Arkansas Department of Energy and Environment

Division of Environmental Quality

Office of Water Quality

Planning Branch

Data Collection of Selected Lakes at Risk for Harmful Algal Blooms

FY2017 Monitoring Initiative Fund

Final Report

Feb. 2021

Arkansas is home to a myriad of water resources including lakes, reservoirs, streams, rivers, and ponds which are utilized for drinking water, recreation, and other uses. The protection of these resources is vital to safeguarding public health and maintaining healthy ecosystems. Recently, the issue of harmful algal blooms (HABs) has gained national attention due to the threat of harm to humans and wildlife. Additionally, reports of HABs on water bodies in Arkansas have become more frequent.

The Arkansas Department of Energy and Environment, Division of Environmental Quality's (DEQ) Office of Water Quality (OWQ) Planning Branch is responsible for routinely monitoring the Waters of the State for a host of environmental parameters. HABs were not included in this list until the summer of 2014, which brought the first high profile bloom event to the state of Arkansas. This bloom, which happened on the popularly recreated Lake Nimrod at the height of the recreational season, was the impetus for a better understanding of HABs in our state. At the time cyanotoxins were measured, concentrations resulted in little concern for human health (microcystins = <5 ppb), but the lack of coordination and understanding of agency roles and HABs in general was revealed. In an effort to become more prepared for what seemed to be a growing national problem and now something that could and had happened in Arkansas, DEQ and other interested parties formed the Arkansas HAB Workgroup (Workgroup). Since its formation in 2015, the Workgroup has met on a routine basis to discuss and develop response strategies to address the issue.

A need recognized through the Workgroup was the ability to identify and respond to statewide HAB events in a timely manner in light of limited personnel. One of the ways the Workgroup has tried to address this is through the engagement of citizens and natural resource professionals in the identification and reporting of potential HABs. An online HAB reporting tool was launched in 2017 through DEQ's pollution complaint reporting web app, which enabled anyone to document and report potential HAB events (Figure 1). This tool allows the user to directly relay information about a HAB event including location data, bloom size, detailed descriptions of the event, photos, and contact information directly to Planning Branch staff. Since its implementation, this user-friendly reporting tool has been an effective mechanism for rapid notification of HAB events.

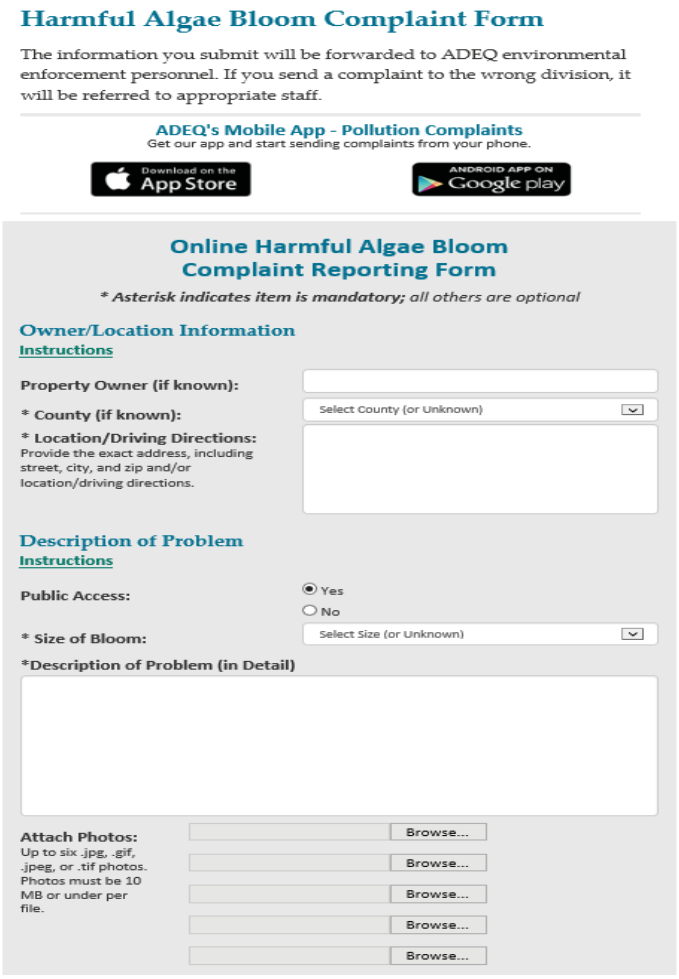

Figure 1. DEQ's HAB Reporting Tool https://www.adeq.state.ar.us/complaints/forms/algae_complaint.aspx.

In October of 2017, the Planning Branch was awarded an EPA Monitoring Initiative Fund (MIF) grant for its proposal entitled "Data Collection of Selected Lakes at Risk for Harmful Algal Blooms". The goal of this project was to develop and implement HAB sampling strategies on reservoirs that have high susceptibility to HAB events based on associated data and conditions generally associated with HABs. This included prioritizing reservoirs in the state, developing sampling and response protocols, and implementing a monitoring strategy. Due to limited information about HABs in Arkansas, DEQ solicited suggestions for determining susceptible lakes through the Workgroup, EPA recommendations, and through two presentations at scientific meetings (North American Lake Management Society, 2018 and Arkansas Chapter of the American Fisheries Society, 2019) before a list of lakes was finalized for HAB sampling.

In between researching which lakes to sample, the Planning Branch invested in in-house cyanotoxin testing capabilities. The Enzyme-Linked Immunosorbent Assay System (ELISA) is a relatively inexpensive and straightforward way of measuring cyanotoxins. Given staff's previous experience using ELISA, the lower investment in technical skill set, time, and initial cost as other quantitative analytical methods, ELISA was selected for use at DEQ. To ensure high-quality

cyanotoxin data, DEQ has participated in microcystin and cylindrospermopsin Proficiency Testing through Eurofins Abraxis annually since 2019. In addition to purchases for cyanotoxin analysis, funds were also used to service DEQ's inverted microscope for use in phytoplankton identification and enumeration, which was then used to guide cyanotoxin analysis.

Using the information gathered for determining susceptible lakes, DEQ's list of HAB monitoring was ultimately based on 1) 2014 event on Nimrod and any lakes that had similar morphology or watershed characteristics, 2) a history of high nutrients/trophic state index (TSI), and 3) the likelihood of human contact in the event of a HAB. Using these criteria, the Planning Branch finalized a list of 6 lakes that were to be targeted for routine HAB monitoring (Table 1). DEQ partnered with the Arkansas Game and Fish Commission (AGFC) to collect samples monthly throughout the growing season (May – October; n=6 per season). These samples were analyzed for HAB-related water quality parameters including nutrients, chlorophyll *a*, phycocyanin, phytoplankton, and two cyanotoxins (microcystins and cylindrospermopsin).

Table 1. Initial list of lakes to be monitored for HAB event and the agencies responsible for collecting samples.

Lake	Latitude	Longitude	Justification	Sampling Agency
Nimrod	34.49502	-93.22069	2014 HAB	DEQ
Blue Mountain	35.10681	-93.68514	Similar morphology and location as Nimrod	DEQ
Conway	34.99874	-92.39618	Routinely fertilized	AGFC
Chicot	33.32214	-91.27612	High TSI (upper 12th percentile)*/recreational use	DEQ
Horseshoe	34.93262	-90.33493	High TSI (upper 8th percentile)*/ recreational use	AGFC
Harris Break	34.97797	-92.77392	Routinely fertilized	AGFC

*percentiles based on data from a DEQ study on publically owned lakes (DEQ, 2000)

In addition to finalizing the initial list of lakes to be monitored for HAB events, the Planning Branch also developed a document entitled "Monitoring Initiative Fund 2018: Data Collection of Selected Lakes at Risk for Harmful Algal Blooms – Field Operations Manual" (FOM) which detailed sampling methods and how to relinquish samples to DEQ. This document was written specifically for partners participating in the "Data Collection of Selected Lakes at Risk for Harmful Algal Blooms" study and was intended to be a precursor to a state-wide HAB collection Standard Operating Procedure (SOP). Planning Branch staff met with AGFC representatives for a training demonstration on the procedures outlined in the FOM, which has undergone EPA review.

In January 2018, DEQ received a report of a fish kill from a possible HAB on Beaverfork lake. At this time, DEQ did not have the capacity to run microcystins, but collected a sample to be run

at a later date. Histology reports from the dead fish came back indicating that death was caused from a toxic event, although microcystin results were low (0.10 ppb). There has been little evidence in the literature of the toxicity of HABs causing fish kills, but rather the drastic swings in dissolved oxygen resulting from the increased biomass. Although reports from the AGFC biologists who responded to the event noted the very green color of the water, there were also indications of excessive deicing treatment applied to the roads the previous week. At this point, it is still unclear if the event on Beaverfork was HAB related, but there have been no further reports or issues on the lake.

DEQ and AGFC began routine monitoring efforts on the 6 lakes noted in Table 1 in May 2018. On May 18th, a HAB was reported on a US Army Corps of Engineers (USACE) Lake, Lake Gillham, which doubles as source water for the city of Gillham and surrounding area. Lake Gillham was not identified as a susceptible lake as there had been no historic reports of HAB events, and the lake's TSI fell into the upper 67th percentile based on DEQ's most recent statewide lakes study (DEQ, 2000). The Arkansas Department of Health (ADH), which has a representative in the Workgroup, was notified and worked with the drinking water utility. DEQ investigated the event from a recreational perspective and collected samples in accordance with the FOM. Cyanotoxins were not detected at levels harmful to human health (as determined by EPA's draft recreational criteria), but DEQ acknowledged that collecting a sample at one location and point in time didn't necessarily clear the lake for safe recreation while the bloom was ongoing. Therefore, DEQ personnel advised that samples be collected weekly until cyanobacterial cell counts fell below 20,000 cells/mL (in accordance with WHO, 1999). Samples were collected weekly to bi-weekly by USACE and analyzed at the DEQ lab. The USACE elected to close swim beaches until cell counts fell below 20,000 cells/mL, which was indicated by a sample collected on June 13th.

Figure 2. Lake Gillham - May 2018

As the 2018 growing season progressed, 2 more HAB events were reported to DEQ. These included Lake Bennett at Woolly Hollow State Park (primary contact recreation) in July and Lake Brewer (source water for the City of Conway) in August. Fortunately, all of the events reported microcystin values below the EPA recommended draft criteria for primary contact recreational exposure of 4 ppb. The two highest microcystin values reported throughout the 2018 growing season were from the monthly sampling event in August on Lake Harris Brake (visible bloom not reported), with 0.543 ppb, and the event on Lake Brewer with 0.633 ppb (Figure 3). Because microcystins on Lake Brewer exceeded 10-day drinking water health advisory for bottle-fed infants and pre-school children (0.3 ppb), both the drinking water utility and the Arkansas Department of Health (ADH), were notified of the results. All samples were also analyzed for cylindrospermopsin, however no concentrations above 0.02 ppb were reported.

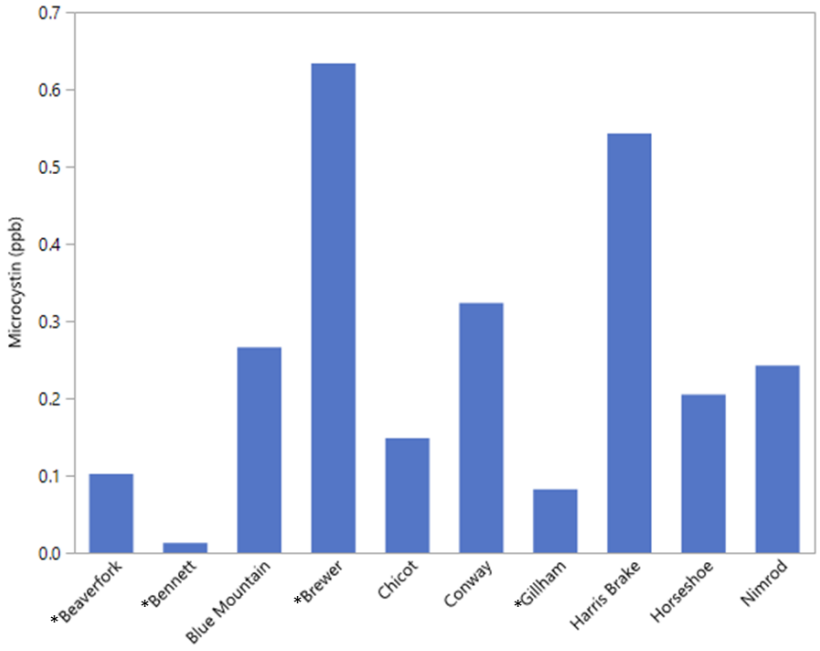

Figure 3. Highest microcystin concentrations reported by lake from samples collected in 2018. *Sampled in response to a HAB report.

In the winter months of 2018, under advisement from the Workgroup, the Planning Branch began to draft DEQ's Harmful Algal Bloom Management Plan, which was targeted toward water resource managers or members of the public who may come across HAB events. This document outlined general information about HABs, differentiation of HABs from non-cyanobacterial blooms, reporting and notification procedures, sample collection methods, and other relevant information.

In addition to drafting the Management Plan, Planning Branch also drafted a Standard Operating Procedure (SOP) entitled Phytoplankton Counting and Biovolume Estimates, which outlined sample processing and handling procedures, preservation techniques, enumeration methods, and biovolume calculations. Phytoplankton enumeration was conducted using the Utermohl, 1931 method. Some samples (n=9) were split to allow for independent analysis and verification through BSA Environmental, Inc. at a later date. There was a 29.6% overlap in species identified between the two phytoplankton identifications/enumerations, with BSA identifying more species in each sample. Based on the minimal overlap in results, investment in already limited staff time to process phytoplankton, and long shelf-life of preserved phytoplankton, the Planning Branch decided that future samples would be conducted by a third party consultant if and when funding was available.

Three lakes, Gillham, Bennett and Brewer, were added to the HAB monitoring program - those that had bloom reports in the summer of 2018. DEQ partnered with USACE and the Arkansas State Parks (ASP) to add Lakes Gillham and Bennett to the list of monthly growing season samples. The USACE also requested sampling Lake Millwood, which is a shallow, large, open-

basin lake with a high watershed-to-lake ratio and history of high nutrients (upper 22nd percentile (ADEQ, 2000)), and one that was thought to be more likely to bloom than Gillham.

In February 2019, AGFC reported a bloom on Lake Overcup near Morrilton, AR (Figure 4). Given the convenience in location to Lake Brewer (~9 miles) and, being that Lake Overcup had bloomed so early in the growing season, it was also added to the monthly growing season sampling resulting in an additional 5 lakes for the 2019 sampling season (Table 2).

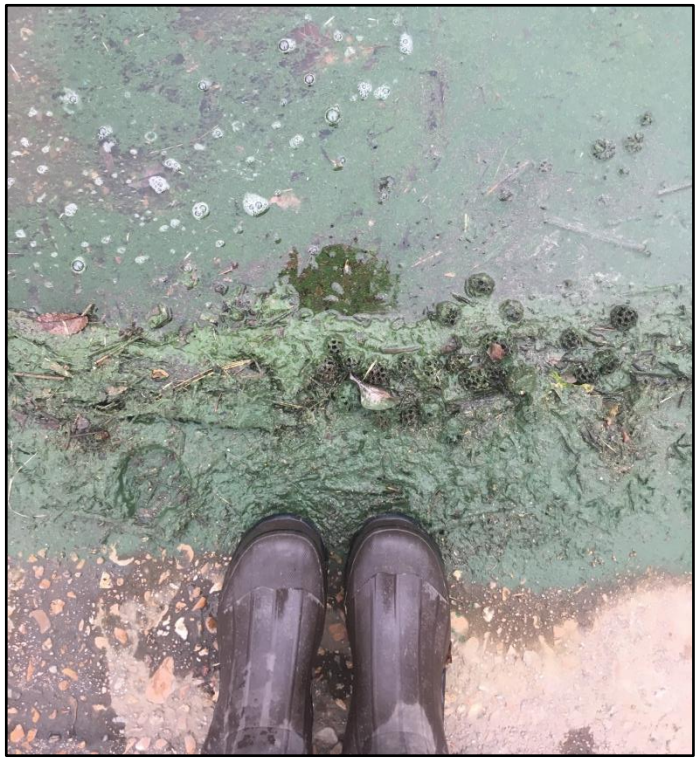

Figure 4. Lake Overcup - February 2019

Table 2. List of lakes that were monitored on a routine basis in the 2019 growing season. *Indicates lakes that were added in 2019

Lake	Latitude	Longitude	Justification	Sampling Agency
Nimrod	34.9502	-93.22069	2014 HAB	DEQ
Blue Mountain	35.10681	-93.68514	Similar morphology and location as Nimrod	DEQ
Conway	34.99874	-92.39618	Routinely fertilized	AGFC
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Horseshoe	34.93262	-90.33493	High TSI (upper 8th percentile)*/ recreational use	AGFC
Harris Break	34.97797	-92.77392	Routinely fertilized	AGFC
Gillham*	34.21194	-94.22917	2018 HAB	USACE
Brewer*	35.23	-92.5969	2018 HAB	DEQ
Millwood*	33.74377	-93.97764	Shallow, subcircular, low-lying, eutrophic	USACE
Bennett*	35.28284	-92.28486	2018 HAB	ASP
Overcup*	35.1967	-92.7303	2019 HAB	DEQ

In 2019, the Planning Branch experienced an increase in the amount of HAB events being reported through the online reporting tool. Although this increase could have been attributed to an increase in HABs, the upsurge in HAB reports was likely, in part due to increased public awareness through both education efforts and national news coverage. Reports of potential HABs occurred on 3 of the lakes that were undergoing monthly sampling as part of the HAB study: Lakes Conway, Harris Brake, and Horseshoe. Maximum microcystin values at all of these lakes remained very low (Figure 5), even during visible HAB reports. The only routinely sampled lake whose maximum concentration coincided with the response to complaint was Lake Conway. Eight additional lakes were sampled in response to complaints throughout the growing season either by DEQ, the Arkansas Water Resources Center (AWRC) (a HAB Workgroup member), or GreenWater Laboratories (Figure 5).

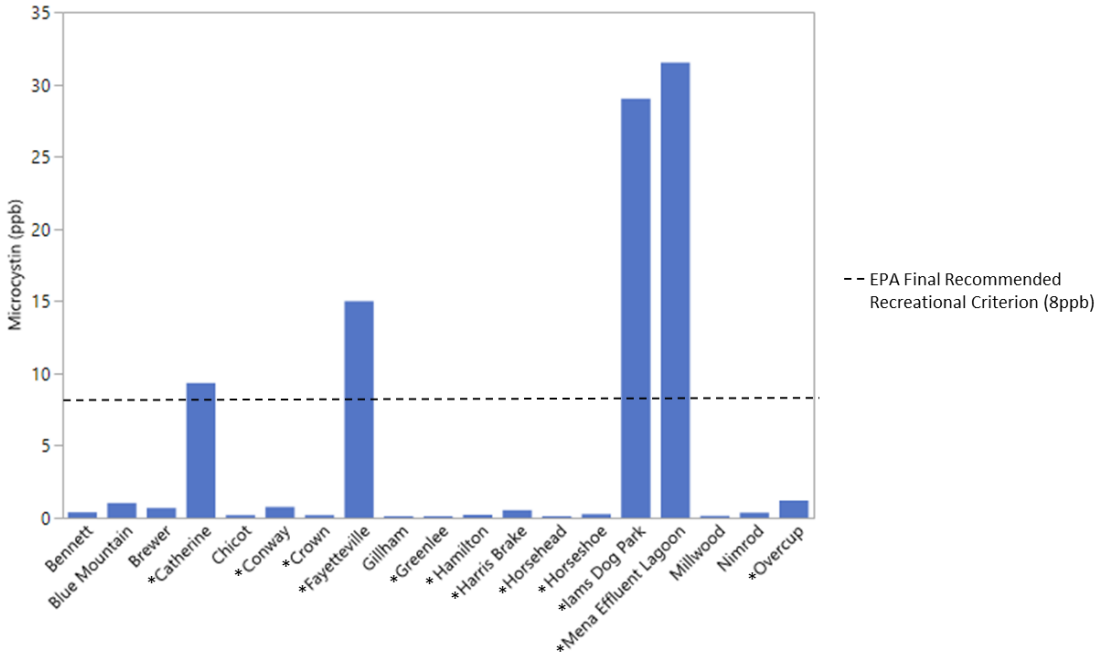

Figure 5. Highest microcystin (ppb) values reported by lake from samples collected in 2019. *Sampled in response to a HAB report.

Lake Fayetteville, which bloomed in May 2019, was the first lake to be measured at values exceeding EPA recommended draft criteria of 4 ppb (microcystins = 15 ppb). Sampling at Lake Fayetteville was conducted by AWRC who also coordinated public outreach with the City of Fayetteville. The City posted warning signs around the lake and submitted a press release to local news outlets. Since this bloom, AWRC has been routinely monitoring Lake Fayetteville.

In late August, a citizen reported a bloom through the DEQ HAB reporting app at a small pond contained within a dog park. As with the Lake Fayetteville bloom, DEQ's partners at the AWRC sampled, ran the analysis, and discovered microcystins were greater than 29 ppb. The City of Fayetteville, having already experienced a bloom in May, was quick to respond with signs, press releases, and closure of the area.

That September, the Enforcement Branch of DEQ received an email from a citizen concerned about a wastewater lagoon with an active bloom discharging to a nearby creek. DEQ requested that samples be collected in the lagoon, the effluent, and out of the mixing zone in the receiving creek. Microcystin samples were sent to GreenWater Labs, and were detected at 31.5 ppb, 3.7 ppb, and below detection limit, respectively. Consultation with an independent contractor determined that the blooms were being caused by a build-up of nutrient-rich sludge in the benthos and recommended dredging the pond. DEQ requested that the facility continue to sample throughout the growing season and ensure that levels in the receiving waters were not exceeding recreational recommended criteria.

Finally, a bloom occurred on Lake Catherine, where microcystins were near 9 ppb (Figure 6.) Unlike most of the other blooms during the 2019 season, Lake Catherine occurred at the end of October – outside of the primary contact season. The lake manager, Entergy, was contacted with the results, but the bloom dissipated quickly with decreasing temperature.

During all of these reported events, DEQ and its partners continued monthly monitoring on the, now, 11 selected susceptible lakes (Table 2). It should be noted also, that midway through the 2019 growing season EPA released final recommended recreational criteria for microcystins and cylindrospermopsins, which shifted the action values for microcystin from 4 to 8 ppb while cylindrospermopsin remained at 15 ppb (EPA, 2019). However, the conclusion that 4 lakes exceeded the criteria for microcystin was not affected by this change in recommended criteria. As with the 2018 growing season, cylindrospermopsin was never measured at detectable levels.

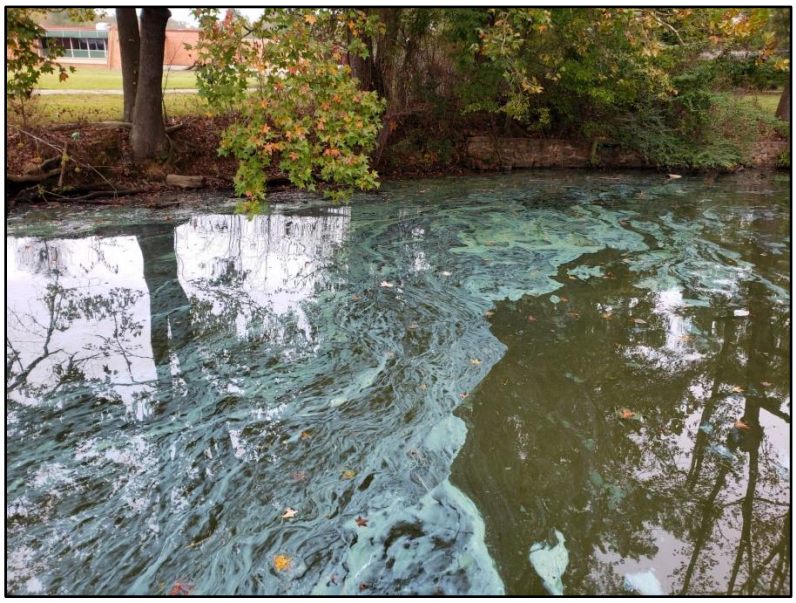

Figure 6. Lake Catherine - October 2019

Prior to the 2019 growing season, Planning Branch coordinated with DEQ lab personnel to develop methods for analyzing phycocyanin, a pigment found only in cyanobacteria, in hopes of finding an alternative to the time intensive and variable phytoplankton enumeration. Lab personnel worked during the 2019 spring and summer months to develop and test the method (modified from Kasinak et al., 2015). Samples that were being collected throughout the season were included in the analysis development and method optimization process. In October of 2019, a review of the season's phycocyanin data was conducted. It was determined that many of the data collected did not pass quality assurance standards or align with what had been reported in the literature. DEQ's lab personnel and Planning Branch staff would like to continue pursuing phycocyanin, but have requested guidance from EPA Office of Research and Development to

optimize analytical methods. Planning Branch staff reviewed cyanotoxin data (microcystin and cylindrospermopsin) that had been reported on samples collected in 2018 and 2019. It was determined that cylindrospermopsin concentrations were almost never being reported from any analyzed samples. To increase efficiency and reduce sample processing time, the Planning Branch decided that, moving forward, samples would be viewed under the inverted microscope upon arriving at the lab, and testing for cylindrospermopsin would only be conducted if species of cyanobacteria that were known to produce cylindrospermopsin were found to be present. Sample analysis would instead be focused on detecting microcystin concentrations.

As mentioned previously, DEQ and other ancillary agencies continued to collect HAB samples for phytoplankton enumeration and cyanotoxin analysis during responses to reports and routine monitoring events despite the decision to not analyze them in house. In the fall of 2019, Planning Branch evaluated funds and was able to send an additional 59 samples to BSA Environmental, Inc. Samples were ranked in order of their microcystin concentrations, and randomly selected across a microcystin gradient. DEQ had also been working closely with the Workgroup to discuss findings from past growing seasons, develop an understanding of what's needed for HAB response, and share the capabilities of representative agencies in these responses. After gathering this information, DEQ developed the "Harmful Algal Bloom Management Plan for Arkansas State Waters" (Management Plan), which was published on the DEQ website December, 2019.

At the beginning of year 2020, as the timeline of the MIF grant was nearing its end, the Planning Branch met to discuss the future of the HAB program and to reevaluate its course based on information gathered. Around this same time, the Planning Branch was developing a new lake monitoring schedule for the period of 2020 – 2022. Out of the original 6 lakes that were selected for HAB sampling, 3 had visual reports of blooms, but no toxins ever exceeded values recommended for the protection of human health at the time of sampling. Three lakes that were not selected for routine HAB sampling experienced blooms with toxins exceeding the recommended criteria and an additional 6 had a visual bloom observed, albeit low toxins. Instead of targeting susceptible lakes for routine sampling, Planning Branch decided to focus the future of its HAB program on response to reports, public education, and prioritizing the ambient lake monitoring to gather quarterly data on some of the lakes that recently experienced HABs. This includes responding to HAB events that were within reasonable driving distance from DEQ headquarters in North Little Rock, while training AGFC staff, academics, water utility companies, and citizens on how to collect HAB samples themselves. The Planning Branch also began planning a public outreach and education strategy integrating the information gathered and data collected from the study as well as future plans for HAB sampling to DEQ's website. This project is still in development. While the Planning Branch decided to stop collecting monthly (during the growing season) samples on the targeted lakes listed in Table 2, a few of the lakes that had experienced recent HAB events such as Lakes Brewer, Overcup, Chicot, and Harris Brake were included in the new 2020 – 2022 routine lake monitoring schedule.

In March of 2020, EPA's Office of Research and Development (ORD) visited DEQ and met with DEQ and ADH staff to discuss a variety of topics, including Arkansas's HAB response program. ORD was subsequently provided a copy of the Planning Branch's HAB Management Plan to review and provide feedback. In April, EPA's ORD returned the draft and provided comments. Over the next few months, Planning Branch staff incorporated EPA's comments into the document, which primarily narrowed the scope and focus to response procedures. At this time, HAB sampling procedures and laboratory analysis protocols were removed from the Manual and were incorporated into two SOPs. All three documents are currently undergoing review from management.

A substantial amount of HAB events occurred during the 2020 growing season producing higher toxins than what had been typically measured. Numerous blooms on lakes were reported on lakes that had previously been sampled for HABs including Bennett, Catherine, Conway, Brewer, Fayetteville, and Overcup - the latter 3 with concentrations well over the recommended recreational criteria (Figure 8). Cyanobacterial blooms were also reported and measured in excess of the recommended criteria at new locations including Lake Elmdale, a lake in a Country Club in Central Arkansas and the Poteau River (first confirmed HAB on a lentic system) in Arkansas, which were all reported to DEQ and tested by AWRC. In 2020, microcystin values ranged from non-detectable to over 1000 ppb, although most of the maximum values were between 20 and >100 ppb. High microcystin values became the norm during the 2020 growing season instead of the rare occurrence as experienced in 2018 and 2019. Advisories were issued on all lakes that exceeded recommended recreational values during the primary contact season.

Figure 7. Lake Fayetteville – June 2020

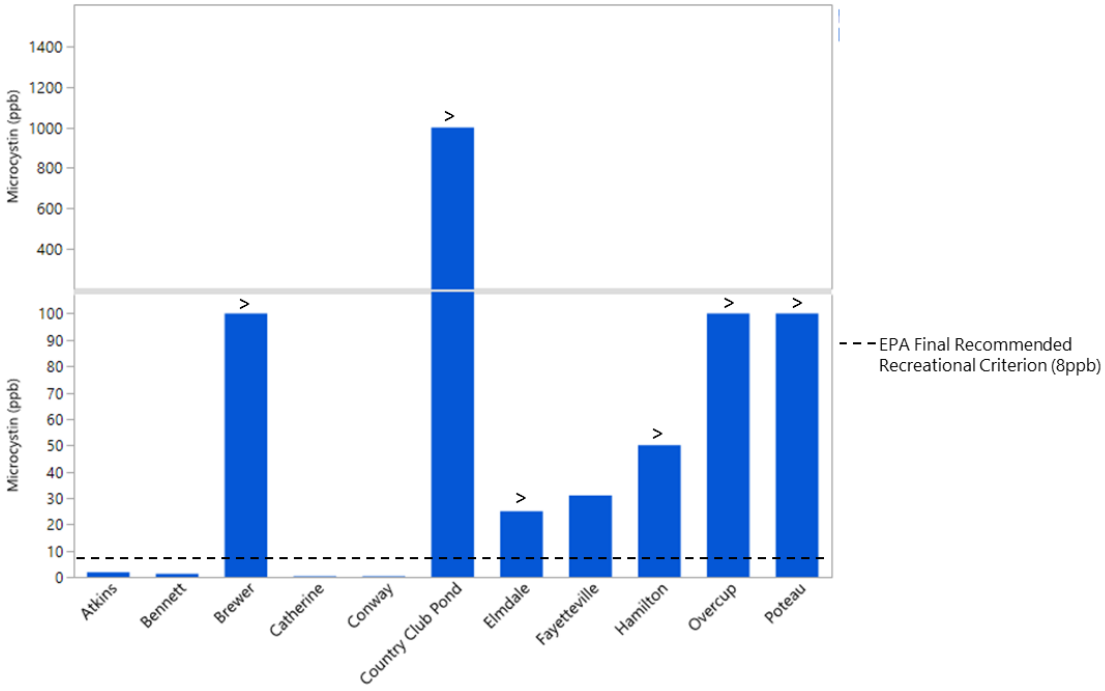

Figure 8. Highest microcystin (ppb) values reported by lake from samples collected in 2020. (>) indicates that samples were at least that value. The gray line represents an axis break.

A particularly high-profile HAB event was reported by multiple sources in July on Lake Hamilton, surrounded by the City of Hot Springs – one of the most heavily toured cities in the state. The initial report cited a putrid smell and visible blueish-green algae on the water's surface in the Little Mazarn arm of Lake Hamilton (Figure 9).

Figure 9. Lake Hamilton – July 2020

The area where the bloom occurred was in a highly-populated location at the peak of the recreation season, which drew alarm from many of the residents in the area. A biologist with AGFC first sampled the HAB on July 9, which was subsequently analyzed by Planning Branch staff. This first sample yielded an average microcystin concentration of ~10 ppb. The following day, Planning Branch staff responded to numerous citizens reports of the HAB event, and collected several samples for analysis. These samples were analyzed for cyanotoxins, and yielded results as high as 33 ppb, four times the finalized EPA recommended primary contact criteria of 8 ppb. Planning Branch staff sampled the HAB again the following day, and reported an average microcystin concentration of 0.422 ppb, signifying that the HAB may be dissipating. Three days later, the bloom was visibly worse and results came back with microcystins >50 ppb. Reports of the HAB continued to be submitted over the following week, and Planning Branch staff continued to collect samples every few days. DEQ submitted a press release indicating that an advisory was issued on the lake, and posted several signs at public access locations to inform the public of the danger posed by the HAB. Planning Branch staff then met with and trained staff from Hot Springs Utility (HSU) on how to collect HAB samples. Samples were collected on a weekly basis until August 11, where average microcystin values were reported below 0.4 ppb for 2 weeks (Figure 10).

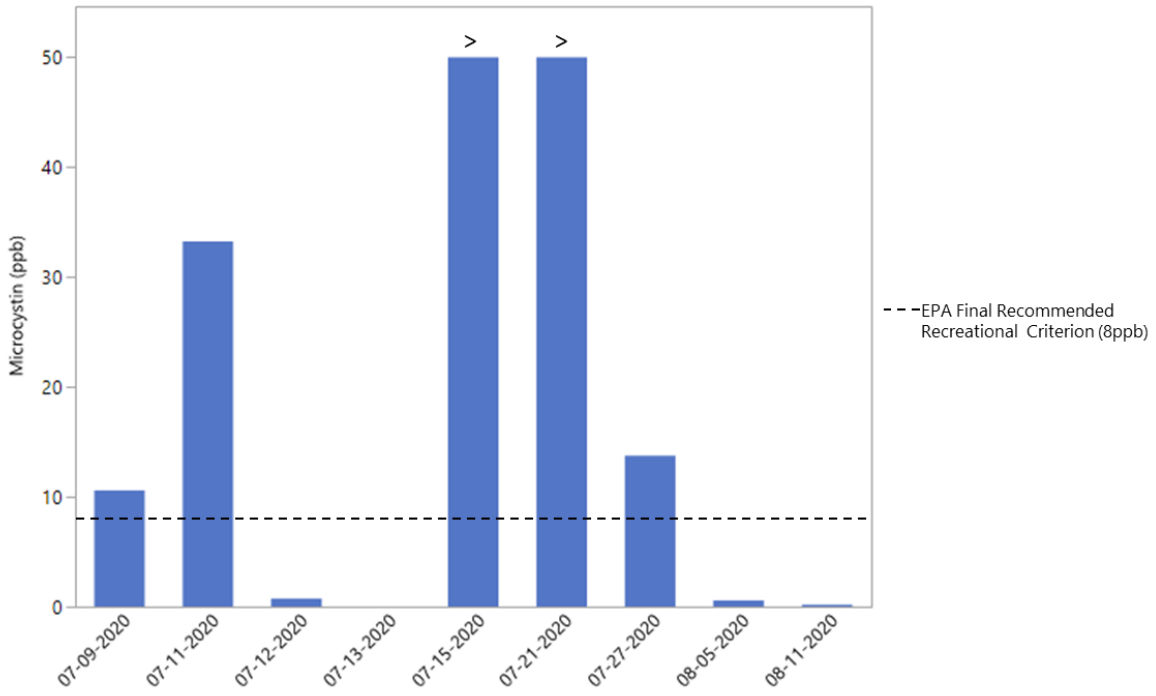

Figure 10. Highest microcystin values (ppb) measured from samples collected on Lake Hamilton during the July – August 2020 HAB event. (>) indicates that samples were at least that value.

Throughout the three year project, DEQ responded to 50 incidences of potential HAB reports from the public or water resource managers (Figure 11). The level of response varied depending on resource availability, public access, timeliness of reporting, and information about the bloom in question. Given that there were only 6 reports in 2018, DEQ was able to respond to all of them via sample collection. There were a considerable amount of reports or inquiries made in 2019. Fourteen of the 22 reports in 2019 were either visually confirmed or tested for cyanobacterial toxins by DEQ or AWRC. The rest included reports on private ponds (the owners of which were contacted and referred to private labs or given information regarding avoidance and potential causes), general inquiries about HABs, or filamentous algae blooms. Many of the inquirers made reference to the HAB events in Georgia and North Carolina responsible for the death of several dogs, which is likely a factor in the increase in reports that year. Reports in 2020 followed a similar pattern to 2019, but there were generally less inquiries on private residences, and some waterbodies bloomed more than once throughout the growing season.

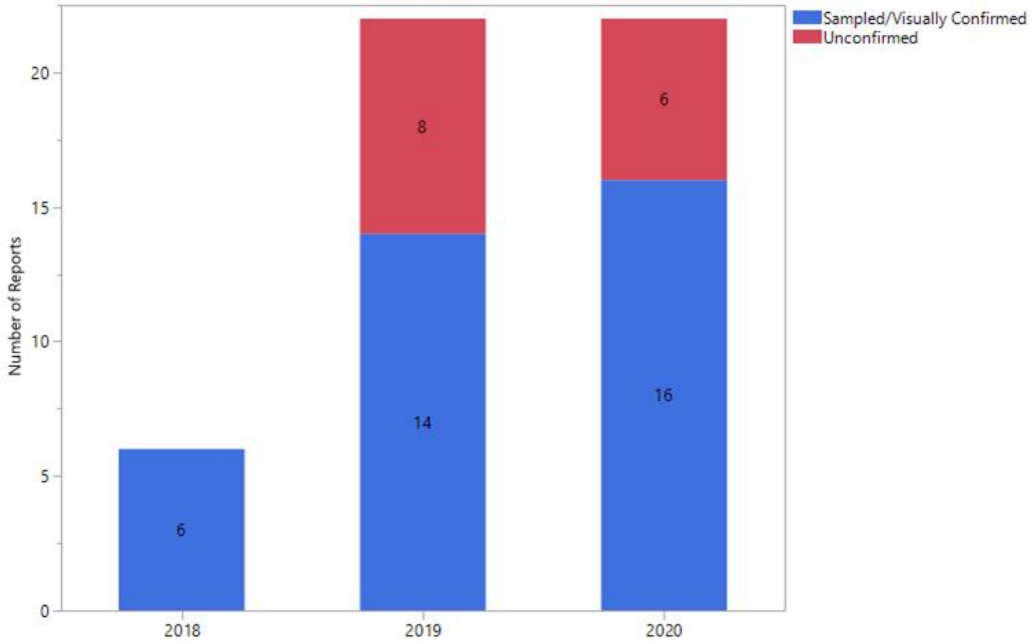

Figure 11. Number of HAB inquiries or reports by year.

There were 27 locations across the state where HABs were reported from 2018 – 2020. Samples were collected at most of these locations, although visual confirmation was enough to recommend lake advisories when resource availability was low. Several of these locations experienced multiple blooms (Figure 12 – red symbols), such as Lakes Brewer, Overcup, Conway, Fayetteville, and Hamilton. Greater than 60% of the repeated bloom events occur in or on the border of the Arkansas River Valley. Additionally, ~41% of waters on which blooms have been reported occur in or near the Arkansas River Valley, and of those locations, ~35% had, at some point, exceeded recommended recreational criteria (Figure 12 – square symbols).

Almost 30% of locations that were reported throughout 2018 – 2020 were seen in or on the border of the Ozarks, with ~37% exceeding the recommended recreational criteria at least once. There is a clear cluster of reports in the northwest portion of the Ozarks, which coincides with a series of metropolitan areas and another vigilant partner, the AWRC. Whether or not this cluster is an effect of more awareness of HABs, visibility of water bodies, or an effect of higher nutrients in a more densely populated is still unclear.

Although there weren't as many reports in the Ouachitas (~15% of total locations), almost all of them (80%) had, at some point, exceeded recommended recreational criteria at the time of sampling. Conversely, the Delta, despite having 18% of the reported locations had not experienced repeated bloom events or exceeded recommended recreational criteria. The results seen in the Delta and the Gulf Coastal Plains (which had no reports, aside from one that occurred on the border of the Ouachitas) were unexpected given the agricultural and silvicultural activities that take place, the area of land (each ecoregion being greater than 25% of the land area in the state), and the higher watershed to waterbody ratio typically seen in low-lying areas. Some of this could be explained by the relatively low amount of lotic systems typically associated with HABs (~7% and ~16% of lakes in the state found in the Delta and Gulf Coastal Plains, respectively). This reasoning also coincides with the minimal amount of reporting in the Boston Mountains, which only contains 11% of the states lakes. However, given that the Arkansas River Valley contains around 14% of the lakes in the state, but occupies the position of most blooms reported, it's more likely that the Gulf Coastal Plains and the Delta are getting under reported and education efforts should be more targeted to the areas.

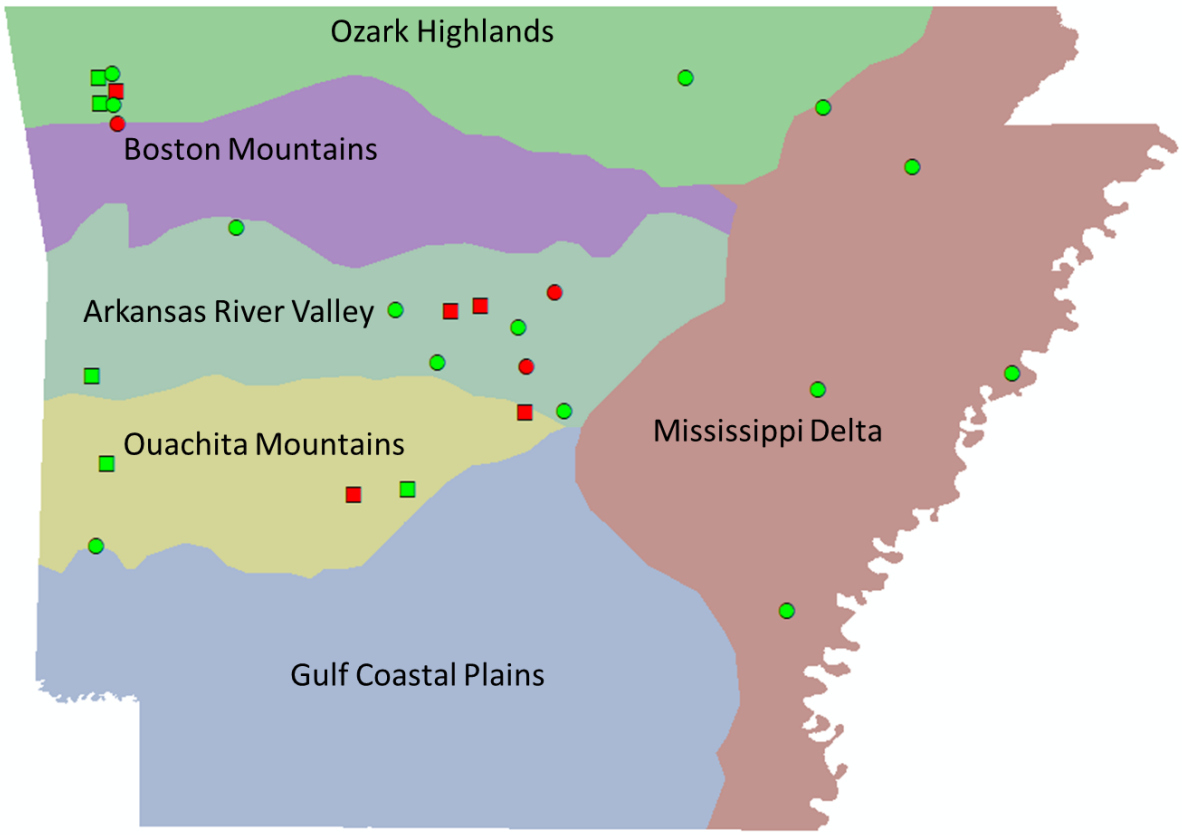

Figure 12. Locations of reported, observed, and/or sampled HAB events from 2018 to 2020. Shape indicates locations where measurements exceeded 8 ppb microcystins (square) and those that fell below 8ppb (circle). Color indicates locations that were reported multiple times (red) and those that were reported only once (green).

No correlation was found between total nitrogen and microcystin (n=107, r^2=-0.001, p=0.726), total phosphorous and microcystin (n=105, r^2=-.009, p=0.322), or chlorophyll *a* and microcystin (n = 107, p = 0.596, r = 0.052). These results could be explained by a lack of paired nutrient or chlorophyll and toxin data available. Although nutrients and chlorophyll were collected during routine HAB sampling on the 6 – 10 lakes identified as susceptible, the majority of toxicity samples were collected in response to an ongoing complaint. Generally, these sampling events would take place immediately to identify toxicity for the protection of public health. Given the lack of nutrient sampling materials and the DEQ lab's ability to run nutrients within holding time on select days, nutrient analysis was often not possible during unscheduled HAB responses. Additionally, no toxic events in excess of the recommended recreational criteria were observed during routine sampling when paired data was collected.

No correlation was found with the phytoplankton data received from BSA, Inc. for both cyanobacterial biovolume and microcystin (n=57, r^2=0.002, p=0.748) and percent composition and microcystin (n=60, r^2=-0.005, p=0.583). However, most of the phytoplankton samples were collected during the 2018 and 2019 seasons, which generally exhibited low microcystin values.

Although this study didn't identify direct predictors for HAB events in Arkansas, it did allow for identification of hotspots, response mechanisms and the capacity for DEQ to develop and build a HAB program. DEQ plans to continue responding to HAB reports, by utilizing in-house testing capabilities, building sampling partnerships, educating the public, and exploring explanatory variables when data is available.

DEQ's acquisition of the MIF grant provided the crucial resources to develop a robust and efficient HAB response program orchestrated by the Planning Branch. The collaborative efforts of the ADH, AGFC, USACE, ASP, citizens, and academics across the state have greatly expanded the capacity to monitor and report HAB events.

References

Arkansas DEQ. (2018). “Monitoring Initiative Fund 2018: Data Collection of Selected Lakes at Risk for Harmful Algal Blooms – Field Operations Manual”.

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