

Water Quality Annual Report 2020

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**Louisville District, U.S. Army Corps of Engineers
Water Quality Program**



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Executive Summary

- Temperature and dissolved oxygen profiles were collected at the tailwater and damsite of all LRL reservoirs approximately once every two weeks during the 2020 stratification season. Ambient surveys were conducted at all LRL reservoirs in the summer of 2020. During ambient surveys, sites were sampled for physical, chemical, and biological parameters at multiple depths. Sites were located on the reservoir, in major tributaries to the reservoir, and the tailwater immediately downstream of the dam.
- Harmful algal bloom (HAB) advisories were issued at all five LRL reservoirs in Indiana (Brookville Lake, Cagles Mill Lake, Harden Lake, Monroe Lake, and Patoka Lake). No HAB advisories were issued at LRL projects in Kentucky or Ohio in 2020.
- In 2020, E. coli samples were collected at the public beaches located at Barren River Lake, Green River Lake, Nolin River Lake, and Rough River Lake approximately once per week throughout the recreation season. No beaches were closed due to E. coli exceedances in 2020.
- Non-federal hydropower operators at LRL locks and dams on the Ohio River are subject to comply with dissolved oxygen criteria. There were no exceedances of criteria in 2020 at non-federal hydropower stations as a result of hydropower operations.
- Tailwater data from LRL reservoirs in 2020 was assessed for compliance with state-defined water quality criteria.
 - Indiana: There were no exceedances of Indiana state water quality criteria at the tailwater of any LRL reservoirs in Indiana.
 - Kentucky: There were exceedances for temperature at six tailwaters (per USGS provisional gage data): Barren River Lake, Carr Creek Lake, Cave Run Lake, Green River Lake, Nolin River Lake, and Rough River Lake.
 - Ohio: There were exceedances for temperature at two tailwaters (per USGS provisional gage data): Harsha Lake and Caesar Creek Lake.
- 2020 tailwater temperatures were assessed for compliance with LRL-defined temperature guide curves. Tailwater temperatures fell outside the temperature guide curve at some point in 2020 at all reservoirs (except for West Fork Lake which does not have a temperature guide curve). Many of the deviations from guide curves were minor.
- LRL tailwaters were screened for exceedances of USEPA recommended criteria for nutrients for rivers and streams. 16/17 tailwaters exceeded the recommended criteria for total phosphorus, and 10/17 tailwaters exceeded the recommended criteria for total nitrogen.
- Of all nutrient samples collected in 2020 (including samples from reservoir, tailwater, and tributary sites), 74% and 99% of samples were greater than the USEPA recommended criteria for total nitrogen and total phosphorus, respectively.

*Please note the technically correct term “reservoir” is used interchangeably with “lake” throughout this document.

Water Quality Program Overview

The US Army Corps of Engineers (USACE) operates a water quality management program to ensure that all applicable state and federal water quality criteria are met, water quality degradation of USACE resources is avoided or minimized, and project responsibilities are attained. More information on the operation of the Louisville District (LRL) Water Quality Program can be found in the LRL Water Quality Program Management Plan.

In 2020, LRL was responsible for the water quality management of 20 reservoirs until October 1, 2020, at which time the water quality management responsibility for the three projects located in the Upper Wabash Basin (Mississinewa Lake, J. Edward Roush Lake, and Salamonie Lake) was transferred to the Chicago District (LRC). The water quality activities and results from those activities were reported by LRC in their annual water quality report and will not be discussed in this report. Hence, this report will discuss the activities and findings in 2020 of the 17 reservoirs remaining within LRL (Figure 1).

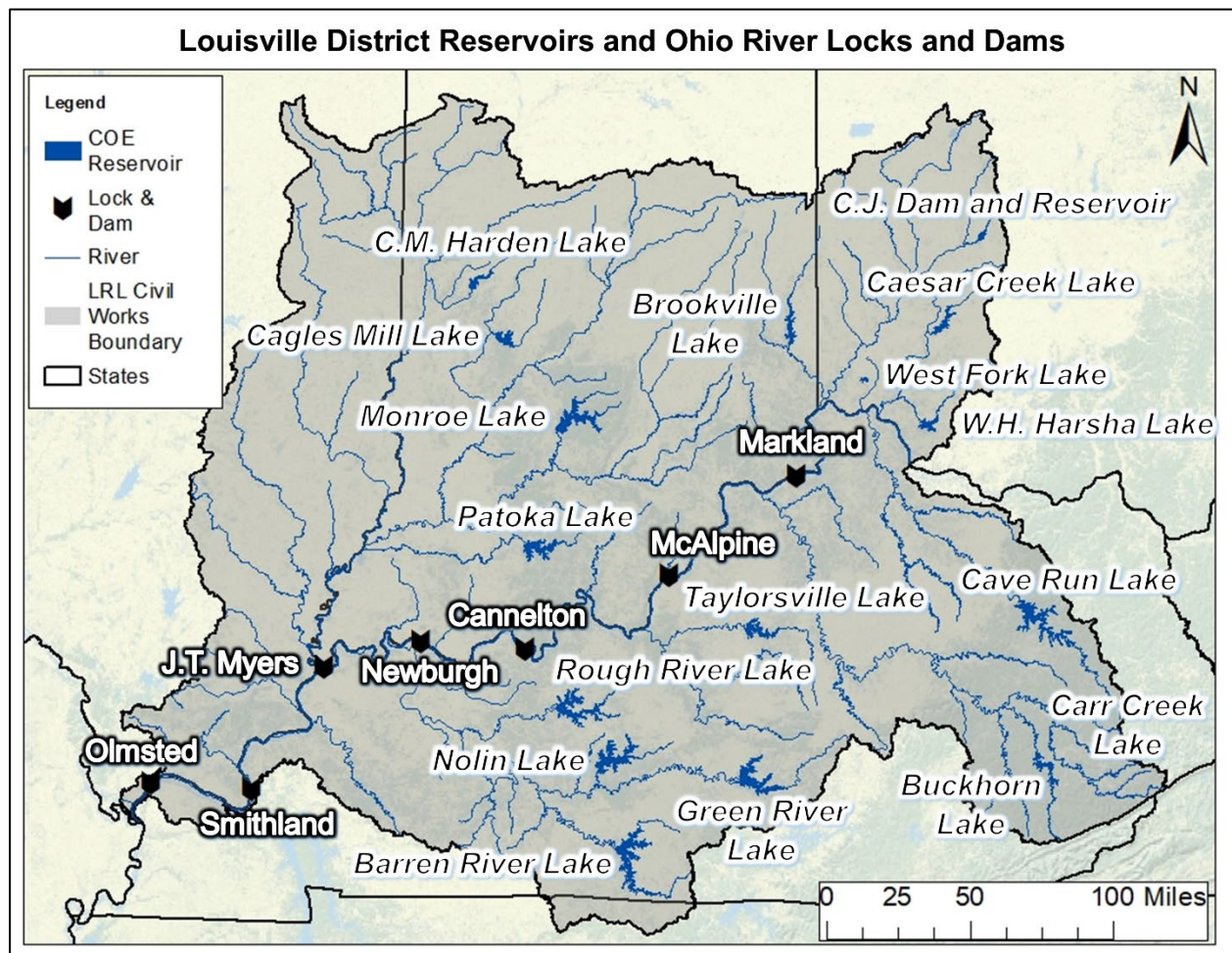


Figure 1. Louisville District area of responsibility for water quality management for 2020 Annual Report.

Water Quality Activities in 2020

2020 Project Profiles

Project profiles monitor the status and progression of thermal and chemical stratification in a reservoir. A project profile is the measurement of temperature and dissolved oxygen (DO) taken from the surface to the bottom of the reservoir at the damsite. Temperature and DO are also measured in the tailwater. Reservoir project personnel record temperature and DO readings approximately once every two weeks during reservoir stratification.

These profiles are essential to the Water Quality Program as they provide vital information for making determinations for daily operations that can affect water quality conditions downstream of LRL projects. Without regularly collected profiles, we would not be able to determine what multi-level intakes need to be employed to optimize water quality conditions in our tailwaters. Profiles are also critical to assessing water quality conditions of the reservoir and tailwater and monitoring compliance with applicable temperature and DO criteria. Project profiles in 2020 were completed successfully thanks to the diligence of LRL reservoir personnel.

2020 Ambient Surveys

Data and water samples for ambient surveys are collected each year during the summer, typically at the height of thermal stratification. This effort is conducted through an annual contract. In 2020, the contractor visited each reservoir once to sample sites selected by the WQ team. Sample parameter groups that were collected varied depending on the type of sample site: tailwater site (located in the tailwater below the dam); damsite (located on the reservoir nearest to the dam inlet structure); reservoir site (located on the reservoir excluding the damsite); and stream site (located in streams that are major tributaries to the reservoir). The general sampling schema for 2020 ambient surveys and the parameters associated with parameter groups can be found in Table 1 and Table 2, respectively. The 17 reservoirs discussed in this report generally followed this schema with some exceptions; details for each reservoir can be found in the reservoir summaries in Appendix A.

Three different types of quality control (QC) samples were collected in conjunction with chemical and biological parameters: duplicates (a separate grab of water from the same location sent to the same lab as the original sample); splits (from the same grab of water as the original and sent to a different lab than the original sample); and rinses (deionized water rinsed in the equipment that is used to collect samples, sent to the same lab as the original sample). It is standard practice that 10% of your samples should be QC samples (USEPA 1996). Therefore, the following schema was followed in 2020 for QC samples collection: one of each duplicate, split, and rinse samples were collected for each reservoir for routine and total metals; one split sample was collected for each reservoir for dissolved metals; one of each duplicate and split samples were collected for each reservoir for chlorophyll and phytoplankton; and two reservoirs were

haphazardly selected for collections of duplicate samples for zooplankton (Cagles Mill Lake and Patoka Lake).

Table 1. Number of samples per reservoir by site type and parameter group in 2020.

Parameter Group	Tailwater	Damsite	Reservoir	Stream
Routine chemical	1 ^a	3 ^b	3 ^b	1 ^a
Total metals	1 ^a	3 ^b	1 ^c	-
Dissolved metals	1 ^a	3 ^b	-	-
Chlorophyll	-	4 ^d	4 ^d	-
Phytoplankton	-	4 ^d	4 ^d	-
Zooplankton	-	1 ^c	-	-

^a Collected at surface

^b Collected in epilimnion, metalimnion, and hypolimnion

^c Collected in hypolimnion

^d Collected at 0, 5, 10, and 20 ft

^e Collected as vertical pull from 20 ft to the surface

Table 2. Parameters analyzed for ambient surveys listed by parameter group.

Routine Chemical	Total Metals	Dissolved Metals	Chlorophyll
Alkalinity, Total	Aluminum, Total	Aluminum, Dissolved	Chlorophyll a
Ammonia, Total	Antimony, Total	Antimony, Dissolved	Chlorophyll b
Atrazine, Total	Arsenic, Total	Arsenic, Dissolved	Chlorophyll c
Chloride, Total	Barium, Total	Barium, Dissolved	Pheophytin a
Hardness, Total (as CaCO ₃)	Beryllium, Total	Beryllium, Dissolved	
Kjeldahl Nitrogen, Total	Cadmium, Total	Cadmium, Dissolved	
Nitrite + Nitrate Nitrogen, Total	Calcium, Total	Calcium, Dissolved	
Nitrogen, Total	Chromium, Total	Chromium, Dissolved	
Organic Carbon, Dissolved	Copper, Total	Copper, Dissolved	
Organic Carbon, Total	Iron, Total	Iron, Dissolved	
Orthophosphate as P	Lead, Total	Lead, Dissolved	
Phosphorus, Total	Magnesium, Total	Magnesium, Dissolved	
Silica, Dissolved	Manganese, Total	Manganese, Dissolved	
Silica, Total	Mercury, Total	Mercury, Dissolved	
Solids, Dissolved	Nickel, Total	Nickel, Dissolved	
Solids, Suspended	Potassium, Total	Phosphorus, Dissolved	
Solids, Total	Selenium, Total	Potassium, Dissolved	
Sulfate, Total	Silver, Total	Selenium, Dissolved	
	Sodium, Total	Silver, Dissolved	
	Strontium, Total	Sodium, Dissolved	
	Zinc, Total	Strontium, Dissolved	
		Zinc, Dissolved	

2020 Emergency and Situational Response Activities

E. coli Monitoring

Escherichia coli (E. coli) is a type of bacteria that is used to measure levels of fecal contamination in order to prevent illness. Fecal contamination is monitored at Corps-operated public beaches, which is limited to only Barren River Lake, Green River Lake, Nolin River Lake and Rough River Lake in LRL. Reservoir project staff conduct monitoring of E. coli at beaches and the Water Quality Team provides technical assistance as needed.

In 2020, E. coli samples were collected at the public beaches located at Barren River Lake, Green River Lake, Nolin River Lake, and Rough River Lake approximately once per week throughout the recreation season (roughly Memorial Day to Labor Day). No beaches were closed due to E. coli exceedances in 2020.

Harmful Algal Bloom Response

Harmful algal blooms (HABs) are monitored using visual observations from project staff, reports from the public, and tools provided by state water quality authorities. LRL response to potential/confirmed HABs follow the LRL HAB Response Plan. These efforts occur on an as-needed basis. State authorities are responsible for issuing HAB advisories and more information on their HAB procedures can be found on their respective websites.

In 2020, Kentucky Division of Water (KDOW) and Ohio Environmental Protection Agency (Ohio EPA) did not issue any HAB advisories. At some point during the recreation season, Indiana Department of Environmental Management (IDEM) issued Advisory Alert Levels at beaches or state recreation areas for 5 reservoirs: Brookville Lake, Cagles Mill Lake, Harden Lake, Monroe Lake, and Patoka Lake. The Advisory Alert Level indicates that cyanobacterial cell counts were over 100,000 cells/mL but toxin levels did not meet thresholds for the Caution or Closed alert levels. More details about HAB advisories at LRL reservoirs can be found in Appendix A.

Ohio River

The LRL Water Quality Program conducts water quality monitoring at LRL projects on the Ohio River primarily by partnering with the Ohio River Valley Water Sanitation Commission (ORSANCO). ORSANCO is an interstate commission that operates programs to improve water quality in the Ohio River and its tributaries. ORSANCO routinely monitors pools of the Ohio River and provides an annual report that can be found on their website (www.orsanco.org).

Hydropower Monitoring

There are four non-Federal hydropower projects at LRL locks and dams on the Ohio River. Temperature and DO are monitored at each of these projects to meet DO criteria that aligns with ORSANCO criteria. In 2020, there were no exceedances of DO criteria at hydropower projects while the projects were operating.

Markland L&D Hydropower Project

The Markland hydropower project has been operating since 1967 and is operated by Duke Energy. Hydropower at Markland L&D met all water quality criteria during the 2020 monitoring season and is illustrated by Figure 2.

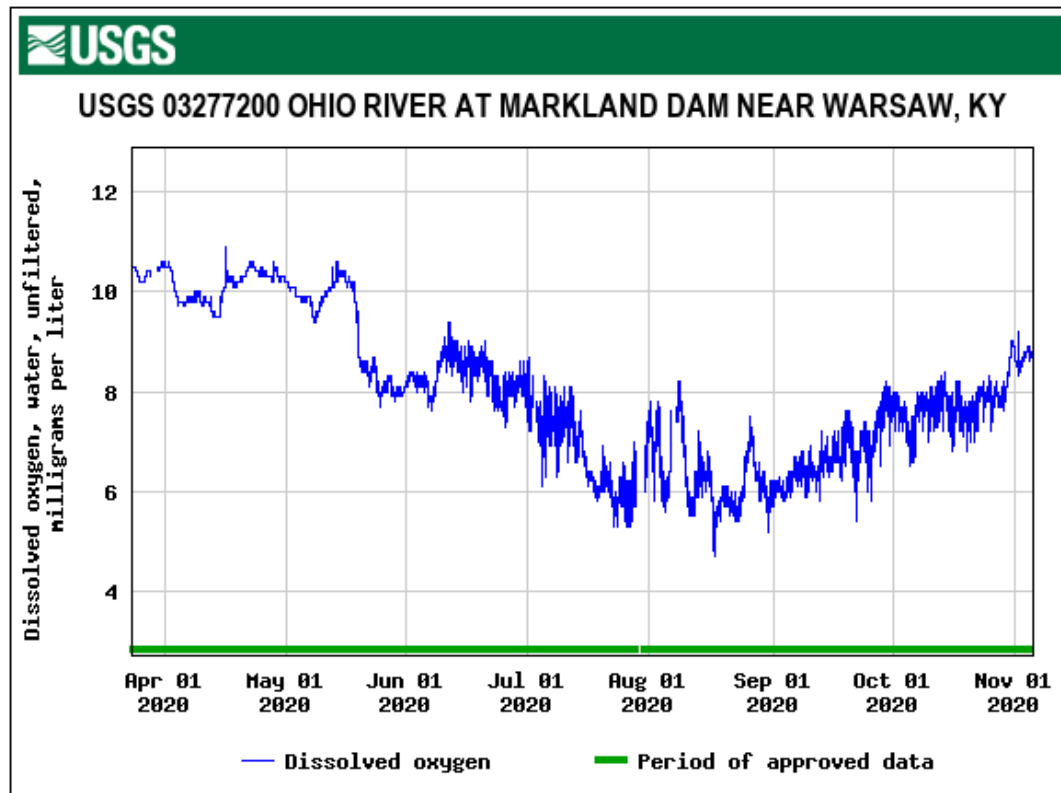


Figure 2. Instantaneous dissolved oxygen measurements during the 2020 monitoring season downstream of the hydropower project at Markland L&D (graph produced by the US Geological Survey National Water Information System web interface).

McAlpine L&D Hydropower Project

The hydropower project at McAlpine L&D, also known as the Ohio Falls Generating Station, has been operating since 1927 and is operated by the Louisville Gas and Electric Company (LG&E). LG&E monitors dissolved oxygen and water temperature at the project. No water quality issues were reported for hydropower at McAlpine L&D during the 2020 monitoring season.

Cannelton L&D Hydropower Project

The hydropower project at Cannelton L&D has been operating since 2016 and is operated by American Municipal Power (AMP). AMP monitors dissolved oxygen and water temperature at the project. Hydropower at Cannelton L&D met all water quality criteria during the 2020 monitoring season and is illustrated by Figure 3.

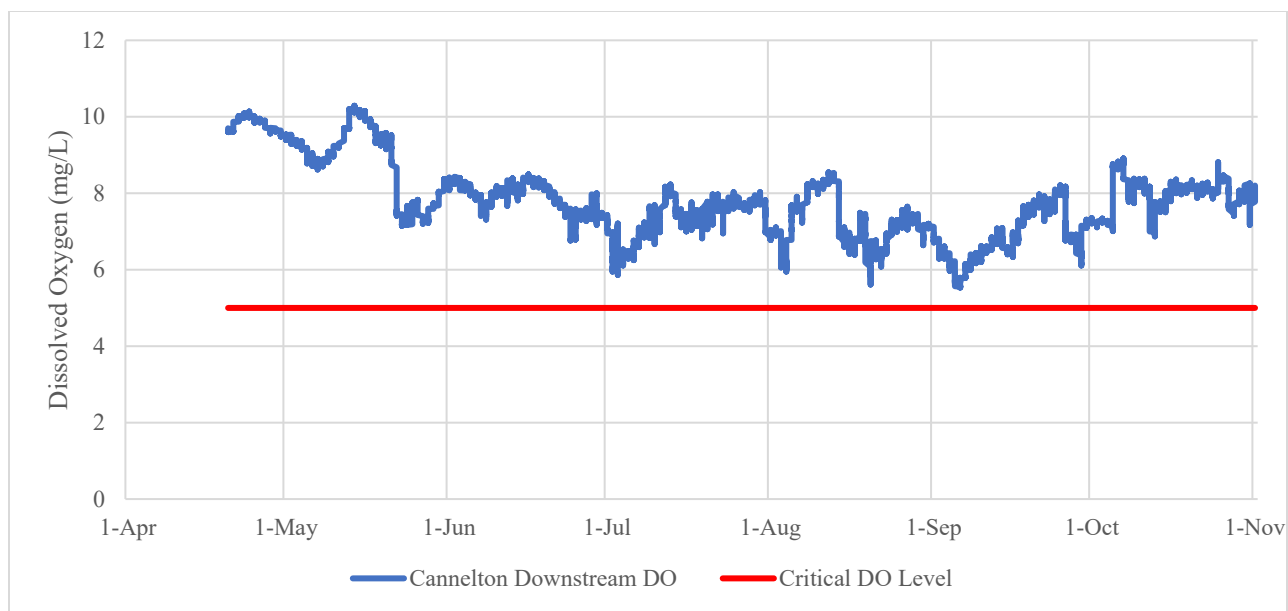


Figure 3. Instantaneous dissolved oxygen measurements during the 2020 monitoring season downstream of the hydropower project at Cannelton L&D.

Smithland L&D Hydropower Project

The hydropower project at Smithland L&D has been operating since 2017 and is operated by AMP (same as the Cannelton project). AMP monitors dissolved oxygen and water temperature at the project. Hydropower at Smithland L&D met all water quality criteria during the 2020 monitoring season and is illustrated by Figure 4.

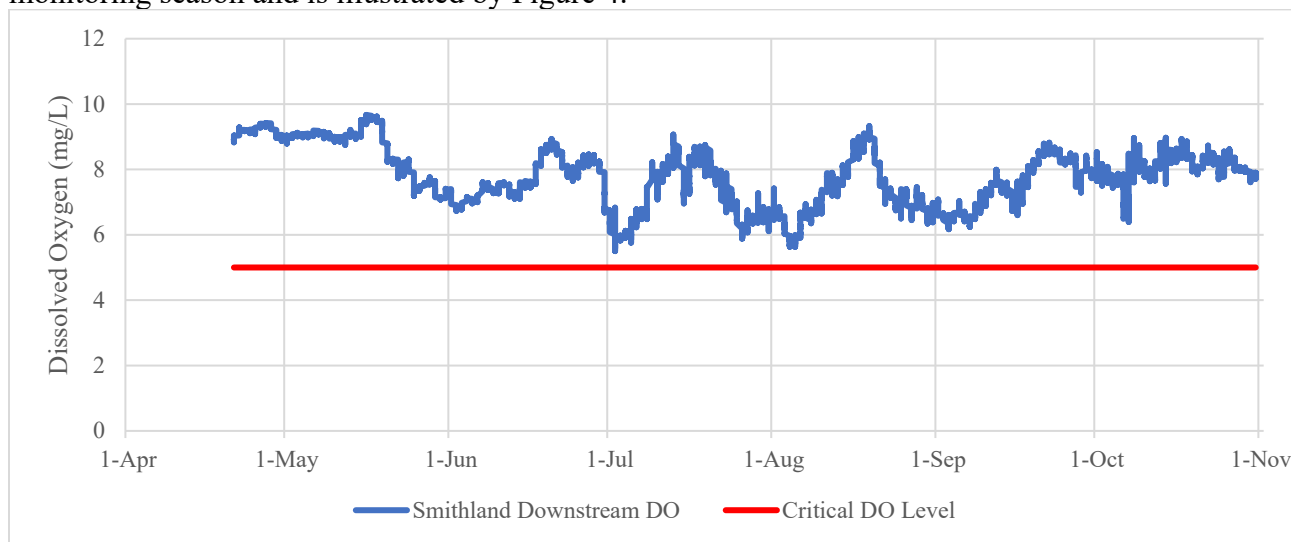


Figure 4: Instantaneous dissolved oxygen measurements during the 2020 monitoring season downstream of the hydropower project at Smithland L&D.

Data Analyses and Findings

Various analyses have been completed to assess the performance of LRL projects for water quality management. Analyses and results for individual reservoirs can be found in the

reservoir summaries in Appendix A. Additional analyses are ongoing for determining how operations can be modified to improve water quality management at projects, including improving compliance with state criteria and temperature guide curves.

Exceedances of State Water Quality Criteria

Per federal water quality laws and USACE policy (e.g., the Federal Water Pollution Control Act of 1948 and its amendments including the Clean Water Act of 1977 and the Water Quality Act of 1987, Executive Order 12088 “Federal Compliance with Pollution Control Standards”), LRL is responsible for compliance with local and state pollution abatement laws for LRL projects, including discharges from reservoir dams. The Water Quality Team monitors the tailwaters of all 17 LRL reservoirs to assess compliance with state water quality criteria and modifies dam operations as appropriate to meet criteria. Parameters collected at LRL projects in 2020 that have state criteria can be found in Table 3.

Table 3. Parameters collected in 2020 that have state water quality criteria. A “X” indicates that the state has a criterion for the parameter.

Parameter	Indiana ^a	Kentucky ^b	Ohio ^c
Dissolved Oxygen	X	X	X
Water Temperature	X	X	X
pH	X	X	X
Ammonia	X	X	X
Chloride	X	X	
Sulfate	X		
Nitrates + Nitrites (total)			X
Phosphorus (total)			X
Antimony (total and dissolved)			X
Arsenic (total and dissolved)		X	X
Barium (total and dissolved)			X
Beryllium (total and dissolved)			X
Cadmium (total and dissolved)	X	X	X
Chromium (total and dissolved)			X
Copper (total and dissolved)	X	X	X
Iron (total and dissolved)	X	X	X
Lead (total and dissolved)	X	X	X
Mercury (total and dissolved)	X	X	X
Nickel (total and dissolved)	X	X	X
Selenium (total and dissolved)	X		X
Silver (total and dissolved)	X	X	X
Zinc (total and dissolved)	X	X	X

^a Indiana Administrative Code Article 2

^b Kentucky Administrative Regulation Title 401 Chapter 10:031

^c Ohio Administrative Code Chapter 3745-1

Indiana

There were no exceedances of Indiana state water quality criteria at the tailwater of any LRL reservoirs in Indiana.

Kentucky

Based on the US Geological Survey (USGS) provisional data from the tailwater and/or the tailwater temperatures collected by project staff, the following reservoirs exceeded the Kentucky state water quality criteria for temperature (warm water aquatic habitat instantaneous maximum) in 2020: Barren River Lake, Carr Creek Lake, Cave Run Lake, Green River Lake,

Nolin River Lake, and Rough River Lake (Table 4). There were no other exceedances of Kentucky water quality criteria in 2020.

All 2020 KY temperature exceedances occurred during times where LRL projects were de-stratified. Therefore, it was not possible to release water from a colder stratum to decrease tailwater temperature. It appears air temperatures peaked in mid-January and early February, which may have affected some of the tailwater temperatures. For Cave Run Lake, it appears the reservoir held temperatures slightly higher than the criteria for January and February (criteria: 10 deg C; mean temperature of USGS data between January 1 and February 29: 10.7 deg C). It is important to note that these exceedances are based on provisional data, which means data credibility may be in question. The provisional status of this data is due to limited funding provided to the USGS to operate these temperature gages at a minimal level of service.

Table 4. Tailwater temperature exceedances per USGS gage data in Kentucky in 2020.

Reservoir	Date(s) of Exceedance(s)	# Days with Exceedance	% of days with Exceedance for Year
Barren	1/11/2020 1/15/20 - 1/17/20	4	1.1%
Carr Creek	1/15/2020	1	0.3%
Cave Run	1/1/20 - 2/29/20 3/28/20 - 3/31/20 12/1/20 - 12/9/20 12/11/20 - 12/13/20	76	20.8%
Green	1/16/20 - 1/17/20 2/4/2020 12/1/20 - 12/3/20	6	1.6%
Nolin	1/11/2020	1	0.3%
Rough	1/11/20 - 1/12/20	2	0.5%

Ohio

Based on USGS provisional data from the tailwater and/or the tailwater temperatures collected by project staff, the following reservoirs exceeded the Ohio state water quality criteria for temperature (daily maximum for aquatic life and wildlife in Ohio River basin) in 2020: Harsha Lake and Caesar Creek Lake (Table 5). There were no other exceedances of Ohio water quality criteria in 2020.

Temperature exceedances at Caesar Creek Lake occurred while the lake was de-stratified (profile on 12/3/21 showed reservoirs temperatures ranged 9.7-10 deg C; criteria: 11.1 deg C); therefore, no operations could have decreased tailwater temperature. Temperature exceedances at Harsha Lake occurred while the lake was stratified; therefore, there were opportunities to better utilize selective withdrawal gates to reduce tailwater temperature to meet criteria. Lessons learned from the exceedances at Harsha Lake in 2020 will be used to improve conditions in future years. It is important to note that these exceedances are based on provisional data, which means data credibility may be in question. The provisional status of this data is due to limited funding provided to the USGS to operate these temperature gages at a minimal level of service.

Table 5. Tailwater temperature exceedances per USGS gage data in Ohio in 2020.

Reservoir	Date(s) of Exceedance(s)	# Days with Exceedance	% of Days with Exceedance for Year
Harsha	7/16/2020	14	3.84%
	7/18/20-7/21/20		
	7/24/20-7/29/20		
	8/3/2020		
	9/16/2020-9/17/20		
Caesar Creek	12/1/2020-12/5/20	6	1.64%
	12/12/2020		

Temperature Analyses

In addition to analyzing 2020 tailwater temperatures for exceedances of state water quality criteria (see previous section), 2020 tailwater temperatures were also analyzed for compliance with LRL-defined temperature guide curves. These temperature guide curves were developed by LRL in coordination with project stakeholders and are detailed in each project's Water Control Manual. Tailwater temperatures fell outside the temperature guide curve at some point in 2020 at all reservoirs (see reservoir summaries in Appendix A for project-specific details), except for West Fork Lake which does not have a temperature guide curve. Many of the deviations from guide curves were minor. The WQ Program will use these findings to inform future operational decisions to improve performance of downstream temperature management wherever possible.

Nutrient Analyses

USEPA Ecoregional Nutrient Criteria Exceedances

As HABs have increasingly become more significant, the Water Quality Team monitors the LRL reservoir tailwaters for nutrients, which are a major contributor to HABs. Although Indiana, Kentucky, and Ohio have not developed water quality criteria for nutrients (specifically

for aquatic life use), the US Environmental Protection Agency (USEPA) published criteria recommendations in 2000 for total nitrogen (TN) and total phosphorus (TP) for rivers and streams (USEPA, 2000a-c) and lakes and reservoirs (USEPA, 2000d-f). The Water Quality Team uses the USEPA nutrient criteria recommendations to monitor nutrient levels in LRL reservoirs and tailwaters. These recommended criteria are defined by ecoregion (Table 6).

Table 6. USEPA recommended nutrient criteria for each aggregated ecoregion and reservoir.

Reservoir	Aggregate Ecoregion	Stream Criteria		Reservoir Criteria	
		TN (mg/L)	TP (mg/L)	TN (mg/L)	TP (mg/L)
C.J. Brown Caesar Creek Harsha West Fork	6 (Corn Belt and Northern Great Plains)	2.18	0.07625	0.78	0.0375
Barren Harden ^a Cagles Mill Green Monroe Nolin Patoka Rough Taylorsville	9 (Southeastern Temperate Forested Plains and Hills)	0.69	0.03656	0.36	0.02
Buckhorn Carr Creek Cave Run	11 (Central and Eastern Forested Uplands)	0.31	0.01	0.46	0.008

^a Harden Lake is split between aggregated ecoregions 6 and 9. In 2020, ecoregion 9 criteria were used for Harden Lake's nutrient analyses.

All LRL reservoir tailwaters exceeded at least one of the USEPA recommended criteria. Table 7 shows which criteria were exceeded by each reservoir's tailwater. These results indicate that the majority of LRL reservoirs are passing high concentrations of nutrients downstream. This is not surprising considering the widespread problem of eutrophication in the US, especially in regions where agriculture (e.g., row crops, pasture, and concentrated animal feeding operations) make up a significant portion of land use (Dodds and Smith, 2016). Reservoirs can act as simultaneous sinks and sources for nutrients, where nutrient loads collected from tributaries are retained in sediments and may be released into the water column at a later date depending on physical, chemical, or biological conditions (Lee et al., 2019; Shaughnessy et al., 2019). When reviewing all nutrient samples collected in 2020 in the reservoirs and their tailwaters and tributaries, 74.13% and 99.2% of samples were greater than the USEPA recommended criteria for TN and TP, respectively. The frequency of high nutrient values

supports that many of LRL reservoirs are collecting high concentrations of nutrients which may lead to their tailwaters passing high levels of nutrients.

Table 7. Exceedances of USEPA recommended nutrient criteria at LRL tailwaters in 2020. An “X” indicates the criteria for that parameter was exceeded.

Reservoir	Exceedance of USEPA Nutrient Criteria	
	Total Nitrogen	Total Phosphorus
Buckhorn	X	X
Barren	X	X
Brookville	X	
C.J. Brown		X
Caesar Creek	X	X
Carr Creek		X
Harden	X	X
Cagles Mill	X	X
Cave Run	X	X
Harsha		X
Green		X
Monroe		X
Nolin	X	X
Patoka		X
Rough	X	X
Taylorsville	X	X
West Fork		X

Historical Nutrient Analyses

Analysis of historical nutrient values were completed using box-and-whisker plots of TN and TP data from 2012-2019. This allows comparison of 2020 nutrient values to historical averages as well as to USEPA recommended criteria. These plots provide insight into potential trends or changes over time in nutrients at LRL reservoirs. Plots can be seen in the reservoir summaries in Appendix A. For this analysis, non-detect results were given a value of zero. When compared to historical values from 2012 through 2019, 94% of all 2020 TP samples exceeded the historical median and 81% of samples exceeded the historical average. 34% of all 2020 TN samples exceeded the historical median and 42% of samples exceeded the historical average.

Trophic State Index Analyses

Trophic state index (TSI) was calculated for each reservoir, as described by Carlson (1977). TSI values were determined from near-surface Secchi depth transparency, total phosphorus, and chlorophyll-*a* measurements. Non-detect results were given a value of zero.

Values for these three parameters were converted to an index number ranging from 0 to 100 according to the following equations:

$$\begin{aligned}\text{TSI}(\text{Secchi Depth}) &= \text{TSI}(\text{SD}) = 10(6 - (\ln \text{SD}/\ln 2)) \\ \text{TSI}(\text{Chlorophyll-}a) &= \text{TSI}(\text{Chl}) = 10(6 - ((2.04 - 0.68 \ln \text{Chl})/\ln 2)) \\ \text{TSI}(\text{Total Phosphorus}) &= \text{TSI}(\text{TP}) = 10(6 - (\ln (48/\text{TP})/\ln 2))\end{aligned}$$

For each index, the average score for all reservoir sites and range of scores is calculated. These values are used by LRL as an overall indicator of a reservoir's trophic state. Generally, a higher TSI value indicates more potential for biological productivity, which can indicate a greater potential for HAB production. LRL uses the criteria defined in Table 8 for determining reservoir trophic status category from TSI values.

Table 8. Reservoir trophic status category based on calculated TSI values (modified from Carlson 1977).

TSI	Trophic Condition
0-35	Oligotrophic
36-50	Mesotrophic
51-55	Moderately Eutrophic
56-65	Eutrophic
66-100	Hypereutrophic

TSI was calculated for multiple sites at each reservoir in 2020. Table 9 represents the average TSI status category for each index at each reservoir. Based on these results, TSI(TP) classified all reservoirs as either eutrophic or hypereutrophic. The reservoirs fell into the eutrophic or hypereutrophic categories at 10 reservoirs based on TSI(Chl) and at 14 reservoirs for TSI(SD). These results indicate that all LRL reservoirs have high biological activity potential and may have a high potential for HABs.

Table 9. Average TSI categories by index for each LRL reservoir in 2020.

Reservoir	Average TSI Category		
	TSI(SD)	TSI(Chl)	TSI(TP)
Buckhorn	Mesotrophic	Oligotrophic	Hypereutrophic
Barren	Eutrophic	Eutrophic	Hypereutrophic
Brookville	Eutrophic	Eutrophic	Eutrophic
C.J. Brown	Hypereutrophic	Hypereutrophic	Hypereutrophic
Caesar Creek	Eutrophic	Oligotrophic	Hypereutrophic
Carr Creek	Mesotrophic	Oligotrophic	Hypereutrophic
Harden	Hypereutrophic	Hypereutrophic	Hypereutrophic
Cagles Mill	Hypereutrophic	Eutrophic	Hypereutrophic
Cave Run	Eutrophic	Mesotrophic	Eutrophic
Harsha	Hypereutrophic	Hypereutrophic	Hypereutrophic
Green	Moderately Eutrophic	Moderately Eutrophic	Eutrophic
Monroe	Eutrophic	Eutrophic	Eutrophic
Nolin	Eutrophic	Eutrophic	Hypereutrophic
Patoka	Eutrophic	Eutrophic	Eutrophic
Rough	Eutrophic	Eutrophic	Hypereutrophic
Taylorville	Hypereutrophic	Hypereutrophic	Hypereutrophic
West Fork	Hypereutrophic	Eutrophic	Hypereutrophic

Cyanobacteria Analyses

As part of the 2020 ambient surveys, phytoplankton (i.e., free-floating algae) communities were identified and quantified at most reservoir sites for multiple depths per site. One of the most important components of the phytoplankton community to monitor in LRL is cyanobacteria (a.k.a. blue-green algae) which is the primary group of organisms that cause HABs in the United States. For our analyses, cell counts for all cyanobacteria species at a specific sample (one sample is one depth at one site) were aggregated to find a total cyanobacteria cell count (in number of cells per mL). We then screened for the number of samples that exceeded 100,000 cells/mL. Cell counts of 100,000 cells/mL are used as a guideline value for moderate health risk, per the World Health Organization's Guidelines for Safe and Recreational Water Environments (2003), and are often used as a measure of a potential HAB.

In 2020, 13 out of 17 reservoirs had at least one sample with cyanobacteria cell counts greater than 100,000 cells/mL. The four reservoirs that did not exceed 100,000 cells/mL were Buckhorn Lake, Cave Run Lake, Carr Creek Lake, and West Fork Lake. Further, there were two reservoirs (C.J. Brown Reservoir and Harden Lake) that exceeded 1,000,000 cells/mL in multiple samples collected. The prevalence of high cyanobacteria cell counts in the majority of LRL reservoirs is not surprising given the elevated nutrient levels and TSI classifications.

Coordination with External Partners

The LRL Water Quality Program regularly coordinates with various entities inside and outside of USACE, including:

- USACE Engineer Research and Development Center (ERDC)
- USACE Cold Regions Research and Engineering Laboratory (CRREL)
- US Environmental Protection Agency (USEPA)
- US Geological Service (USGS)
- Kentucky Division of Water (KDOW)
- Kentucky Department of Fish and Wildlife Resources (KDFWR)
- Indiana Department of Environmental Management (IDEM)
- Indiana Department of Natural Resources (IDNR)
- Ohio Environmental Protection Agency (Ohio EPA)
- Ohio Department of Natural Resources (ODNR)
- Ohio River Valley Water Sanitation Commission (ORSANCO)
- The Nature Conservancy (TNC)
- Local watershed groups

Partnership efforts include coordinating sampling efforts, funding lab analysis, serving on boards or steering committees, and sharing data. These partnerships benefit multiple parties and help us in the collective effort to optimize conditions in the environment at LRL projects.

One great example of this is our partnership with the East Fork Watershed Cooperative (EFWCoop). EFWCoop is a collaboration of several federal, state, and local organizations that partner to improve the water quality of the watershed of the East Fork of the Little Miami River, where Harsha Lake resides. The LRL Water Quality Program coordinates sampling efforts to leverage resources and share data that is not duplicated with other efforts. Additionally, the LRL Water Quality Program co-funded a USGS stream gage on the river just upstream of the reservoir that is critical to the water quality model that is used by the EFWCoop to determine the nutrients balance of the watershed and is ultimately being utilized to develop water quality targets and the implementation of best management practices in the watershed to reduce eutrophication. Several research projects have resulted from the efforts of the EFWCoop that not only benefit the local watershed but have also been applied to other watersheds to improve water quality conditions.

Looking Forward

In 2021, surveys will be conducted mostly in the same manner as in 2020. Two major changes to ambient sampling will be the addition of sampling for sediment quality and algal toxins.

Sediment quality monitoring has not been conducted at LRL reservoirs in several years, despite some LRL tailwaters exhibiting exceedances in state criteria for metals. Because

reservoir sediments can retain and release various pollutants, such as metals, nutrients, and pesticides, we intend to begin sediment quality monitoring as part of our ambient surveys for all reservoirs with a subset of reservoirs being analyzed every year within a 5-year rotation. For 2021, sediment quality sampling will be conducted at Harden Lake, Cagles Mill Lake, and Monroe Lake. These analyses will contribute to a more comprehensive monitoring strategy of our reservoirs.

In conjunction with ambient surveys, algal toxins will be collected at all reservoirs (one sample will be collected in the tailwater, and 3 samples [one each from the surface, metalimnion, and hypolimnion] at the damsite). Despite several reservoirs exhibiting cyanobacteria cell counts potentially indicative of active HABs in 2020, no associated algal toxin data was collected. In 2021, collecting phytoplankton data and algal toxin data will provide the WQ team with more information to help assess severity of potential HABs in LRL reservoirs and to evaluate the potential release of algal toxins downstream of our reservoirs.

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Appendix A: 2020 Water Quality Summaries for LRL Reservoirs

Buckhorn Lake (BHR) Water Quality Summary

Summary of 2020 Water Quality Results

Buckhorn Lake had no exceedances of Kentucky's water quality criteria at the tailwater (BHR10000). When compared with USEPA's recommended nutrient criteria, total phosphorus (TP) levels at all sample locations exceeded the criteria, and one sample (taken from the tailwater) exceeded the USEPA recommended total nitrogen criteria. TSI categories from all three indices ranged from oligotrophic to hypereutrophic. There were no cyanobacteria samples collected that exceeded 100,000 cells/mL. While cell counts were not indicative of HABs at the time of sampling, the high TP levels could indicate some potential for HAB development in the lake.

2020 Activities

In 2020, one sampling event was conducted at Buckhorn Lake. Field data and chemical samples were collected at all sampling locations (Figure 1). Chlorophyll and phytoplankton were collected at all reservoir sites, and zooplankton samples were collected at the damsite (BHR20001).

Additionally, temperature and dissolved oxygen (DO) profiles were collected by the project staff at the damsite and tailwater approximately every two weeks from late April through early December.

Exceedances of KY State Water Quality Criteria

There were no exceedances of KY state water quality criteria at the tailwater.

Tailwater Temperature and DO Conditions

Tailwater temperature data was compared to KY state water quality criteria for temperature and to the Louisville District's temperature guide curve for Buckhorn Lake (Figure 2a). While tailwater temperature never exceeded the KY

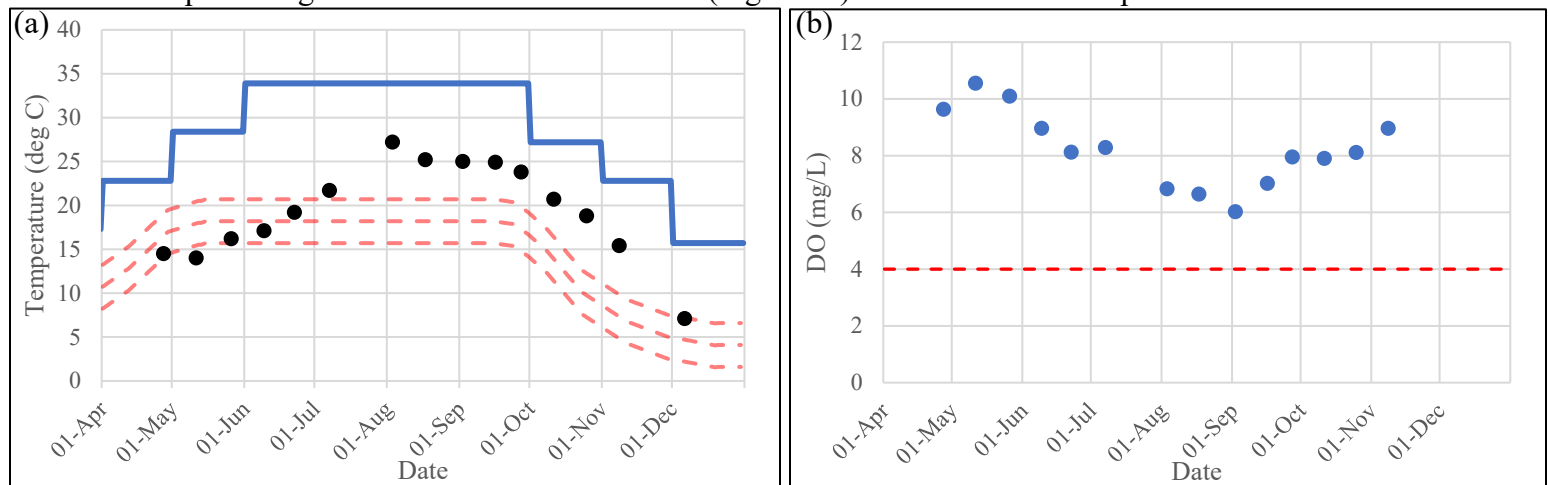


Figure 2. Buckhorn Lake tailwater temperature and dissolved oxygen data. (a) Tailwater temperature data collected in 2020 is represented by the black dots. The temperature guide curve is represented by the dashed red lines, and the blue line represents the KY water quality criteria for temperature. (b) Tailwater dissolved oxygen data collected in 2020 is represented by the blue dots. The KY water quality criteria for DO is represented by the dashed red line.

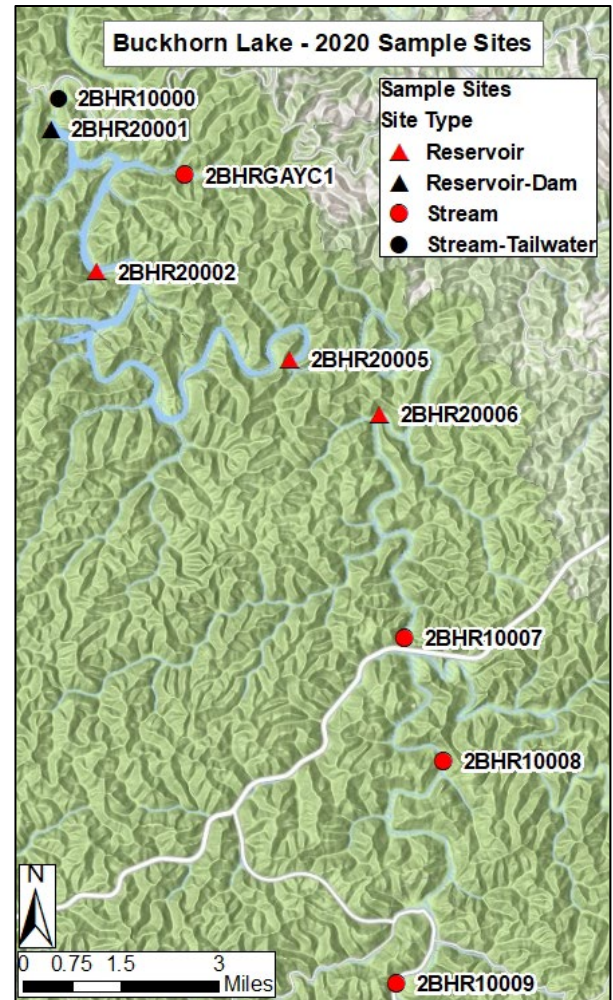


Figure 1. Water quality sampling locations for Buckhorn Lake in 2020.

state criteria for temperature, tailwater temperature fell outside the guide curve from August through early November. However, profile data indicates that the reservoir did not contain adequate cold water necessary to meet the guide curve, so no operation changes could have been made to mitigate this issue. Tailwater dissolved oxygen temperatures were compared to state criteria for DO (Figure 2b). Tailwater DO remained above minimum DO criteria throughout the year.

Nutrient Analyses

Nutrient data, including total nitrogen (TN) and total phosphorus (TP) data, were collected at all sample sites in 2020. The 2020 TP and TN values were compared to historical data from 2012 through 2019 (Figure 3). The TP and TN values at each site were compared to their respective USEPA recommended criteria. Nutrient levels are an area of concern because elevated nutrients can lead to high biological activity, especially with respect to HABs.

Total Phosphorus

2020 TP values at all sites were higher than historical medians and were at or above the top of the distribution of historical values for each location. Also, 2020 TP levels at all locations were above the USEPA recommended nutrient criteria for the respective locations.

Total Nitrogen

2020 TN values were generally lower than historical medians and were at or below the distribution of historical values for each location. Only one 2020 TN value (at the tailwater site) exceeded the USEPA recommended nutrient criteria.

Cyanobacteria Data, HABs and Trophic State Index

Cyanobacteria Data

12 phytoplankton samples were collected from various depths at 3 sites. Total cyanobacteria cell counts at all sample locations did not exceed 100,000 cells/mL (guideline value for moderate health risk from the World Health Organization's

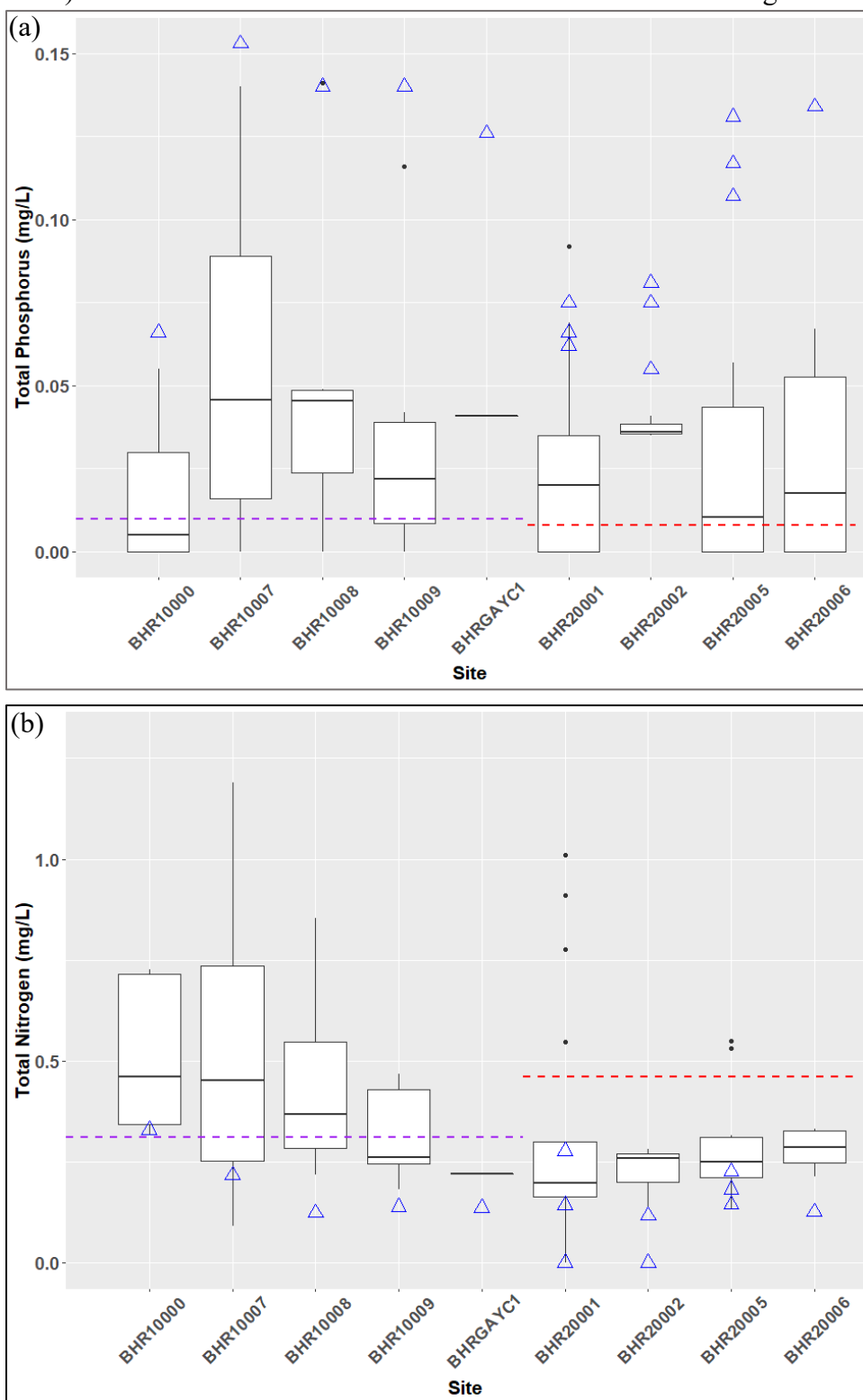


Figure 3. Comparison of Buckhorn Lake's 2020 nutrient data to historical samples. Boxplots represent data collected in 2012-2019 and blue triangles represent 2020 data. Purple and red dotted lines represent USEPA recommended nutrient criteria for streams and reservoirs, respectively. (a) Comparison of total phosphorus data. (b) Comparison of total nitrogen data. One historical outlier (value = 2.81 mg/L) was excluded to make the plot easier to interpret.

Harmful Algal Bloom (HAB) Response

KY Division of Water (KDOW) is the lead agency for HAB response in Kentucky. KDOW did not issue any advisories for HABs at Buckhorn Lake in 2020.

Trophic State Index (TSI)

The trophic state indices for Secchi depth [TSI(SD)], chlorophyll-a [TSI(CHL)], and total phosphorus [TSI(TP)] were calculated for five reservoir sites at Buckhorn Lake (Table 1). The mean categories of the three indices ranged from mesotrophic to hypereutrophic, indicating varying levels of biological activity potential.

Table 1. Summary of calculated trophic state indices at Buckhorn Lake.

	Mean Score (range)	Mean Category (range)
TSI(SD)	50 (44-57)	Mesotrophic (Mesotrophic-Eutrophic)
TSI(CHL)	34 (31-45)	Oligotrophic (Oligotrophic-Mesotrophic)
TSI(TP)	69 (62-75)	Hypereutrophic (Eutrophic-Hypereutrophic)

Barren River Lake (BRR) Water Quality Summary

Summary of 2020 Water Quality Results

Barren River Lake had no exceedances of KY's water quality criteria at the tailwater (BRR10000). Total phosphorus and total nitrogen levels at all sample locations exceeded the USEPA nutrient criteria. TSI for all three indices classified the lake as eutrophic or hypereutrophic, indicating a high level of biological activity. Finally, our sampling showed cyanobacteria cell counts over 100,000 cells/mL in only one sample at the time of the sampling event. While cell counts were under 100,000 cells/mL at most sites at the time of sampling, the elevated nutrient levels and eutrophic/hypereutrophic classification indicate there is a high potential for HAB development in the lake.

2020 Activities

In 2020, one sampling event was conducted at Barren River Lake. Field data and chemical samples were collected at 9 sample sites, and only field data was collected at 4 sites (Figure 1). Chlorophyll and phytoplankton were collected at 4 sites, and zooplankton samples were collected at the damsite (BRR20001).

Additionally, temperature and dissolved oxygen (DO) profiles were collected by the project staff at the damsite and tailwater approximately every two weeks from early May through late December.

Exceedances of KY State Water Quality Criteria

There were two exceedance events of KY state water quality criteria for temperature at the tailwater on January 11 and January 15-17. There were no other exceedances of KY state WQ criteria.

Tailwater Temperature and Dissolved Oxygen Conditions

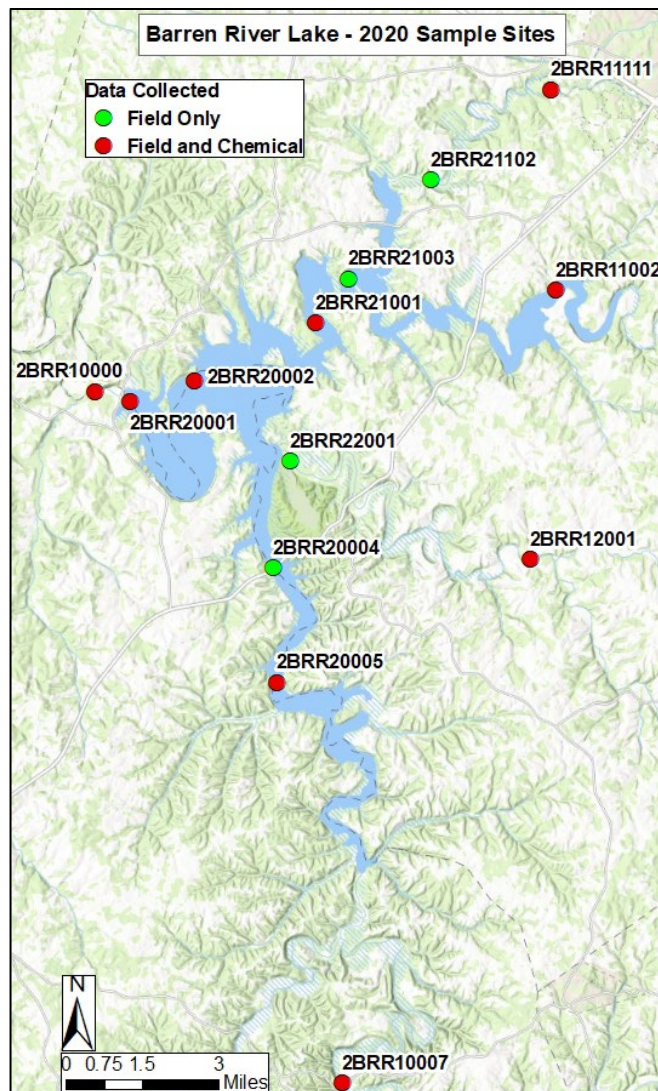
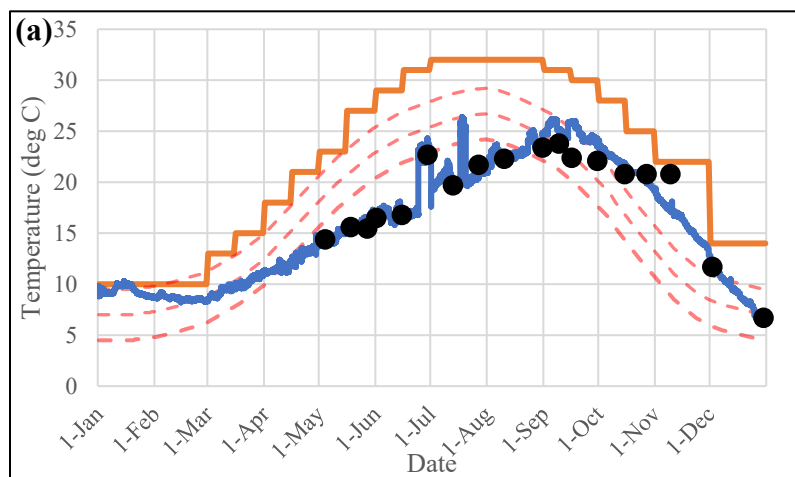


Figure 1. Water quality sampling locations for Barren River Lake in 2020.

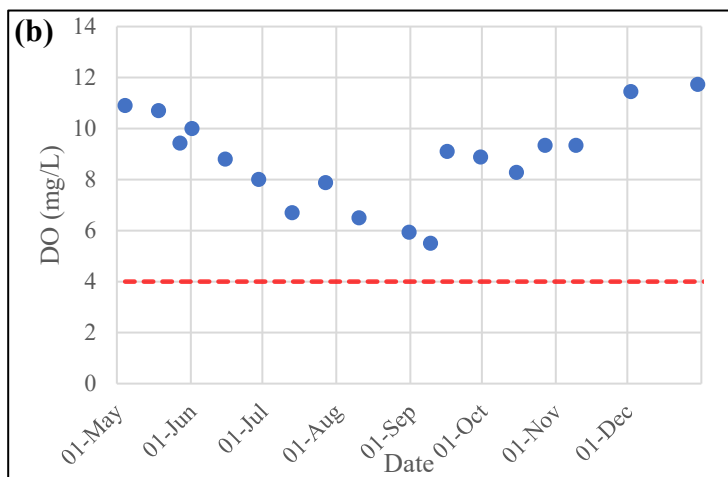


Figure 2. Barren River Lake tailwater temperature and dissolved oxygen data. (a) Tailwater temperature data collected by project staff in 2020 is represented by the black dots. The blue line represents USGS gage data (provisional) from a gage downstream from the project. The temperature guide curve is represented by the dashed red lines, and the orange line represents the KY water quality criteria for temperature. (b) Tailwater DO data collected in 2020 is represented by the blue dots. The KY water quality criteria for DO is represented by the dashed red line.

Tailwater data was compared to KY state water quality criteria for temperature and to the Louisville District's temperature guide curve for Barren River Lake (Figure 2a). According to the provisional USGS data, tailwater temperature exceeded the state criteria for temperature on January 11 and January 15-17. During this time, the reservoir was de-stratified; therefore, nothing could be done operationally to prevent these exceedances. Also, tailwater temperatures fell outside the guide curve mid-April through mid-August and mid-October through early December. Maintenance issues with the selective withdrawal gates limited the capacity to operate for temperature; however, repairs have been made and LRL intends to utilize these gates to improve performance of downstream temperature management wherever possible. Tailwater DO levels did not exceed state criteria at any time throughout the year (Figure 2b).

Nutrient Analyses

Nutrient data, including total nitrogen (TN) and total phosphorus (TP) data, were collected at all sample sites in 2020. The 2020 TP and TN values were compared to historical data from 2012 through 2019 (Figure 3 and Figure 4). The TP and TN values at each site were compared to their respective USEPA recommended criteria. Nutrient levels are an area of concern because elevated nutrients can lead to high biological activity, especially with respect to HABs. One site (BRR11111) exhibits considerably high levels of nutrients compared to the other sites. BRR11111 is just downstream the city of Glasgow and appears to have residential and industrial land-use within its drainage. Further investigation into the nutrient issues at this location is needed.

Total Phosphorus

2020 TP values at Barren River Lake were above the historical medians in all samples (except for BRR11111) and 2020 values were near the top or above the historical distribution for TP values. Also, 2020 TP levels at all sites were above the USEPA recommended nutrient criteria for the respective locations.

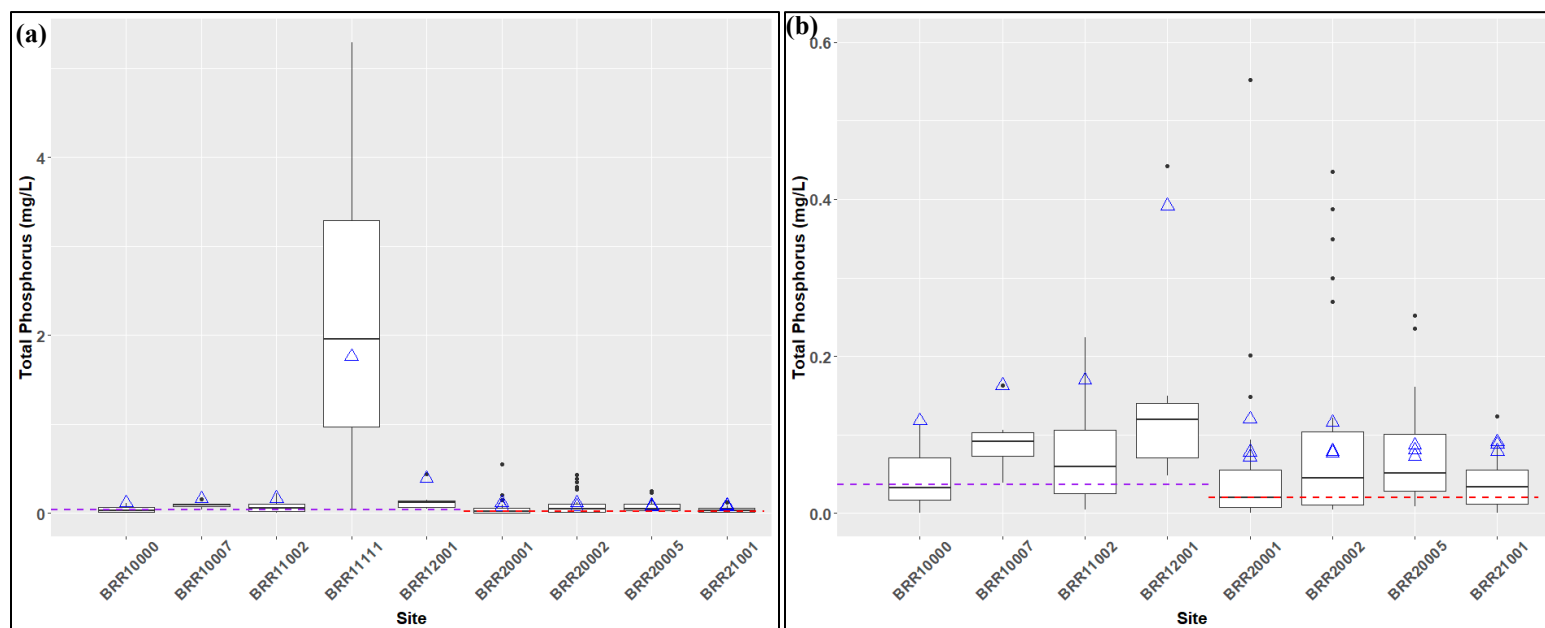


Figure 3. Comparison of 2020 total phosphorus (TP) data to historical samples and nutrient criteria. Boxplots represent data collected in 2012-2019 and blue triangles represent 2020 data. Purple and red dotted lines represent USEPA recommended nutrient criteria for streams and reservoirs, respectively. (a) Comparison of TP data from all BRR sites. (b) Comparison of TP data excluding data from site BRR11111.

Total Nitrogen

2020 TN values at Barren River Lake were above the historical medians in all samples (except for BRR11111) and 2020 values were near the top or above the historical distribution for each location. Also, 2020 TN levels at all locations were above the USEPA recommended nutrient criteria for the respective locations.

Cyanobacteria Data, HABs, and Trophic State Index

Cyanobacteria Data

12 phytoplankton samples were collected from various depths at 3 sites. Total cyanobacteria cell counts exceeded 100,000 cells/mL (guideline value for moderate health risk from the World Health Organization’s Guidelines for Safe Recreational Water Environments [2003]) in 1 out of 12 samples collected. None of these samples exceeded 1,000,000 cells/mL. These results indicate Barren River Lake did not have cell count levels potentially indicative of a HAB for most samples at the time of sampling.

Harmful Algal Bloom (HAB) Response

The KY Division of Water (KDOW) is the lead agency for HAB response in Kentucky. KDOW did not issue any advisories for HABs at Barren River Lake in 2020.

Trophic State Index

The trophic state indices for Secchi depth [TSI(SD)], chlorophyll-a [TSI(CHL)], and total phosphorus [TSI(TP)] were calculated for six reservoir sites at Barren River Lake (Table 1). The mean category of all three indices ranged from eutrophic to hypereutrophic, indicating a high to very high level of biological activity.

Table 1. Summary of calculated trophic state indices at Barren River Lake.

	Mean Score (range)	Mean Category (range, if different)
TSI(SD)	60 (57-64)	Eutrophic
TSI(CHL)	59 (56-64)	Eutrophic (Moderately Eutrophic-Eutrophic)
TSI(TP)	67 (67-68)	Hypereutrophic

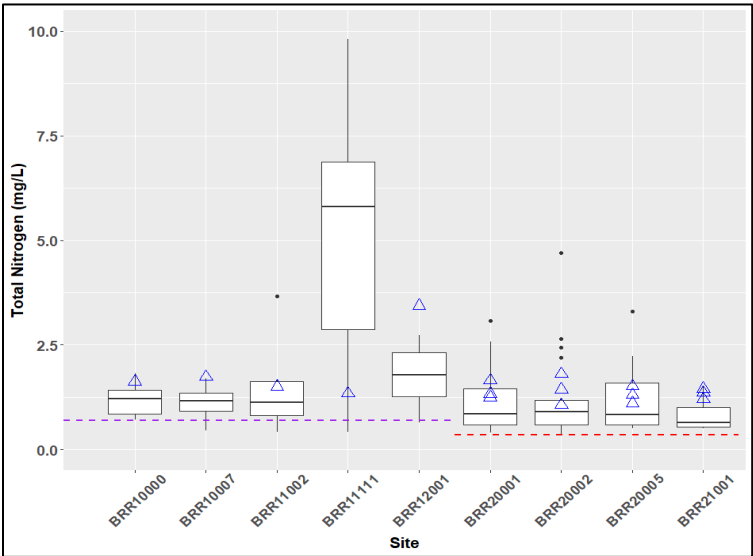


Figure 4. Comparison of 2020 total nitrogen data to historical samples and nutrient criteria. Boxplots represent data collected in 2012-2019 and blue triangles represent 2020 data. Purple and red dotted lines represent USEPA recommended nutrient criteria for streams and reservoirs, respectively. One historical outlier (value = 19.9 mg/L) was excluded to make the plot easier to interpret.

Brookville Lake (BVR) Water Quality Summary

Summary of 2020 Water Quality Results

Brookville Lake had no exceedances of Indiana’s water quality criteria at the tailwater (BVR10000). Total phosphorus and total nitrogen levels at most sample locations exceeded the USEPA nutrient criteria. The mean TSI category for all three indices classified the lake as eutrophic, indicating a high level of biological activity. Finally, our sampling showed cyanobacteria cell counts over 100,000 cells/mL in half of the samples at the time of sampling. The elevated nutrient levels and eutrophic classification indicate there is a high potential for HAB development in the lake.

2020 Activities

In 2020, one sampling event was conducted at Brookville Lake. Field data and chemical samples were collected at all seven sites (Figure 1). Chlorophyll and phytoplankton were collected at three sites, and zooplankton samples were collected at the damsite (BVR20001).

Additionally, temperature and dissolved oxygen (DO) profiles were collected by the project staff at the damsite and tailwater approximately every two weeks from late May through late December.

Exceedances of IN State Water Quality Criteria

There were no exceedances of IN state water quality criteria at the tailwater.

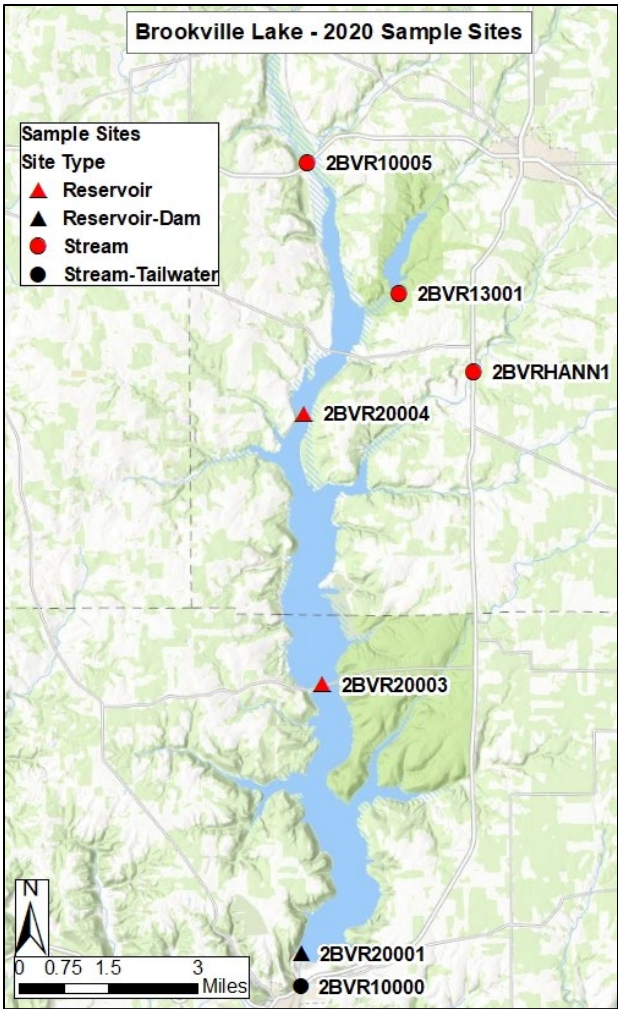


Figure 1. Water quality sampling locations for Brookville Lake in 2020.

Tailwater Temperature and DO Conditions

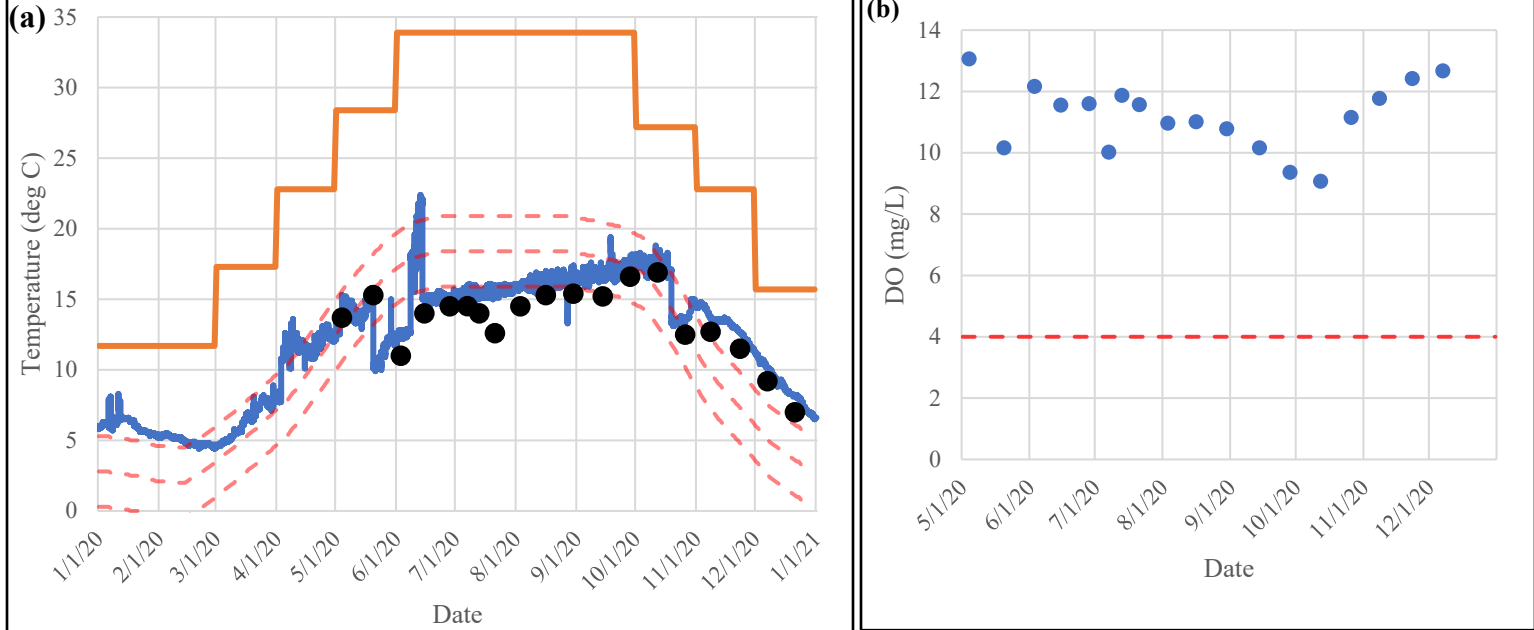


Figure 2. Brookville Lake tailwater temperature and DO data. (a) Tailwater temperature data collected by project staff in 2020 is represented by the black dots. The blue line represents USGS gage data (provisional) from a gage downstream from the project. The temperature guide curve is represented by the dashed red lines, and the orange line represents the IN water quality criteria for temperature. (b) Tailwater dissolved oxygen data collected in 2020 is represented by the blue dots. The IN water quality criteria for DO is represented by the dashed red line.

Tailwater data was compared to IN state water quality criteria for temperature and to the Louisville District's temperature guide curve for Brookville Lake (Figure 2a). Tailwater temperature did not exceed the state criteria for temperature at any time. However, tailwater temperatures fell outside the guide curve late-May through July and November through December. The WQ Program will use these findings to inform future operational decisions to improve performance of downstream temperature management wherever possible. Tailwater dissolved oxygen levels did not exceed state criteria at any time throughout the year (Figure 2b).

Nutrient Analyses

Nutrient data, including total nitrogen (TN) and total phosphorus (TP) data, were collected at all sample sites in 2020. The 2020 TP and TN values were compared to historical data from 2012 through 2019 (Figure 3). The TP and TN values at each site were compared to their respective USEPA recommended criteria. Nutrient levels are an area of concern because elevated nutrients can lead to high biological activity, especially with respect to HABs.

Total Phosphorus

2020 TP values at Brookville Lake were above the historical medians and were near the top or above the historical distributions in all but two sites. Also, 2020 TP levels in 11 out of 13 samples were above the USEPA recommended nutrient criteria for the respective locations.

Total Nitrogen

2020 TN values at Brookville Lake were near or below the historical medians at all sites, and 2020 values fell within or below the historical distribution. Also, 2020 TN levels in 12 out of 13 samples collected were above the USEPA recommended nutrient criteria for the respective locations.

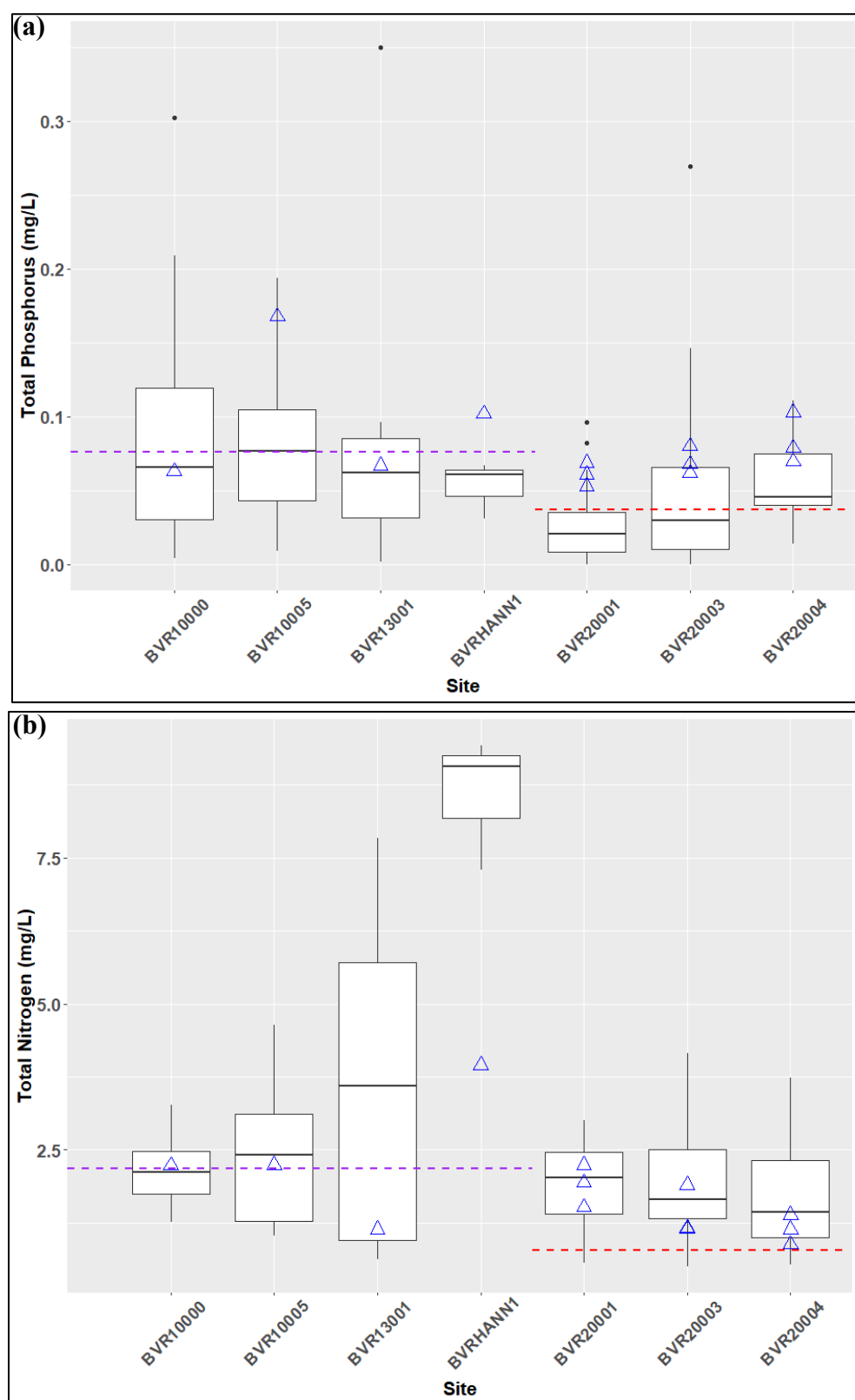


Figure 3. Comparison of 2020 nutrient data to historical samples. Boxplots represent data collected in 2012-2019 and blue triangles represent 2020 data. Purple and red dotted lines represent USEPA recommended nutrient criteria for streams and reservoirs, respectively. (a) Comparison of total phosphorus data. (b) Comparison of total nitrogen data.

Cyanobacteria Data, HABs, and Trophic State Index

Cyanobacteria Data

12 phytoplankton samples were collected at various depths from 3 sites. Total cyanobacteria cell counts exceeded 100,000 cells/mL (guideline value for moderate health risk from the World Health Organization’s Guidelines for Safe Recreational Water Environments [2003]) in 6 out of 12 samples collected from 3 sites. None of these samples exceeded 1,000,000 cells/mL. These results indicate Brookville Lake had cell count levels potentially indicative of a HAB at the time of sampling in half the samples collected.

Harmful Algal Bloom (HAB) Response

Indiana Department of Environmental Management (IDEM) is the lead agency for HAB response in Indiana. IDEM samples State Recreation Areas (SRAs) biweekly during the recreation season and issues appropriate HAB alert levels based on the results. IDEM issued HAB Advisory alert levels at the Quakertown SRA from 6/19/20 through 6/26/20 and at Mounds SRA from 6/19/20 through 6/26/20. The Advisory alert level indicates that cell counts were over 100,000 cells/mL, but toxin levels did not meet thresholds for the Caution or Closed alert levels. At an Advisory alert level, the following precautions apply: swimming and boating permitted; avoid contact with algae; don’t drink the water; and shower after you swim.

Trophic State Index

The trophic state indices for Secchi depth [TSI(SD)], chlorophyll-*a* [TSI(CHL)], and total phosphorus [TSI(TP)] were calculated for three reservoir sites at Brookville Lake (Table 1). The mean category of all three indices was eutrophic, indicating a high level of biological activity.

Table 1. Summary of calculated trophic state indices at Brookville

	Mean Score (range)	Mean Category (range)
TSI(SD)	56 (52-60)	Eutrophic (Moderately Eutrophic-Eutrophic)
TSI(CHL)	60 (53-68)	Eutrophic (Moderately Eutrophic-Hypereutrophic)
TSI(TP)	64 (61-67)	Eutrophic (Eutrophic-Hypereutrophic)

CJ Brown Dam and Reservoir (CBR) Water Quality Summary

Summary of 2020 Water Quality Results

CJ Brown Reservoir had no exceedances of OH's water quality criteria at the tailwater (CBR10000). Total phosphorus and total nitrogen levels at most sample locations exceeded the USEPA nutrient criteria. The mean TSI category for all three indices classified the lake as hypereutrophic, indicating a very high level of biological activity. Finally, our sampling showed cyanobacteria cell counts over 100,000 cells/mL in all samples, and cell counts over 1,000,000 cells/mL in 6 out of 7 samples at the time of sampling. Cell counts over 100,000 cells/mL are potentially indicative of HAB conditions. The elevated nutrient levels and hypereutrophic classification indicate there is a high potential for HAB development in the lake.

2020 Activities

In 2020, one sampling event was conducted at CJ Brown Reservoir. Field data and chemical samples were collected at all seven sites (Figure 1). Chlorophyll and phytoplankton were collected at 2 sites, and zooplankton samples were collected at the damsite (CBR20001).

Additionally, temperature and dissolved oxygen (DO) profiles were collected by the project staff at the damsite and tailwater approximately every two weeks from early May through early October.

Exceedances of OH State Water Quality Criteria

There were no exceedances of OH state water quality criteria at the tailwater.

Tailwater Temperature and DO Conditions

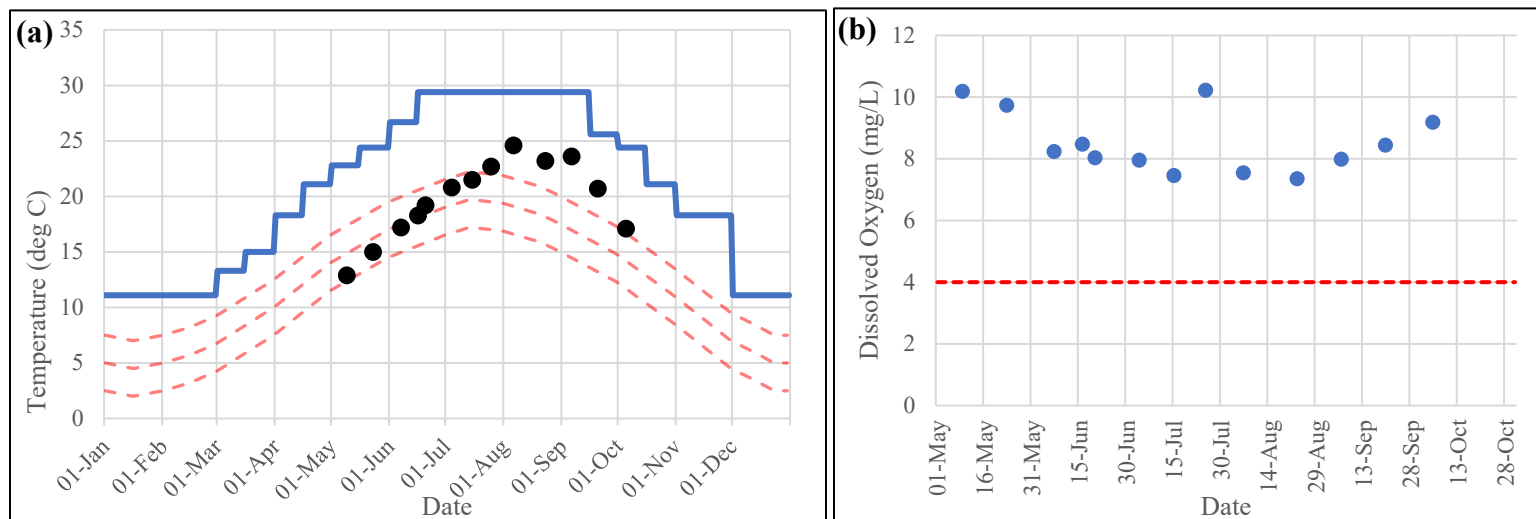


Figure 2. CJ Brown Reservoir tailwater temperature and DO data. (a) Tailwater temperature data collected by project staff in 2020 is represented by the black dots. The temperature guide curve is represented by the dashed red lines, and the blue line represents the OH water quality criteria for temperature. (b) Tailwater dissolved oxygen data collected in 2020 is represented by the blue dots. The OH water quality criteria for DO is represented by the dashed red line.

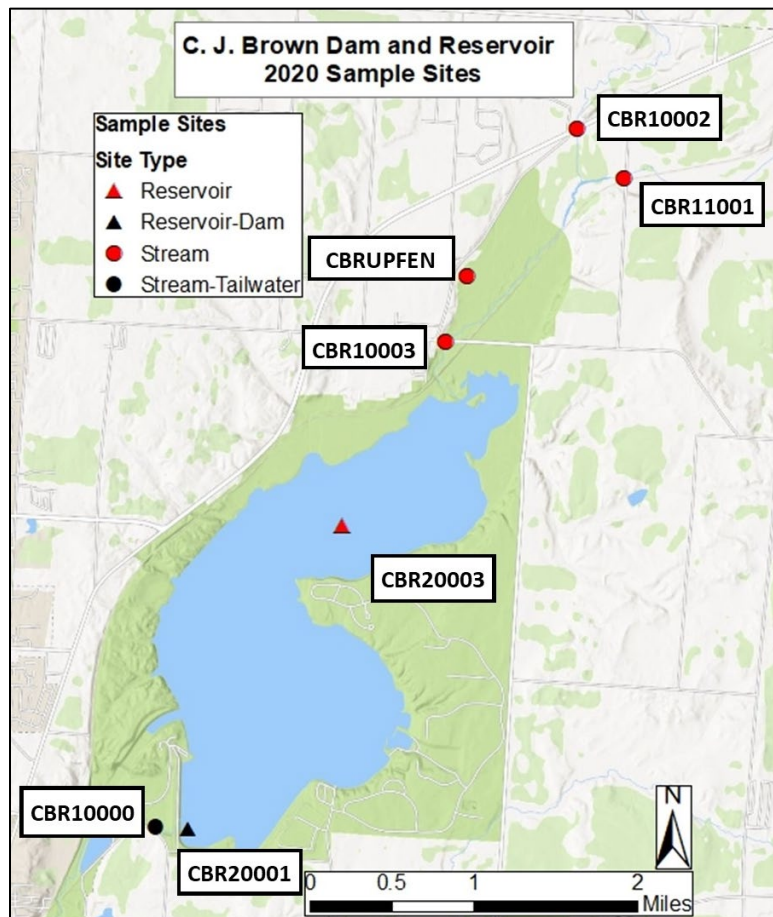


Figure 1. Water quality sampling locations for CJ Brown Reservoir in 2020.

Tailwater data was compared to OH state water quality criteria for temperature and to the Louisville District's temperature guide curve for CJ Brown Reservoir (Figure 2a). Tailwater temperature did not exceed the state criteria for temperature at any time; however, tailwater temperatures fell outside the guide curve late July through early October. The WQ Program will use these findings to inform future operational decisions to improve performance of downstream temperature management wherever possible. Tailwater dissolved oxygen levels did not exceed state criteria at any time throughout the year (Figure 2b).

Nutrient Analyses

Nutrient data, including total nitrogen (TN) and total phosphorus (TP) data, were collected at all sample sites in 2020. The 2020 TP and TN values were compared to historical data from 2012 through 2019 (Figure 3). The TP and TN values at each site were compared to their respective USEPA recommended criteria. Nutrient levels are an area of concern because elevated nutrients can lead to high biological activity, especially with respect to HABs.

Total Phosphorus

2020 TP values at all sites at CJ Brown Reservoir were above the historical medians and historical distributions, and above the USEPA recommended nutrient criteria for the respective locations.

Total Nitrogen

2020 TN values at CJ Brown Reservoir were near or below the historical medians and distributions at all sites. However, 2020 TN levels in 10 out of 11 samples were above the USEPA recommended nutrient criteria for the respective locations.

Cyanobacteria Data, HABs, and Trophic State Index

Cyanobacteria Data

7 phytoplankton samples were collected from various depths at 2 sites. Total cyanobacteria cell counts exceeded 100,000 cells/mL (guideline value for moderate health risk from the World Health Organization's Guidelines for Safe Recreational Water Environments [2003]) in all 7 samples collected. 6 out of 7 of these samples exceeded 1,000,000 cells/mL. These results indicate CJ Brown Reservoir had cell

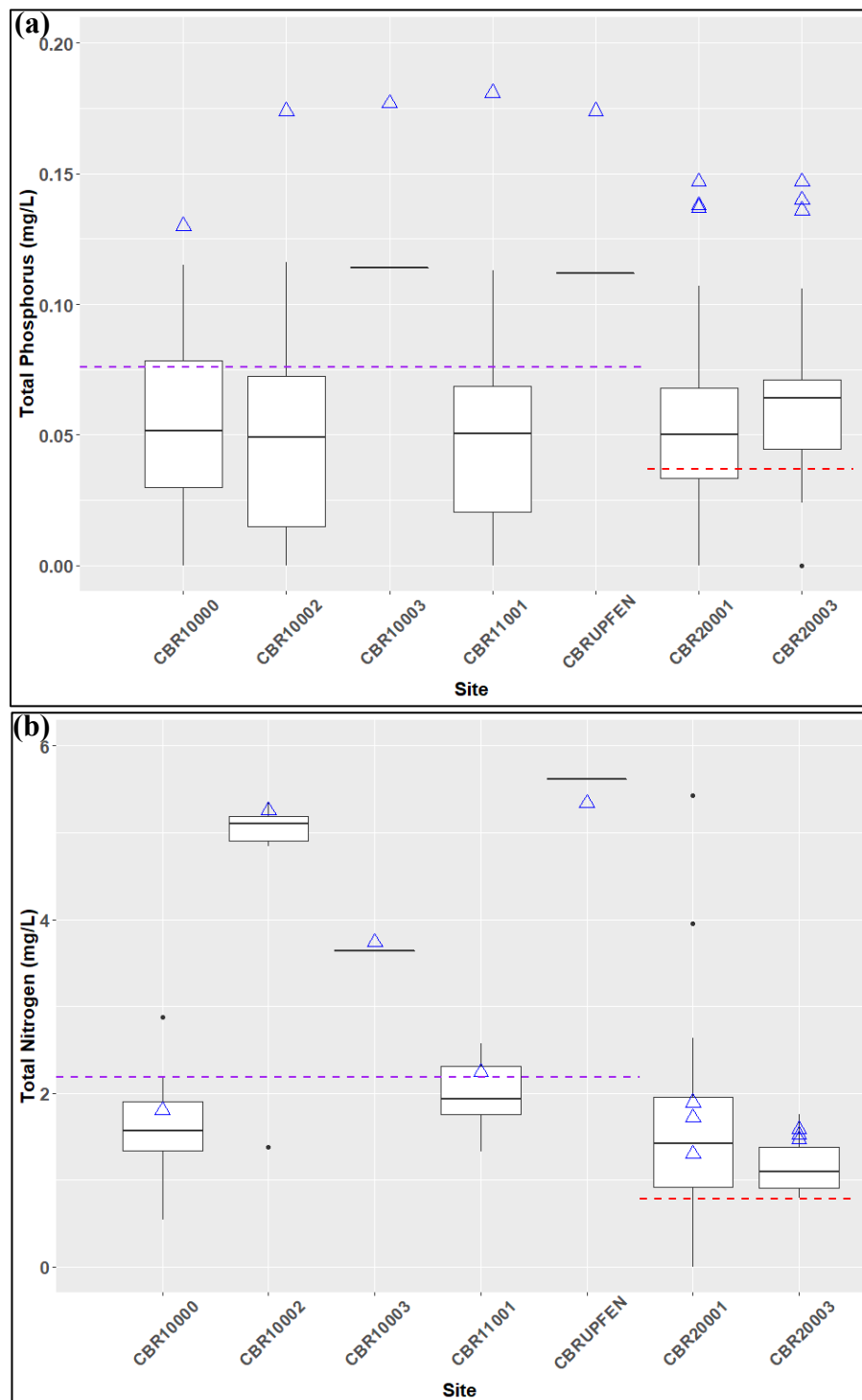


Figure 3. Comparison of 2020 nutrients data to historical samples and nutrient criteria. Boxplots represent data collected in 2012-2019 and blue triangles represent 2020 data. Purple and red dotted lines represent USEPA recommended nutrient criteria for streams and reservoirs, respectively. (a) Comparison of total phosphorus data. One outlier (value = 0.275 mg/L) was excluded to make plot easier to interpret. (b) Comparison of total nitrogen data. One outlier (value = 7.7 mg/L) was excluded to make plot easier to interpret.

count levels potentially indicative of a HAB at the time of sampling.

Harmful Algal Bloom (HAB) Response

Ohio EPA is the lead agency for HAB response in Ohio. Ohio EPA did not issue any advisories for HABs at CJ Brown Reservoir.

TSI

The trophic state indices for Secchi depth [TSI(SD)], chlorophyll-*a* [TSI(CHL)], and total phosphorus [TSI(TP)] were calculated for two reservoir sites at CJ Brown Reservoir (Table 1). The mean category of all three indices was hypereutrophic, indicating a very high level of biological activity.

Table 1. Summary of calculated trophic state indices at CJ Brown Reservoir.

	Mean Score (range)	Mean Category
TSI(SD)	68 (68-68)	Hypereutrophic
TSI(CHL)	76 (76-76)	Hypereutrophic
TSI(TP)	76 (75-79)	Hypereutrophic

Caesar Creek Lake (CCK) Water Quality Summary
Summary of 2020 Water Quality Results

Caesar Creek Lake had two exceedances of OH’s water quality criteria for temperature at the tailwater (CCK10000). Total phosphorus and total nitrogen levels at most sample locations exceeded the USEPA nutrient criteria. The mean TSI category for all three indices classified the lake as eutrophic or hypereutrophic, indicating a very high level of biological activity. Finally, our sampling showed cyanobacteria cell counts over 100,000 cells/mL in 9 out of 16 samples. The elevated nutrient levels and eutrophic/hypereutrophic classification indicate there is a high potential for HAB development in the lake.

2020 Activities

In 2020, one sampling event was conducted at Caesar Creek Lake. Field data and chemical samples were collected at all nine sites (Figure 1). Chlorophyll and phytoplankton were collected at four sites (however chlorophyll samples were lost during shipping), and zooplankton samples were collected at the damsite (CCK20001).

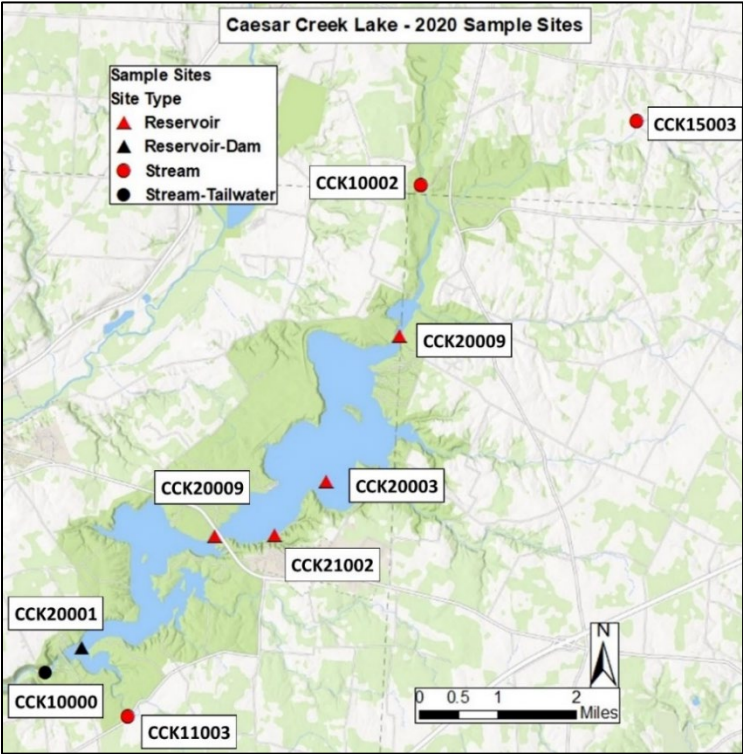


Figure 1. Water quality sampling locations for Caesar Creek Lake in 2020.

Additionally, temperature and dissolved oxygen (DO) profiles were collected by the project staff at the damsite and tailwater approximately every two weeks from early May through late December.

Exceedances of OH State Water Quality Criteria

There were two exceedance events of OH state water quality criteria for temperature at the tailwater. These events occurred December 1 through December 5, and on December 12. There were no other exceedances of Ohio state WQ criteria.

Tailwater Temperature and DO Conditions

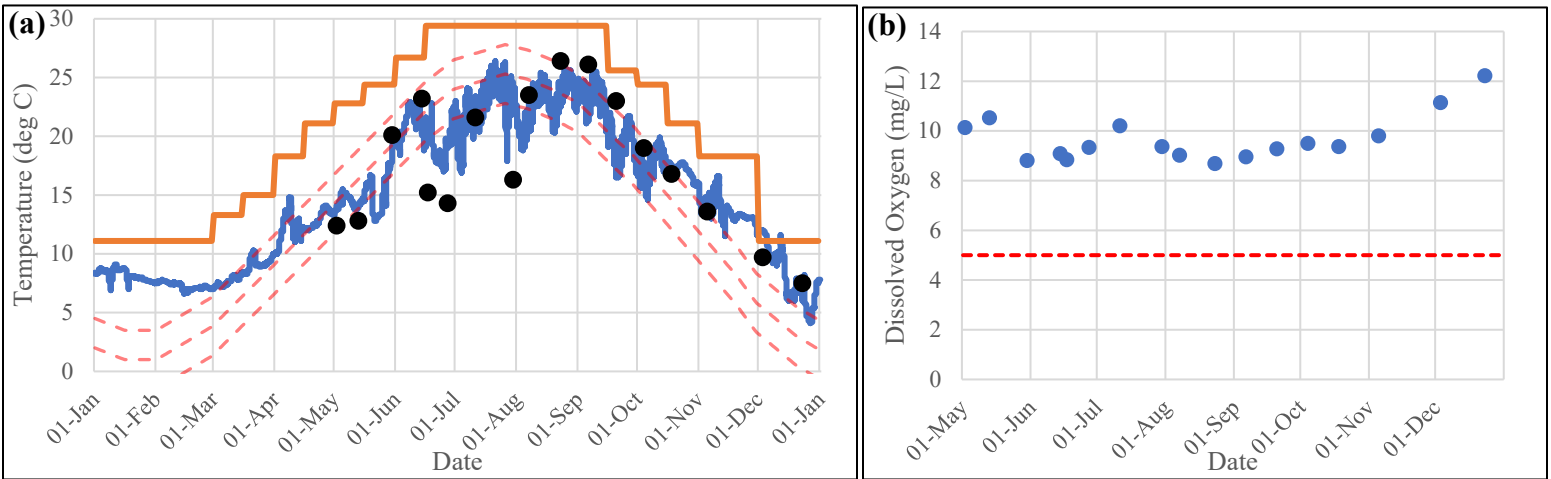


Figure 2. Caesar Creek Lake tailwater temperature and DO data. (a) Tailwater temperature data collected by project staff in 2020 is represented by the black dots. The blue line represents USGS gage data (provisional) from a gage downstream from the project. The temperature guide curve is represented by the dashed red lines, and the orange line represents the OH water quality criteria for temperature. (b) Tailwater dissolved oxygen data collected in 2020 is represented by the blue dots. The OH water quality criteria for DO is represented by the dashed red line.

Tailwater data was compared to OH state water quality criteria for temperature and to the Louisville District's temperature guide curve for Caesar Creek Lake (Figure 2a). According to the provisional USGS data, tailwater temperature exceeded the state criteria for temperature December 1 through December 5, and on December 12. During this time, the reservoir was de-stratified; therefore, nothing could be done operationally to prevent these exceedances. Also, tailwater temperatures fell outside the guide curve January through early March, various times in the summer, and mid-October through the end of the year. The WQ Program will use these findings to inform future operational decisions to improve performance of downstream temperature management wherever possible. Tailwater dissolved oxygen levels (Figure 2b) did not exceed state criteria at any time throughout the year.

Nutrient Analyses

Nutrient data, including total nitrogen (TN) and total phosphorus (TP) data, were collected at all sample sites in 2020. The 2020 TP and TN values were compared to historical data from 2012 through 2019 (Figure 3). The TP and TN values at each site were compared to their respective USEPA recommended criteria. Nutrient levels are an area of concern because elevated nutrients can lead to high biological activity, especially with respect to HABs.

Total Phosphorus

2020 TP values from all samples at Caesar Creek Lake were above the historical medians and historical distributions for their respective location. Also, 2020 TP levels at all sample locations were above the USEPA recommended nutrient criteria for the respective locations.

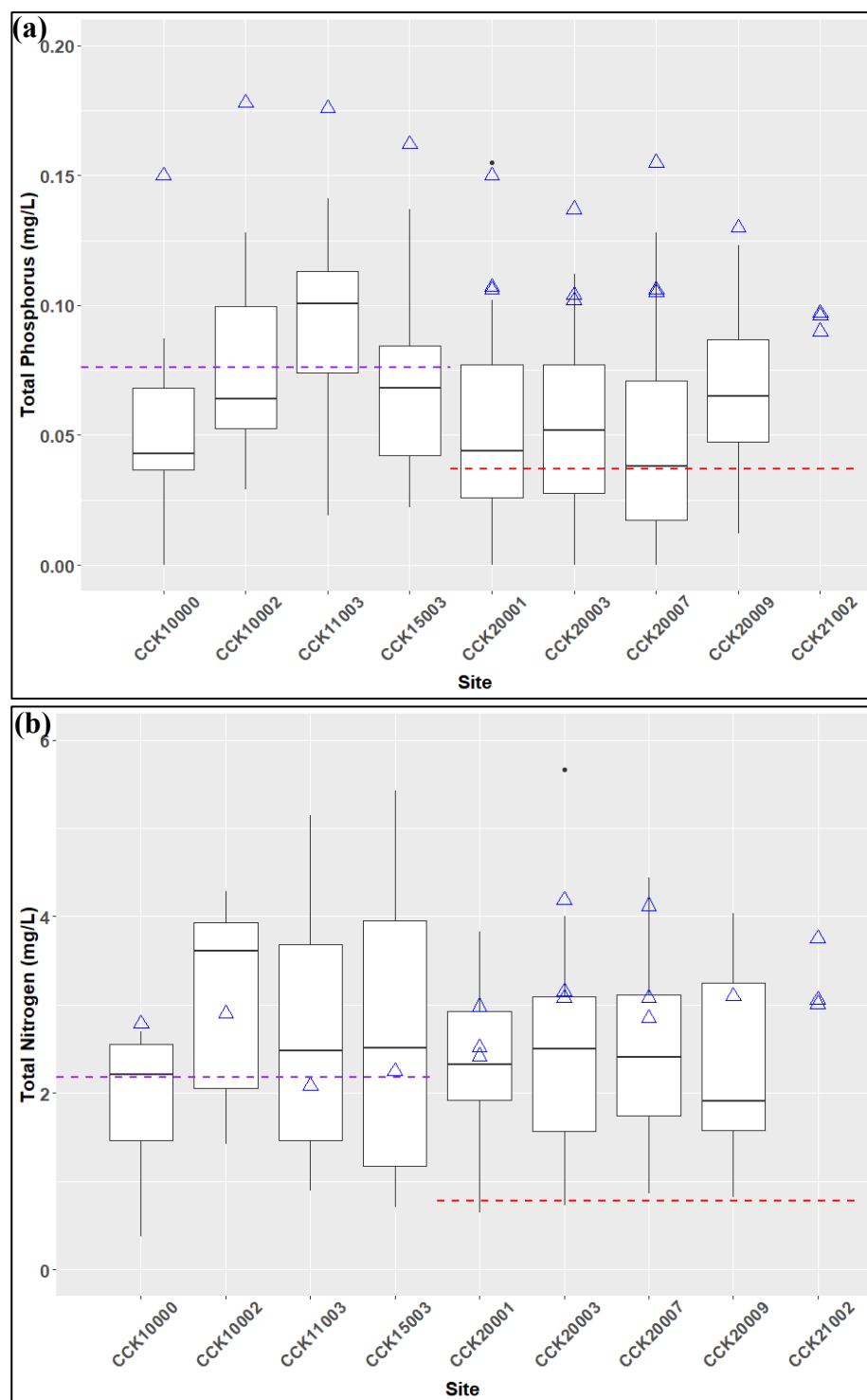


Figure 3. Comparison of 2020 nutrients data to historical samples and nutrient criteria. Boxplots represent data collected in 2012-2019 and blue triangles represent 2020 data. Purple and red dotted lines represent USEPA recommended nutrient criteria for streams and reservoirs, respectively. (a) Comparison of total phosphorus data. Two outliers (values range from 0.205 to 0.286 mg/L) were excluded to make plot easier to interpret. (b) Comparison of total nitrogen data. One outlier (value = 14.2 mg/L) was excluded to make plot easier to interpret.

Total Nitrogen

2020 TN values at Caesar Creek Lake were near or below the historical medians in five samples and were above historical medians in the remaining samples. Also, 2020 TN levels in 16 out of 17 samples were above the USEPA recommended nutrient criteria for the respective locations.

Cyanobacteria Data, HABs, and Trophic State Index

Cyanobacteria Data

16 phytoplankton samples were collected at various depths from 4 sites. Total cyanobacteria cell counts exceeded 100,000 cells/mL (guideline value for moderate health risk from the World Health Organization's Guidelines for Safe Recreational Water Environments [2003]) in 9 of the samples collected from 3 of the sites. No samples exceeded 1,000,000 cells/mL. These results indicate Caesar Creek Lake had cell count levels potentially indicative of a HAB at the time of sampling.

Harmful Algal Bloom (HAB) Response

Ohio EPA is the lead agency for HAB response in Ohio. Ohio EPA did not issue any advisories for HABs at Caesar Creek Lake.

TSI

The trophic state indices for Secchi depth [TSI(SD)], and total phosphorus [TSI(TP)] were calculated for five reservoir sites at Caesar Creek Lake (Table 1; chlorophyll samples were lost during shipping). The mean category of all three indices ranged from eutrophic to hypereutrophic, indicating a high to very high level of biological activity.

Table 1. Summary of calculated trophic state indices at Caesar Creek Lake.

	Mean Score (range)	Mean Category (Range)
TSI(SD)	58 (53-69)	Eutrophic (Moderately Eutrophic-Hypereutrophic)
TSI(TP)	72 (70-74)	Hypereutrophic

Carr Creek Lake (CFK) Water Quality Summary

Summary of 2020 Water Quality Results

Carr Creek Lake had one exceedance of KY's water quality criteria for temperature at the tailwater (CFK10000). Total phosphorus (TP) levels at all sample locations exceeded the USEPA nutrient criteria, while only two total nitrogen samples exceeded USEPA criteria. TSI for the three indices classified the lake as oligotrophic, mesotrophic, or hypereutrophic, indicating varying levels of biological activity potential. Finally, our sampling showed there were no samples with cyanobacteria cell counts over 100,000 cells/mL at the time of the sampling event. While cell counts were not indicative of HABs at the time of sampling, and the TSI categories were variable, the high TP levels indicates the potential for HAB development in the lake.

2020 Activities

In 2020, one sampling event was conducted at Carr Creek Lake. Field data and chemical samples were collected at all 11 sample locations (Figure 1). Chlorophyll and phytoplankton were collected at 4 sites, and zooplankton samples were collected at the damsite (CFK20001).

Additionally, temperature and dissolved oxygen (DO) profiles were collected by the project staff at the damsite and tailwater approximately every two weeks from early May through late December.

Exceedances of KY State Water Quality Criteria

There was one exceedance event of KY state water quality criteria for temperature at the tailwater on January 15th. There were no other exceedances of KY state WQ criteria.

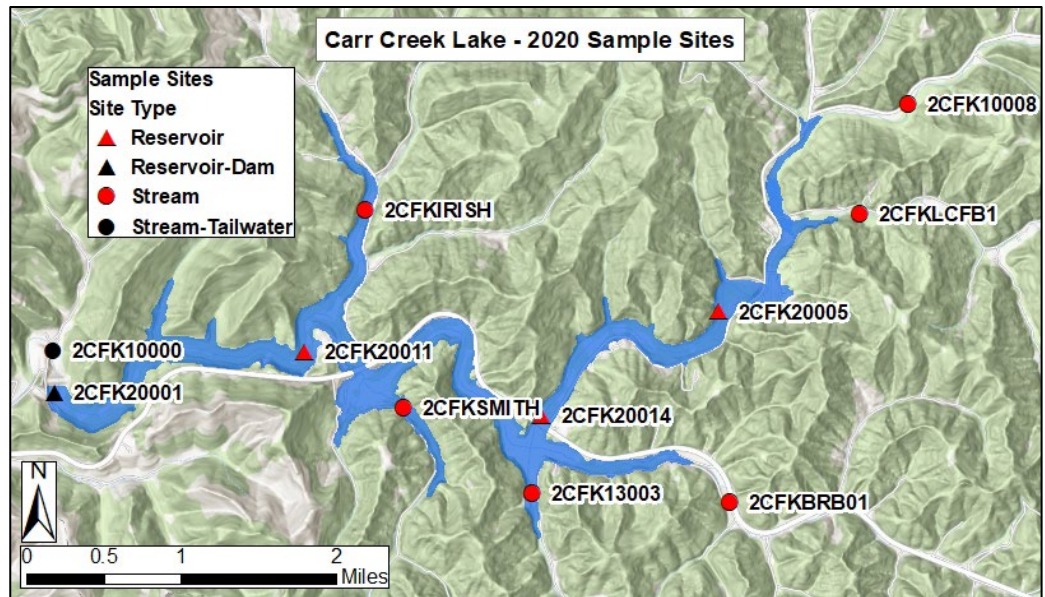


Figure 1. Water quality sampling locations for Carr Creek Lake in 2020.

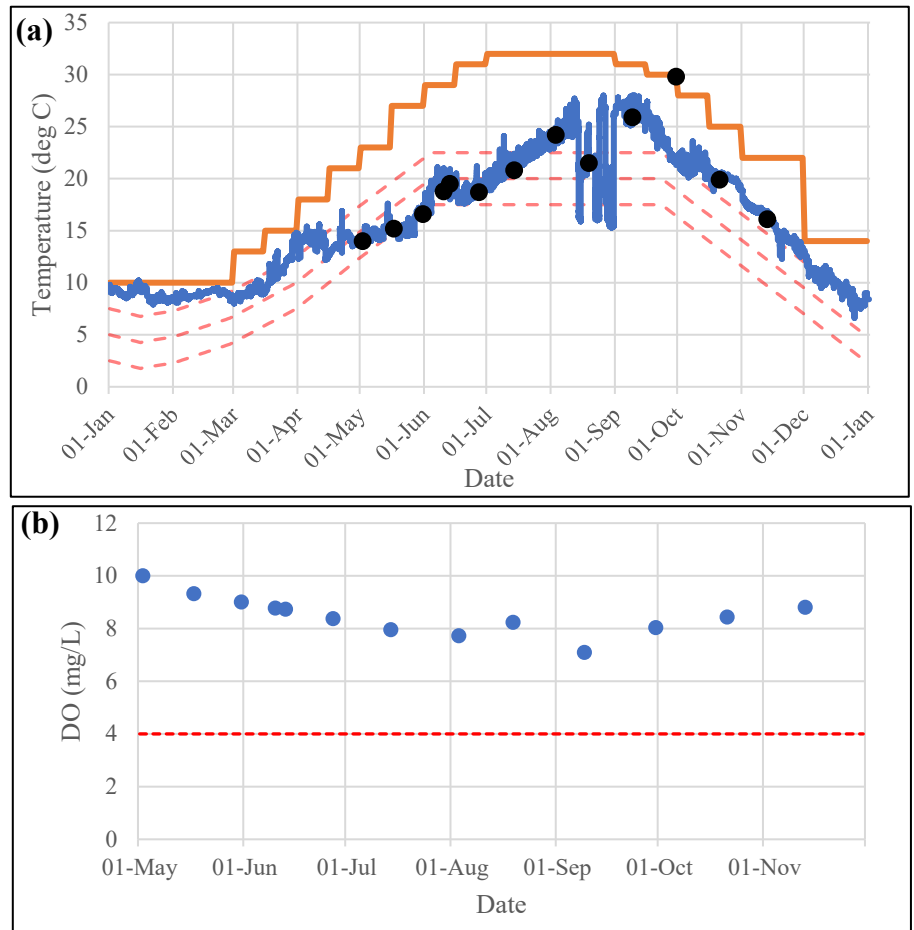


Figure 2. Carr Creek Lake tailwater temperature and DO data. (a) Tailwater temperature data collected by project staff in 2020 is represented by the black dots. The blue line represents USGS gage data (provisional) from a gage downstream from the project. The temperature guide curve is represented by the dashed red lines, and the orange line represents the KY water quality criteria for temperature. (b) Tailwater dissolved oxygen data collected in 2020 is represented by the blue dots. The KY water quality criteria for DO is represented by the dashed red line.

Tailwater Temperature and DO Conditions

Tailwater data was compared to KY state water quality criteria for temperature and to the Louisville District's temperature guide curve for Carr Creek Lake (Figure 2a). According to the provisional USGS data, tailwater temperature exceeded the state criteria for temperature on January 15. During this time, the reservoir was de-stratified; therefore, nothing could be done operationally to prevent this exceedance. Also, tailwater temperatures fell outside the guide curve January through February and most of the time August through early December. The WQ Program will use these findings to inform future operational decisions to improve performance of downstream temperature management wherever possible. Tailwater dissolved oxygen levels (Figure 2b) did not exceed state criteria at any time throughout the year.

Nutrient Analyses

Nutrient data, including total nitrogen (TN) and total phosphorus (TP) data, were collected at all sample sites in 2020. The 2020 TP and TN values were compared to historical data from 2012 through 2019 (Figure 3). The TP and TN values at each site were compared to their respective USEPA recommended criteria. Nutrient levels are an area of concern because elevated nutrients can lead to high biological activity, especially with respect to HABs.

Total Phosphorus

2020 TP values at all sites were higher than historical medians and were above the top of the distribution of historical values for each location. Also, 2020 TP levels at all sites were above the USEPA recommended nutrient criteria for the respective locations.

Total Nitrogen

2020 TN values at all sites were lower than historical medians and were at or

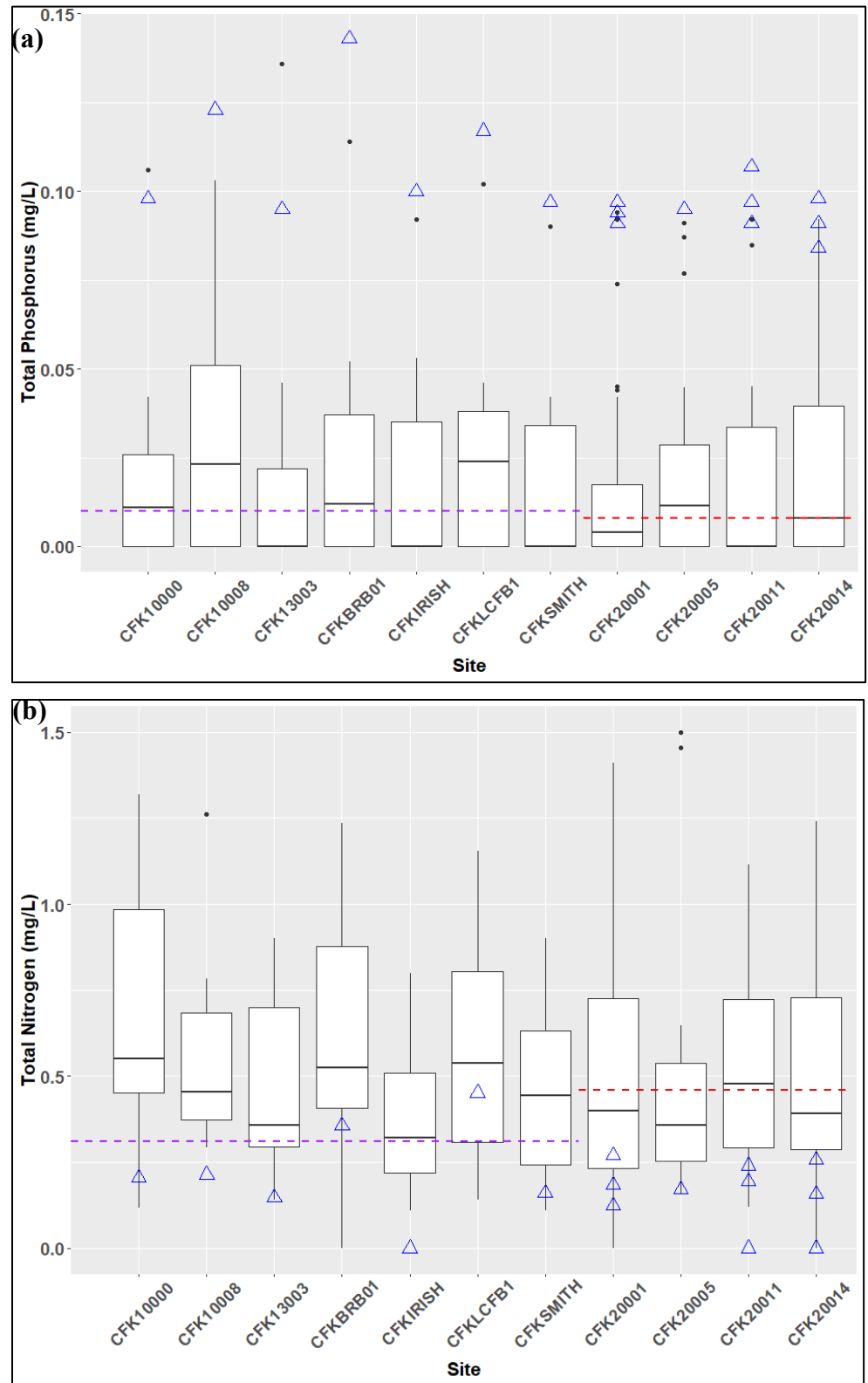


Figure 3. Comparison of 2020 Carr Creek Lake nutrient data to historical samples and nutrient criteria. Boxplots represent data collected in 2012-2019 and blue triangles represent 2020 data. Purple and red dotted lines represent USEPA recommended nutrient criteria for streams and reservoirs, respectively. (a) Comparison of total phosphorus data. (b) Comparison of total nitrogen data. Two outliers (values range from 1.654 to 3.79 mg/L) were excluded to make plot easier to interpret.

below the distribution of historical values for each location. 2020 TN values in only two samples exceeded the USEPA recommended nutrient criteria.

Cyanobacteria Data, HABs, and Trophic State Index (TSI)

Cyanobacteria Data

13 phytoplankton samples were collected from various depths at 4 sites. Total cyanobacteria cell counts did not exceed 100,000 cells/mL (guideline value for moderate health risk from the World Health Organization’s Guidelines for Safe Recreational Water Environments [2003]) at Carr Creek Lake. These results indicate Carr Creek Lake did not have cell count levels potentially indicative of a HAB at the time of sampling.

Harmful Algal Bloom (HAB) Response

The KY Division of Water (KDOW) is the lead agency for HAB response in Kentucky. KDOW did not issue any advisories for HABs at Carr Creek Lake in 2020.

TSI

The trophic state indices for Secchi depth [TSI(SD)], chlorophyll-*a* [TSI(CHL)], and total phosphorus [TSI(TP)] were calculated for four reservoir sites at Carr Creek Lake (Table 1). The mean categories of all three indices ranged from oligotrophic to hypereutrophic, indicating varying levels of biological activity potential.

Table 1. Summary of calculate trophic state indices at Carr Creek Lake.

	Mean Score (range)	Mean Category
TSI(SD)	47 (44-50)	Mesotrophic
TSI(CHL)	32 (32-32)	Oligotrophic
TSI(TP)	69 (69-70)	Hypereutrophic

Cecil M. Harden Lake (CHL) Water Quality Summary

Summary of 2020 Water Quality Results

Harden Lake had no exceedances of Indiana's water quality criteria at the tailwater (CHL10000). Total phosphorus and total nitrogen levels at all sample locations exceeded the USEPA nutrient criteria. The mean TSI category for all three indices classified the lake as hypereutrophic, indicating a very high level of biological activity. Finally, our sampling showed cyanobacteria cell counts over 100,000 cells/mL in all but one of the samples at the time of sampling, and four samples exceeded 1,000,000 cells/mL. The elevated nutrient levels and hypereutrophic TSI classification indicate there is a high potential for HAB development in the lake.

2020 Activities

In 2020, one sampling event was conducted at Harden Lake. Field data and chemical samples were collected at all sites (Figure 1). Chlorophyll and phytoplankton were collected at five sites, and zooplankton samples were collected at the damsite (CHL20001).

Additionally, temperature and dissolved oxygen (DO) profiles were collected by the project staff at the damsite and tailwater approximately every two weeks from early May through late December.

Exceedances of IN State Water Quality Criteria

There were no exceedances of IN state water quality criteria at the tailwater.

Tailwater Temperature and DO Conditions

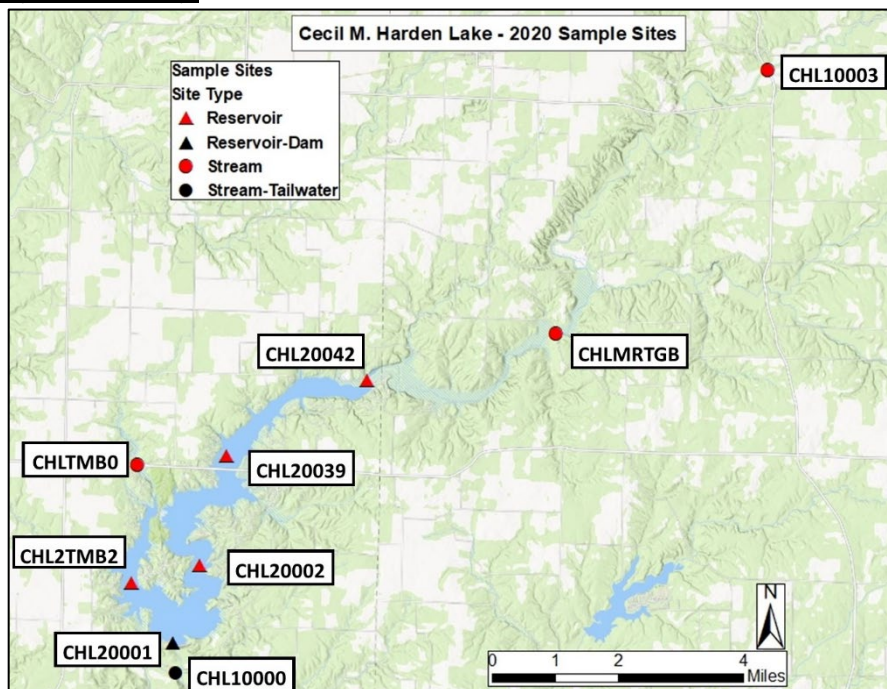


Figure 1. Water quality sampling locations for Harden Lake in 2020.

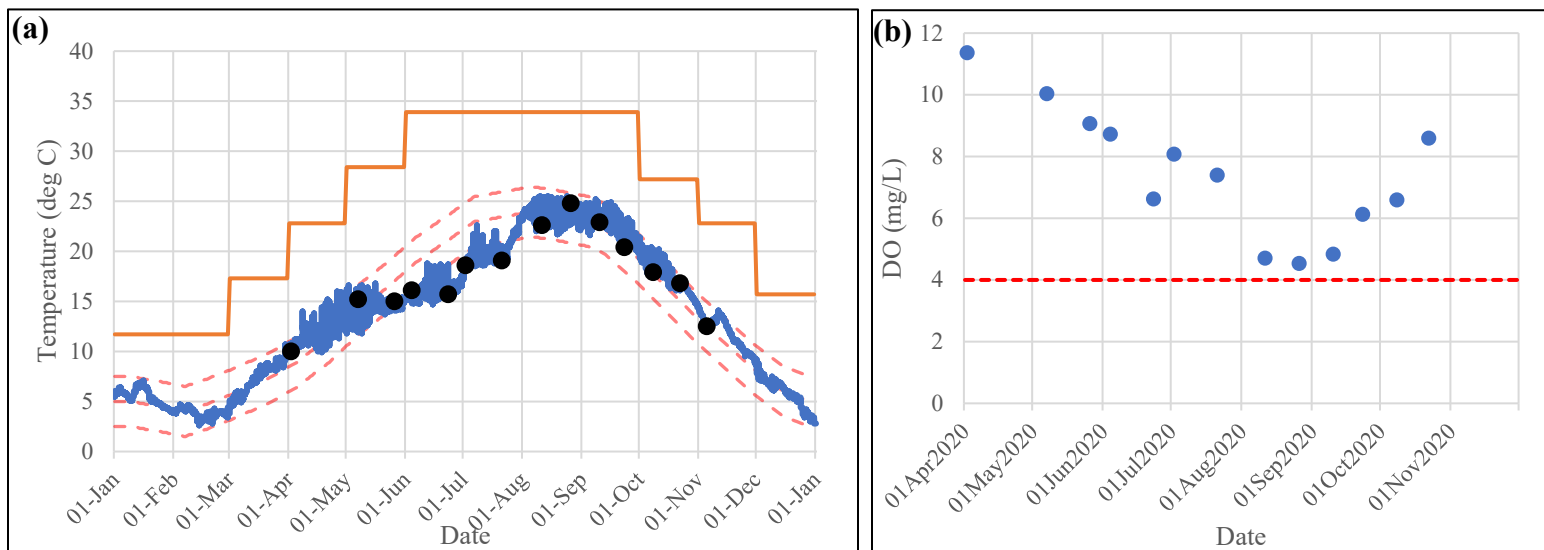


Figure 2. Harden Lake tailwater temperature and DO data. (a) Tailwater temperature data collected by project staff in 2020 is represented by the black dots. The blue line represents USGS gage data (provisional) from a gage downstream from the project. The temperature guide curve is represented by the dashed red lines, and the orange line represents the IN water quality criteria for temperature. (b) Tailwater dissolved oxygen data collected in 2020 is represented by the blue dots. The IN water quality criteria for DO is represented by the dashed red line.

Tailwater data was compared to IN state water quality criteria for temperature and to the Louisville District's temperature guide curve for Harden Lake (Figure 2a). Tailwater temperature did not exceed the state criteria for temperature at any time, but it did fall below guide curve late May through late July. The WQ Program will use these findings to inform future operational decisions to improve performance of downstream temperature management wherever possible. Tailwater dissolved oxygen levels (Figure 2b) did not exceed state criteria at any time throughout the year.

Nutrient Analyses

Nutrient data, including total nitrogen (TN) and total phosphorus (TP) data, were collected at all sample sites in 2020. The 2020 TP and TN values were compared to historical data from 2012 through 2019 (Figure 3). The TP and TN values at each site were compared to their respective USEPA recommended criteria. Nutrient levels are an area of concern because elevated nutrients can lead to high biological activity, especially with respect to HABs.

Total Phosphorus

2020 TP values at all sites at Harden Lake were above the historical medians and the USEPA recommended nutrient criteria.

Total Nitrogen

2020 TN values at Harden Lake were near or below the historical medians for all but one sample, and 2020 values fell within or below the historical distribution for TN values. Also, 2020 TN levels at all sites were above the USEPA recommended nutrient criteria for the respective locations.

Cyanobacteria Data, HABs and Trophic State Index

Cyanobacteria Data

17 phytoplankton samples were collected at various depths from 5 sites. Total cyanobacteria cell counts exceeded

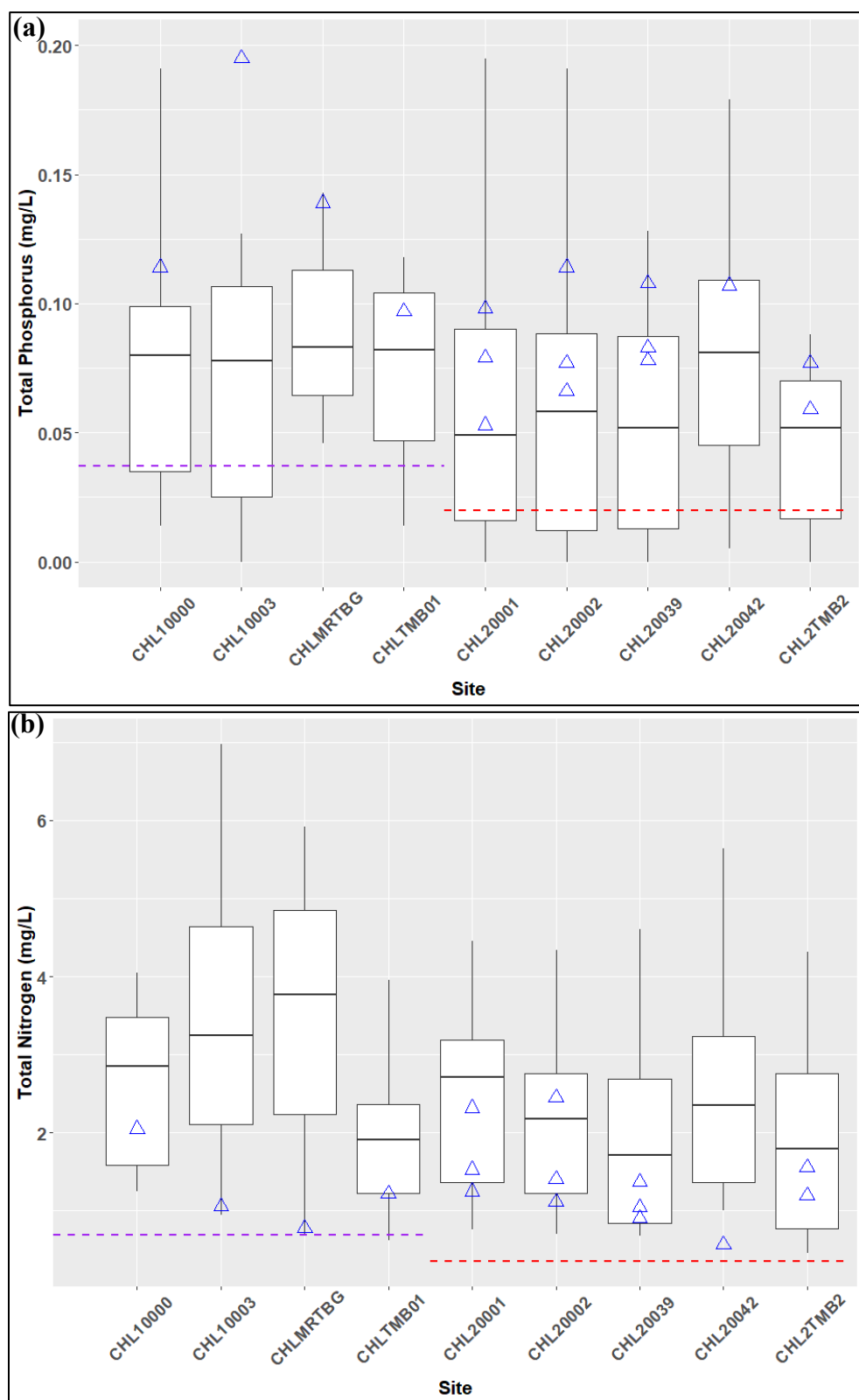


Figure 3. Comparison of 2020 nutrients data to historical samples and nutrient criteria. Boxplots represent data collected in 2012-2019 and blue triangles represent 2020 data. Purple and red dotted lines represent USEPA recommended nutrient criteria for streams and reservoirs, respectively. (a) Comparison of total phosphorus data. Four outliers (values ranging from 0.427-0.465 mg/L) were excluded to make graph easier to interpret. (b) Comparison of total nitrogen data.

100,000 cells/mL (guideline value for moderate health risk from the World Health Organization’s Guidelines for Safe Recreational Water Environments [2003]) in 16 out of 17 samples collected from 5 sites. Four of these samples exceeded 1,000,000 cells/mL. These results indicate Harden Lake had cell count levels potentially indicative of a HAB at the time of sampling.

Harmful Algal Bloom (HAB) Response

Indiana Department of Environmental Management (IDEM) is the lead agency for HAB response in Indiana. IDEM samples State Recreation Areas (SRA) biweekly during the recreation season and issues appropriate HAB alert level based on the results. IDEM issued HAB Advisory alert levels at the Raccoon Lake SRA from 5/22/20 through 6/12/20 and from 7/2/20 through 9/4/20. The Advisory alert level indicates that cell counts were over 100,000 cells/mL, but toxin levels did not meet thresholds for the Caution or Closed alert levels. At an Advisory alert level, the following precautions apply: swimming and boating permitted; avoid contact with algae; don’t drink the water; and shower after you swim.

TSI

The trophic state indices for Secchi depth [TSI(SD)], chlorophyll-*a* [TSI(CHL)], and total phosphorus [TSI(TP)] were calculated for five reservoir sites at Harden Lake (Table 1). The mean category of all three indices was hypereutrophic, indicating a very high level of biological activity.

Table 1. Summary of calculated trophic state indices at Harden Lake.

	Mean Score (range)	Mean Category (range)
TSI(SD)	66 (61-73)	Hypereutrophic (Eutrophic-Hypereutrophic)
TSI(CHL)	67 (64-72)	Hypereutrophic (Eutrophic-Hypereutrophic)
TSI(TP)	66 (61-72)	Hypereutrophic (Eutrophic-Hypereutrophic)

Cagles Mill Lake (CMR) Water Quality Summary

Summary of 2020 Water Quality Results

Cagles Mill Lake had no exceedances of Indiana's water quality criteria at the tailwater (CMR10000). Total phosphorus and total nitrogen levels at all sample locations exceeded the USEPA nutrient criteria. The mean TSI categories for all three indices ranged from eutrophic to hypereutrophic, indicating a very high level of biological activity. Finally, our sampling showed cyanobacteria cell counts over 100,000 cells/mL in 10 out of 13 samples at the time of sampling. The elevated nutrient levels and eutrophic/hypereutrophic TSI classification indicate there is a high potential for HAB development in the lake.

2020 Activities

In 2020, one sampling event was conducted at Cagles Mill Lake. Field data and chemical samples were collected at all sites (Figure 1). Chlorophyll and phytoplankton were collected at four sites, and zooplankton samples were collected at the damsite (CMR20001).

Additionally, temperature and dissolved oxygen (DO) profiles were collected by the project staff at the damsite and tailwater approximately every two weeks from late May through late November.

Exceedances of IN State Water Quality Criteria

There were no exceedances of Indiana state water quality criteria at the tailwater.

Tailwater Temperature and DO Conditions

Tailwater data was compared to IN state water quality criteria for temperature and to the Louisville District's temperature guide curve for Cagles Mill Lake (Figure 2a). Tailwater temperature did not exceed

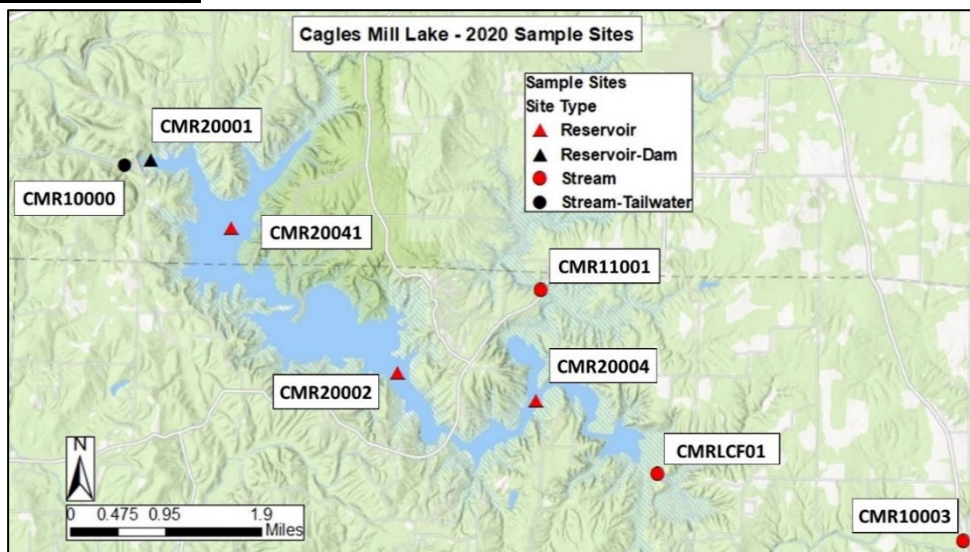


Figure 1. Water quality sampling locations for Cagles Mill Lake in 2020.

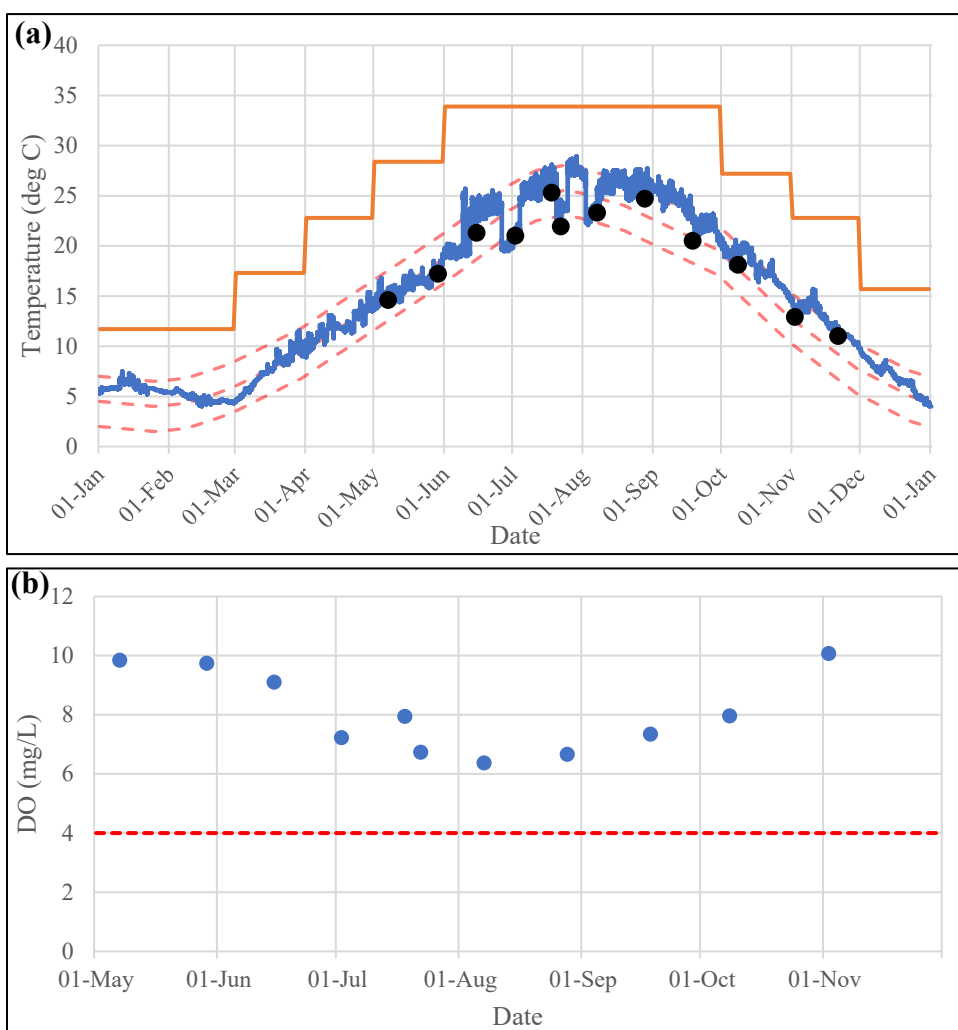


Figure 2. Cagles Mill Lake tailwater temperature and DO data. (a) Tailwater temperature data collected by project staff in 2020 is represented by the black dots. The blue line represents USGS gage data (provisional) from a gage downstream from the project. The temperature guide curve is represented by the dashed red lines, and the orange line represents the IN water quality criteria for temperature. (b) Tailwater dissolved oxygen data collected in 2020 is represented by the blue dots. The IN water quality criteria for DO is represented by the dashed red line.

the state criteria for temperature at any time; however, tailwater temperatures fell outside the guide curve for brief periods of time intermittently throughout the year (mostly minor deviations from the guide curve). The WQ Program will use these findings to inform future operational decisions to improve performance of downstream temperature management wherever possible. Tailwater dissolved oxygen levels (Figure 2b) did not exceed state criteria at any time throughout the year.

Nutrient Analyses

Nutrient data, including total nitrogen (TN) and total phosphorus (TP) data, were collected at all sample sites in 2020. The 2020 TP and TN values were compared to historical data from 2012 through 2019 (Figure 3). The TP and TN values at each site were compared to their respective USEPA recommended criteria. Nutrient levels are an area of concern because elevated nutrients can lead to high biological activity, especially with respect to HABs.

Total Phosphorus

2020 TP values at all sites at Cagles Mill Lake were above the historical medians and the USEPA recommended nutrient criteria.

Total Nitrogen

2020 TN values at Cagles Mill Lake were near or below the historical medians at all but two sites. Also, 2020 TN levels at all sites were above the USEPA recommended nutrient criteria for the respective locations.

Cyanobacteria Data, HABs, and Trophic State Index

Cyanobacteria Data

13 phytoplankton samples were collected at various depths from 4 sites. Total cyanobacteria cell counts exceeded 100,000 cells/mL (guideline value for moderate health risk from the World Health Organization's Guidelines for Safe Recreational Water Environments [2003]) in 10 out of 13 samples collected from 3 sites. None of these samples

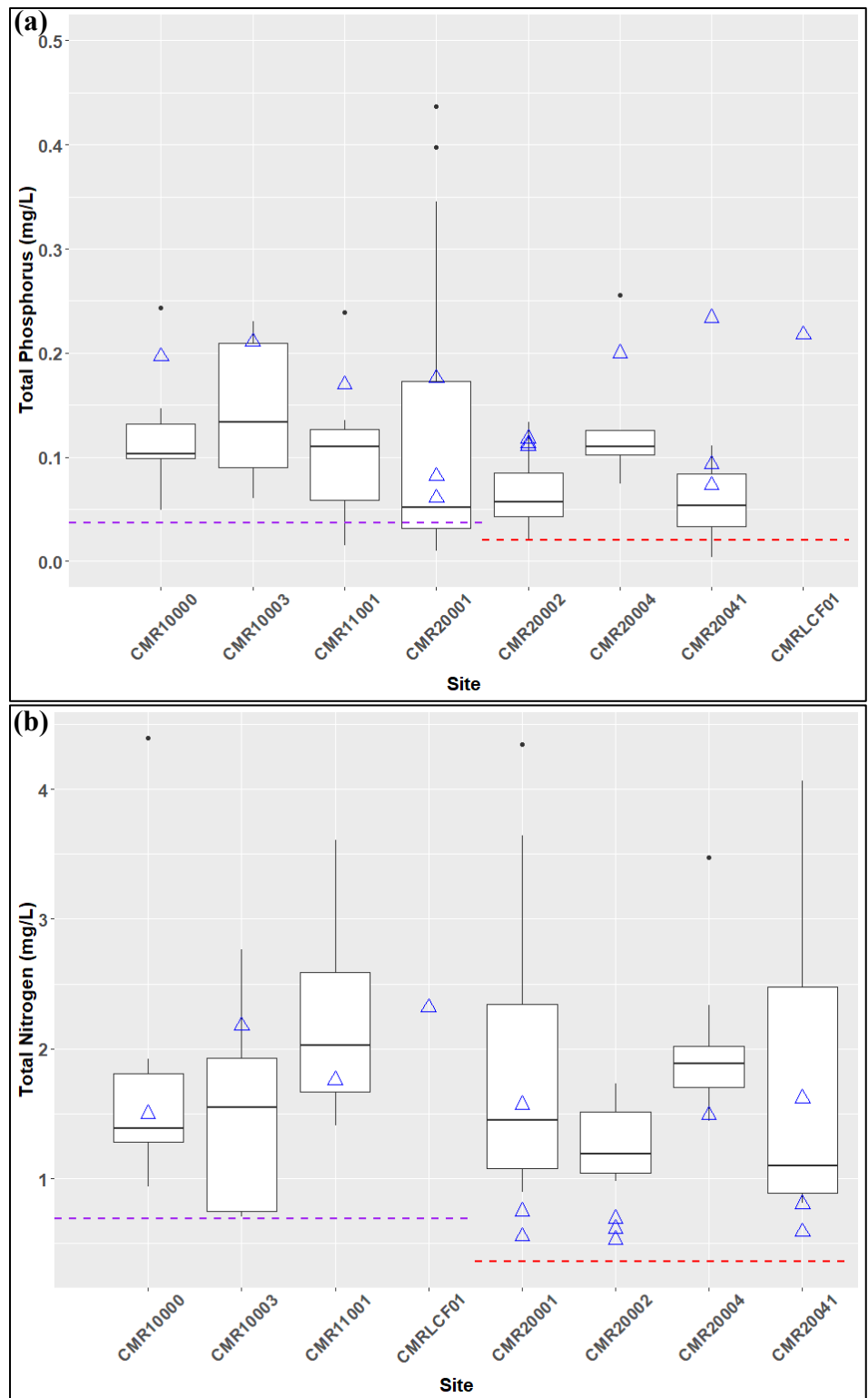


Figure 3. Comparison of 2020 Cagles Mill Lake nutrient data to historical samples and nutrient criteria. Boxplots represent data collected in 2012-2019 and blue triangles represent 2020 data. Purple and red dotted lines represent USEPA recommended nutrient criteria for streams and reservoirs, respectively. (a) Comparison of total phosphorus data. Four outliers (values ranging from 0.427-0.465 mg/L) were excluded to make graph easier to interpret. (b) Comparison of total nitrogen data.

exceeded 1,000,000 cells/mL. These results indicate Cagles Mill Lake had cell count levels potentially indicative of a HAB at the time of sampling.

Harmful Algal Bloom (HAB) Response

Indiana Department of Environmental Management (IDEM) is the lead agency for HAB response in Indiana. IDEM samples Cagles Mill Lake Beach biweekly during the recreation season and issues appropriate HAB alert level based on the results. IDEM issued HAB Advisory alert levels at the Cagles Mill Lake Beach from 5/22/20 through 5/29/20 and from 7/2/20 through 9/4/20. The Advisory alert level indicates that cell counts were over 100,000 cells/mL, but toxin levels did not meet thresholds for the Caution or Closed alert levels. At an Advisory alert level, the following precautions apply: swimming and boating permitted; avoid contact with algae; don't drink the water; and shower after you swim.

TSI

The trophic state indices for Secchi depth [TSI(SD)], chlorophyll-*a* [TSI(CHL)], and total phosphorus [TSI(TP)] were calculated for four reservoir sites at Cagles Mill Lake (Table 1). The mean categories of all three indices ranged from eutrophic to hypereutrophic, indicating a very high level of biological activity.

Table 1. Summary of calculated trophic state indices at Cagles Mill Lake.

	Mean Score (range)	Mean Category (Range)
TSI(SD)	68 (63-81)	Hypereutrophic (Eutrophic-Hypereutrophic)
TSI(CHL)	65 (51-76)	Eutrophic (Moderately Eutrophic-Hypereutrophic)
TSI(TP)	71 (63-81)	Hypereutrophic (Eutrophic-Hypereutrophic)

Cave Run Lake (CRR) Water Quality Summary

Summary of 2020 Water Quality Results

Cave Run Lake had eight exceedance events of KY's water quality criteria for temperature at the tailwater (CRR10000) in 2020. Total phosphorus levels at all sample locations exceeded the USEPA nutrient criteria, while only one total nitrogen sample exceeded USEPA criteria. TSI for the three indices classified the lake as mesotrophic or eutrophic, indicating varying levels of biological activity potential. Finally, our sampling showed there were no samples with cyanobacteria cell counts over 100,000 cells/mL at the time of the sampling event. The elevated nutrient levels and eutrophic TSI classification indicate there is a potential for HAB development in the lake.



Figure 1. Water quality sampling locations for Cave Run Lake in 2020.

2020 Activities

In 2020, one sampling event was conducted at Cave Run Lake. Field data and chemical samples were collected at six sample locations, and field data was collected at 3 sample location (Figure 1). Chlorophyll and phytoplankton were collected at two sites, and zooplankton samples were collected at the damsite (CRR20001).

Additionally, temperature and dissolved oxygen (DO) profiles were collected by the project staff at the damsite and tailwater approximately every two weeks from late May through late November.

Exceedances of KY State Water Quality Criteria

There were eight exceedance events of KY state water quality criteria for temperature at the tailwater in 2020 based on provisional USGS gage data. There were no other exceedances of KY state WQ criteria.

Tailwater Temperature and DO Conditions

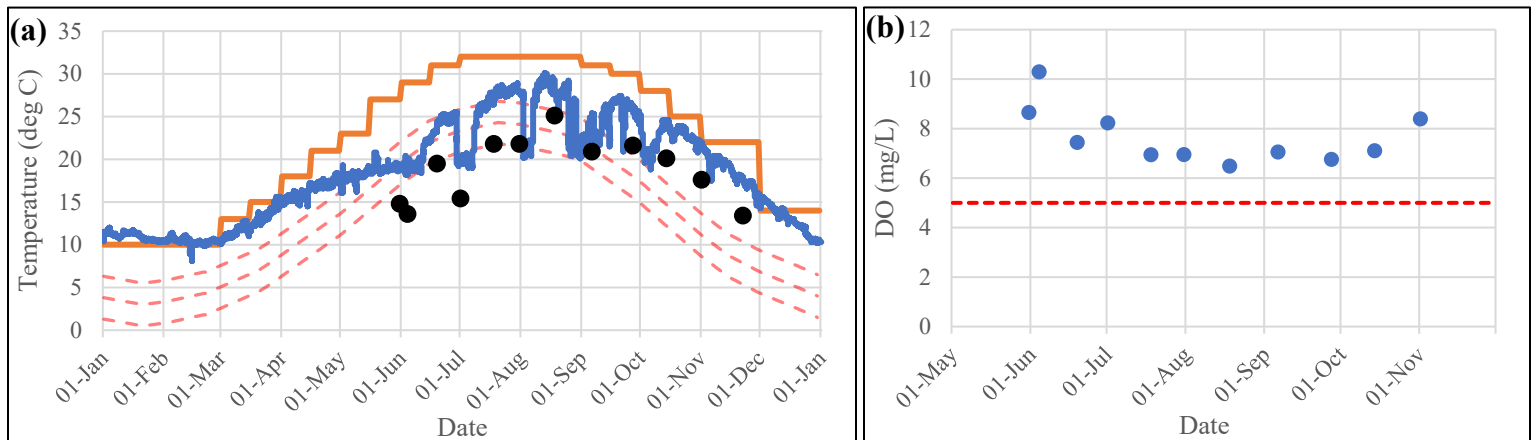


Figure 2. Cave Run Lake tailwater temperature and DO data. (a) Tailwater temperature data collected by project staff in 2020 is represented by the black dots. The blue line represents USGS gage data (provisional) from a gage downstream from the project. The temperature guide curve is represented by the dashed red lines, and the orange line represents the KY water quality criteria for temperature. (b) Tailwater dissolved oxygen data collected in 2020 is represented by the blue dots. The KY water quality criteria for DO is represented by the dashed red line.

Tailwater data was compared to KY state water quality criteria for temperature and to the Louisville District's temperature guide curve for Cave Run Lake (Figure 2a). According to the provisional USGS data, tailwater temperature exceeded the state criteria for temperature on multiple occasions: January 1-February 29, March 28, March 29-30, March 31, December 1-8, December 9, December 11, and December 12-13. These events totaled to 76 days (or 20% of the year) where for some or all of the day, the tailwater did not meet state temperature criteria. During this time, the reservoir was de-stratified; therefore, nothing could be done operationally to prevent these exceedances. In addition, tailwater temperatures fell outside the guide curve January through early May and most of the time from mid-July through the end of the year. The WQ Program will use these findings to inform future operational decisions to improve performance of downstream temperature management wherever possible. Tailwater dissolved oxygen levels (Figure 2b) did not exceed state criteria at any time throughout the year.

Nutrient Analyses

Nutrient data, including total nitrogen (TN) and total phosphorus (TP) data, were collected at all sample sites in 2020. The 2020 TP and TN values were compared to historical data from 2012 through 2019 (Figure 3). The TP and TN values at each site were also compared to their respective USEPA recommended criteria. Nutrient levels are an area of concern because elevated nutrients can lead to high biological activity, especially with respect to HABs.

Total Phosphorus

2020 TP values at all sites were higher than historical medians and were near or above the top of the distribution of historical values for each location. Also, 2020 TP levels at all sites were above the USEPA recommended nutrient criteria for the respective locations.

Total Nitrogen

2020 TN values at all sites were near or below the historical medians and were at or below the distribution of historical values for each location. Only one 2020 TN value exceeded the USEPA recommended nutrient criteria.

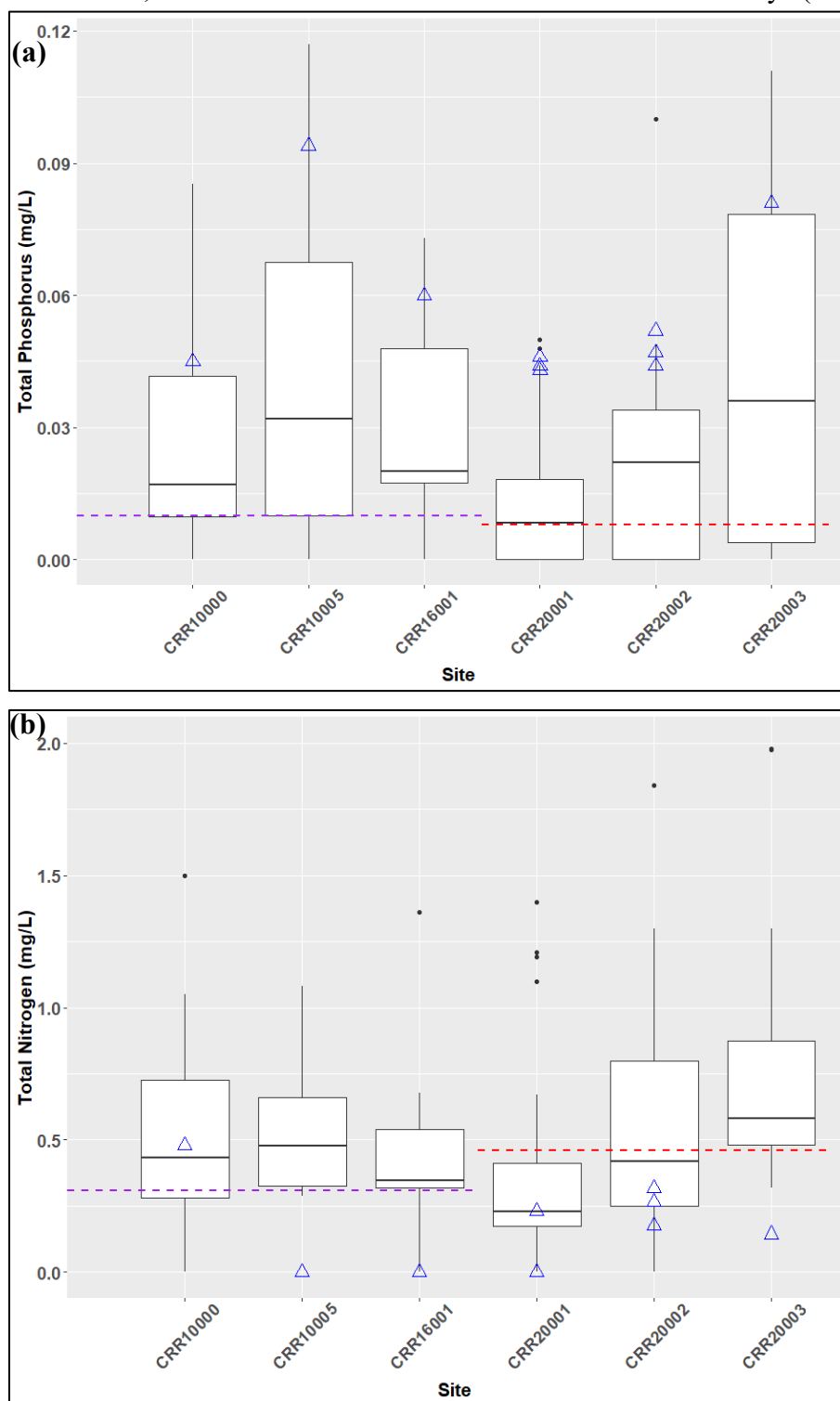


Figure 3. Comparison of 2020 Cave Run Lake nutrient data to historical samples and nutrient criteria. Boxplots represent data collected in 2012-2019 and blue triangles represent 2020 data. Purple and red dotted lines represent USEPA recommended nutrient criteria for streams and reservoirs, respectively. (a) Comparison of total phosphorus data. (b) Comparison of total nitrogen data. Two outliers (values range from 2.39 to 6.3 mg/L) were excluded to make plot easier to interpret.

Cyanobacteria Data, HABs, and Trophic State Index

Cyanobacteria Data

8 phytoplankton samples were collected from various depths at 2 sites. Total cyanobacteria cell counts did not exceed 100,000 cells/mL (guideline value for moderate health risk from the World Health Organization’s Guidelines for Safe Recreational Water Environments [2003]) at Cave Run Lake. These results indicate Cave Run Lake did not have cell count levels potentially indicative of a HAB at the time of sampling.

Harmful Algal Bloom (HAB) Response

The KY Division of Water (KDOW) is the lead agency for HAB response in Kentucky. KDOW did not issue any advisories for HABs at Cave Run Lake in 2020.

TSI

The trophic state indices for Secchi depth [TSI(SD)], chlorophyll-a [TSI(CHL)], and total phosphorus [TSI(TP)] were calculated for six reservoir sites at Cave Run Lake (Table 1). The mean categories of all three indices ranged from mesotrophic to eutrophic, indicating moderate to high levels of biological activity potential.

Table 1. Summary of calculated trophic state indices at Cave Run Lake.

	Mean Score (range)	Mean Category (Range)
TSI(SD)	60 (47-73)	Eutrophic (Mesotrophic-Hypereutrophic)
TSI(CHL)	39 (31-46)	Mesotrophic (Oligotrophic-Mesotrophic)
TSI(TP)	62 (58-68)	Eutrophic (Eutrophic-Hypereutrophic)

William H. Harsha Lake (EFR) Water Quality Summary

Summary of 2020 Water Quality Results

Harsha Lake had several exceedances of OH's water quality criteria for temperature at the tailwater (EFR10000). Total phosphorus and total nitrogen levels at most sample locations exceeded the USEPA nutrient criteria. The mean TSI category for all three indices classified the lake as hypereutrophic, indicating a very high level of biological activity. Finally, our sampling showed cyanobacteria cell counts over 100,000 cells/mL in 5 out of 16 samples. The elevated nutrient levels and hypereutrophic TSI classification indicate there is a high potential for HAB development in the lake.

2020 Activities

In 2020, one sampling event was conducted at Harsha Lake. Field data and chemical samples were collected at eight sites, and only field data were collected at three sites (Figure 1). Chlorophyll, phytoplankton, and zooplankton were collected at four sites.

Additionally, temperature and dissolved oxygen (DO) profiles were collected by the project staff at the damsite and tailwater approximately every two weeks from early May through late December.

Exceedances of OH State Water Quality Criteria

There were several exceedance events of OH state water quality criteria for temperature at the tailwater, based on provisional USGS gage data. These events occurred intermittently July 16 through July 29 and on August 3, September 16, and September 17. There were no other exceedances of OH state WQ criteria.

Tailwater Temperature and DO Conditions

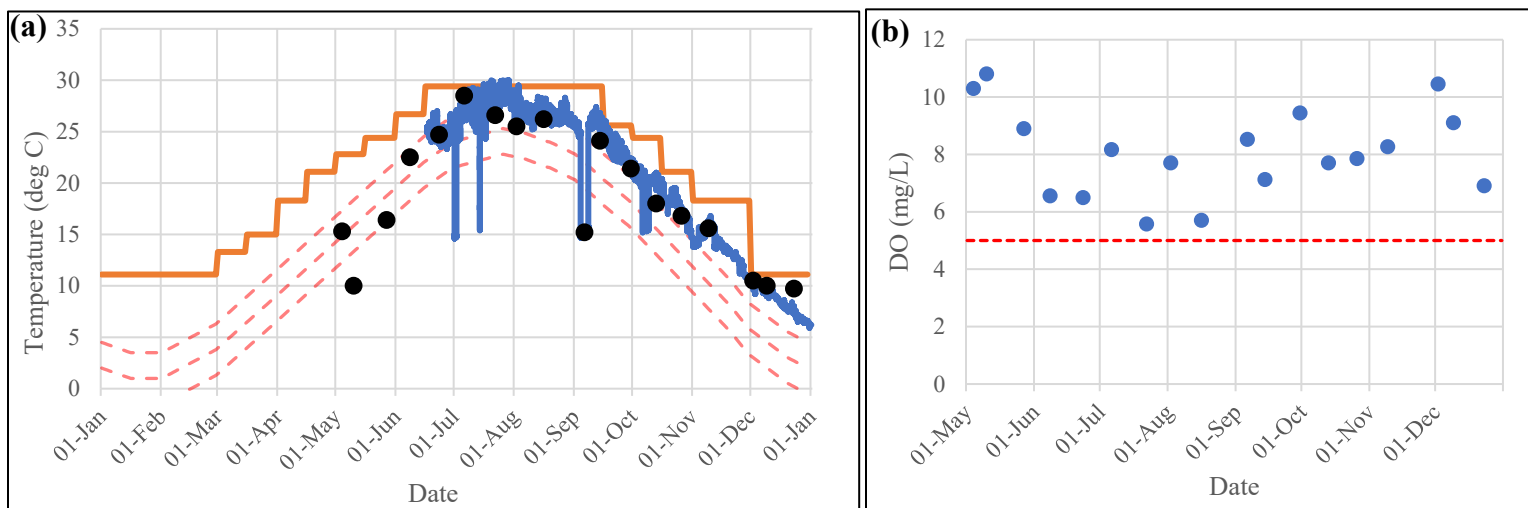


Figure 2. Harsha Lake tailwater temperature and DO data. (a) Tailwater temperature data collected by project staff in 2020 is represented by the black dots. The blue line represents USGS gage data (provisional) from a gage downstream from the project. The temperature guide curve is represented by the dashed red lines, and the orange line represents the OH water quality criteria for temperature. (b) Tailwater dissolved oxygen data collected in 2020 is represented by the blue dots. The OH water quality criteria for DO is represented by the dashed red line.

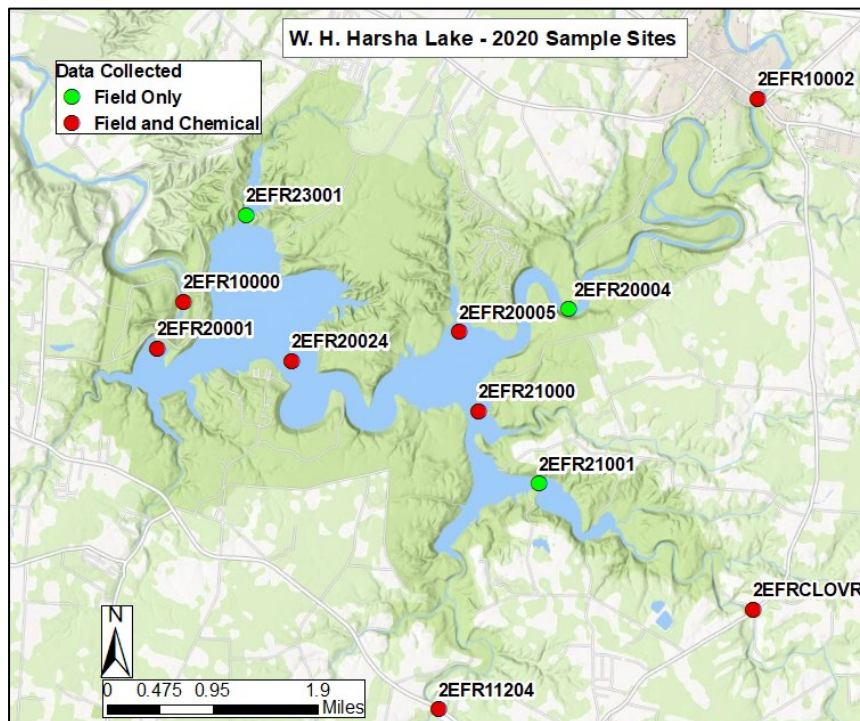


Figure 1. Water quality sampling locations for Harsha Lake in 2020.

Tailwater data was compared to OH state water quality criteria for temperature and to the Louisville District's temperature guide curve for Harsha Lake (Figure 2a). According to the provisional USGS data, tailwater temperature exceeded the state criteria for temperature intermittently July 16 through July 29 and on August 3, September 16, and September 17. These exceedances occurred while the lake was stratified; therefore, there were opportunities to better utilize selective withdrawal gates to reduce tailwater temperature to meet criteria. Also, tailwater temperatures fell outside the guide curve in early May, intermittently early June through early September, and most of the time mid-September through the end of the year. The WQ Program will use these findings to inform future operational decisions to improve performance of downstream temperature management wherever possible. Tailwater dissolved oxygen levels (Figure 2b) did not exceed state criteria at any time throughout the year.

Nutrient Analyses

Nutrient data, including total nitrogen (TN) and total phosphorus (TP) data, were collected at all sample sites in 2020. The 2020 TP and TN values were compared to historical data from 2012 through 2019 (Figure 3). The TP and TN values at each site were compared to their respective USEPA recommended criteria. Nutrient levels are an area of concern because elevated nutrients can lead to high biological activity, especially with respect to HABs.

Total Phosphorus

2020 TP values at Harsha Lake were above the historical medians and near the top of or above the historical distribution at all but two sites. Also, 2020 TP levels at all sample sites were above the USEPA recommended nutrient criteria for the respective locations.

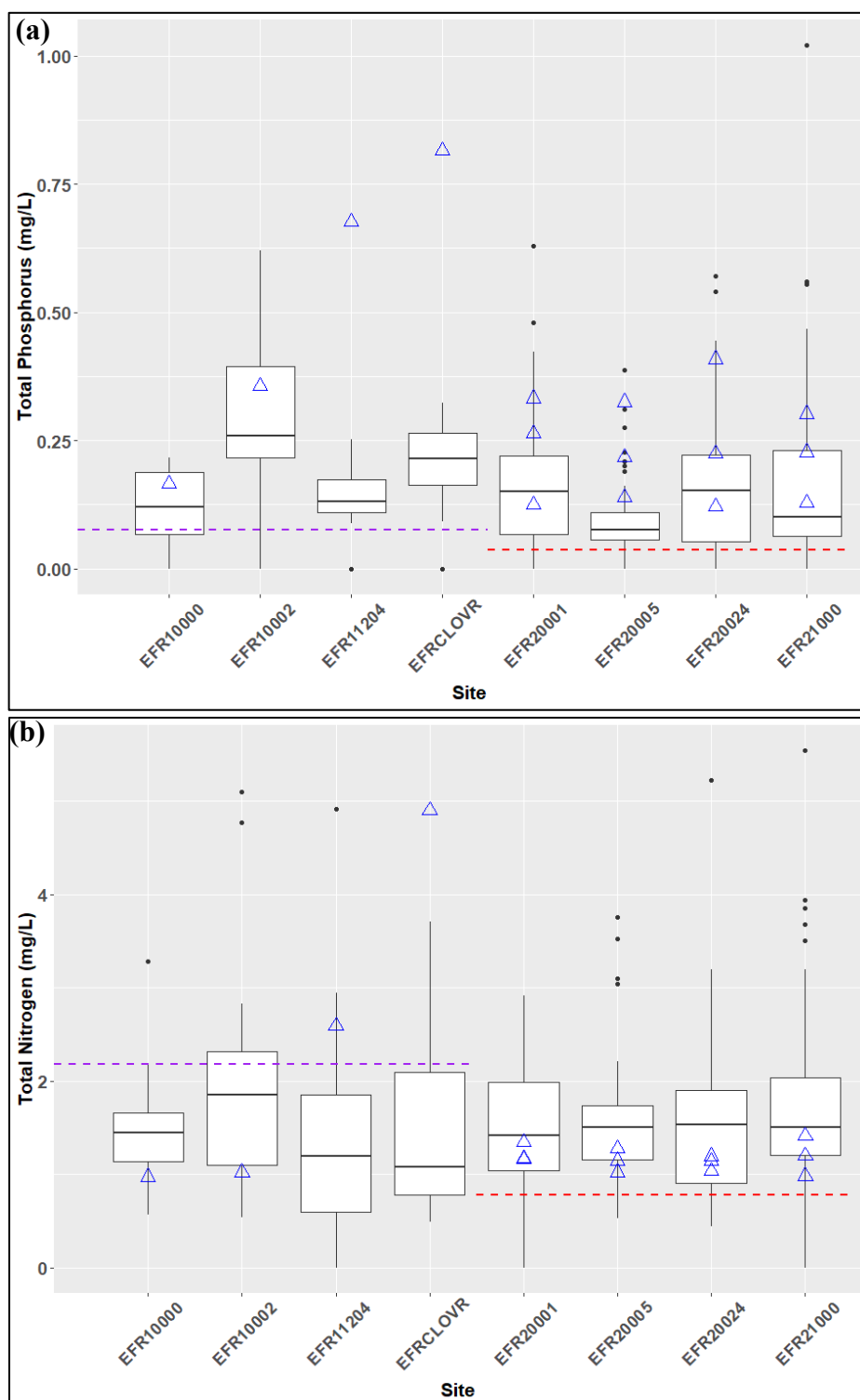


Figure 3. Comparison of 2020 Harsha Lake nutrient data to historical samples and nutrient criteria. Boxplots represent data collected in 2012-2019 and blue triangles represent 2020 data. Purple and red dotted lines represent USEPA recommended nutrient criteria for streams and reservoirs, respectively. (a) Comparison of total phosphorus data. (b) Comparison of total nitrogen data.

Total Nitrogen

2020 TN values at Harsha Lake were near or below the historical medians at all but two sites. Also, 2020 TN levels at 14 out of 16 samples were above the USEPA recommended nutrient criteria for the respective locations.

Cyanobacteria Data, HABs, and Trophic State Index

Cyanobacteria Data

16 phytoplankton samples were collected at various depths from 4 sites. Total cyanobacteria cell counts exceeded 100,000 cells/mL (guideline value for moderate health risk from the World Health Organization's Guidelines for Safe Recreational Water Environments [2003]) in 5 of the samples collected from 4 of the sites. No samples exceeded 1,000,000 cells/mL. These results indicate Harsha Lake had cell count levels potentially indicative of a HAB at the time of sampling.

Harmful Algal Bloom (HAB) Response

Ohio EPA is the lead agency for HAB response in Ohio. One potential HAB was reported to Ohio EPA on June 9, 2020 based on a visual observation by USACE operations staff at the reservoir. Ohio EPA did not issue any advisories for HABs at Harsha Lake.

TSI

The trophic state indices for Secchi depth [TSI(SD)], and total phosphorus [TSI(TP)] were calculated for seven reservoir sites at Harsha Lake (Table 1). The mean category of all three indices was hypereutrophic, indicating a very high level of biological activity.

Table 1. Summary of calculated trophic state indices at Harsha Lake.

	Mean Score (range)	Mean Category (Range)
TSI(SD)	69 (67-76)	Hypereutrophic
TSI(CHL)	79 (78-79)	Hypereutrophic
TSI(TP)	74 (73-75)	Hypereutrophic

Green River Lake (GRR) Water Quality Summary

Summary of 2020 Water Quality Results

Green River Lake had three exceedances of KY's water quality criteria for temperature at the tailwater (GRR10000). Total phosphorus and total nitrogen levels at most sample locations exceeded the USEPA nutrient criteria. TSI for the three indices classified the lake as moderately eutrophic or eutrophic, indicating moderate to high levels of biological activity potential. Finally, our sampling showed there was one sample with cyanobacteria cell counts over 100,000 cells/mL at the time of sampling. The elevated nutrient levels and moderately eutrophic/eutrophic TSI classification indicate there is a high potential for HAB development in the lake.

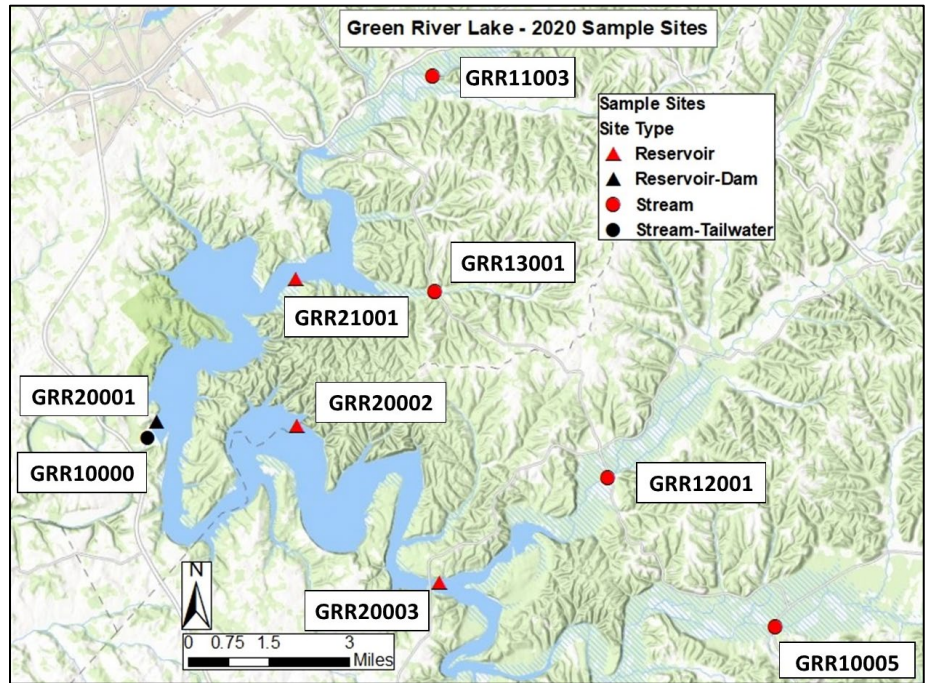


Figure 1. Water quality sampling locations for Green River Lake in 2020.

2020 Activities

In 2020, one sampling event was conducted at Green River Lake. Field data and chemical samples were collected at nine sample locations (Figure 1). Chlorophyll and phytoplankton were collected at four sites, and zooplankton samples were collected at the damsite (GRR20001).

Additionally, temperature and dissolved oxygen (DO) profiles were collected by the project staff at the damsite and tailwater approximately every two weeks from early May through early December.

Exceedances of KY State Water Quality Criteria

There were three exceedance events of KY state water quality criteria for temperature at the tailwater. There were no other exceedances of KY state WQ criteria.

Tailwater Temperature and DO Conditions

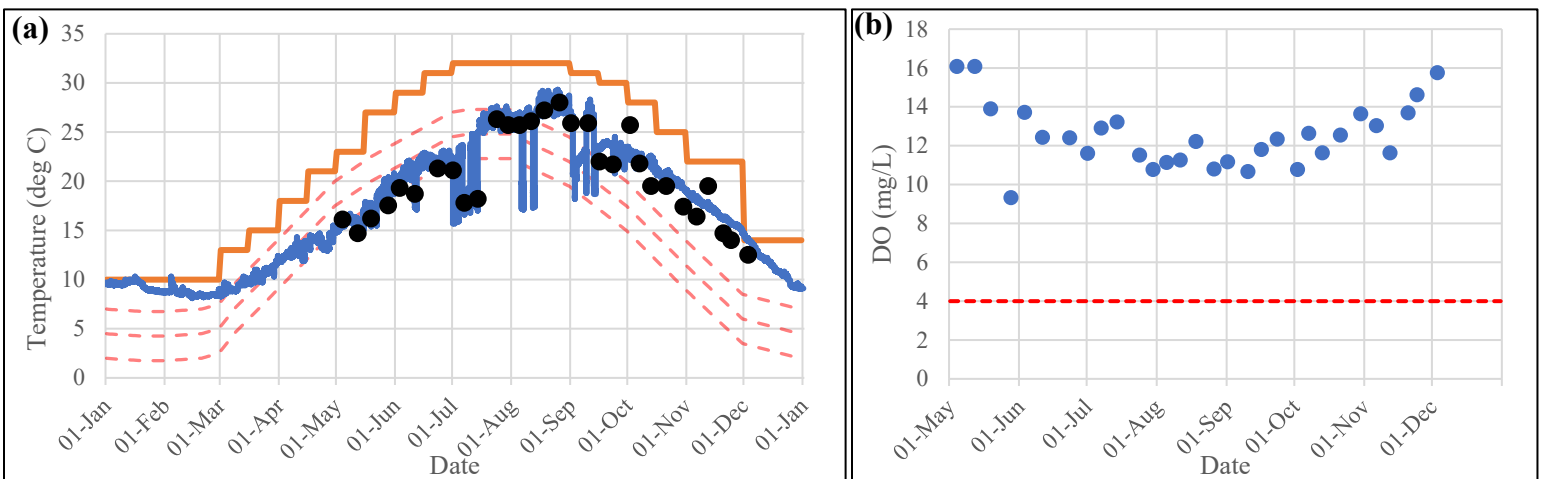


Figure 2. Green River Lake tailwater temperature and DO data. (a) Tailwater temperature data collected by project staff in 2020 is represented by the black dots. The blue line represents USGS gage data (provisional) from a gage downstream from the project. The temperature guide curve is represented by the dashed red lines, and the orange line represents the KY water quality criteria for temperature. (b) Tailwater DO data collected in 2020 is represented by the blue dots. The KY water quality criteria for DO is represented by the dashed red line.

Tailwater data was compared to KY state water quality criteria for temperature and to the Louisville District's temperature guide curve for Green River Lake (Figure 2a). According to the provisional USGS data, tailwater temperature exceeded the state criteria for temperature: January 16-17, February 4, and December 1-3. During these times, the reservoir was de-stratified; therefore, nothing could be done operationally to prevent these exceedances. Also, tailwater temperatures fell outside the guide curve early January through early March, early to mid-July, and mid-August through the end of the year. The WQ Program will use these findings to inform future operational decisions to improve performance of downstream temperature management wherever possible. Tailwater dissolved oxygen levels (Figure 2b) did not exceed state criteria at any time throughout the year.

Nutrient Analyses

Nutrient data, including total nitrogen (TN) and total phosphorus (TP) data, were collected at all sample sites in 2020. The 2020 TP and TN values were compared to historical data from 2012 through 2019 (Figure 3). The TP and TN values at each site were compared to their respective USEPA recommended criteria. Nutrient levels are an area of concern because elevated nutrients can lead to high biological activity, especially with respect to HABs.

Total Phosphorus

2020 TP values at all stream sites were higher than historical medians and distributions. 2020 TP values at reservoir sites were near historical medians. Also, 2020 TP levels at all sites were above the USEPA recommended nutrient criteria for the respective locations.

Total Nitrogen

2020 TN values at most sites were near historical medians and distributions. 15 out of 17 TN values in 2020 exceeded the USEPA recommended nutrient criteria.

Cyanobacteria Data, HABs, and Trophic State Index

Cyanobacteria Data

15 phytoplankton samples were collected from various depths at 4 sites. Total

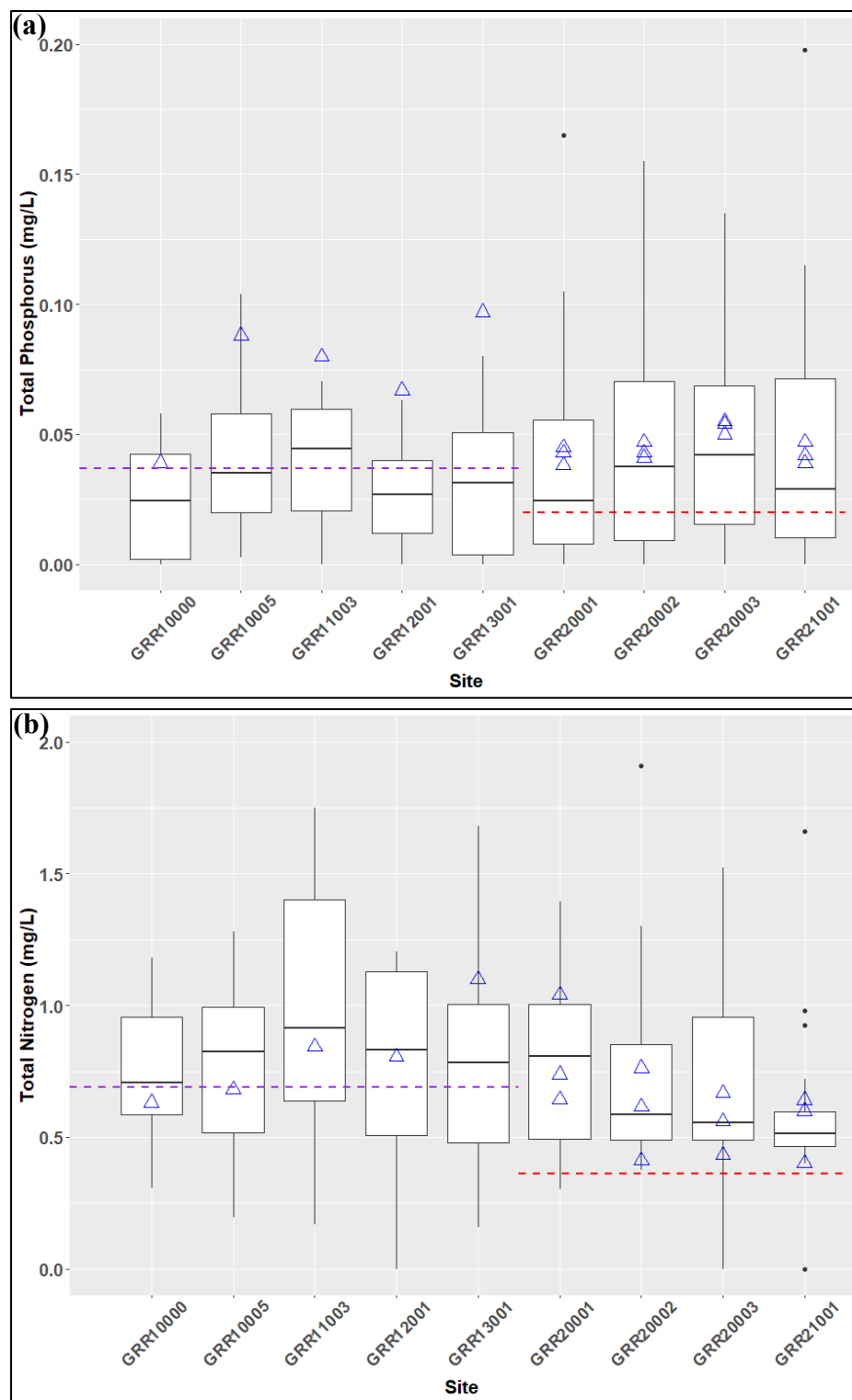


Figure 3. Comparison of 2020 Green River Lake nutrient data to historical samples and nutrient criteria. Boxplots represent data collected in 2012-2019 and blue triangles represent 2020 data. Purple and red dotted lines represent USEPA recommended nutrient criteria for streams and reservoirs, respectively. (a) Comparison of total phosphorus data. Four outliers (values ranging from 0.246 to 0.359 mg/L) were excluded to make plot easier to interpret. (b) Comparison of total nitrogen data. One outlier (value = 4.54 mg/L) was excluded to make plot easier to interpret.

cyanobacteria cell counts exceeded 100,000 cells/mL (guideline value for moderate health risk from the World Health Organization’s Guidelines for Safe Recreational Water Environments [2003]) in one sample. These results indicate Green River Lake did not have cell count levels potentially indicative of a HAB at the time of sampling.

Harmful Algal Bloom (HAB) Response

The KY Division of Water (KDOW) is the lead agency for HAB response in Kentucky. KDOW did not issue any advisories for HABs at Green River Lake in 2020.

TSI

The trophic state indices for Secchi depth [TSI(SD)], chlorophyll-*a* [TSI(CHL)], and total phosphorus [TSI(TP)] were calculated for four reservoir sites at Green River Lake (Table 1). The mean categories of all three indices ranged from moderately eutrophic to eutrophic, indicating moderate to high levels of biological activity potential.

Table 1. Summary of calculated trophic state indices at Green River Lake.

	Mean Score (range)	Mean Category (Range)
TSI(SD)	53 (51-56)	Moderately Eutrophic (Moderately Eutrophic-Eutrophic)
TSI(CHL)	55 (53-59)	Moderately Eutrophic (Moderately Eutrophic-Eutrophic)
TSI(TP)	59 (57-61)	Eutrophic

Monroe Lake (MNR) Water Quality Summary

Summary of 2020 Water Quality Results

Monroe Lake had no exceedances of IN's water quality criteria at the tailwater (MNR10000). Total phosphorus levels at all sample locations exceeded the USEPA nutrient criteria, and 10 out of 18 samples exceeded the total nitrogen criteria. The mean TSI category for all three indices classified the lake as eutrophic, indicating a high level of biological activity. Finally, our sampling showed cyanobacteria cell counts over 100,000 cells/mL in 10 out of 17 samples and, based on their own sampling, IDEM issued HAB Advisory alert levels at

both SRAs in 2020. The elevated nutrient levels and eutrophic TSI classification indicate there is a high potential for HAB development in the lake.

2020 Activities

In 2020, one sampling event was conducted at Monroe Lake. Field data and chemical samples were collected at all sample sites (Figure 1). Chlorophyll and phytoplankton were collected at all reservoir sites, and zooplankton samples were collected at the damsite (MNR20001).

Additionally, temperature and dissolved oxygen (DO) profiles were collected by the project staff at the damsite and tailwater approximately every two weeks from late May through early November.

Exceedances of IN State Water Quality Criteria

There were no exceedances of IN state water quality criteria at the tailwater.

Tailwater Temperature and DO Conditions

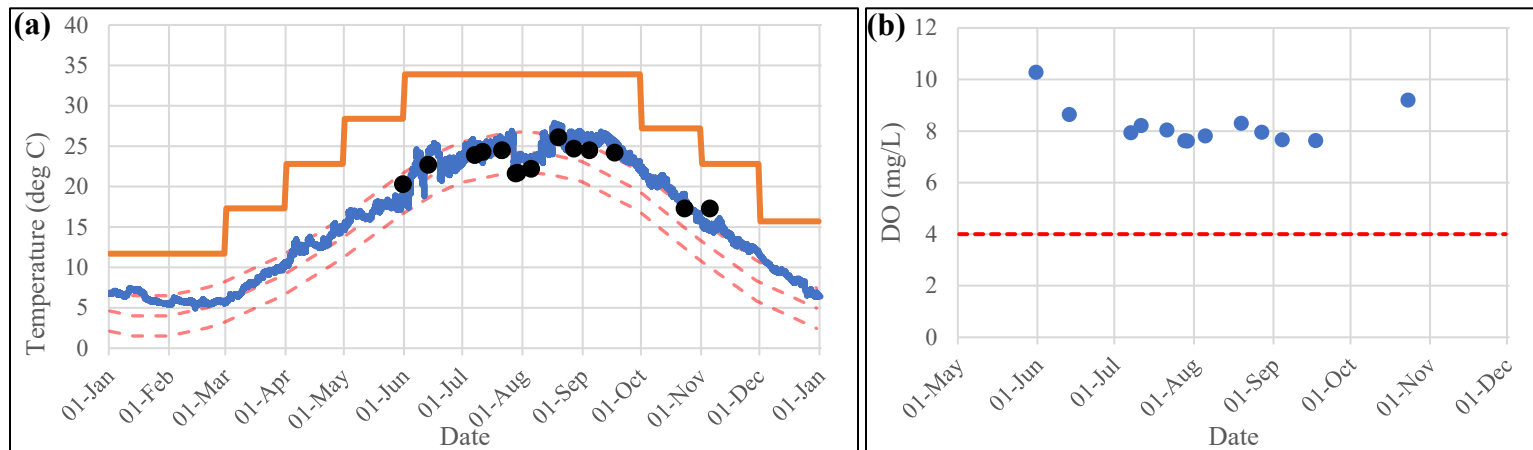


Figure 2. Monroe Lake tailwater temperature and DO data. (a) Tailwater temperature data collected by project staff in 2020 is represented by the black dots. The blue line represents USGS gage data (provisional) from a gage downstream from the project. The temperature guide curve is represented by the dashed red lines, and the orange line represents the IN water quality criteria for temperature. (b) Tailwater dissolved oxygen data collected in 2020 is represented by the blue dots. The IN water quality criteria for DO is represented by the dashed red line.

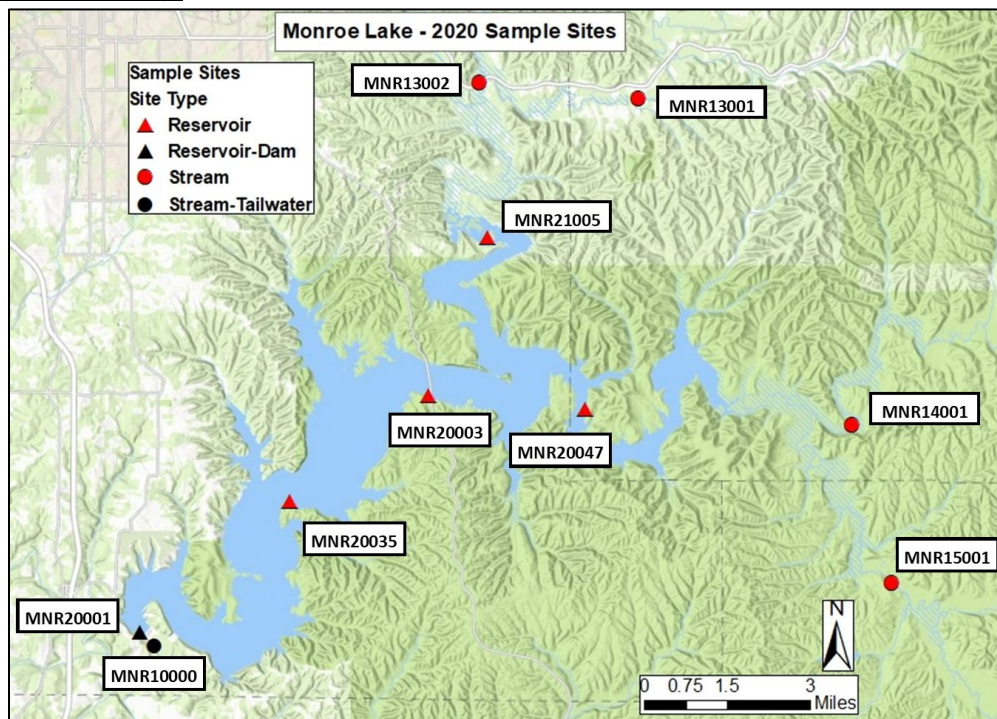


Figure 1. Water quality sampling locations for Monroe Lake in 2020.

Tailwater data was compared to IN state water quality criteria for temperature and to the Louisville District's temperature guide curve for Monroe Lake (Figure 2a). Tailwater temperature did not exceed the state criteria for temperature at any time; however, tailwater temperatures fell outside the guide curve in early June and much of the time mid-August through the end of the year (mostly minor deviations from the guide curve). The WQ Program will use these findings to inform future operational decisions to improve performance of downstream temperature management wherever possible. Tailwater dissolved oxygen levels were compared to the state criteria for DO (Figure 2b). Tailwater DO did not exceed state criteria at any time throughout the year.

Nutrient Analyses

Nutrient data, including total nitrogen (TN) and total phosphorus (TP) data, were collected at all sample sites in 2020. The 2020 TP and TN values were compared to historical data from 2012 through 2019 (Figure 3). The TP and TN values at each site were compared to their respective USEPA recommended criteria. Nutrient levels are an area of concern because elevated nutrients can lead to high biological activity, especially with respect to HABs.

Total Phosphorus

2020 TP values at Monroe Lake were near or below historical medians at all sites, except for three sites which had elevated 2020 TP levels compared to historical values. Also, 2020 TP levels at all sites were above the USEPA recommended nutrient criteria for the respective locations.

Total Nitrogen

2020 TN values at Monroe Lake were generally at or below the historical TN median. However, when compared to USEPA nutrient criteria, 10 out of 18 samples were above the recommended TN criteria in 2020.

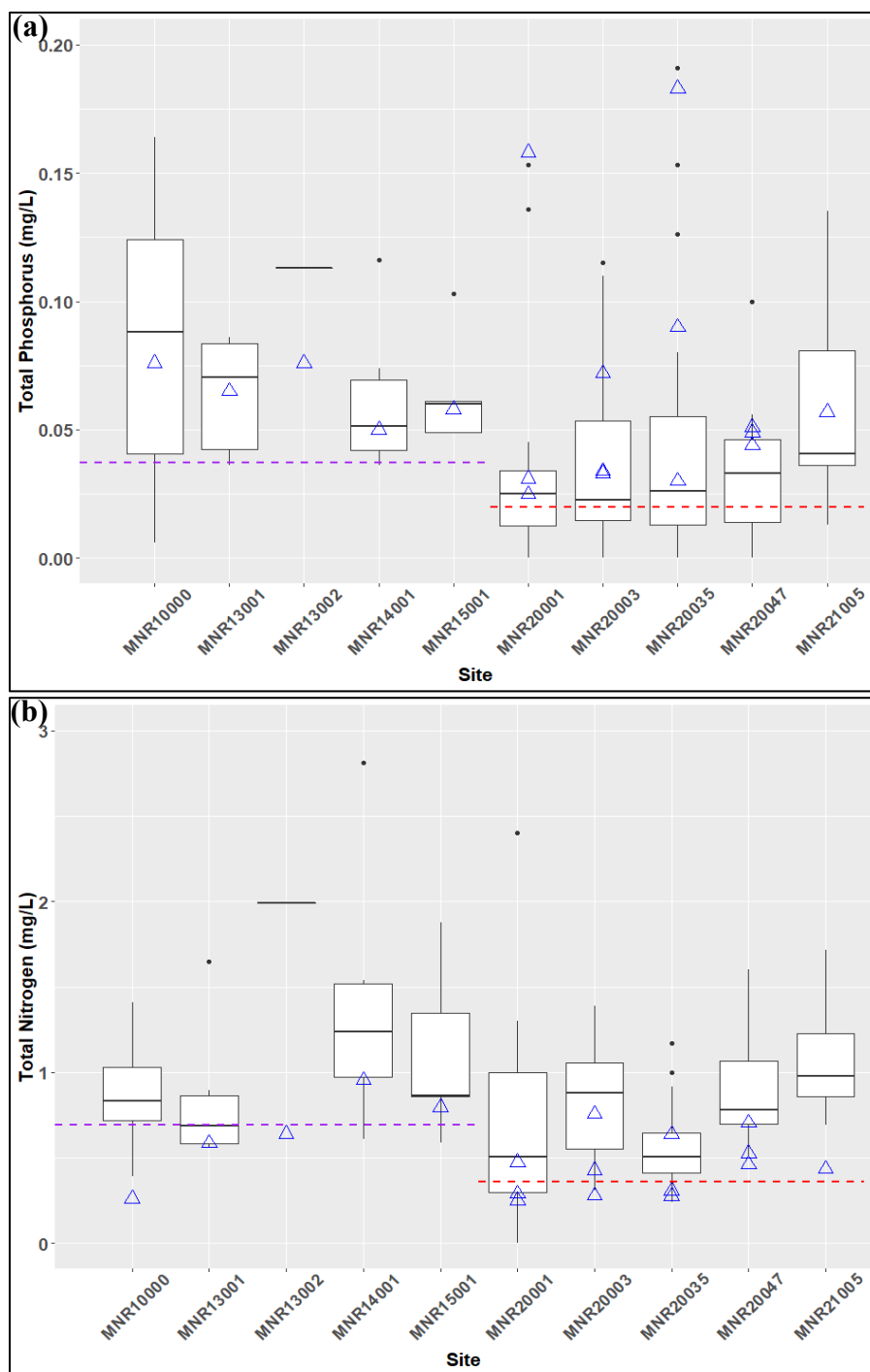


Figure 3. Comparison of 2020 Monroe Lake nutrient data to historical samples and nutrient criteria. Boxplots represent data collected in 2012-2019 and blue triangles represent 2020 data. Purple and red dotted lines represent USEPA recommended nutrient criteria for streams and reservoirs, respectively. (a) Comparison of total phosphorus data. Four historical outliers were excluded to make the plot easier to interpret (outlier values ranged from 0.22 to 0.31 mg/L). (b) Comparison of total nitrogen data. One historical outlier was excluded to make the plot easier to interpret (value of outlier was 21.049 mg/L).

Cyanobacteria Data, HABs, and Trophic State Index

Cyanobacteria Data

17 phytoplankton samples were collected at various depths from 5 sites. Total cyanobacteria cell counts exceeded 100,000 cells/mL (guideline value for moderate health risk from the World Health Organization's Guidelines for Safe Recreational Water Environments [2003]) in 10 out of 17 samples collected from 4 sites. None of these samples exceeded 1,000,000 cells/mL. These results indicate Monroe Lake had cell count levels potentially indicative of a HAB at the time of sampling.

Harmful Algal Bloom (HAB) Response

IDEM is the lead agency for HAB response in Indiana. IDEM samples State Recreation Areas (SRA) biweekly during the recreation season and issues appropriate HAB alert level based on the results. IDEM issued HAB Advisory alert levels at the Paynetown SRA from 7/31/20 through 9/4/20 and at Fairfax SRA from 8/14/20 through 9/4/20. The Advisory alert level indicates that cell counts were over 100,000 cells/mL, but toxin levels did not meet thresholds for the Caution or Closed alert levels. At an Advisory alert level, the following precautions apply: swimming and boating permitted; avoid contact with algae; don't drink the water; and shower after you swim.

TSI

The trophic state indices for Secchi depth [TSI(SD)], chlorophyll-*a* [TSI(CHL)], and total phosphorus [TSI(TP)] were calculated for five reservoir sites at Monroe Lake (Table 1). The mean category of all three indices was eutrophic, indicating a high level of biological activity.

Table 1. Summary of calculated trophic state indices at Monroe Lake.

	Mean Score (range)	Mean Category (Range)
TSI(SD)	60 (45-75)	Eutrophic (Mesotrophic-Hypereutrophic)
TSI(CHL)	57 (46-67)	Eutrophic (Mesotrophic-Hypereutrophic)
TSI(TP)	56 (51-62)	Eutrophic (Moderately Eutrophic-Eutrophic)

Nolin River Lake (NRR) Water Quality Summary

Summary of 2020 Water Quality Results

Nolin River Lake had one exceedance of KY's water quality criteria for temperature at the tailwater (NRR10000). Total phosphorus and total nitrogen levels at most sample locations exceeded the USEPA nutrient criteria. TSI for three indices classified the lake as eutrophic or hypereutrophic, indicating high to very high levels of biological activity potential. Finally, our sampling showed there were two samples with cyanobacteria cell counts over 100,000 cells/mL at the time of the sampling event. The elevated nutrient levels and eutrophic/hypereutrophic TSI classification indicate there is a high potential for HAB development in the lake.

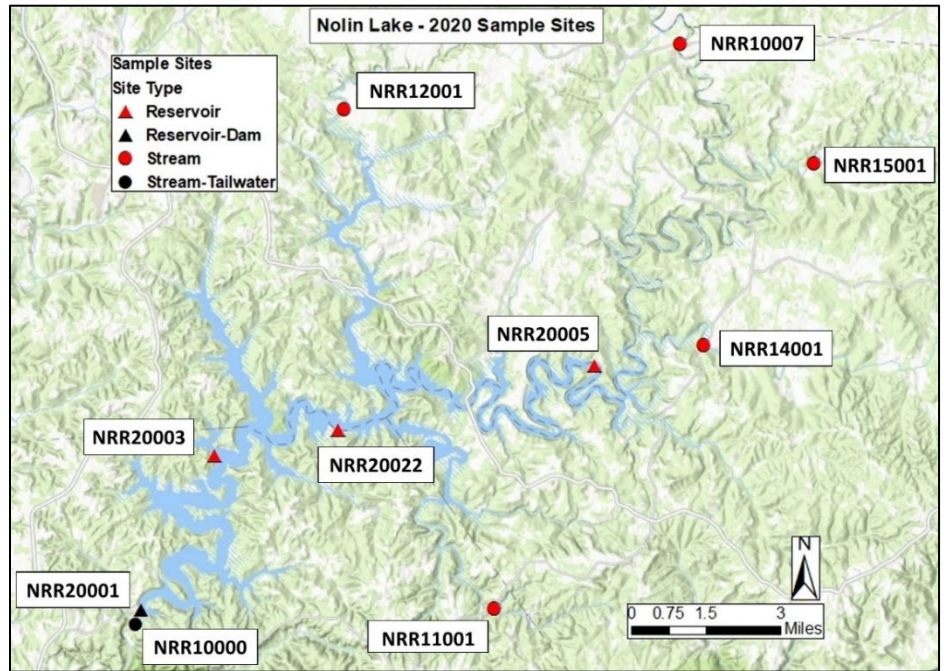


Figure 1. Water quality sampling locations for Nolin River Lake in 2020.

2020 Activities

In 2020, one sampling event was conducted at Nolin River Lake. Field data and chemical samples were collected at ten sample locations (Figure 1). Chlorophyll and phytoplankton were collected at four sites, and zooplankton samples were collected at the damsite (NRR20001).

Additionally, temperature and dissolved oxygen (DO) profiles were collected by the project staff at the damsite and tailwater approximately every two weeks from early May through mid-December.

Exceedances of KY State Water Quality Criteria

There was one exceedance event of KY state water quality criteria for temperature at the tailwater on January 11. There were no other exceedances of KY state WQ criteria.

Tailwater Temperature and DO Conditions

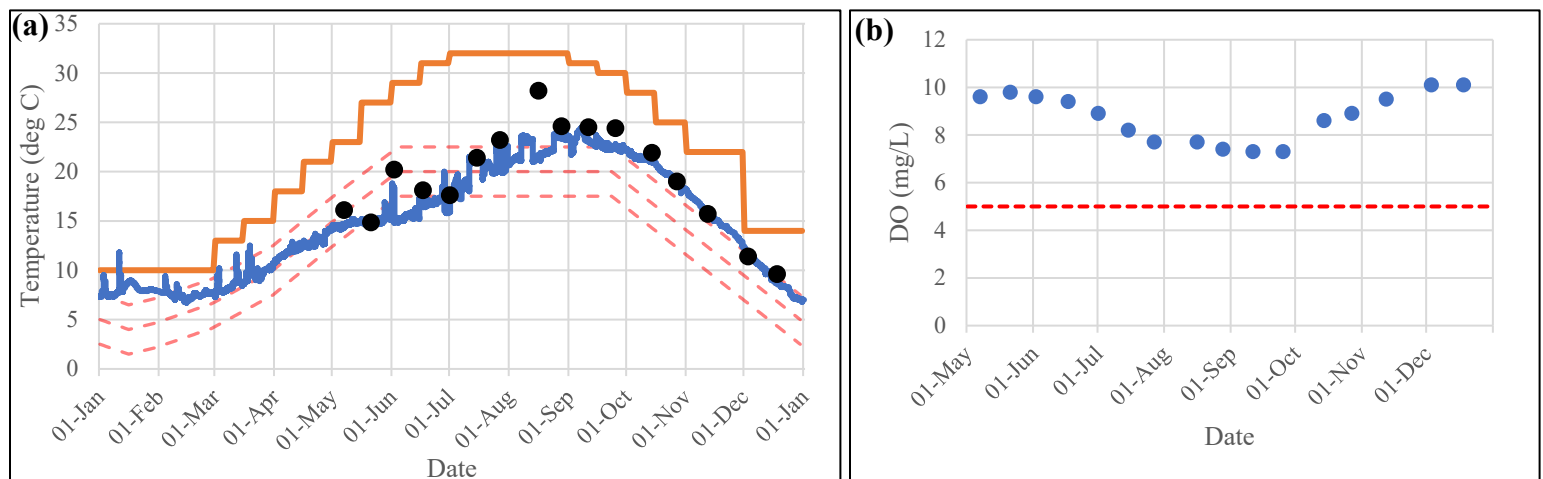


Figure 2. Nolin River Lake tailwater temperature and DO data. (a) Tailwater temperature data collected by project staff in 2020 is represented by the black dots. The blue line represents USGS gage data (provisional) from a gage downstream from the project. The temperature guide curve is represented by the dashed red lines, and the orange line represents the KY water quality criteria for temperature. (b) Tailwater dissolved oxygen data collected in 2020 is represented by the blue dots. The KY water quality criteria for DO is represented by the dashed red line.

Tailwater data was compared to KY state water quality criteria for temperature and to the Louisville District's temperature guide curve for Nolin River Lake (Figure 2a). According to the provisional USGS data, tailwater temperature exceeded the state criteria for temperature on January 11. During this time, the reservoir was de-stratified; therefore, nothing could be done operationally to prevent this exceedance. Also, tailwater temperatures fell outside the guide curve early January through early February, late May through June, and much of the time late August through early December. The WQ Program will use these findings to inform future operational decisions to improve performance of downstream temperature management wherever possible. Tailwater dissolved oxygen levels did not exceed state criteria at any time throughout the year (Figure 2b).

Nutrient Analyses

Nutrient data, including total nitrogen (TN) and total phosphorus (TP) data, were collected at all sample sites in 2020. The 2020 TP and TN values were compared to historical data from 2012 through 2019 (Figure 3). The TP and TN values at each site were compared to their respective USEPA recommended criteria. Nutrient levels are an area of concern because elevated nutrients can lead to high biological activity, especially with respect to HABs.

Total Phosphorus

2020 TP values were higher than historical medians and distributions at all sites except for one. Also, 2020 TP levels at all sites were above the USEPA recommended nutrient criteria for the respective locations.

Total Nitrogen

2020 TN values were above historical medians in 13 out of 18 samples and were above historical distributions in around half of the samples. 17 out of 18 TN values exceeded the USEPA recommended nutrient criteria in 2020.

Cyanobacteria Data, HABs, and Trophic State Index

Cyanobacteria Data

16 phytoplankton samples were collected from various depths at 4 sites. Total cyanobacteria cell counts exceeded 100,000 cells/mL (guideline value for moderate health risk from the World Health Organization's Guidelines for Safe Recreational Water Environments [2003]) in two samples collected from one site.

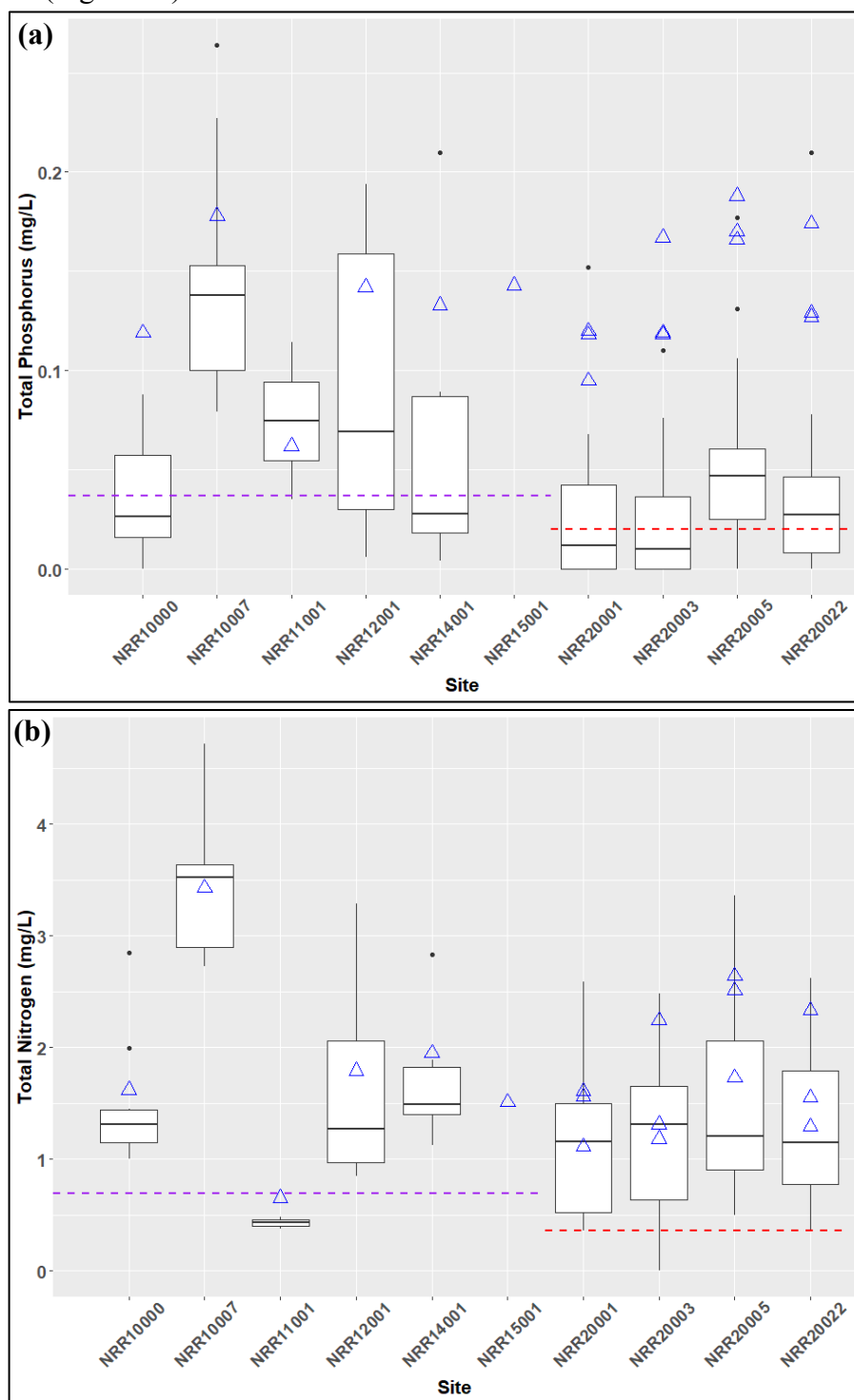


Figure 3. Comparison of Nolin River Lake nutrient data to historical samples and nutrient criteria. Boxplots represent data collected in 2012-2019 and blue triangles represent 2020 data. Purple and red dotted lines represent USEPA recommended nutrient criteria for streams and reservoirs, respectively. (a) Comparison of total phosphorus data. (b) Comparison of total nitrogen data.

These results indicate Nolin River Lake had cell count levels potentially indicative of a HAB at one site at the time of sampling.

Harmful Algal Bloom (HAB) Response

The KY Division of Water (KDOW) is the lead agency for HAB response in Kentucky. KDOW did not issue any advisories for HABs at Nolin River Lake in 2020.

TSI

The trophic state indices for Secchi depth [TSI(SD)], chlorophyll-*a* [TSI(CHL)], and total phosphorus [TSI(TP)] were calculated for four reservoir sites at Nolin River Lake (Table 1). The mean categories of the three indices ranged from eutrophic to hypereutrophic, indicating a high to very high level of biological activity.

Table 1. Summary of calculated trophic state indices at Nolin River Lake.

	Mean Score (range)	Mean Category (Range)
TSI(SD)	58 (53-65)	Eutrophic (Moderately Eutrophic-Eutrophic)
TSI(CHL)	63 (61-65)	Eutrophic
TSI(TP)	74 (70-78)	Hypereutrophic

Patoka Lake (PRR) Water Quality Summary

Summary of 2020 Water Quality Results

Patoka Lake had no exceedances of IN's water quality criteria at the tailwater (PRR10000). Total phosphorus at all sample locations and total nitrogen levels in over half of the sample locations exceeded the USEPA nutrient criteria. The mean TSI category for all three indices was eutrophic, indicating a high level of biological activity. Finally, our sampling showed cyanobacteria cell counts over 100,000 cells/mL in 17 out of 23 samples at the time of sampling. The elevated nutrient levels and eutrophic TSI classification indicate there is a high potential for HAB development in the lake.

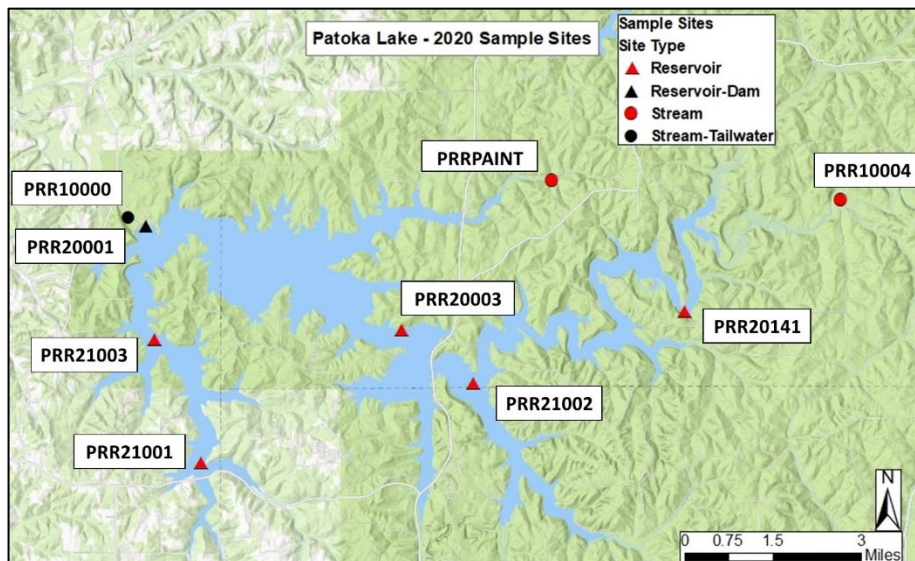


Figure 1. Water quality sampling locations for Patoka Lake in 2020.

2020 Activities

In 2020, one sampling event was conducted at Patoka Lake. Field data and chemical samples were collected at all nine sites (Figure 1). Chlorophyll and phytoplankton were collected at six sites, and zooplankton samples were collected at the damsite (PRR20001).

Additionally, temperature and dissolved oxygen (DO) profiles were collected by the project staff at the damsite and tailwater approximately every two weeks from late May through mid-November.

Exceedances of IN State Water Quality Criteria

There were no exceedances of IN state water quality criteria at the tailwater.

Tailwater Temperature and DO Conditions

Tailwater data was compared to IN state water quality criteria for temperature and to the Louisville District's temperature guide curve for Patoka Lake (Figure 2a). Tailwater temperature did not exceed the state criteria for

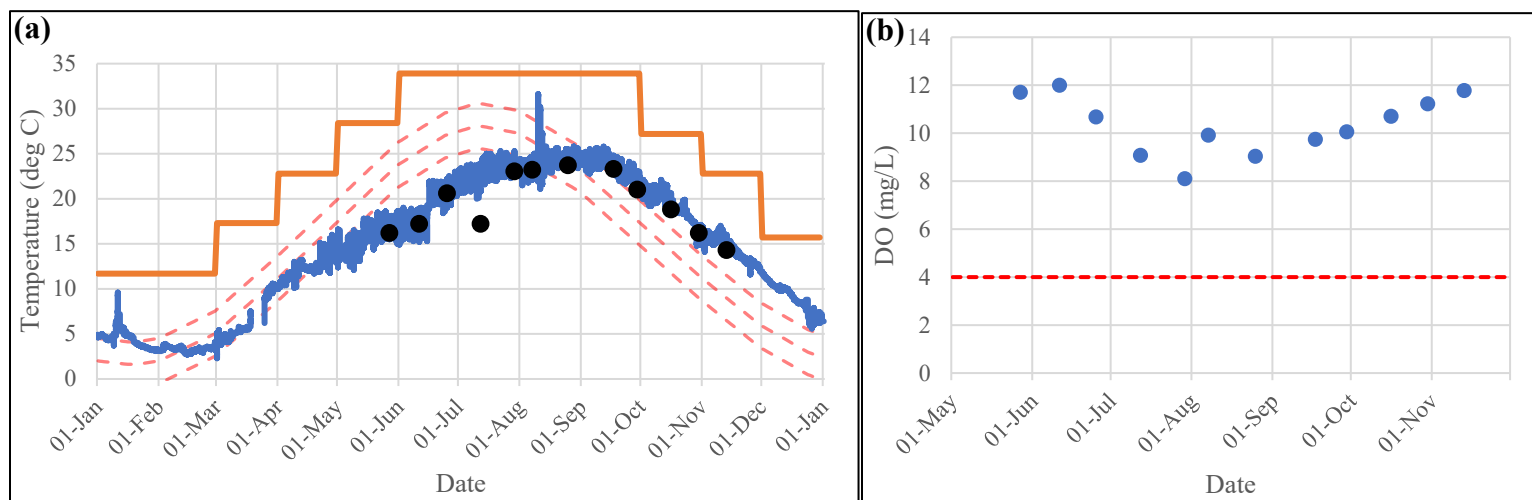


Figure 2. Patoka Lake tailwater temperature and DO data. (a) Tailwater temperature data collected by project staff in 2020 is represented by the black dots. The blue line represents USGS gage data (provisional) from a gage downstream from the project. The temperature guide curve is represented by the dashed red lines, and the orange line represents the IN water quality criteria for temperature. (b) Tailwater dissolved oxygen data collected in 2020 is represented by the blue dots. The IN water quality criteria for DO is represented by the dashed red line.

temperature at any time; however, tailwater temperature fell outside the guide curve mid-January, mid-April through mid-August, and early September through the end of the year. During January and from late October to the end of the year, the reservoir was de-stratified; therefore, nothing could be done operationally to maintain guide curve during those times. Additionally, maintenance issues with the selective withdrawal gates limited the capacity to operate for temperature in 2020. The WQ Program will use these findings to inform future operational decisions to improve performance of downstream temperature management wherever possible. Tailwater dissolved oxygen levels did not exceed state criteria at any time throughout the year (Figure 2b).

Nutrient Analyses

Nutrient data, including total nitrogen (TN) and total phosphorus (TP) data, were collected at all sample sites in 2020. The 2020 TP and TN values were compared to historical data from 2012 through 2019 (Figure 3). The TP and TN values at each site were compared to their respective USEPA recommended criteria. Nutrient levels are an area of concern because elevated nutrients can lead to high biological activity, especially with respect to HABs.

Total Phosphorus

2020 TP values at Patoka Lake were above the historical medians and at the top of historical distributions at all sites, except one. Also, 2020 TP levels were above the USEPA recommended nutrient criteria at all sites.

Total Nitrogen

2020 TN values at Patoka Lake were near or below the historical medians in 13 out of 19 samples. Also, 2020 TN levels in 11 out of 19 samples were above the USEPA recommended nutrient criteria for the respective locations.

Cyanobacteria Data, HABs, and Trophic State Index

Cyanobacteria Data

23 phytoplankton samples were collected at various depths from 6 sites. Total cyanobacteria cell counts exceeded 100,000 cells/mL (guideline value for moderate health risk from the World Health Organization's Guidelines for Safe Recreational Water Environments [2003]) in 17 out of 23 samples collected from 5 sites. None of these samples

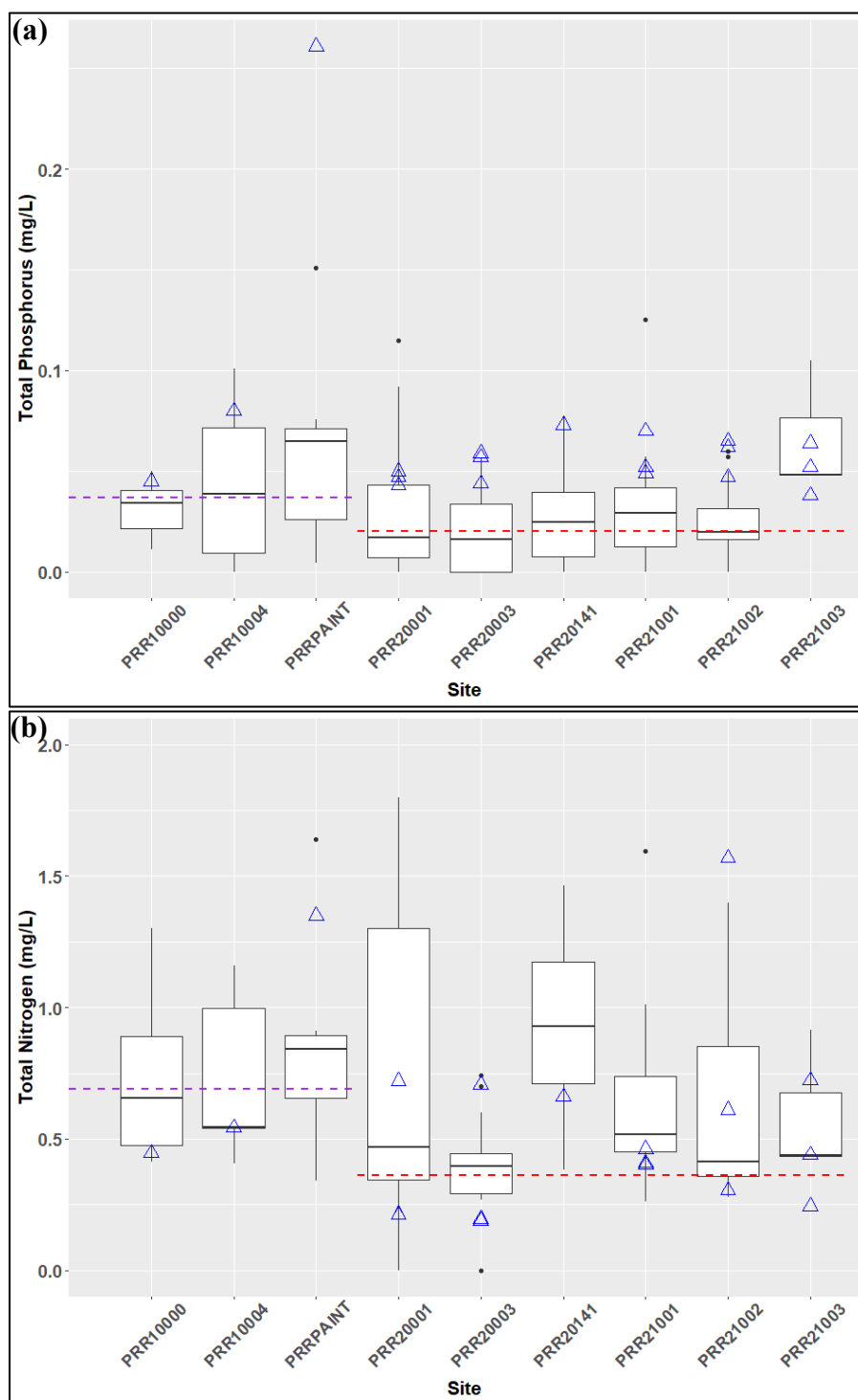


Figure 3. Comparison of Patoka Lake 2020 nutrients data to historical samples and nutrient criteria. Boxplots represent data collected in 2012-2019 and blue triangles represent 2020 data. Purple and red dotted lines represent USEPA recommended nutrient criteria for streams and reservoirs, respectively. (a) Comparison of total phosphorus data. (b) Comparison of total nitrogen data. Three outliers (values ranging from 2.2-2.894 mg/L) were removed to make the graph easier to interpret.

exceeded 1,000,000 cells/mL. These results indicate Patoka Lake had cell count levels potentially indicative of a HAB at the time of sampling.

Harmful Algal Bloom (HAB) Response

IDEM is the lead agency for HAB response in Indiana. IDEM samples State Recreation Areas (SRAs) biweekly during the recreation season and issues appropriate HAB alert level based on the results. IDEM issued HAB Advisory alert levels at the Patoka SRA Beach from 7/17/20 through 9/4/20. The Advisory alert level indicates that cell counts were over 100,000 cells/mL, but toxin levels did not meet thresholds for the Caution or Closed alert levels. At an Advisory alert level, the following precautions apply: swimming and boating permitted; avoid contact with algae; don’t drink the water; and shower after you swim.

TSI

The trophic state indices for Secchi depth [TSI(SD)], chlorophyll-*a* [TSI(CHL)], and total phosphorus [TSI(TP)] were calculated for six reservoir sites at Patoka Lake (Table 1). The mean category of all three indices was eutrophic, indicating a high level of biological activity.

Table 1. Summary of calculated trophic state indices at Patoka Lake.

	Mean Score (range)	Mean Category (Range)
TSI(SD)	56 (48-76)	Eutrophic (Mesotrophic-Hypereutrophic)
TSI(CHL)	57 (50-64)	Eutrophic (Mesotrophic-Eutrophic)
TSI(TP)	60 (57-66)	Eutrophic (Eutrophic-Hypereutrophic)

Rough River Lake (RRR) Water Quality Summary

Summary of 2020 Water Quality Results

Rough River Lake had one exceedance of KY's water quality criteria for temperature at the tailwater (RRR10000). Total phosphorus and total nitrogen levels at all sample locations exceeded the USEPA nutrient criteria. TSI for the three indices classified the lake as eutrophic or hypereutrophic, indicating high to very high levels of biological activity potential. Finally, our sampling showed there were three samples with cyanobacteria cell counts over 100,000 cells/mL at the time of the sampling event. The elevated nutrient levels and eutrophic/hypereutrophic TSI classification indicate there is a high potential for HAB development in the lake.

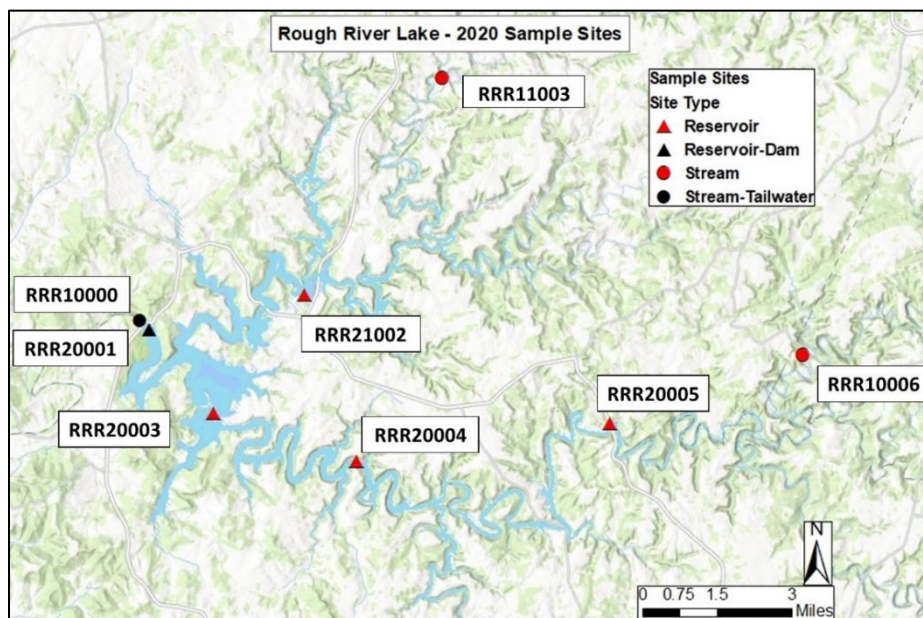


Figure 1. Water quality sampling locations for Rough River Lake in 2020.

2020 Activities

In 2020, one sampling event was conducted at Rough River Lake. Field data and chemical samples were collected at eight sample locations (Figure 1). Chlorophyll and phytoplankton were collected at five sites, and zooplankton samples were collected at the damsite (RRR20001).

Additionally, temperature and dissolved oxygen (DO) profiles were collected by the project staff at the damsite and tailwater approximately every two weeks from early May through mid-December.

Exceedances of KY State Water Quality Criteria

There was one exceedance event of KY state water quality criteria for temperature at the tailwater on January 11-12. There were no other exceedances of KY state WQ criteria.

Tailwater Temperature and DO Conditions

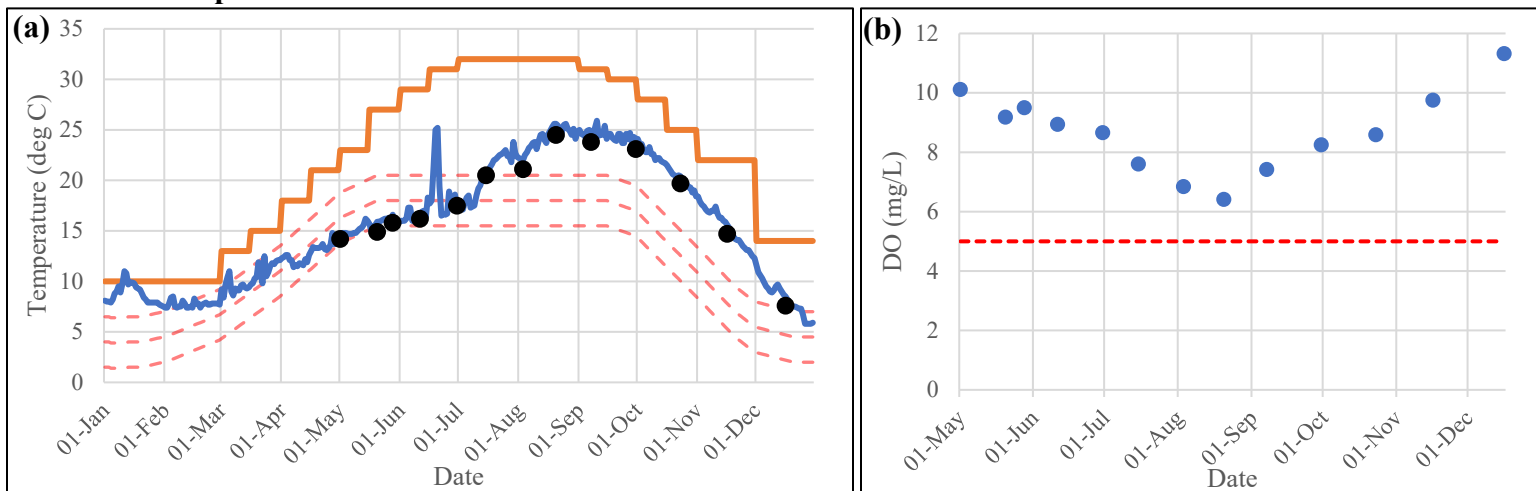


Figure 2. Rough River Lake tailwater temperature and DO data. (a) Tailwater temperature data collected by project staff in 2020 is represented by the black dots. The blue line represents USGS gage data (provisional) from a gage downstream from the project. The temperature guide curve is represented by the dashed red lines, and the orange line represents the KY water quality criteria for temperature. (b) Tailwater dissolved oxygen data collected in 2020 is represented by the blue dots. The KY water quality criteria for DO is represented by the dashed red line.

Tailwater data was compared to KY state water quality criteria for temperature and to the Louisville District's temperature guide curve for Rough River Lake (Figure 2a). According to the provisional USGS data, tailwater temperature exceeded the state criteria for temperature on January 11-12. During this time, the reservoir was de-stratified; therefore, nothing could be done operationally to prevent this exceedance. Also, tailwater temperatures fell outside the guide curve January through early February, mid-June, and mid-July through late December. Although the WQ Program will use these findings to inform future operational decisions to improve performance of downstream temperature management wherever possible, Rough River Lake has poor selective withdrawal capabilities which severely limits the ability to operate for temperatures downstream. Tailwater dissolved oxygen levels did not exceed state criteria at any time throughout the year (Figure 2b).

Nutrient Analyses

Nutrient data, including total nitrogen (TN) and total phosphorus (TP) data, were collected at all sample sites in 2020. The 2020 TP and TN values were compared to historical data from 2012 through 2019 (Figure 3). The TP and TN values at each site were compared to their respective USEPA recommended criteria. Nutrient levels are an area of concern because elevated nutrients can lead to high biological activity, especially with respect to HABs.

Total Phosphorus

2020 TP values were higher than historical medians and distributions in all but one of the samples. Also, 2020 TP levels at all sites were above the USEPA recommended nutrient criteria for the respective locations.

Total Nitrogen

2020 TN values were above historical medians in 16 out of 18 samples and were above historical distributions in over half of the samples. All 2020 TN values exceeded the USEPA recommended nutrient criteria.

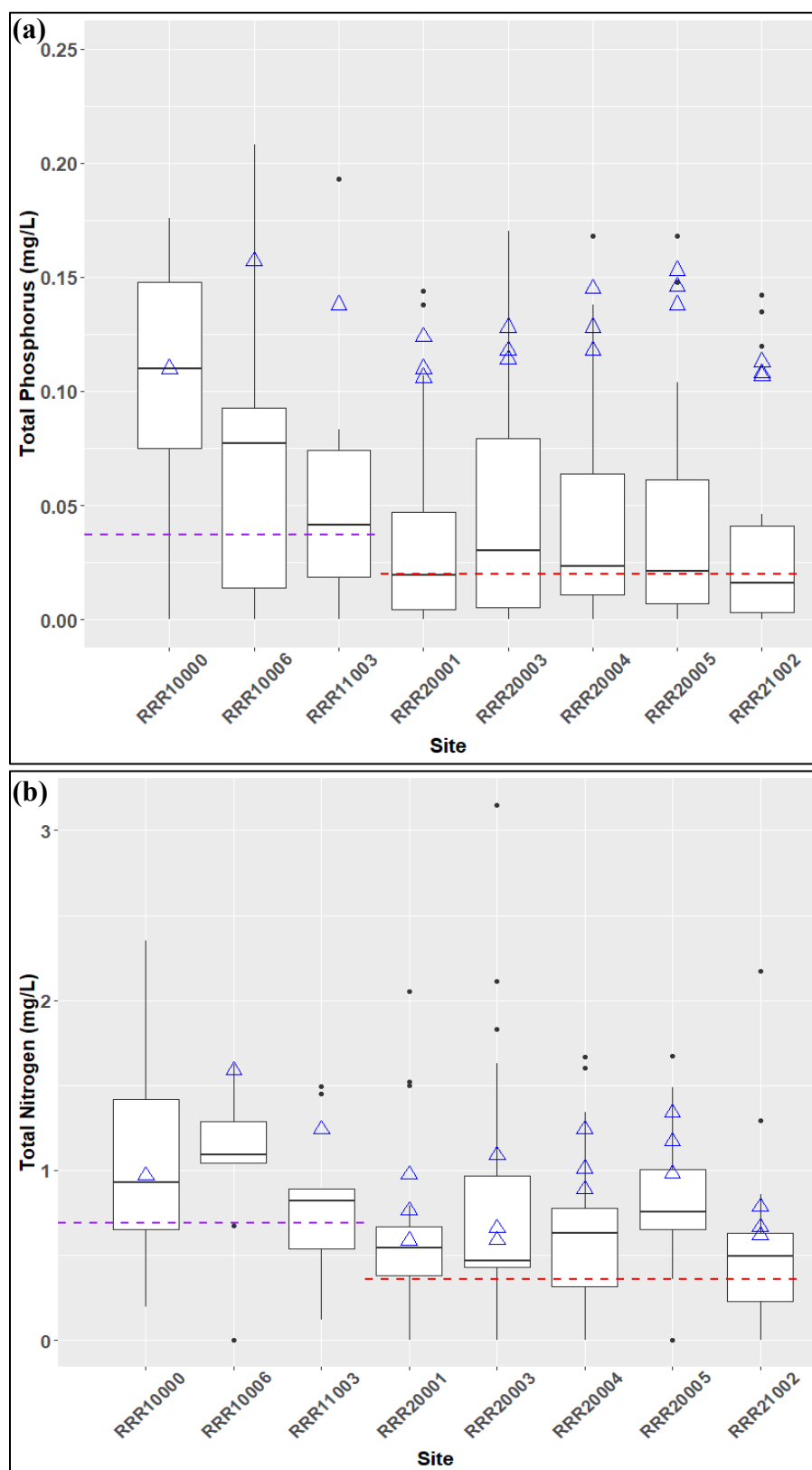


Figure 3. Comparison of Rough River Lake 2020 nutrients data to historical samples and nutrient criteria. Boxplots represent data collected in 2012-2019 and blue triangles represent 2020 data. Purple and red dotted lines represent USEPA recommended nutrient criteria for streams and reservoirs, respectively. (a) Comparison of total phosphorus data. Five outliers (values range from 0.272 to 0.322 mg/L) were excluded to make graph easier to interpret. (b) Comparison of total nitrogen data.

Cyanobacteria Data, HABs, and Trophic State Index

Cyanobacteria Data

20 phytoplankton samples were collected from various depths at 5 sites. Total cyanobacteria cell counts exceeded 100,000 cells/mL (guideline value for moderate health risk from the World Health Organization’s Guidelines for Safe Recreational Water Environments [2003]) in three samples from one site on Rough River Lake. These results indicate Rough River Lake had cell count levels potentially indicative of a HAB at one site at the time of sampling.

Harmful Algal Bloom (HAB) Response

The KY Division of Water (KDOW) is the lead agency for HAB response in Kentucky. KDOW did not issue any advisories for HABs at Rough River Lake in 2020.

TSI

The trophic state indices for Secchi depth [TSI(SD)], chlorophyll-a [TSI(CHL)], and total phosphorus [TSI(TP)] were calculated for five reservoir sites at Rough River Lake (Table 1). The mean categories of all three indices ranged from eutrophic to hypereutrophic, indicating high to very high levels of biological activity potential.

Table 1. Summary of calculated trophic state indices at Rough River Lake.

	Mean Score (range)	Mean Category (Range)
TSI(SD)	58 (52-63)	Eutrophic (Moderately Eutrophic-Eutrophic)
TSI(CHL)	64 (58-75)	Eutrophic (Eutrophic-Hypereutrophic)
TSI(TP)	73 (72-75)	Hypereutrophic

Taylorsville Lake (TAR) Water Quality Summary

Summary of 2020 Water Quality Results

Taylorsville Lake had no exceedances of KY's water quality criteria for temperature at the tailwater (TAR10000). Total phosphorus and total nitrogen levels at most sample locations exceeded the USEPA nutrient criteria. TSI for the three indices classified the lake as hypereutrophic, indicating very high levels of biological activity potential. Finally, our sampling showed there were six samples with cyanobacteria cell counts over 100,000 cells/mL at the time of the sampling event. The elevated nutrient levels and hypereutrophic TSI classification indicate there is a high potential for HAB development in the lake.

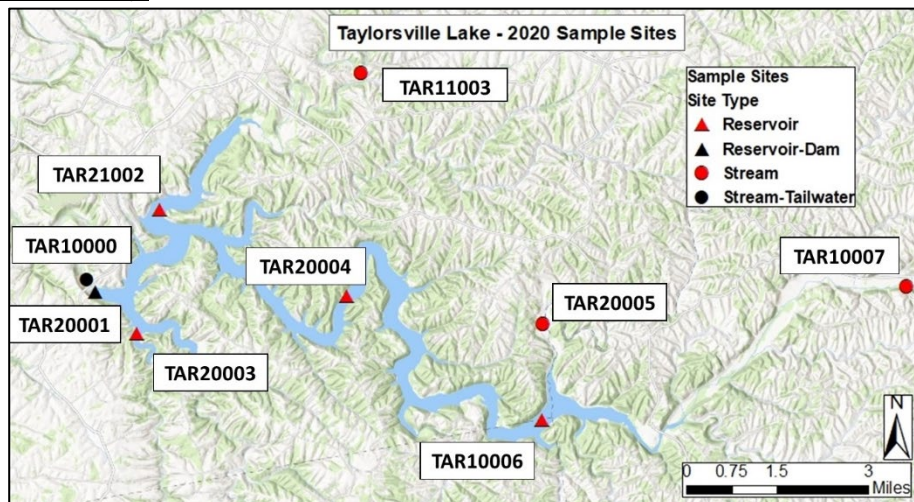


Figure 1. Water quality sampling locations for Taylorsville Lake in 2020.

2020 Activities

In 2020, one sampling event was conducted at Taylorsville Lake. Field data and chemical samples were collected at all nine sample locations (Figure 1). Chlorophyll and phytoplankton were collected at five sites, and zooplankton samples were collected at the damsite (TAR20001).

Additionally, temperature and dissolved oxygen (DO) profiles were collected by the project staff at the damsite and tailwater approximately every two weeks from mid-May through mid-December.

Exceedances of KY State Water Quality Criteria

There were no exceedances of KY state water quality criteria at the tailwater.

Tailwater Temperature and DO Conditions

Tailwater data was compared to KY state water quality criteria for temperature and to the Louisville District's temperature guide curve for Taylorsville Lake (Figure 2a). Tailwater temperature did not exceed state water quality criteria in 2020; however, tailwater temperatures fell outside the guide curve most of the readings from early June through August and October through the end of the year. The WQ Program will use these findings to inform future

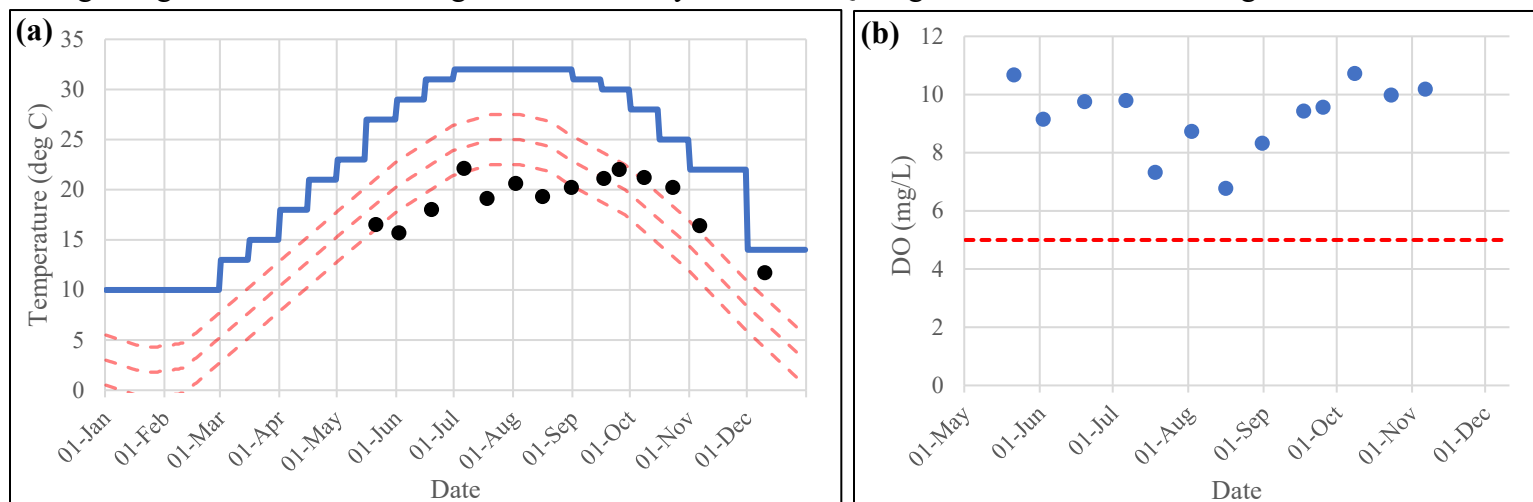


Figure 2. Taylorsville Lake tailwater temperature and DO data. (a) Tailwater temperature data collected by project staff in 2020 is represented by the black dots. The temperature guide curve is represented by the dashed red lines, and the blue line represents the KY water quality criteria for temperature. (b) Tailwater dissolved oxygen data collected in 2020 is represented by the blue dots. The KY water quality criteria for DO is represented by the dashed red line.

operational decisions to improve performance of downstream temperature management wherever possible. Tailwater dissolved oxygen levels did not exceed state criteria at any time throughout the year (Figure 2b).

Nutrient Analyses

Nutrient data, including total nitrogen (TN) and total phosphorus (TP) data, were collected at all sample sites in 2020. The 2020 TP and TN values were compared to historical data from 2012 through 2019 (Figure 3). The TP and TN values at each site were compared to their respective USEPA recommended criteria. Nutrient levels are an area of concern because elevated nutrients can lead to high biological activity, especially with respect to HABs.

Total Phosphorus

2020 TP values were higher than historical medians in all samples. Also, 2020 TP levels at all sites were above the USEPA recommended nutrient criteria for the respective locations.

Total Nitrogen

2020 TN values were near or below historical medians all sample sites. 15 out of 17 TN values in 2020 exceeded the USEPA recommended nutrient criteria.

Cyanobacteria Data, HABs, and Trophic State Index

Cyanobacteria Data

17 phytoplankton samples were collected from various depths at 5 sites. Total cyanobacteria cell counts exceeded 100,000 cells/mL (guideline value for moderate health risk from the World Health Organization's Guidelines for Safe Recreational Water Environments [2003]) in six samples from three sites on Taylorsville Lake. These results indicate Taylorsville Lake had cell count levels potentially indicative of a HAB at three sites at the time of sampling.

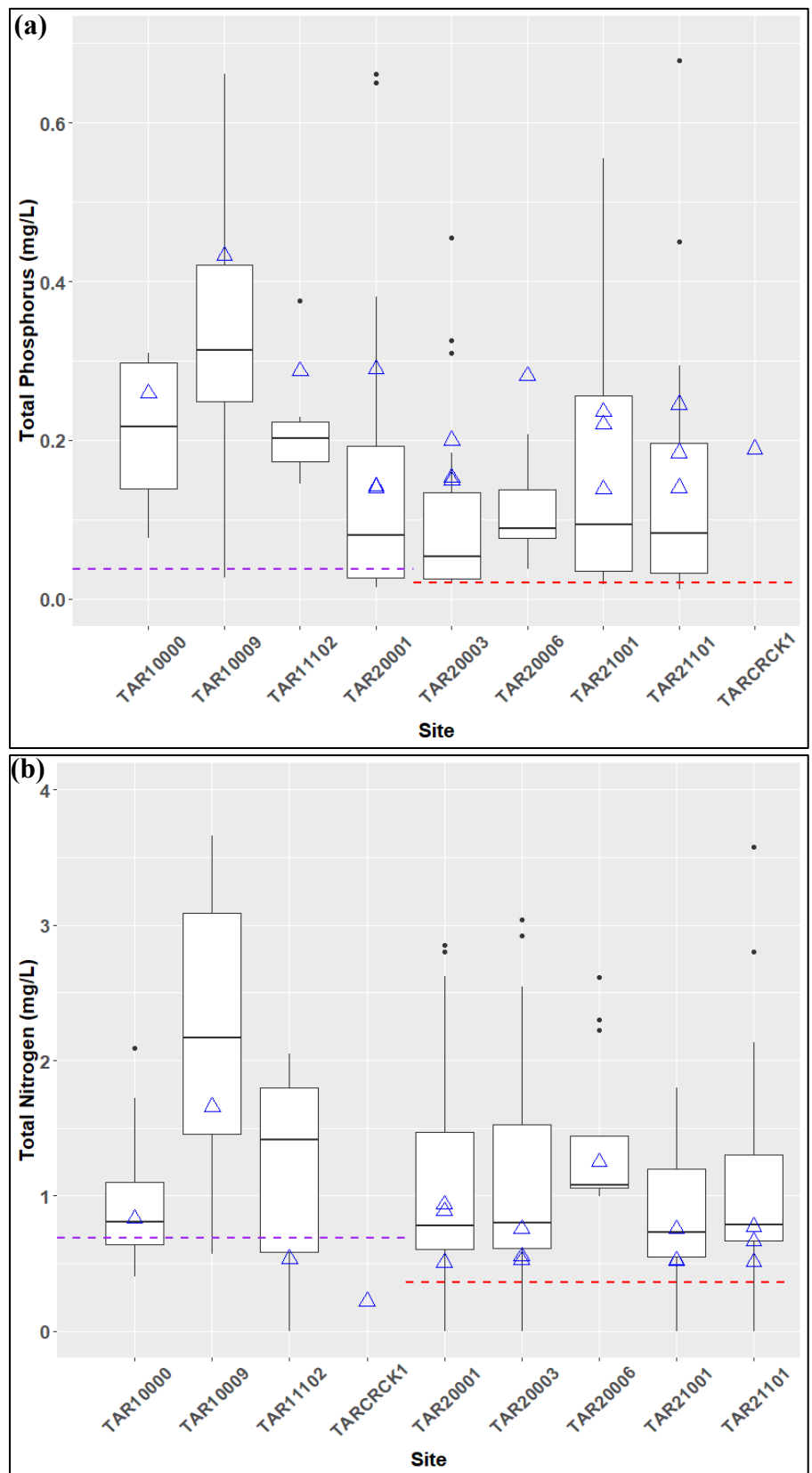


Figure 3. Comparison of Taylorsville Lake 2020 nutrients data to historical samples and nutrient criteria. Boxplots represent data collected in 2012-2019 and blue triangles represent 2020 data. Purple and red dotted lines represent USEPA recommended nutrient criteria for streams and reservoirs, respectively. (a) Comparison of total phosphorus data. Seven outliers (values ranging from 0.734 to 1.47 mg/L) were excluded to make graph easier to interpret. (b) Comparison of total nitrogen data. Two outliers (values of 4.24 and 9.37 mg/L) were excluded to make graph easier to interpret.

Harmful Algal Bloom (HAB) Response

The KY Division of Water (KDOW) is the lead agency for HAB response in Kentucky. KDOW did not issue any advisories for HABs at Taylorsville Lake in 2020.

TSI

The trophic state indices for Secchi depth [TSI(SD)], chlorophyll-*a* [TSI(CHL)], and total phosphorus [TSI(TP)] were calculated for five reservoir sites at Taylorsville Lake (Table 1). The mean category of all three indices was hypereutrophic, indicating very high levels of biological activity potential.

Table 1. Summary of calculated trophic state indices at Taylorsville Lake.

	Mean Score (range)	Mean Category (Range)
TSI(SD)	68 (66-73)	Hypereutrophic
TSI(CHL)	74 (69-78)	Hypereutrophic
TSI(TP)	78 (75-85)	Hypereutrophic

West Fork Lake (WFR) Water Quality Summary

Summary of 2020 Water Quality Results

West Fork Lake had no exceedances of OH's water quality criteria at the tailwater (WFR10000). Total phosphorus at all sample locations exceeded the USEPA nutrient criteria, and total nitrogen exceeded the USEPA nutrient criteria in two out of five samples. The mean TSI categories for all three indices classified the lake as eutrophic or hypereutrophic, indicating a very high level of biological activity. Finally, our sampling showed no samples had cyanobacteria cell counts over 100,000 cells/mL at the time of sampling. The elevated nutrient levels and hypereutrophic TSI classification indicate there is a high potential for HAB development in the lake.

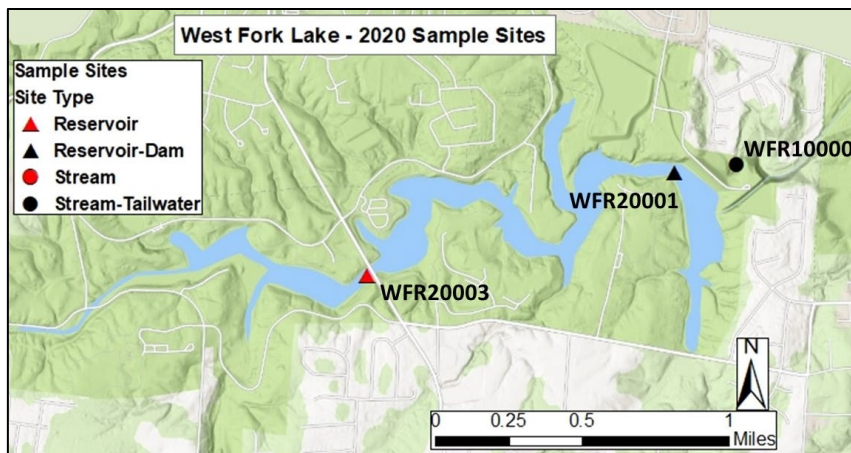


Figure 1. Water quality sampling locations for West Fork Lake in 2020.

2020 Activities

In 2020, one sampling event was conducted at West Fork Lake. Field data and chemical samples were collected at three sites (Figure 1). Chlorophyll and phytoplankton were collected at two sites, and zooplankton samples were collected at the damsite (WFR20001).

Additionally, temperature and dissolved oxygen (DO) profiles were collected by the project staff at the damsite and tailwater approximately every two weeks from early May through early October.

Exceedances of OH State Water Quality Criteria

There were no exceedances of Ohio state WQ criteria in 2020.

Tailwater Temperature and DO Conditions

Tailwater data was compared to OH state water quality criteria for temperature (Figure 2a). Tailwater temperature did not exceed the state criteria for temperature at any time. West Fork Lake has virtually no selective withdrawal

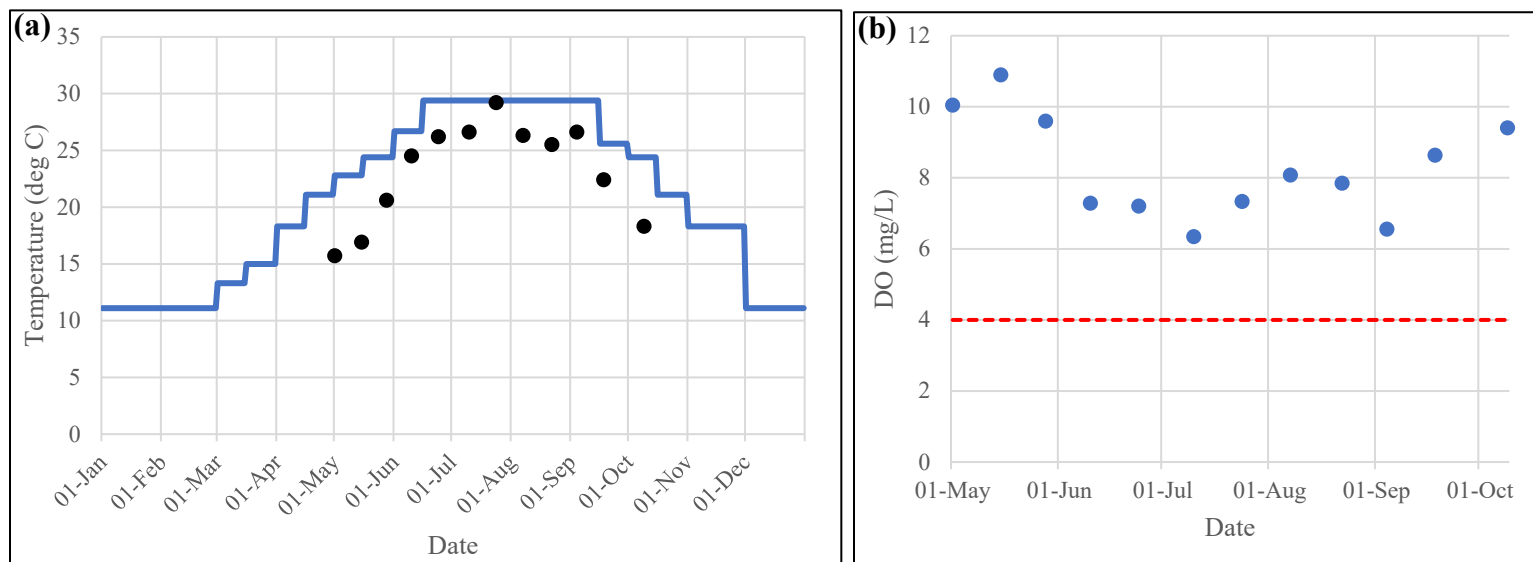


Figure 2. West Fork Lake tailwater temperature and DO data. (a) Tailwater temperature data collected by project staff in 2020 is represented by the black dots, and the blue line represents the OH water quality criteria for temperature. (b) Tailwater dissolved oxygen (DO) data collected in 2020 is represented by the blue dots. The OH water quality criteria for DO is represented by the dashed red line.

capabilities which severely limits the ability to operate for temperatures downstream. Tailwater dissolved oxygen levels did not exceed state criteria at any time throughout the year (Figure 2b).

Nutrient Analyses

Nutrient data, including total nitrogen (TN) and total phosphorus (TP) data, were collected at all sample sites in 2020. The 2020 TP and TN values were compared to historical data from 2012 through 2019 (Figure 3). The TP and TN values at each site were compared to their respective USEPA recommended criteria. Nutrient levels are an area of concern because elevated nutrients can lead to high biological activity, especially with respect to HABs.

Total Phosphorus

2020 TP values were above the historical medians and near the top or above historical distributions at all sites. Also, 2020 TP levels at all sample sites were above the USEPA recommended nutrient criteria for the respective locations.

Total Nitrogen

2020 TN values were below the historical medians at all sites and were near the bottom or below the historical distribution for each site. Also, 2020 TN levels in two samples were above the USEPA recommended nutrient criteria for the respective locations.

Cyanobacteria Data, HABs, and Trophic State Index

Cyanobacteria Data

Five phytoplankton samples were collected at various depths from two sites. Total cyanobacteria cell counts did not exceed 100,000 cells/mL (guideline value for moderate health risk from the World Health Organization's Guidelines for Safe Recreational Water Environments [2003]) in any samples collected. These results indicate West Fork Lake did not have cell count levels potentially indicative of a HAB at the time of sampling.

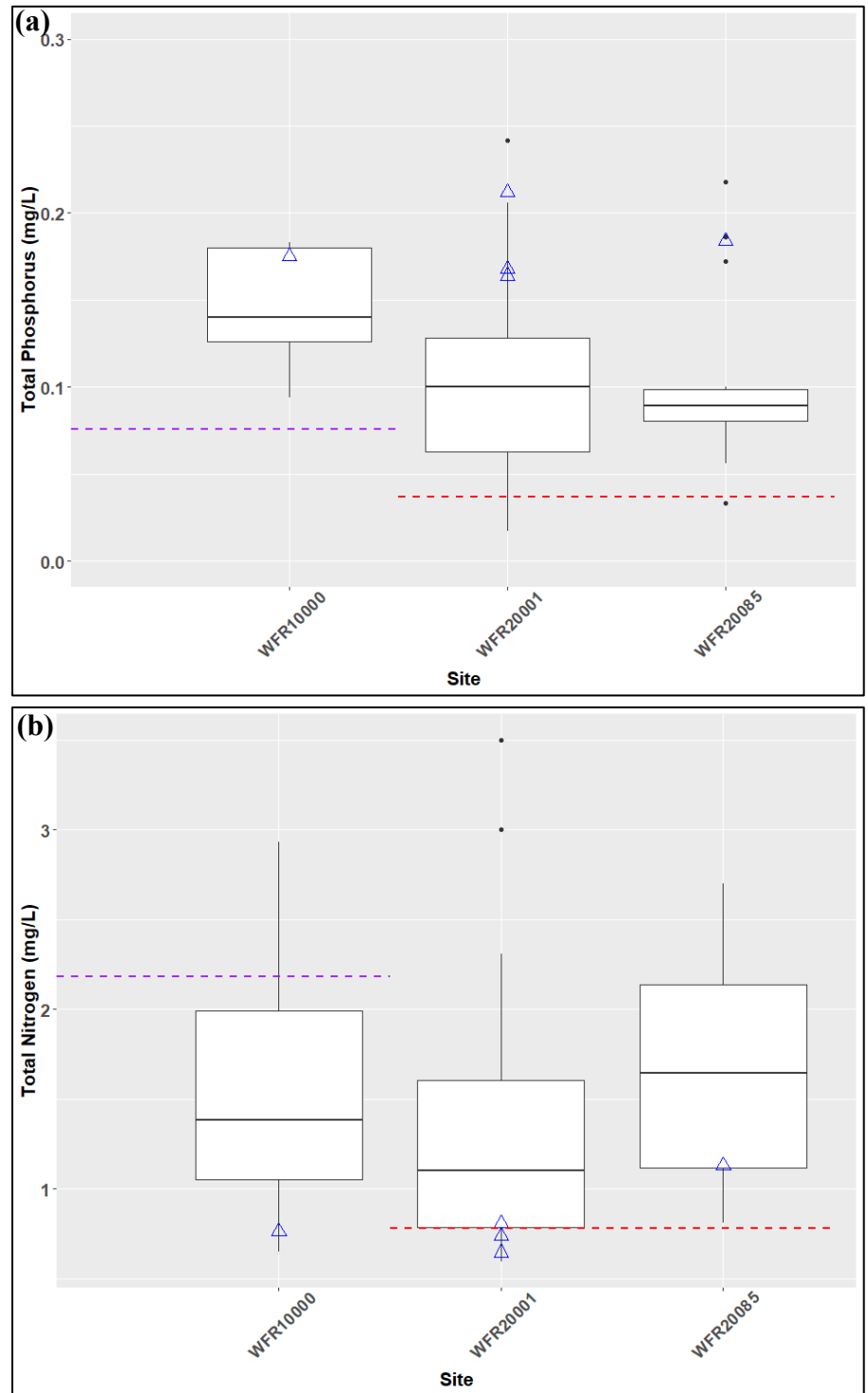


Figure 3. Comparison of West Fork Lake 2020 nutrient data to historical samples and nutrient criteria. Boxplots represent data collected in 2012-2019 and blue triangles represent 2020 data. Purple and red dotted lines represent USEPA recommended nutrient criteria for streams and reservoirs, respectively. (a) Comparison of total phosphorus data. Four outliers (values range from 0.359 to 0.538 mg/L) were excluded to make plot easier to interpret. (b) Comparison of total nitrogen data.

Harmful Algal Bloom (HAB) Response

Ohio EPA is the lead agency for HAB response in Ohio, and Great Parks of Hamilton County (GPHC) manages recreation at West Fork Lake. Ohio EPA/GPHC did not issue any advisories for HABs at West Fork Lake in 2020.

TSI

The trophic state indices for Secchi depth [TSI(SD)], chlorophyll-*a* [TSI(CHL)], and total phosphorus [TSI(TP)] were calculated for two reservoir sites at West Fork Lake (Table 1). The mean categories of the three indices ranged from eutrophic to hypereutrophic, indicating a high to very high level of biological activity.

Table 1. Summary of calculated trophic state indices at West Fork Lake.

	Mean Score (range)	Mean Category (Range)
TSI(SD)	69 (65-73)	Hypereutrophic (Eutrophic-Hypereutrophic)
TSI(CHL)	61 (56-65)	Eutrophic
TSI(TP)	79 (78-79)	Hypereutrophic