Harmful Algal Bloom Monitoring and Research Project: Octoraro Reservoir, 2023 Technical Summary

Publication No. 339

October 2024

Luanne Steffy
Aquatic Ecologist



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 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. More recently, 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).

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 compare equipment types in continuous monitoring applications. 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. Each year additional insights are gained 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 second year of monitoring in Octoraro Reservoir in 2023.

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

METHODS

A YSI EXO sonde was deployed within a buoy in May 2023 on the southern part of Octoraro Reservoir near the dam. Data were collected continuously every 60 minutes through the end of October 2023. 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 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 60-minute intervals at the in-lake monitoring buoy site. Water samples collected from all 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. Additionally, continuous monitoring data sondes were 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 (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

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 routinely exceeded 9.0 from May-July. Super-saturation of dissolved oxygen was observed at the 1 meter depth where the buoy was positioned, but depth profiles revealed steeply declining dissolved oxygen concentrations between 3-4 meters. Depth measurements indicate depth of the sensors from the surface and fluctuates slightly with lake level changes.

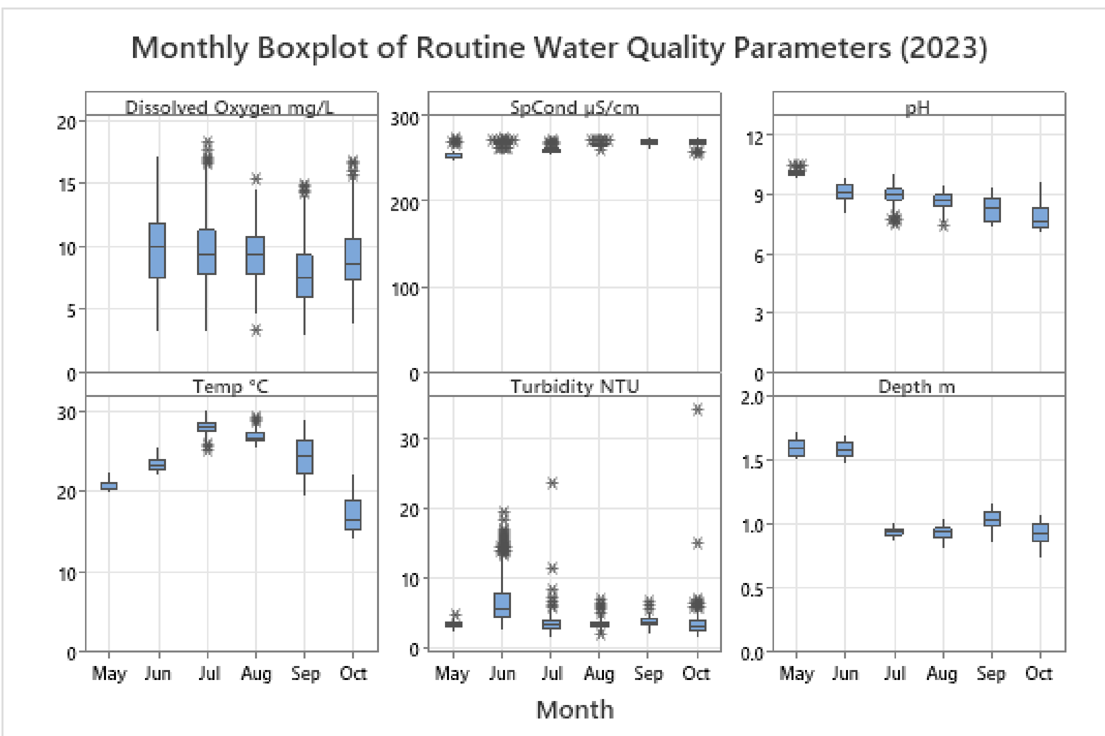

Figure 2. Summary of Monthly Basic Water Chemisty Data Collected at Octoraro Monitoring Buoy, May-October 2023

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. As in 2022, the most variation and greatest concentrations in both pigments was observed late in the season, particularly October 2023 (Figure 3).

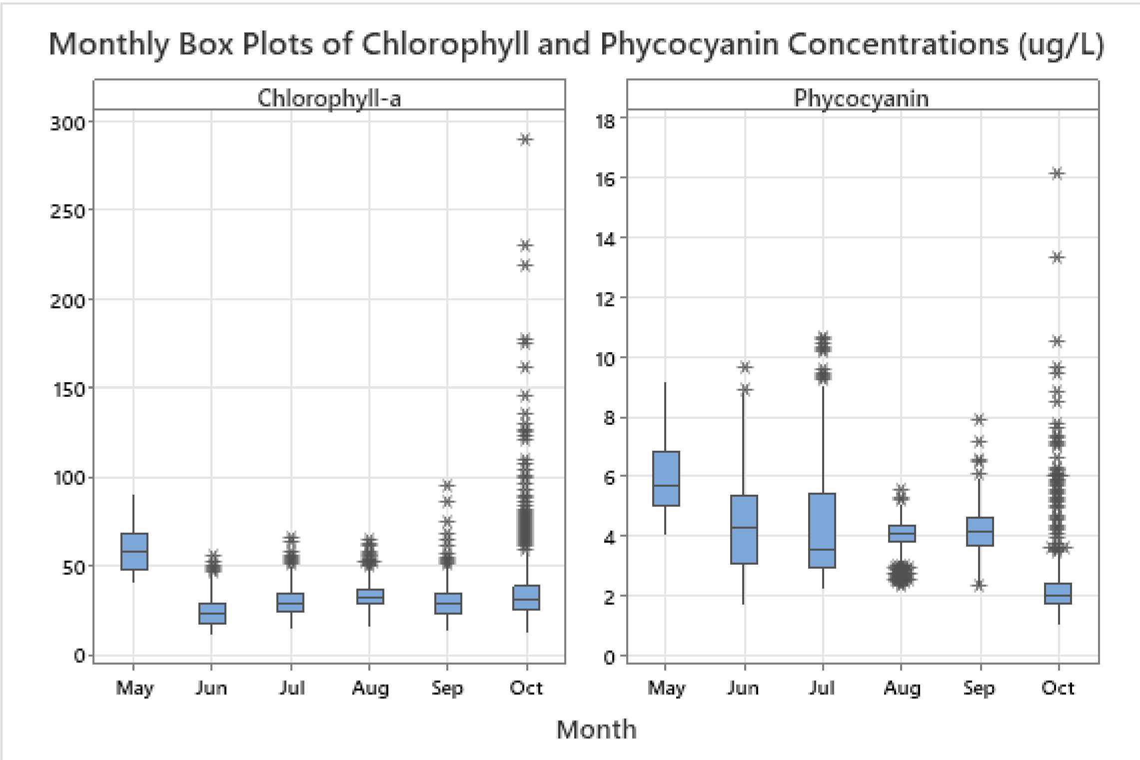

Figure 3. 2023 Monthly Algal Water Chemistry from EXO Total Algal Sensor

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 atttempted 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 (Figure 4). This equation was used to create a corrected continuous record of chlorophyll by adjusting the in-situ record with a correction factor.

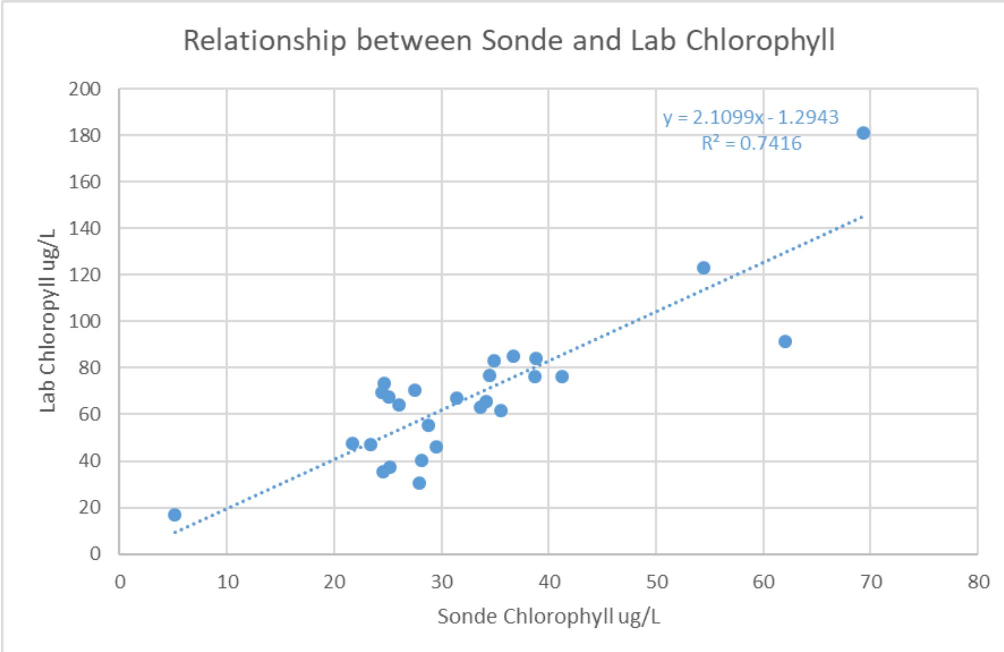

Figure 4. Relationship Between Sonde Chlorophyll Concentrations and Lab Chlorophyll Concentrations

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 most common genera observed and colony counts triggered toxin tests in May, July, and October. However, no toxins were ever detected in 2023. As seen in Figure 2, algal pigments were highest in October but the highest concentrations of all cyanobacteria was seen in July.

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. However, there was no correlation between nitrate concentration and natural units of cyanobacteria observed (Figure 5).

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 7.3 mg/L and 0.42 mg/L in the West Branch and 6.2 mg/L and 0.31 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.

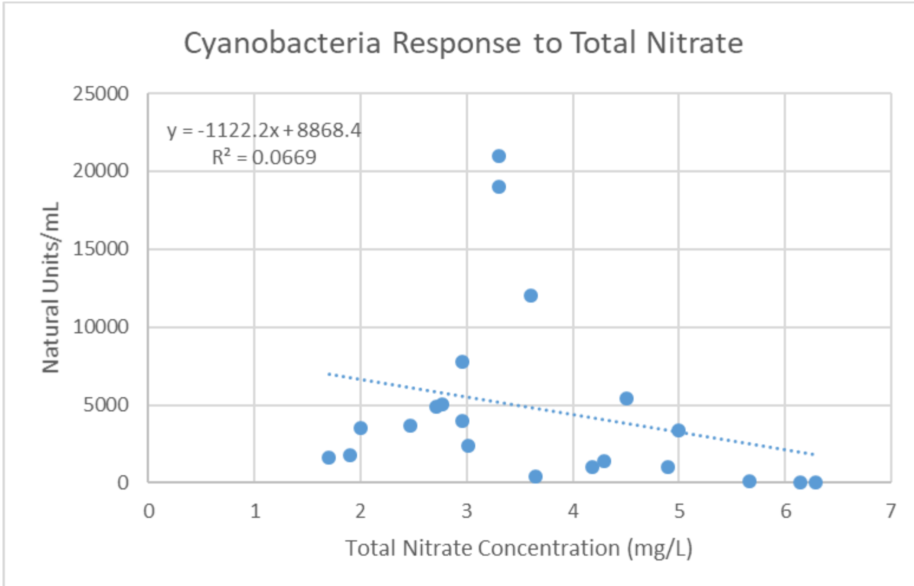

Figure 5. Response of Cyanobacteria to Total Nitrate Concentrations

Total phosphorus concentrations did show a positive but weak correlation with cyanobacteria counts during 2023 (Figure 6). 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 nutients and algal counts.

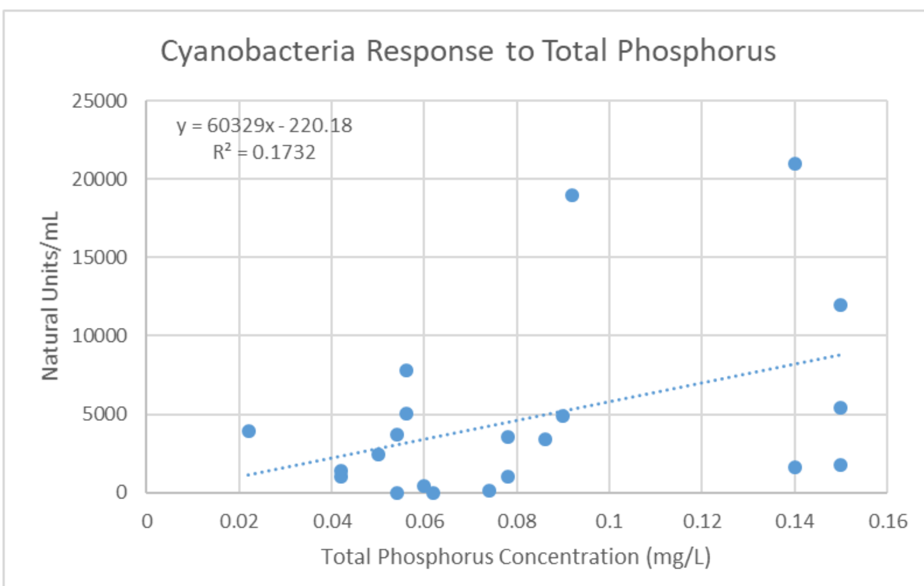

Figure 6. Response of Cyanobacteria to Total Phosphorus Concentration

One new supplementary piece of data analysis for 2023 was the comparison of two different brands of continuous monitoring equipment. The water supplier installed an LG Sonic brand of continuous monitoring sonde that was designed to respond in real time to changes in water quality to impede cyanobacteria from moving in the water column and entering the water supply intake. The LG Sonic buoy and the Commission YSI buoy were only about 50 m apart in the lake and recorded many of the same parameters. At the request of the water supplier, a cursory analysis of how closely the results tracked across the May – October 2023 field season was completed. Unsurprisingly, more routine parameters like water temperature and pH tracked very closely across both sensors types. The more novel algal sensors showed more variability between sonde types. Chlorophyll tracked more closely than phycocyanin (Figures 7 and 8). Note the similar pattern in phycocyanin but the different scales on each axis. Discussions with the respective manufacturer's technical staff are on-going but 2024 data look to be more closely aligned for phycocanin.

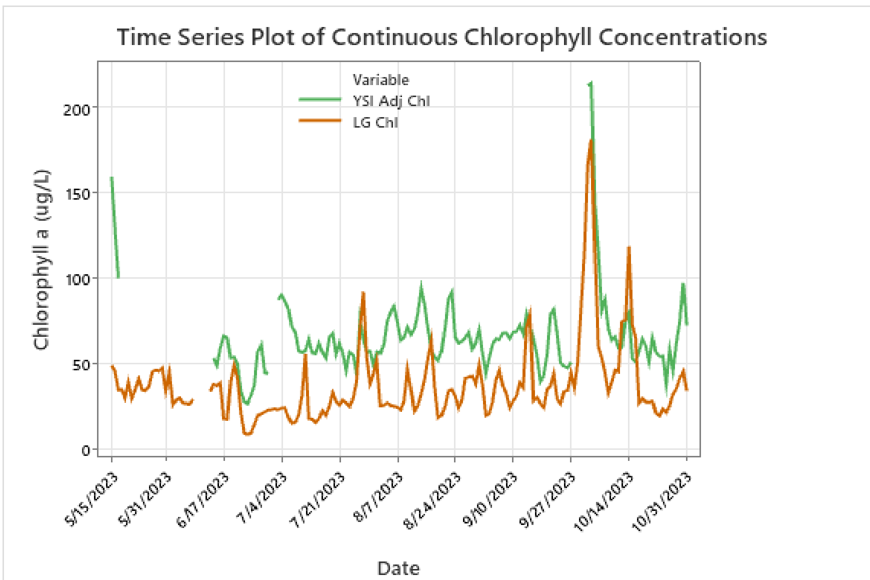

Figure 7. Comparison of Chlorophyll Concentrations Across Different Sensor Brands

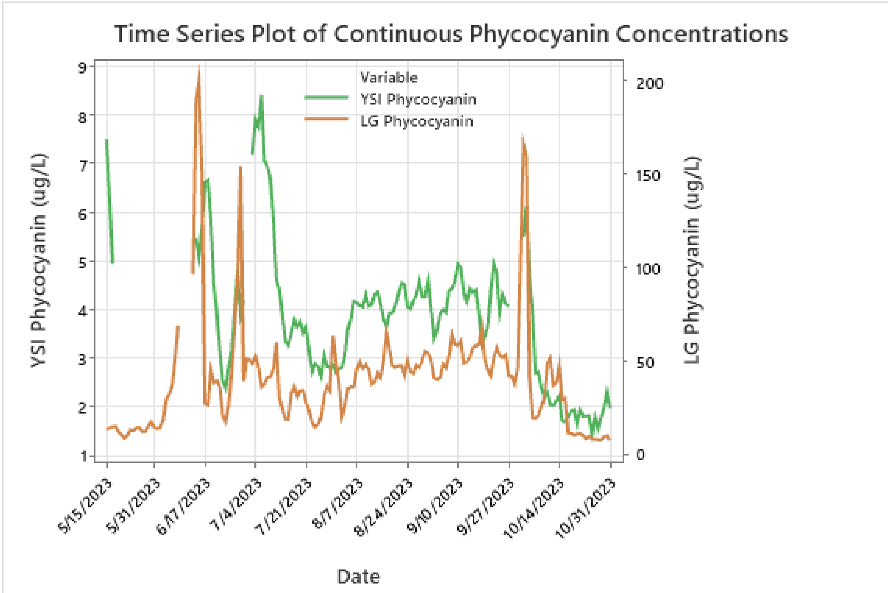

Figure 8. Comparison of Phycocyanin Concentrations Across Different Sensor Brands

PROJECT DEVELOPMENTS

Two significant developments occurred in 2023. First, samples were collected in triplicate and a new lab was used 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.

In order to address some of the issues from the first two years, in addition to monthly samples concurrent with the Sentinel-2 satellite coverage, a sampling blitz was conducted in early September 2023 on a day where the satellite was crossing. Fifteen locations within Octoraro Reservoir were sampled for chlorophyll-a with the expectation that results will be more meaningful in comparing predicted to actual chlorophyll.

As in past years, monthly samples were taken 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. In 2023, the Commission expanded one sampling event into a sampling blitz, where 15 locations on the lake were sampled for chlorophyll on a day that the Sentinel-2 was crossing in an attempt to better use established indices to correlate multispectral data with observed in-situ data. Established indices will be tested using observed data extracted from Sentinel-2 results available to the public (Duan and Bastiaanssen, 2013; Gitelson et al., 2008; Mishra and Mishra, 2012). Due to circumstances beyond our control, that data are not yet available for dissemination. In the next technical summary, two years of satellite-predicted chlorophyll vs observed chlorophyll will be reported.

These results were shared with the PA HABS Task Force in March 2024 and CWA in April 2024 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. 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. These data were also presented at the poster session at the 12th U.S. Symposium on Harmful Algae in October 2024.

REFERENCES

Steffy, L. 2022. Harmful Algal Bloom Monitoring and Research Project: Lackawanna Lake, Lackawanna County, PA. Publication No. 330. Susquehanna River Basin Commission, Harrisburg, Pennsylvania.

Duan, Z. and W. Bastiaanssen. 2013. Estimating water volume variations in lakes and reservoirs from four operational satellite altimetry databases and satellite imagery data. Remote Sensing of Environment. Volume 134, pp. 403-416.

Gitelson, A., G. Dall'Olmo, M. Wesley, D.C. Rundquist, T. Barrow, T.R. Fisher, D. Gurlin, J. Holz. 2008. A simple semi-analytical model for remote estimation of chlorophyll-a in turbid waters: Validation, Remote Sensing of Environment, Volume 112, pp. 3582-3593.

Mishra, S. and D. Mishra. 2012. Normalized difference chlorophyll index: A novel model for remote estimation of chlorophyll-a concentration in turbid productive waters. Remote Sensing of Environment, Volume 117, pp. 394-406.