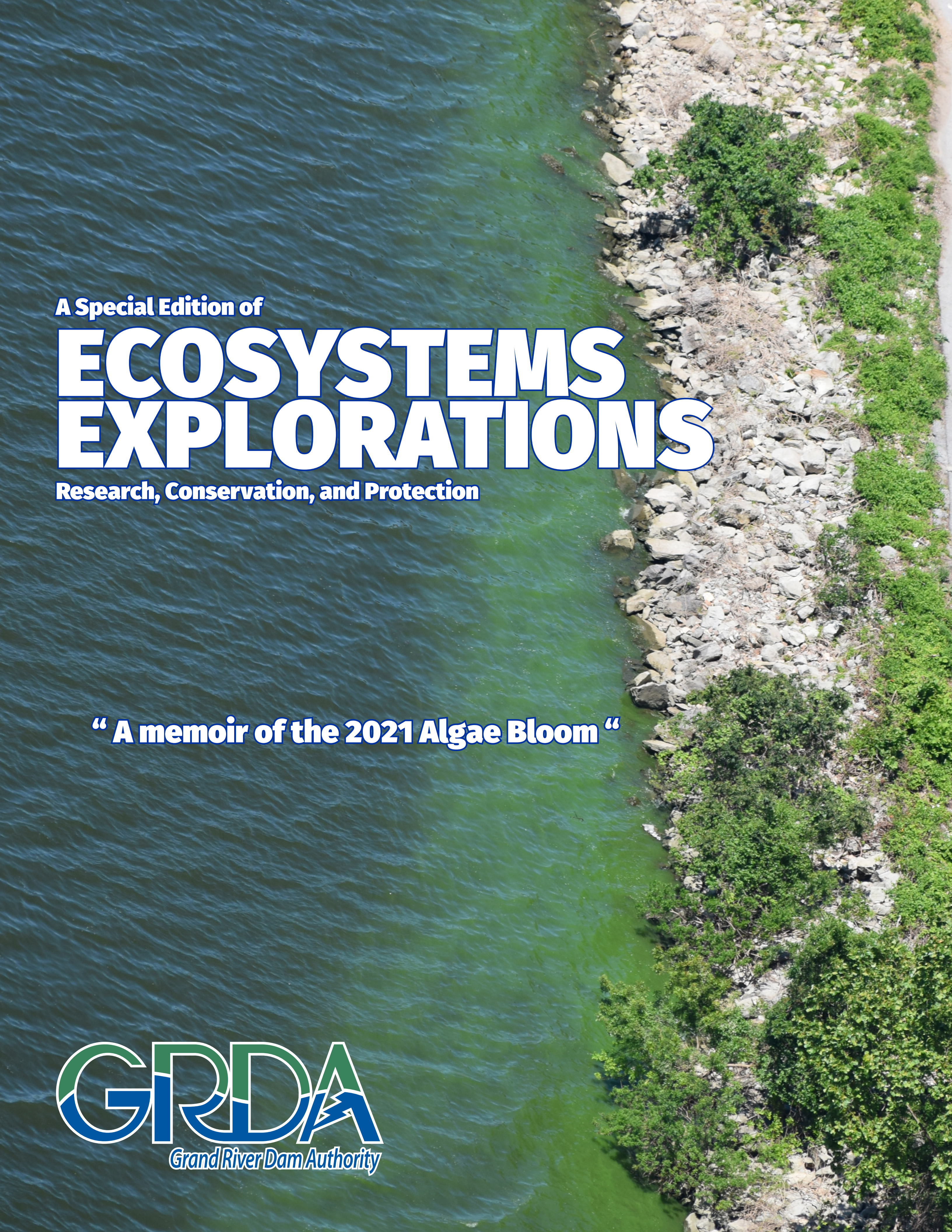


A Special Edition of

ECOSYSTEMS EXPLORATIONS

Research, Conservation, and Protection

" A memoir of the 2021 Algae Bloom "

GRDA
Grand River Dam Authority

Early-warning Water Quality Monitoring Buoys

GRDA with the assistance of the Oklahoma Water Resources Board (OWRB) has been deploying water quality monitoring buoys (Fig. 1) in the Horse Creek cove (Fig. 2) of Grand Lake for several years with the goal that these buoys will provide GRDA personnel with a warning of a developing cyanobacteria bloom. These buoys are outfitted with water quality sensors that continuously measure temperature, dissolved oxygen, pH, chlorophyll-a (pigment present in most types of phytoplankton), phycocyanin (pigment exclusive to cyanobacteria), and turbidity, and these data are visible to GRDA staff in real-time, providing a critical tool for detecting changes in water quality that are indicative of a cyanobacteria bloom.

In early June 2021, GRDA personnel noticed drastic fluctuations in phycocyanin that were associated with a rapid increase in water temperature (Fig. 3). GRDA personnel quickly responded and sampled the cove, learning that there was an abnormally high abundance of the cyanobacteria, *Microcystis*, present in the water column, and that conditions were favorable for a *Microcystis* bloom to form (high water temperatures, low wind, and anoxic hypolimnion). GRDA personnel began sampling daily to monitor the situation, and on the fourth day of sampling, a widespread *Microcystis* bloom had formed in the Horse Creek Cove. GRDA personnel continued to intensively monitor the bloom for several weeks until it crashed in mid-July.

The early detection of the bloom allowed the Water Quality Research Lab staff to adequately notify GRDA Executive Management of the risks of recreating in the Horse Creek Cove days before the bloom produced harmful concentrations of toxins. The buoys also allowed for GRDA personnel to monitor the cove from afar after the bloom crashed to ensure that additional blooms did not form for the remainder of the summer.

Figure 1: Monitoring Buoy deployed in Horse Creek

Figure 2: Horse Creek Buoy locations

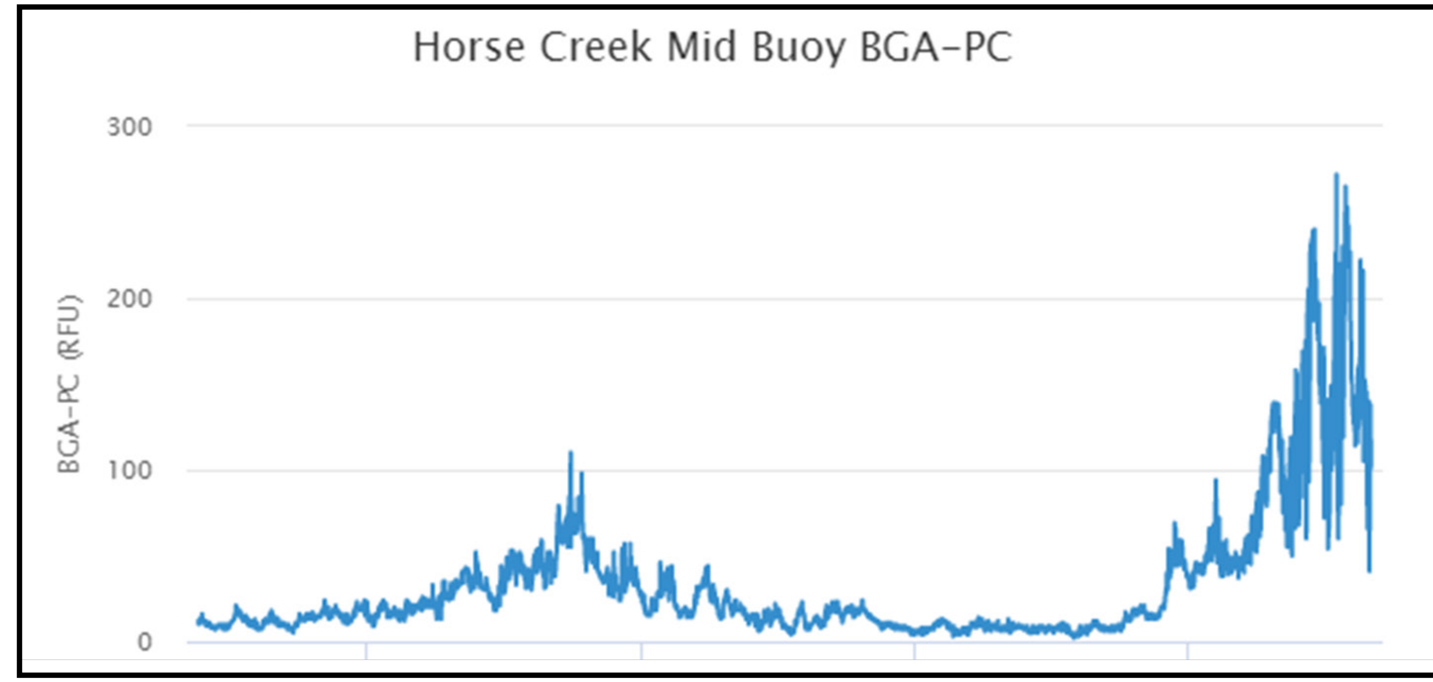


Figure 3: Continuous data series showing the rise of algae in early June of 2021

Monitoring the Cyano-bloom

Harmful cyanobacteria blooms are notoriously sporadic in their arrival and departure, making it challenging for researchers to link bloom formation, persistence, and die-off to causal environmental factors. Cyano-blooms are typically noticed after a surface scum becomes visible along the shoreline, which are often accompanied by high toxin concentrations, therefore, most monitoring efforts are reactionary. The early detection of the Horse Creek cyano-bloom of 2021 in conjunction with a pre-existing cyano-bloom sampling protocol provided GRDA personnel and their OSU research partners with a unique opportunity to capture critical environmental data before, during, and after the cyano-bloom (Fig. 4). The Water Quality Research Laboratory at the GRDA Ecosystems and Education Center in Langley, Oklahoma is one of the best equipped labs in the nation for studying cyano-blooms. The laboratory is equipped with a Cyanotoxin Automated Analysis System (CAAS) to measure cyanotoxins in water samples (Fig. 8), a FlowCam Cyano that takes photos of individual algae particles in the water for rapid identification and enumeration of toxin-producing cyanobacteria (Fig 9), qPCR equipment for detecting the presence of toxin-producing genes in cyanobacteria, YSI sonde water quality probes that can measure a suite of water quality variables in the lake, and additional resources that make the thorough monitoring of a cyano-bloom possible.

GRDA personnel sampled the cyano-bloom multiple times a week from four fixed monitoring stations that included the three early-warning buoys and a routine monitoring site; and they collected surface grab samples from additional areas where surface scums were present, since surface scums are known to move with changes in wind direction. The figure on page 4 demonstrates the types of data collected and the tools used to collect those data.

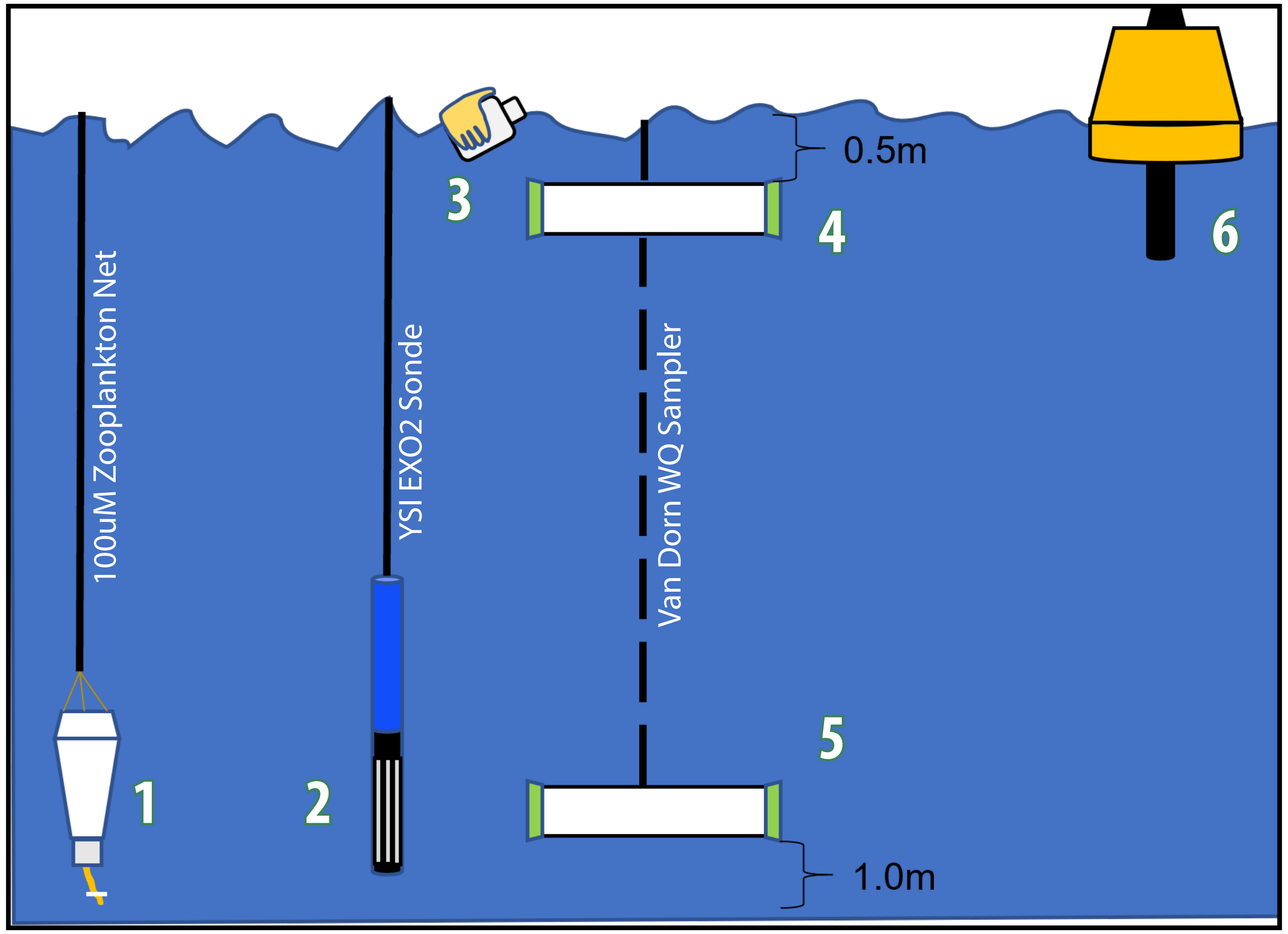


Figure 4: Showing the sampling procedure used for the 2021 intensive sampling.

1. Zooplankton Tow

- Zooplankton

2. YSI Sonde Profiles

- Temperature
- Dissolved Oxygen
- Phycocyanin (RFU)
- Chlorophyll (RFU)
- Dissolved Organics
- Turbidity
- pH
- Conductivity

3. Surface Grab

- Toxins
- Flowcam

4. Subsurface Grab

- Total and Dissolved Nutrients
- Flowcam
- Chlorophyll-a
- Total and Dissolved Ions
- DNA

5. Benthic Grab

- Total and Dissolved Nutrients
- Flowcam
- Total and Dissolved Ions
- DNA

6. Early Warning Buoys

- Temperature
- Turbidity
- Chlorophyll-a
- Phycocyanin
- pH
- Dissolved Oxygen

Lake Profiles

Water quality profiles were measured using a YSI sonde water quality probe that measured dissolved oxygen (DO), temperature, turbidity, dissolved organic matter (fDOM), relative chlorophyll-a, relative phycocyanin, conductivity, and pH. The temperature and DO profiles were critical for tracking changes in the thermal stratification of the water column and predicting internal phosphorus release from benthic sediments. Sediments will start releasing phosphorus when the DO of the hypolimnion is < 2mg/L. Since *Microcystis* and some other cyanobacteria can regulate their buoyancy, they are able to migrate down to the hypolimnion to absorb nutrients, and then float up to the surface to perform photosynthesis. Therefore, internal loading of phosphorus from benthic sediments is often a major source of nutrients for cyano-blooms. As seen in Figure 5, there were several extended periods in which the DO of the hypolimnion was < 2mg/L. The low DO in Horse Creek appeared to be driven by the metabolic breakdown of fDOM, as there is a definitive inverse relationship between DO and fDOM across depth and time (Fig. 5). The large influx of fDOM in late June and early July was caused by intruding stormwater from a large precipitation event in the watershed. The intruding stormwater was originally well oxygenated but became anoxic/hypoxic within two days of discharging into the lake (Fig. 5).

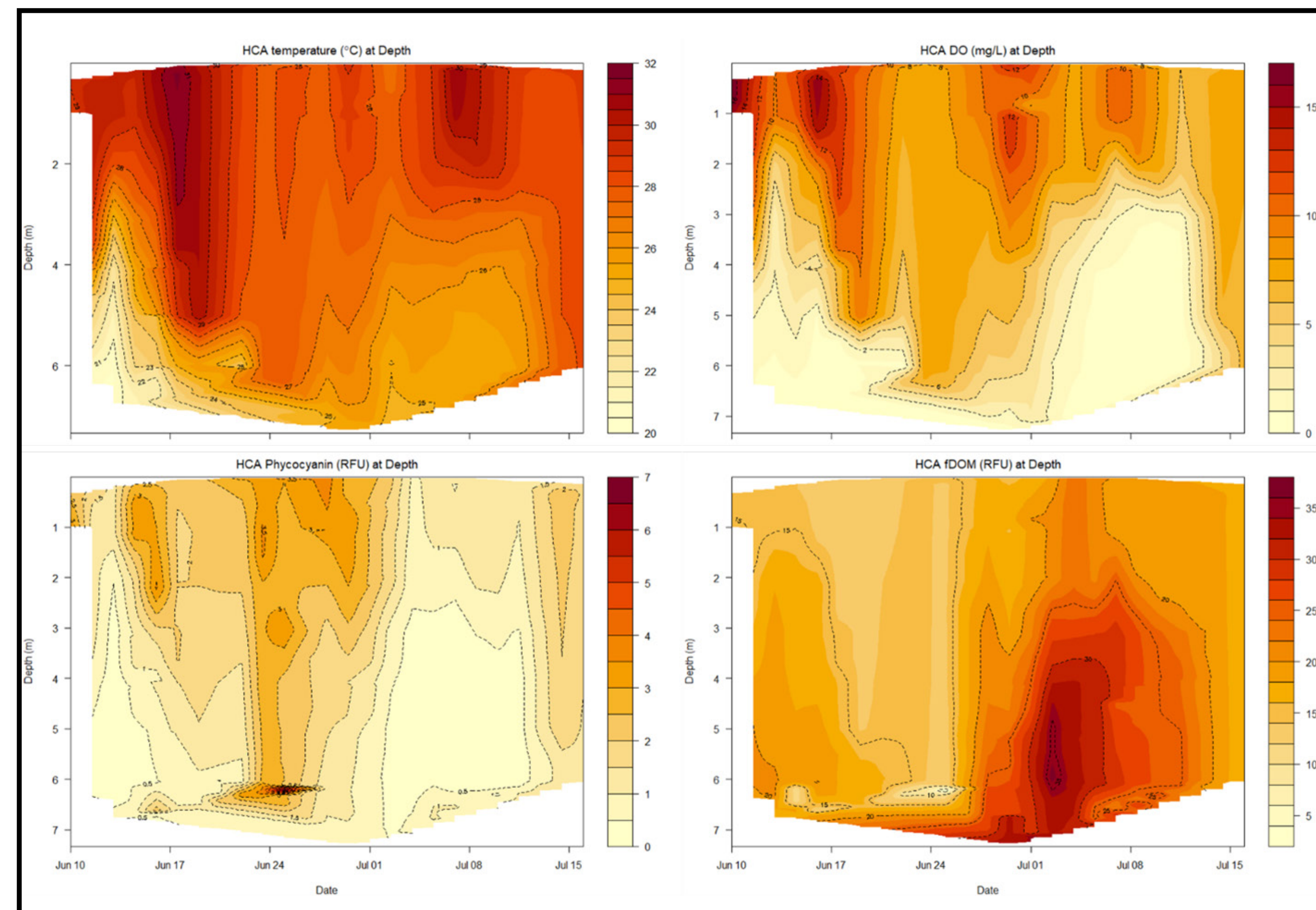


Figure 5: Heat maps for water quality profiles at the HCA early-warning buoy.

Nutrients

Nitrogen (N) and Phosphorus (P) are the most important nutrients for phytoplankton growth in aquatic systems and they are often split into "dissolved" and "total" concentrations. Dissolved N and P are biologically available to phytoplankton, meaning they can readily absorb the nutrients into their cells. Total N and P is the sum of all the N or P in the water whether it is dissolved or bound to particulate matter. Phosphorus is typically the most limiting nutrient, and the increase of P in aquatic systems is linked to increases in cyano-blooms. However, if too much P is added N can become limited, which will slow down phytoplankton growth. Some cyanobacteria species possess specialized cells called heterocytes that can fix biologically unavailable N, allowing them to prosper in aquatic systems that are rich in P but limited by N. While N-fixing cyanobacteria such as *Dolichopermum*, *Anabaenopsis*, and *Aphanizomenon* are present in Grand Lake and their densities increase during cyano-blooms, Grand Lake's cyano-blooms are typically dominated by *Microcystis*, which cannot fix N. The proliferation of *Microcystis* over other common bloom-forming cyanobacteria is probably due to the high concentrations of both N and P in Grand Lake. Dissolved and total N and P were measured from subsurface and benthic samples to monitor nutrient availability for cyanobacteria migrating between the hypolimnion and epilimnion. Low DO in the hypolimnion caused extensive internal nutrient loading for much of the bloom (Fig. 5), fueling the bloom for several weeks. The water column became mixed for a week in late June due to consecutive days of heavy winds, causing the nutrients that were trapped in the hypolimnion to be spread throughout the water column and be taken up by competing phytoplankton such as diatoms and green algae. The water column stratified again when a storm introduced cool nutrient-rich water into the lake that intruded into the bottom of the water column, forming a new nutrient-rich hypolimnion that refueled the dissipating cyano-bloom. The cyano-bloom ultimately died-off by the second week of July when both benthic N and P were depleted.

Internal loading was a dominant source of N and P for this cyano-bloom, however, those nutrients ultimately come from the watershed via stormwater runoff, and those nutrients have been cumulating in the lake sediments for decades. For example, large rainstorms in the Horse Creek watershed in late June and early July deposited high concentrations of N and P (Fig. 6) to the Horse Creek cove. GRDA has been monitoring nutrient loading from sites throughout the Horse Creek watershed to identify areas that are contributing significantly to N and P runoff and how those watershed loadings impact Grand Lake. GRDA has been working with landowners to place several hundreds of acres in the Horse Creek watershed in conservation easements to help reduce the amount of nutrients coming into the lake.

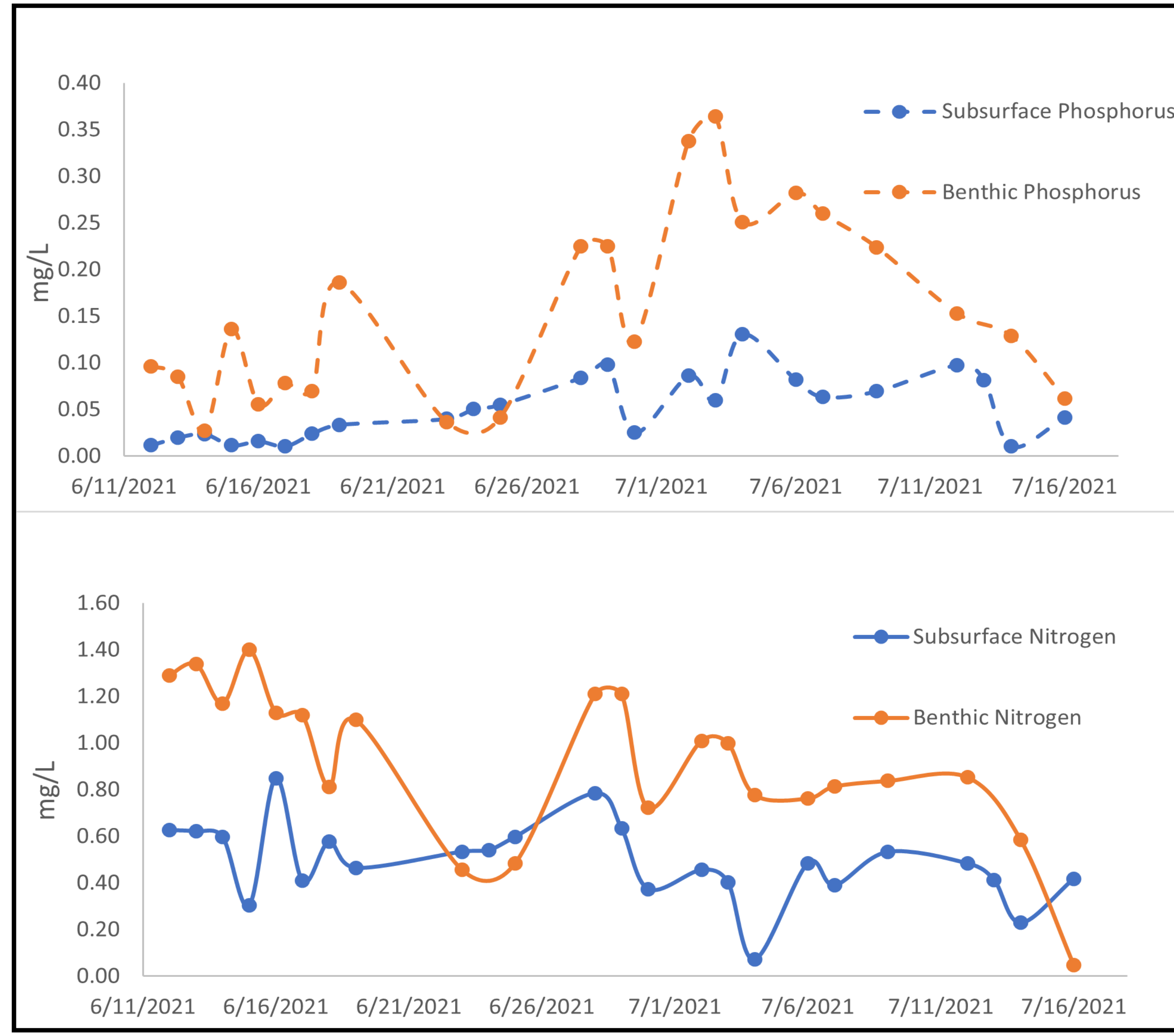


Figure 6: Subsurface and benthic dissolved N and P data from the HCA site in Horse Creek Cove.


Algae scum on the water in Horse Creek


Water Quality personnel preparing to sample


Autonomous drone used by OSU to collect data in Horse Creek


Sample site in the Horse Creek Watershed

Toxins

Different cyanobacteria species can produce different types of toxins. Microcystin is the most common toxin that is detected in Grand Lake and it can be produced by *Microcystis, Dolichospermum*, and *Aphanizomenon*, the three most abundant toxin-producing cyanobacteria that were found in the Horse Creek Cove cyano-bloom. The EPA recommended microcystin concentrations for recreational wasters is 8ug/L, and microcystin concentrations often vary spatially and temporally in a water body. Therefore, GRDA personnel measured toxins in several surface water samples beyond the four routine monitoring sites to ensure the public's safety. The highest toxin concentrations were associated with visible surface scums (Fig. 7) and toxin concentrations in areas without surface scums were usually less than 1ug/L. The rapid changes in toxin concentrations required diligent sampling and quick turnaround to keep the public informed, which was all possible with the Water Research Laboratory's CAAS (Fig. 8).

Figure 7: Surface scum beginning to form in Horse Creek

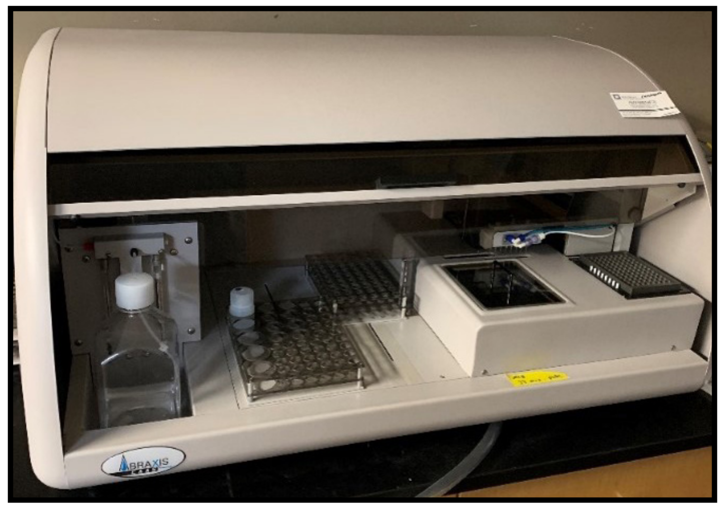


Figure 8: GRDA's Cyanotoxin Automated Analysis System

Phytoplankton Community Composition

The FlowCam Cyano was used to process phytoplankton samples to assess the presence and abundance of cyanobacteria in the surface, subsurface, and benthic portions of the water column. The FlowCam Cyano (Fig. 9) uses flow imagery cytometry to take individual photos of every particle that moves through a narrow flow-cell. The FlowCam Cyano is outfitted with two sensors that measure the fluorescence of chlorophyll-a and phycocyanin pigments in phytoplankton, and it uses the ratio of chlorophyll-a to phycocyanin to classify the phytoplankton as either diatoms and other eukaryotic algae, cyanobacteria, or detritus/debris, allowing the user to quickly quantify changes in cyanobacteria abundances (Fig. 10).

Figure 9: GRDA's Flowcam used to identify & quantify algae

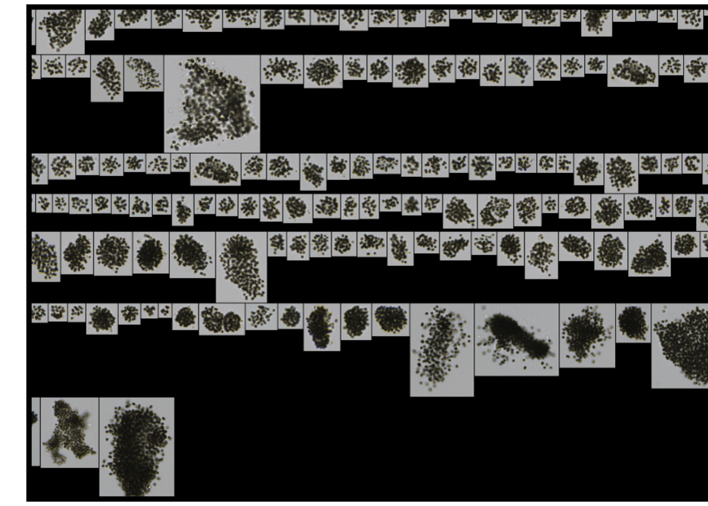


Figure 10: Output from GRDA's flowcam showing *Microcystis* colonies

Zooplankton

Vertical tows of zooplankton were collected using a plankton tow net to document changes in zooplankton community composition throughout a cyano-bloom. Zooplankton are important algal grazers in aquatic systems; however, their interactions with cyano-blooms are poorly understood, therefore, GRDA and the Dzialowski Lab from OSU are working on a project funded by the Oklahoma Water Resource Center to better understand these relationships. In late June, we observed a rapid increase in the abundance of the exotic cladoceran, *Daphnia lumholtzi* (Fig. 11), that coincided with a decline in cyanobacteria. It is possible that D. lumholtzi can serve as a biological control agent for cyano-blooms, therefore, GRDA is working with the Youssef and Dzialowski labs at OSU to analyze the gut contents of the *D. lumholtzi* collected during the bloom to see if cyanobacteria were a dominant component of the *D. lumholtzi* diet.

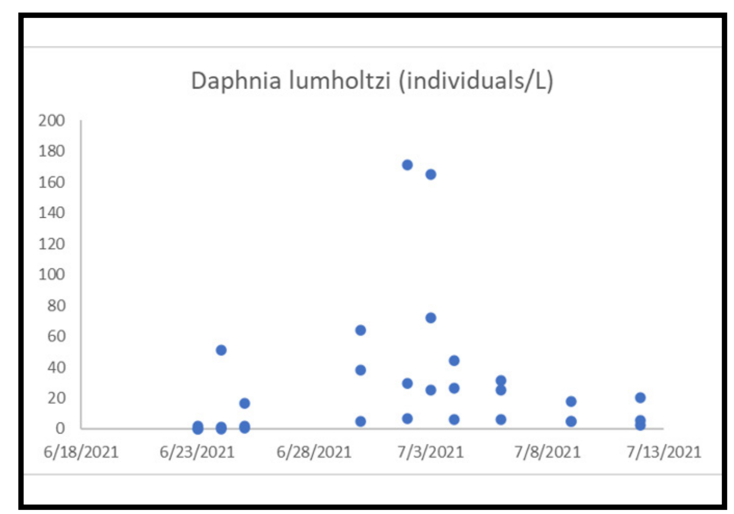
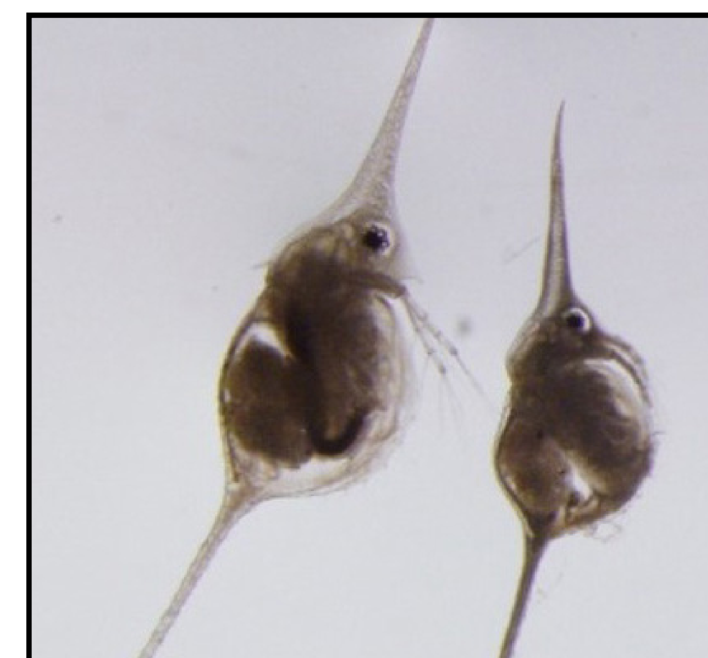


Figure 11: *Daphnia Lumholtzi* densities



Daphnia lumholtzi females

Stages of an Algae Bloom

Not all algae blooms will appear the same. Just because there are not large surface scums does not mean that a bloom is not actively occurring. The descriptions and photos below can help identify algae blooms.

Stage 1: The water begins to look green in appearance. No visible streaks or colonies.

Stage 2: The water becomes increasingly green. Visible streaks begin to appear. Colonies may be submerged.

Stage 3: Streaks are visible, along with clumps that appear "paintlike". These are visible colonies of algae.

Stage 4: Streaks are visible. Colonies begin to clump together causing large surface scums.

Stage 5: Surface scums begin to clump together creating large "mats" of algae in the water.

Stage 2 of an Algae Bloom

Stage 3 of an Algae Bloom

Stage 4 of an Algae Bloom

Stage 5 of an Algae Bloom

Closing thoughts from Bill Mausbach

The 2021 Horse Creek cyanobloom was an anomaly, lasting longer than the usual bloom on Grand Lake and keeping us on our toes with its seemingly unpredictable boom-bust cycles – about to die off one day and roaring back to life days later. Our intensive monitoring program yielded a treasure trove of data that is allowing us to transform uncertainty into foresight. We now know how crucial a nutrient-rich hypolimnion is to fuel a cyano-bloom, and we know that the hypolimnion nutrients can come from the benthic sediments during times of anoxia or from the watershed during rainfall events. We also learned that cyanoblooms can die-off from nutrient depletion in the hypolimnion or over-grazing by the zooplankton, *Daphnia lumholtzi*. Moving forward, we will pre-emptively monitor the presence and condition of the hypolimnion in the Horse Creek Cove in conjunction with keeping an eye on the early warning buoys and the weather so that we can continue to keep the public aware of impending cyanoblooms.

There is little that can be done to effectively manage an already active bloom, but we can make it more difficult for them to form by reducing the amount of nutrients coming into the lake from the watershed. GRDA is tackling this issue on multiple fronts such as public education through our Guard the Grand Program and through our conservation easement program, and we look forward to a time when the cyanoblooms in Horse Creek Cove become a phenomenon of the past and the clear blue waters for which Grand Lake is known are an expectation of the present

If you are interested in learning more about GRDA's conservation, restoration, and protection effforts, check out our website by scanning the QR code below.

William E. Mausbach Ph.D.
Watershed Ecologist

If you are interested in learning more about GRDA's environmental stewardship efforts, please visit our website at www.grda.com or scan the QR Code with your smartphone camera.

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This publication was produced with input from the entire Ecosystems and Watershed Management team. All maps are property of the GRDA GIS Department. All photos and student summaries have been submitted to GRDA via project updates, and are now authorized for use by GRDA.

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