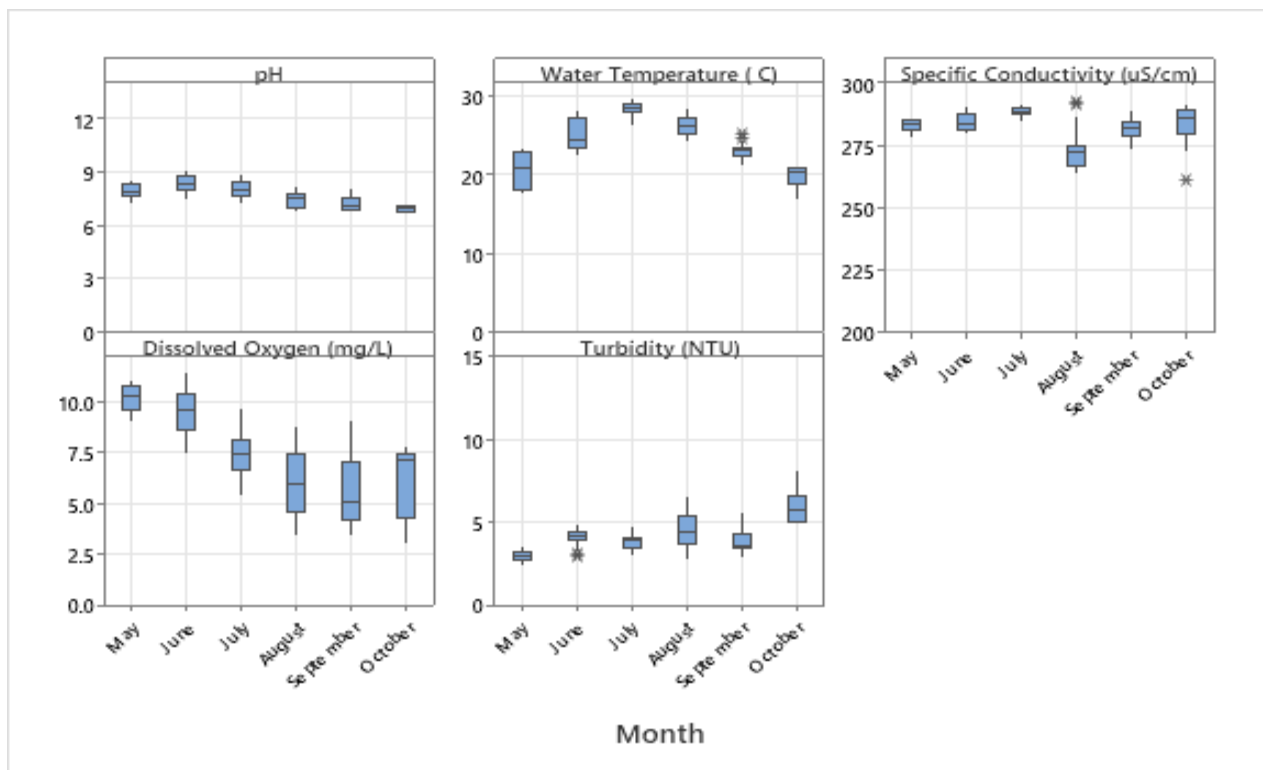
Temperature, pH, dissolved oxygen, conductivity, turbidity, chlorophyll-a, phycocyanin, light intensity, and air temperature was collected continuously at 30-minute intervals at the in-lake monitoring buoy site. Water samples collected from the photic zone from each of three in-lake sites were analyzed for total nitrate, phosphorus, and lab-measured chlorophyll-a. Discrete monthly samples were taken concurrently, or within one day, with the passage of the Sentinel-2 satellite.

While not included in the scope of this project, Commission staff also collected additional samples at PADEP's request (Launch, Station 1, Station 2, Station 3; Figure 1). Algal samples and associated algal toxin analysis (as warranted) were collected by Commission staff and analyzed by PADEP Bureau of Labs. These data will complement 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**

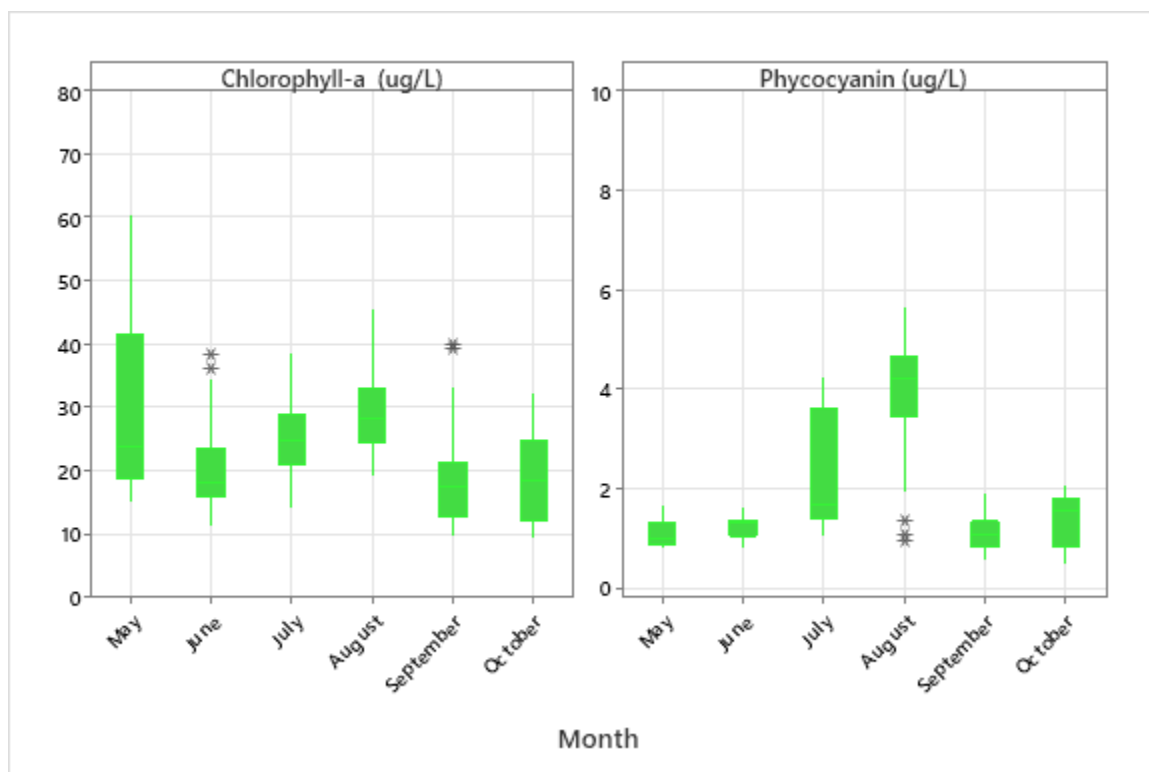
### **Continuous Data**

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 are mainly consistent with past years (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 was rarely above 9.0 as was observed in previous years. Dissolved oxygen declined across the summer with unexpectedly low dissolved oxygen near the surface in September and October. Turbidity was quite steady in 2024 and was always below 10 NTU as a daily mean value.



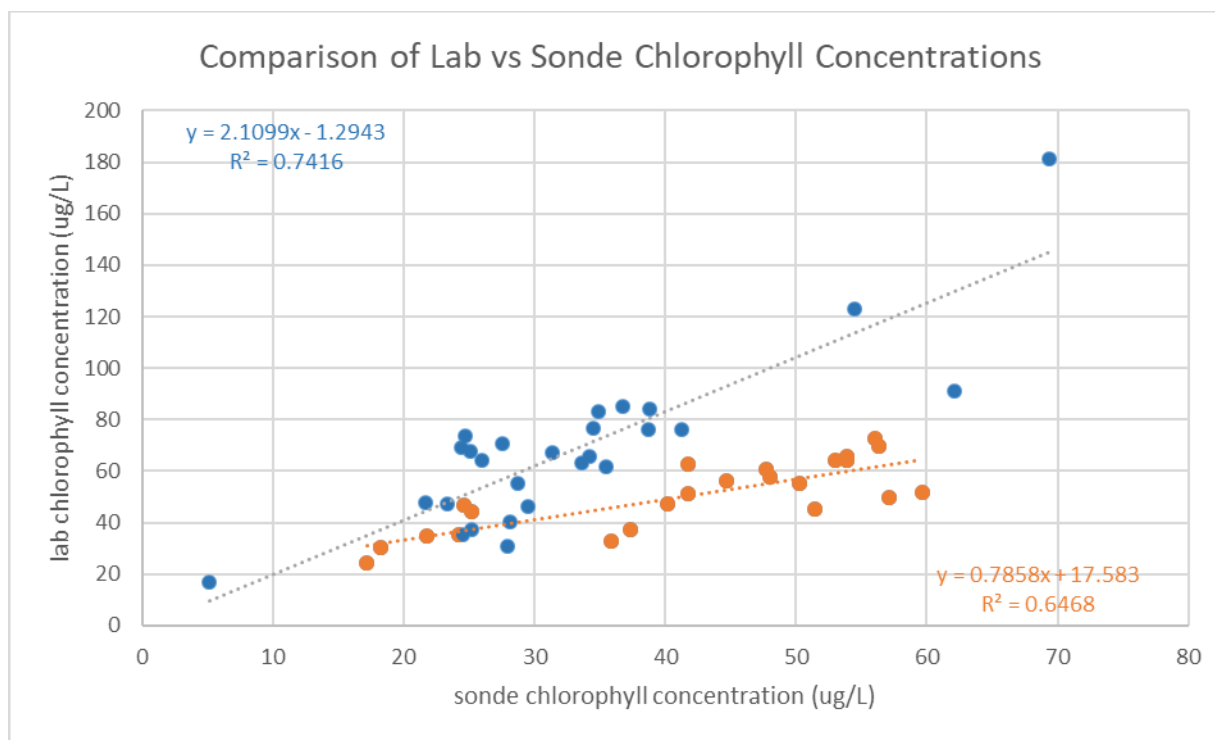
**Figure 2. Summary of Monthly Basic Water Chemistry Data Collected at Octoraro Monitoring Buoy, May-October 2024**

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. Unlike past years when peak algal pigments were in September and October, the most variation and greatest concentration of chlorophyll in 2024 was observed in May, while phycocyanin was highest and most variable in July and August (Figure 3).



**Figure 3. 2024 Monthly Algal Water Chemistry from YSI EXO Total Algal Sensor**

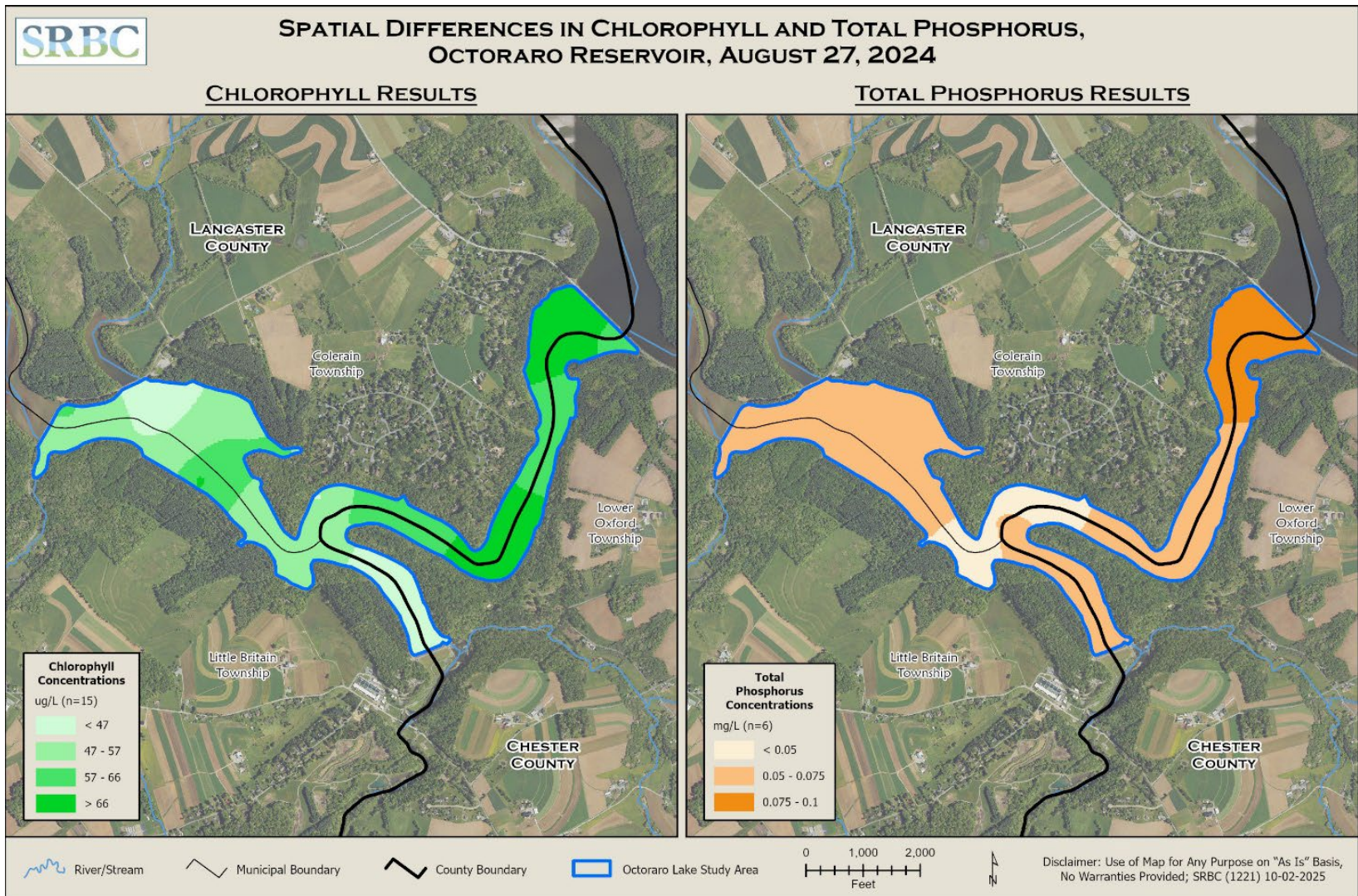
The manufacturer recommendation for best use of the YSI total algal sensor includes lab analysis of chlorophyll to better calibrate the sonde for each individual lake and using a correction factor for RFU to ug/L conversion as needed. In 2022, this was attempted, but accuracy and consistency issues with the lab prevented any meaningful analysis as the data showed no correlation between lab chlorophyll and sonde chlorophyll. In 2023, using a different lab and a stronger triplicate quality assurance sample design, staff was able to get much more reliable and consistent lab results for chlorophyll. In 2024, using the same lab, results were relatively consistent, but because the range of chlorophyll observed was smaller, the slope of the relationship is less steep. Thus, the equation for the 2024 data was used as the correction factor in the conversion of the continuous RFU data collected by the sonde to a discrete chlorophyll concentration (Figure 4).



**Figure 4. Relationship Between Sonde Chlorophyll Concentrations and Lab Chlorophyll Concentrations in 2023 (blue) and 2024 (orange)**

### **August Sampling Blitz**

In order to better understand lake-wide dynamics and how variable lake chemistry is, a sampling blitz was completed on August 27, 2024. This was also a day where the Sentinel-2 satellite was crossing the lake, so it provided an opportunity to get 15 data points to match up chlorophyll readings and satellite imagery. Results from the blitz revealed the nitrate was very consistent across the lake with concentrations between 2.46-2.76 mg/L. However, phosphorus and chlorophyll showed differences across the lake and pointed to higher concentrations of both coming in from East Branch Octoraro Creek (Figure 5). This is notable, as that section of the lake typically is more shallow but also typically has the lowest cyanobacteria counts. In previous years, higher concentrations of chlorophyll were observed coming in from the West Branch Octoraro side of the lake. Chlorophyll and total phosphorus concentrations indicate that the entire lake is eutrophic and sections of the lake can often be considered hypereutrophic (Carlson, 1977).



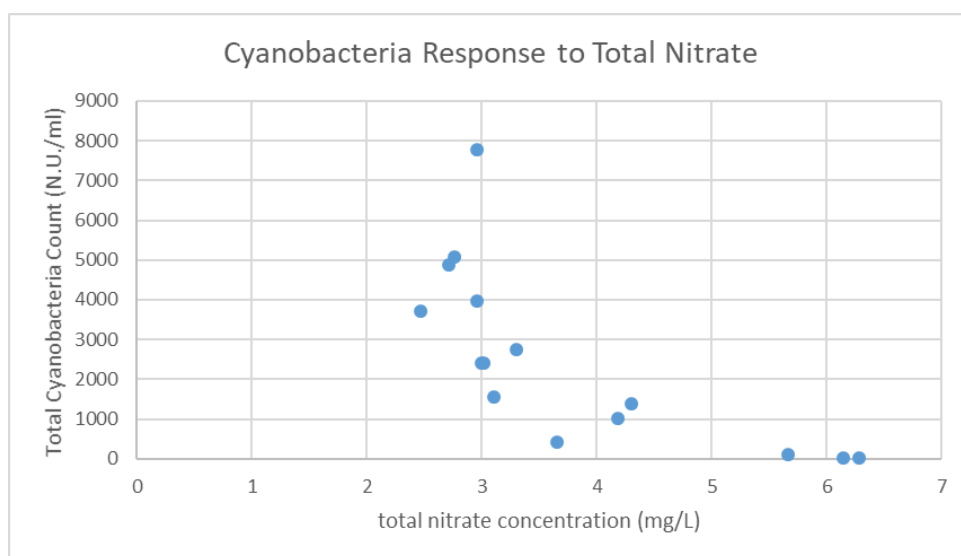
**Figure 5. Spatial Differences in Chlorophyll and Total Phosphorus Concentrations in Octoraro Reservoir, August 27, 2024**

## Cyanobacteria

Concurrently with discrete monthly water sampling, algal samples were collected for PADEP and were analyzed for the presence of potentially toxin-producing algae and toxin tests if algal cell thresholds were exceeded ( $> 300$  natural units/ml). This work was completed for PADEP, and overall results are beyond the scope of this project, but in general, *Pseudanabaena* were the dominant genera observed. There were also high counts of *Aphanocapsa*, *Raphidiopsis*, and *Planktolyngbya* throughout the season. Total sample colony counts triggered toxin tests in July, August, September, and October. However, no toxins were ever detected in 2024. As seen in Figure 3, phycocyanin was highest in July and August, while the highest algal colony counts were observed at all sites in August and September.

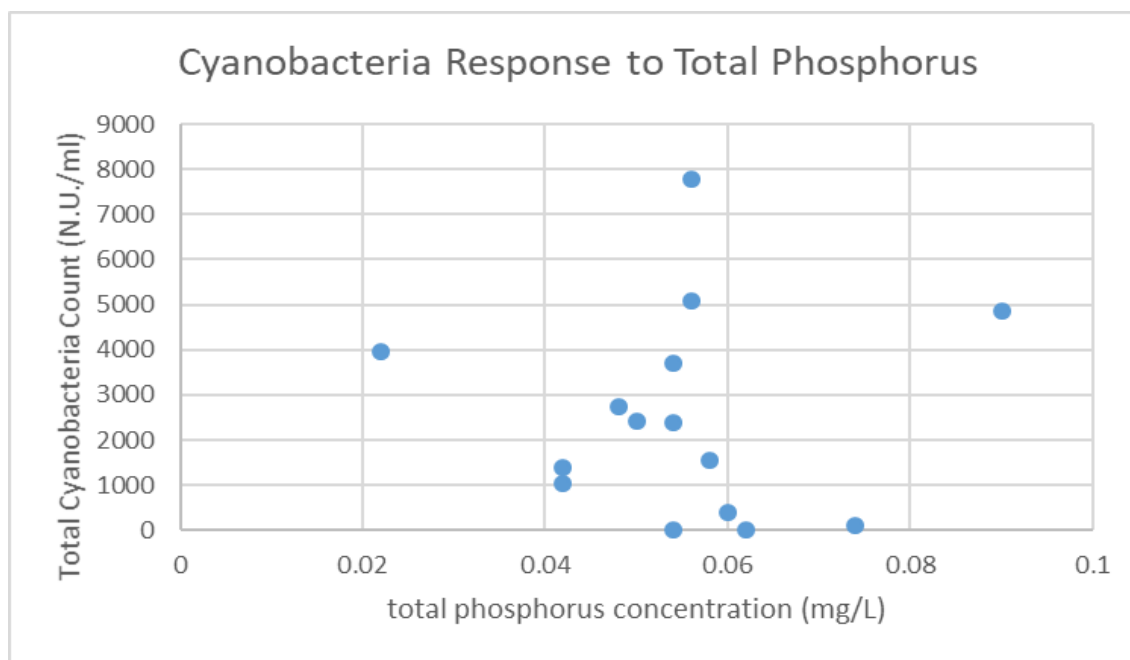
Algal blooms are often associated with high levels of nutrients such as nitrate and phosphorus. Monthly samples of both were taken at three locations in the lake to assess variability. Station 1 represented inputs from West Branch Octoraro Creek, Station 2 represented inputs from the East Branch Octoraro Creek, and Station 3 (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<sup>2</sup> drainage area, so it was no surprise to routinely see nitrate concentrations in the lake exceeding 6 mg/L. However, there was no correlation between nitrate concentration and natural units of cyanobacteria observed (Figure 6).

Data collected for other work within the Octoraro Creek Watershed at the mouths of the East and West Branches of Octoraro Creek before they enter the reservoir showed similar water chemistry coming in from both branches. Instream nitrate and phosphorus concentrations averaged 9.16 mg/L and 0.08 mg/L in the West Branch and 6.81 mg/L and 0.06 mg/L in the East Branch, respectively. Much work is being done within the watershed with local farmers to implement Best Management Practices which will ultimately also be beneficial to the reservoir.



**Figure 6. Response of Cyanobacteria to Total Nitrate Concentrations, 2024**

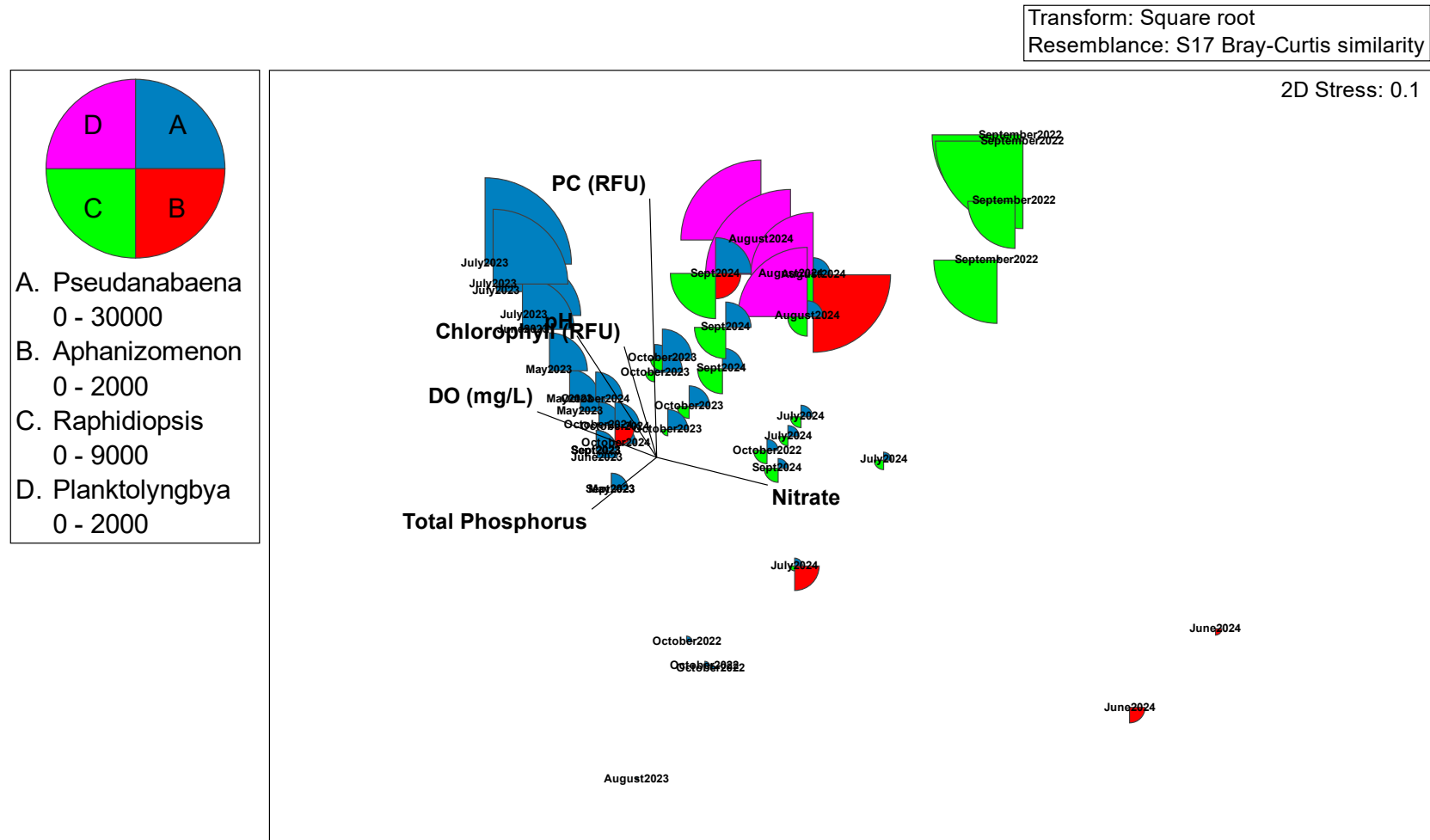
Similarly, total phosphorus concentrations did not show any correlation with cyanobacteria counts during 2024 (Figure 7). It should be noted that water samples for nutrient analysis were taken from the photic zone, and data include samples from all sites sampled in the lake for both nutrients and algal counts.



**Figure 7. Response of Cyanobacteria to Total Phosphorus Concentration, 2024**

With three years of monthly cyanobacteria data and continuous water chemistry, some notable observations can be made looking at how water chemistry is correlated with various types of cyanobacteria. In general, monthly cyanobacteria samples are often dominated by one genera of cyanobacteria (Figure 8). Looking at community composition similarity of all monthly samples from 2022-2024, samples dominated by *Pseudanabaena* are correlated with elevated chlorophyll and phycocyanin levels and *Planktolyngbya* is correlated with elevated phycocyanin, which is potentially helpful in predicting future blooms of those specific genera. However, *Rahidiopsis*-dominated samples were not correlated well with any of the chlorophyll or toxin parameters (Figure 8).

## Monthly Cyanobacteria Composition and Correlating Factors 2022-2024



**Figure 8. nMDS Plot Showing Similarity of Cyanobacteria Communities From 2022-2024 and Associated Correlations with Water Chemistry Parameters**

## **Sentinel-2 Satellite Data Developments**

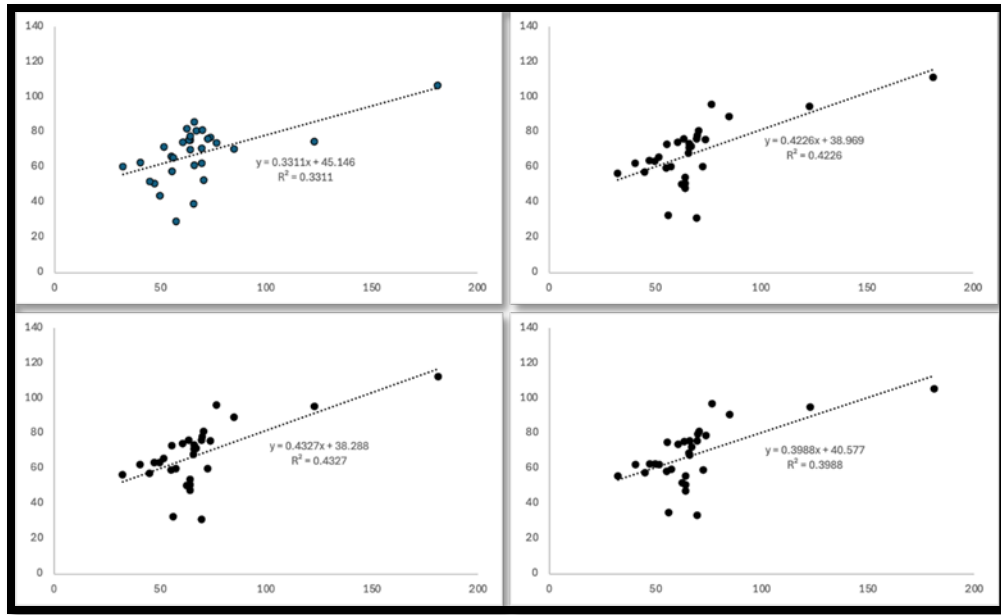
One of the long-term goals of this work is to use multispectral imagery to understand and eventually predict the potential for a HAB in smaller lakes. Multispectral imagery returns from remote satellite imagery have been used in numerous applications regarding HABs. Larger, more advanced satellite technology 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.

Two years of concurrent chlorophyll concentrations and satellite imagery were used to create a relationship between the two using established algorithms available in the literature (Table 1). Between 2023 and 2024, there were 30 usable paired values, and results were promising. About 40-50 percent of the satellite images were not viable due to excessive cloud cover, which will likely continue to be an issue and a drawback of working in small lakes.

| Algorithm | Index                                          | Reference             | Sample Size | Chlorophyll- <i>a</i> Range (ug/l) |
|-----------|------------------------------------------------|-----------------------|-------------|------------------------------------|
| BGI       | B(2)/B(3)                                      | Nguyen et al.         | 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 et al.           | 75          | 0.99 - 42.44                       |
| 3BDA      | (B(4) <sup>-1</sup> -B(5) <sup>-1</sup> )*B(6) | Gitelson et al.       | 8           | 19.67 - 93.14                      |

***Table 1. References and Chlorophyll Ranges for Algorithms Used in Analysis***

Each algorithm tested showed a positive relationship, but the results were not significant, and are largely driven by the one high outlier value (Figure 9). Only between 33-43 percent of the variability in the observed chlorophyll concentrations can be explained by the index algorithms that use satellite spectral band returns. This suggests there is still potential for this approach to provide valuable data in small eutrophic lakes like Octoraro Lake, but that the dataset needs to be bolstered and include higher values, or perhaps the predictive value only starts above a certain threshold and is not as useful in lower concentrations.



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

## Next Steps

Results from 2024 add to the growing dataset of environmental and climate variables that impact cyanobacteria and potentially harmful algal blooms in Octoraro Lake. While some of the data are consistent with past years, much is different, which points to the complexity of HABs and the need to conduct long-term monitoring to better understand all of the shifting dynamics. While strides were made in the effort to use satellite imagery over the last two years, more data are needed. Staff followed the same sampling design in 2025, and initial data results show even more variability in the data.

These results were shared at the 12<sup>th</sup> U.S. Symposium on Harmful Algae in November 2024 and CWA in April 2025 and have been incorporated into the wider PADEP Statewide HABS database. Partners in the PA HABS Task Force include PADEP, PADCNr, PA Department of Health, PA Fish and Boat Commission, and PA Bureau of Labs. Commission staff has been in contact with partners in the U.S. Environmental Protection Agency (USEPA) who are working on a nationwide model using Sentinel-2 data and intend to be an active participant in testing those data models. The satellite imagery data results to this point are roughly in line with those in the national dataset which was also presented at the 12<sup>th</sup> U.S. Symposium on Harmful Algae.

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