2018 R.L. Harris Reservoir Report

Rivers and Reservoirs Monitoring Program

Alabama Department of Environmental Management

Field Operations Division
Rivers and Reservoirs Unit
March 2022

Rivers and Reservoirs Monitoring Program

2018

R.L. Harris Reservoir

Tallapoosa River Basin

Alabama Department of Environmental Management
Field Operations Division
Rivers and Reservoirs Unit

March 2022

TABLE OF CONTENTS

LIST OF ACRONYMS

A&I	Agriculture and Industry water supply use classification
ADEM	Alabama Department of Environmental Management
AGPT	Algal Growth Potential Test
APCo	Alabama Power Company
CHL a	Chlorophyll a
DO	Dissolved Oxygen
F&W	Fish and Wildlife
MAX	Maximum
MDL	Method Detection Limit
MIN	Minimum
MSC	Mean Standing Crop
NTU	Nephelometric Turbidity Units
OAW	Outstanding Alabama Waters
ONRW	Outstanding National Resource Water
PWS	Public Water Supply
QAPP	Quality Assurance Project Plan
RRMP	Rivers and Reservoirs Monitoring Program
S	Swimming and Other Whole Body Water-Contact Sports
SD	Standard Deviation
SOP	Standard Operating Procedures
TEMP	Temperature
TN	Total Nitrogen
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSI	Trophic State Index
TSS	Total Suspended Solids
USACE	United States Army Corp of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

R.L. Harris Reservoir, also known as Lake Wedowee, is located on the Tallapoosa River near Lineville, Alabama. The reservoir encompasses 9,870 acres and has approximately 367 miles of shoreline in Clay and Randolph Counties. While Harris was primarily constructed for hydro-power generation, it is also utilized for flood control, recreation, irrigation, and drinking water.

The Alabama Department of Environmental Management (ADEM) monitored Harris Reservoir as part of the 2015 and 2018 assessments of the Tallapoosa River basin under the Rivers and Reservoirs Monitoring Program (RRMP). ADEM began monitoring lake water quality statewide in 1985, followed by a second statewide survey in 1989. In 1990, the Reservoir Water Quality Monitoring Program (now known as the RRMP) was initiated by the Field Operations Division of the ADEM. The current objectives of this program are to provide data that can be used to assess current water quality conditions, to identify trends in water quality conditions, and to develop Total Maximum Daily Loads (TMDLs) and water quality criteria. Descriptions of all RRMP monitoring activities are available in ADEM's 2017 Monitoring Strategy (ADEM 2017). The original 50 year license issued by the Federal Power Commission (now the Federal Energy Regulatory Commission or FERC) for the Harris project took effect when the dam was completed in 1983 and will expire in 2023. The data contained in this report, while being utilized by the Department for normal operations, will also be included in the Alabama Power Company re-licensing process.

A consumption advisory was issued for Harris Reservoir by the Alabama Department of Public Health (ADPH) in 2016 due to mercury found in fish tissue. As a result, Harris was placed on Alabama's 2018 Clean Water Act (CWA) §303(d) list of impaired waters for not meeting its Swimming and Fish & Wildlife (S/F&W) water use classifications for mercury caused by atmospheric deposition.

Specific water quality criteria for nutrient management were implemented in 2001 at two locations on Harris (Table 1). These criteria represent growing season mean (April-October) chlorophyll *a* (chl *a*) concentrations that are protective of the reservoir's Swimming and Fish & Wildlife (S/F&W) use classifications.

The purpose of this report is to summarize data collected at six stations in Harris Reservoir during the 2015 and 2018 growing seasons and to evaluate trends in mean lake trophic status and nutrient concentrations using ADEM's historic dataset. Monthly and mean concentrations of nutrients [total nitrogen (TN); total phosphorus (TP)], algal biomass/productivity [chl *a*; algal growth potential testing (AGPT)], sediment [total suspended solids (TSS)], and trophic state [Carlson's trophic state index (TSI)] were compared to ADEM's existing data and established criteria.

METHODS

Sampling stations were selected using historical data and previous assessments (Figure 1). Specific location information is provided in Table 1. Harris was sampled in the upper reservoir, mid reservoir (just upstream of its confluence with the Little Tallapoosa River) and dam forebay. Tributary embayment monitoring stations include the Little Tallapoosa River, Mad Indian Creek, and Wedowee Creek.

Water quality sampling was conducted at monthly intervals throughout the growing season, April-October. All samples were collected, preserved, stored, and transported according to procedures in the ADEM Field Operations Division Standard Operating Procedures (ADEM 2018a), Surface Water Quality Assurance Project Plan (ADEM 2018b) and Quality Management Plan (ADEM 2018c).

Mean growing season TN, TP, chl *a,* and TSS were calculated to evaluate water quality conditions at each site. For mainstem stations, monthly concentrations of these parameters were graphed with the closest available Alabama Power flow data and ADEM's previously collected data to help interpret the results.

Figure 1. Harris Reservoir with sampling locations. A description of each sampling location is provided in Table 1.

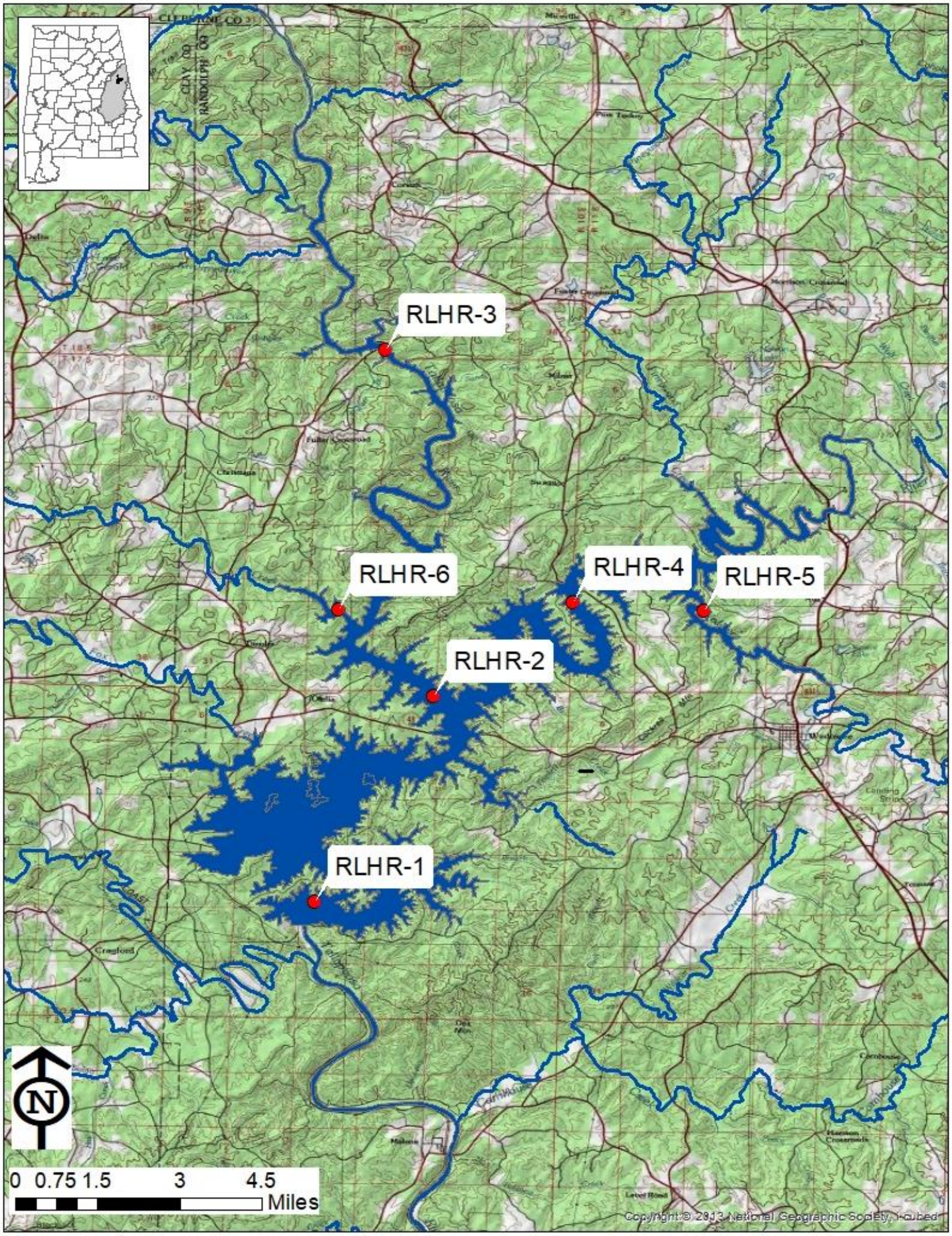


Table 1. Location information, station description, county, waterbody, chl *a* criteria, and latitude and longitude for monitoring stations in Harris Reservoir.

Station	Report Designation	12 digit HUC	County	Waterbody	Station Description	Chl *a* Criteria	Latitude	Longitude
RLHR-1*	Lower	0315-0109-0105	Randolph	Tallapoosa R	Deepest point, main river channel, dam forebay.	10 μg/L	33.2641	-85.6127
RLHR-2*	Mid	0315-0108-1006	Randolph	Tallapoosa R	Deepest point, main river channel, immediately upstream of Tallapoosa River/Little Tallapoosa River confluence.	12 μg/L	33.3184	-85.5811
RLHR-3	Upper	0315-0108-1006	Randolph	Tallapoosa R	Deepest point, main river channel, immediately downstream of Randolph Co. Hwy 82 bridge.		33.4100	-85.5939
RLHR-4	L. Tallapoosa	0315-0108-0906	Randolph	Little Tallapoosa R	Deepest point, Little Tallapoosa River channel, immediately downstream of Randolph Co. Hwy 29.		33.3431	-85.5444
RLHR-5	Wedowee	0315-0108-0904	Randolph	Wedowee Cr	Deepest point, main creek channel, Wedowee Creek embayment, approximately 0.5 miles upstream of lake confluence.		33.3408	-85.5097
RLHR-6	Mad Indian	0315-0108-1005	Randolph	Mad Indian Cr	Deepest point, main creek channel, Mad Indian Creek embayment, approximately 0.5 miles upstream of lake confluence.		33.3414	-85.6064

*Growing season mean chl *a* criteria implemented at this station in 2001

RESULTS

Growing season mean graphs for TN, TP, chl *a*, and TSS are provided in this section (Figure 2-5). Monthly graphs for TN, TP, chl *a*, TSS, DO, and TSI are also provided (Figures 6-11 and 16-17), with mean monthly discharge included as an indicator of flow and retention time in the months sampled. AGPT results appear in Table 2. Depth profile graphs of temperature, conductivity, and DO appear in Figures 12-15. Summary statistics of all data collected during 2015 and 2018 are presented in Appendix Table 1 and Appendix Table 2. The tables contain the minimum, maximum, median, mean, and standard deviation of each parameter analyzed.

Stations with the highest concentrations of nutrients, chlorophyll *a*, and TSS are noted in the paragraphs to follow. Though stations with lowest concentrations may not be mentioned, review of the graphs that follow will indicate these stations that may be potential candidates for reference waterbodies and watersheds.

In 2015 and 2018, the highest mean growing season TN value among mainstem stations was in the upper station, while the highest value among tributary stations was in Wedowee Creek (Figure 2). In 2015, historic monthly high TN concentrations were measured in the Little Tallapoosa in April, in the mid station in July and October, and in the lower station in September (Figure 6). In 2018, historic monthly high TN concentrations were measured in the upper station in April.

In 2015 and 2018, the highest mean growing season TP value among mainstem stations was in the upper station, while the highest value among tributary stations was in Wedowee Creek (Figure 3). Growing season mean TP values at mainstem stations appeared to decline 1997 through 2008 and have stabilized since 2010. Mean values in tributary stations also appear to have stabilized since 2010. All 2015 and 2018 monthly TP concentrations were below historic means (Figure 7).

Mean growing season chl *a* concentrations in both the mid and lower stations increased between 2015 and 2018 but remained below the established criteria for nutrient management. In 2015 and 2018, the highest mean growing season chl *a* value among mainstem stations was in the upper station. The highest value among tributary stations was in Mad Indian Creek in 2015 and in Little Tallapoosa River in 2018 (Figure 4). Mean concentrations in all stations were lower in 2018 than they were in 2005 and appear to have stabilized. Monthly chl *a* concentrations during 2015 were highest in August in the Little Tallapoosa and upper stations and highest in July in the mid and lower stations (Figure 8). During 2018, concentrations were highest in April and May in the lower and Little Tallapoosa stations, respectively, and then values declined through the growing season. The highest concentrations in the mid and upper stations were measured in June and July, respectively. Historic high chl *a* concentrations were measured in the upper station in August 2015 and July 2018.

In both 2015 and 2018, the highest mean growing season TSS value among mainstem stations was in the upper station, while the highest value among tributary stations was in Little Tallapoosa in 2015 and in Wedowee Creek in 2018 (Figure 5). Overall, growing season mean TSS concentrations appeared to decrease at all mainstem stations since sampling began in 1997. Most monthly TSS concentrations were near or below historic means (Figure 9).

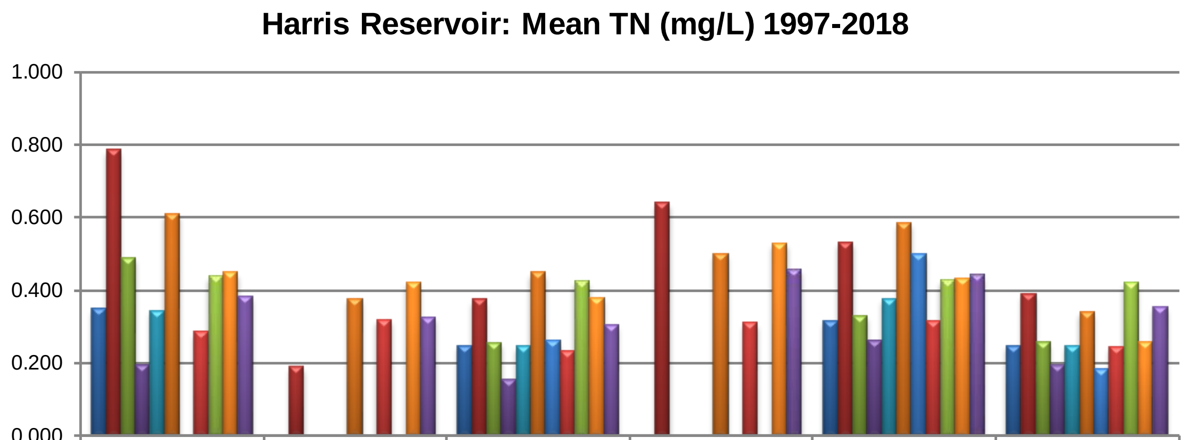
AGPT results from 2015 indicate a mix of nitrogen, phosphorus, and co-limited locations. MSC results were less than 5 mg/L in the lower, mid, Little Tallapoosa River, and Mad Indian Creek stations, the value the Raschke and Schultz (1987) defined as protective of reservoir and lake systems (Table 2). MSC results for the upper and Wedowee Creek stations were less than 20 mg/L, the value that Raschke and Schultz (1987) defined as protective of flowing stream and river systems.

All measurements of dissolved oxygen concentrations in Harris Reservoir during 2015 and 2018 were above the ADEM criteria limit of 5.0 mg/L at 5.0 ft (1.5 m) (ADEM Admin. Code R. 335-6-10-.09) (Figures 10 & 11). Based on monthly profiles, DO and temperature stratification occurred at both the lower and mid stations April-October of 2015 and May-October of 2018 (Figures 12-15). DO concentrations were generally much lower below the 5 meter depth. Highest water temperatures were measured in July during both 2015 and 2018. Conductivity measurements in the lower part of the water column of the mid station increased sharply during September and October in 2015. Conductivity measurements also increased sharply in the lower part of the water column of the mid station in June through October of 2018.

Monthly TSI values were calculated using chl *a* values and Carlson's Trophic State Index (Carlson 1977). During 2015, TSI values at the upper station were eutrophic July through October (Figures 16 & 17). The mid station was eutrophic in July, while the lower station did not reach eutrophic conditions. The Little Tallapoosa River station was eutrophic July-September, Mad

Indian Creek was eutrophic in August, and Wedowee Creek was eutrophic, or near eutrophic, July-October. During 2018, the upper station was eutrophic April, July, August, and October. The mid station was eutrophic June-September, and the lower station was eutrophic April, June, and July. The Little Tallapoosa River station was eutrophic, or near eutrophic, April-September. The Mad Indian Creek station was eutrophic April, June, August, and October, and Wedowee Creek was eutrophic May, July, and October.

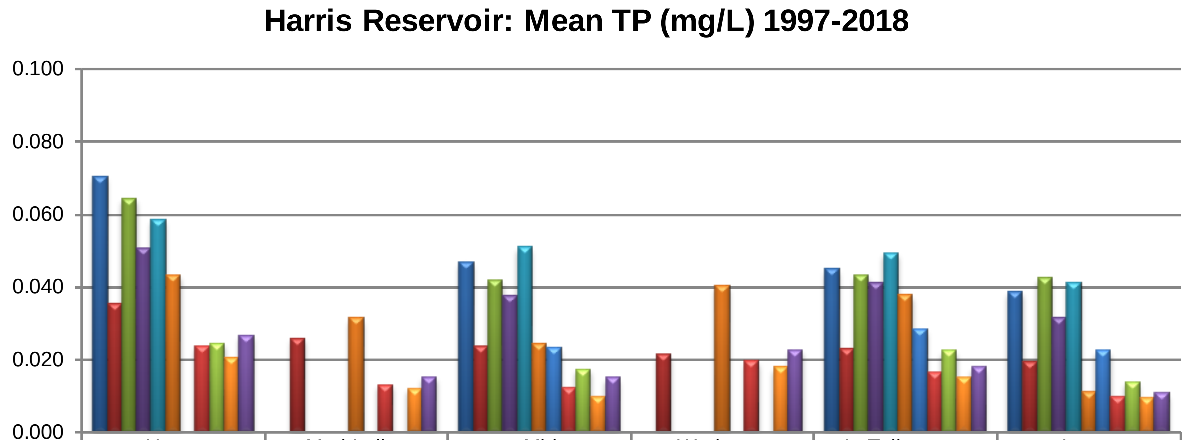
Figure 2. Mean growing season TN measured in Harris Reservoir, April-October 1997-2018. Bar graphs consist of multiple stations, illustrated from upstream to downstream as the graph is read from left to right.



	Upper	Mad Indian	Mid	Wedowee	L. Tallapoosa	Lower
1997	0.349		0.249		0.317	0.248
2000	0.788	0.189*	0.375	0.641*	0.532	0.391
2002	0.491		0.256		0.330	0.257
2003	0.195		0.153		0.260	0.192
2004	0.345		0.246		0.376	0.249
2005	0.612	0.376	0.450	0.502	0.587	0.341
2008			0.261		0.500	0.183
2010	0.286	0.319	0.232	0.311	0.315	0.245
2013	0.439		0.425		0.429	0.422
2015	0.450	0.424	0.381	0.529	0.433	0.258
2018	0.383	0.326	0.305	0.458	0.443	0.355

*Mean of April, June, August.

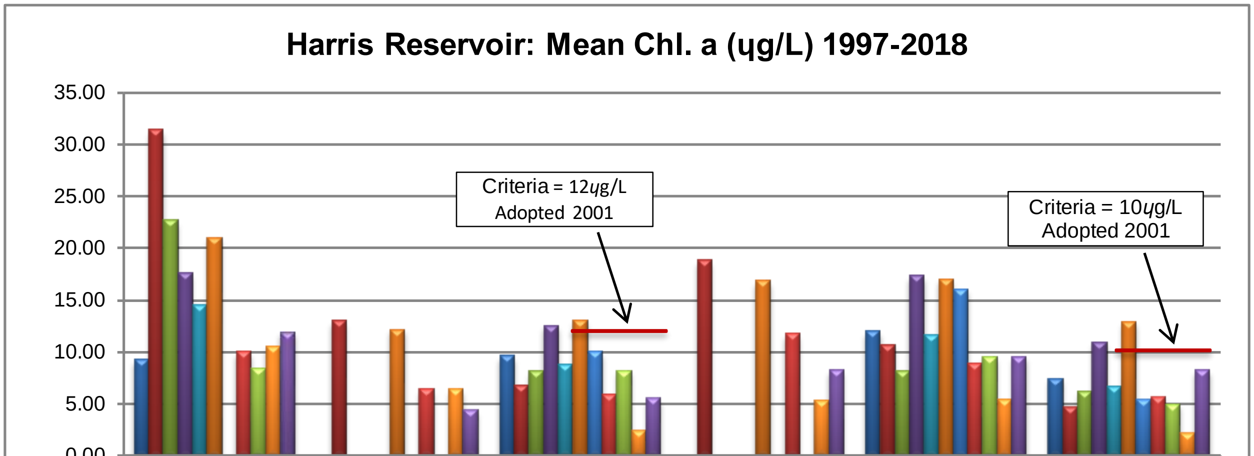
Figure 3. Mean growing season TP measured in Harris Reservoir, April-October 1997-2018. Bar graphs consist of multiple stations, illustrated from upstream to downstream as the graph is read from left to right.



	Upper	Mad Indian	Mid	Wedowee	L. Tallapoosa	Lower
1997	0.071		0.047		0.045	0.039
2000	0.036	0.026 *	0.024	0.022*	0.023	0.019
2002	0.064		0.042		0.043	0.042
2003	0.051		0.037		0.041	0.032
2004	0.059		0.051		0.049	0.041
2005	0.043	0.031	0.024	0.040	0.038	0.011
2008			0.023		0.029	0.023
2010	0.024	0.013	0.012	0.020	0.016	0.010
2013	0.025		0.017		0.023	0.014
2015	0.021	0.012	0.010	0.018	0.015	0.010
2018	0.027	0.015	0.015	0.023	0.018	0.011

*Mean of April, June, August.

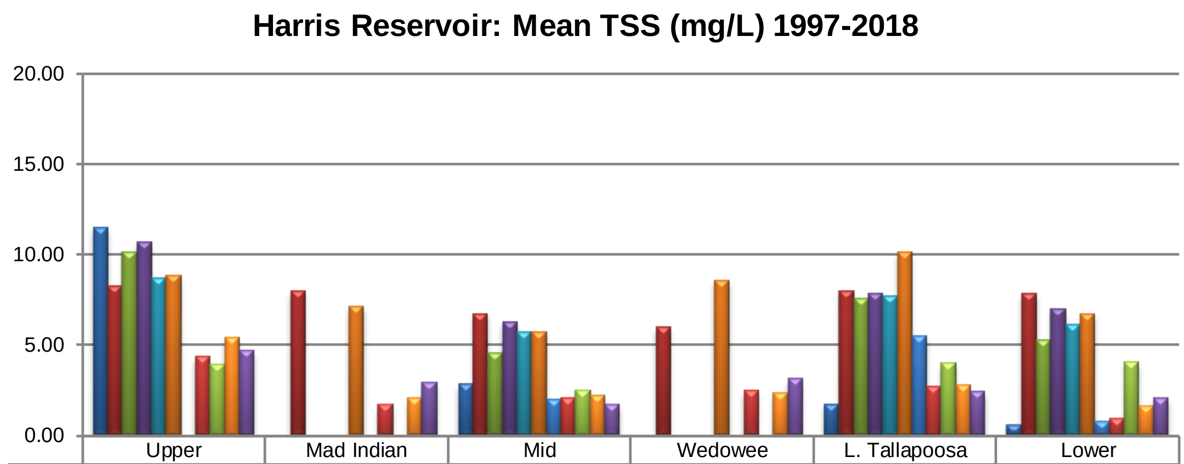
Figure 4. Mean growing season chlorophyll *a* measured in Harris Reservoir, April-October 1997-2018. Bar graphs consist of multiple stations, illustrated from upstream to downstream as the graph is read from left to right.



	Upper	Mad Indian	Mid	Wedowee	L. Tallapoosa	Lower
1997	9.26		9.61		12.02	7.42
2000	31.41	12.99 *	6.83	18.82*	10.68	4.66
2002	22.74		8.11		8.21	6.22
2003	17.57		12.56		17.35	10.95
2004	14.52		8.77		11.62	6.73
2005	21.06	12.18	13.07	16.84	17.01	12.92
2008			9.99		16.02	5.37
2010	10.02	6.39	5.92	11.73	8.93	5.64
2013	8.41		8.19		9.53	4.96
2015	10.50	6.38	2.44	5.32	5.43	2.21
2018	11.92	4.40	5.49	8.24	9.59	8.26

*Mean of April, June, August.

Figure 5. Mean growing season TSS measured in Harris Reservoir, April-October 1997-2018. Bar graphs consist of multiple stations, illustrated from upstream to downstream as the graph is read from left to right.



	Upper	Mad Indian	Mid	Wedowee	L. Tallapoosa	Lower
1997	11.50		2.83		1.75	0.58
2000	8.29	8.00 *	6.71	6.00 *	8.00	7.86
2002	10.14		4.57		7.57	5.29
2003	10.71		6.29		7.86	7.00
2004	8.71		5.71		7.71	6.14
2005	8.86	7.14	5.71	8.57	10.14	6.71
2008			2.00		5.50	0.79
2010	4.36	1.71	2.07	2.50	2.71	0.93
2013	3.93		2.50		4.00	4.07
2015	5.43	2.07	2.21	2.36	2.79	1.64
2018	4.71	2.93	1.71	3.14	2.43	2.07

*Mean of April, June, August.

Figure 6. Monthly TN concentrations measured in Harris Reservoir, April-October 2015 and 2018 vs. average monthly discharge. Monthly discharge acquired from Alabama Power at Harris Reservoir Dam. Each bar graph depicts monthly changes in each station. The historic mean (1992-2018) and min/max ranges are also displayed for comparison. The “n” value equals the number of datapoints included in the monthly historic calculations.

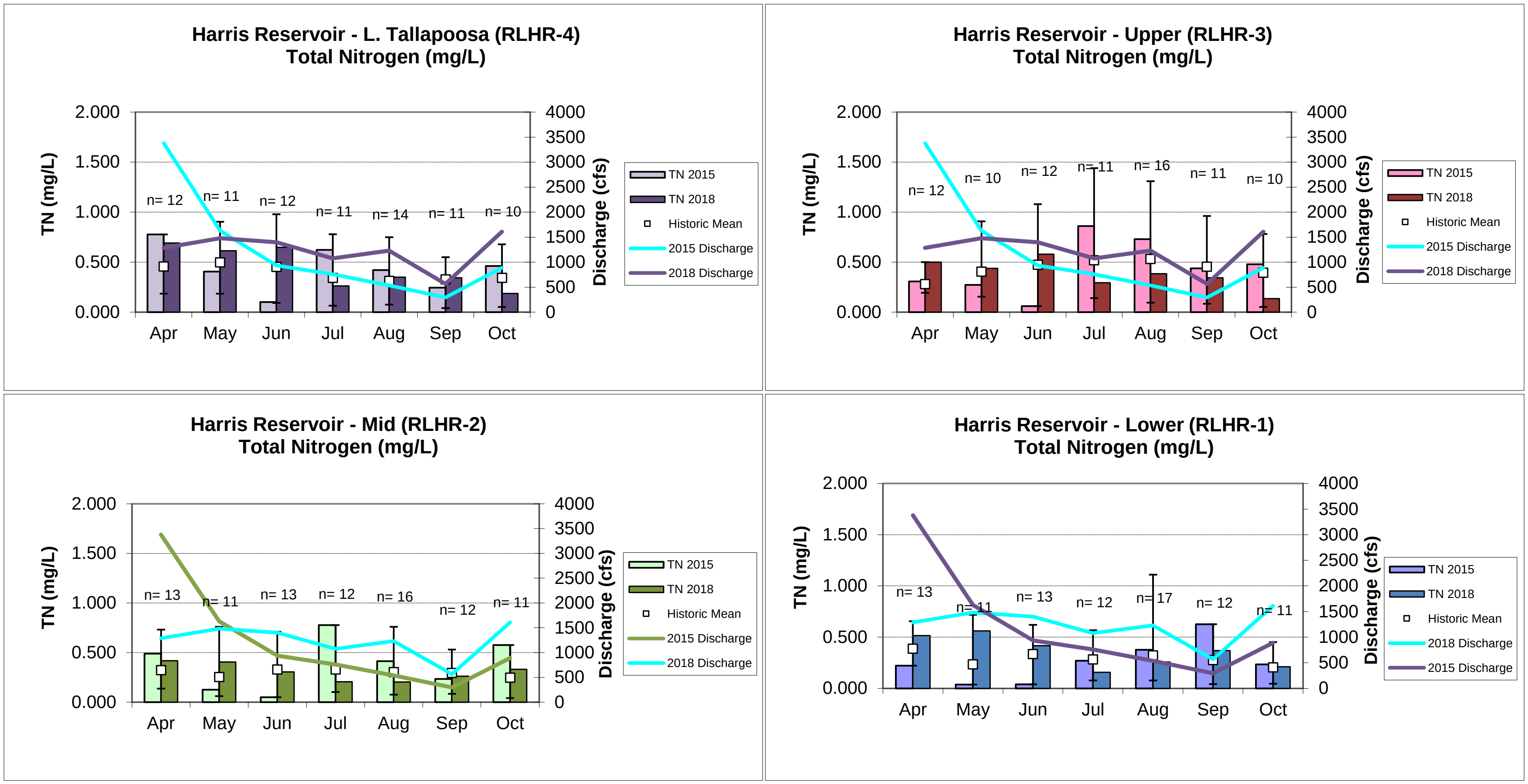


Figure 7. Monthly TP concentrations measured in Harris Reservoir, April-October 2015 and 2018 vs. average monthly discharge. Monthly discharge acquired from Alabama Power at Harris Reservoir Dam. Each bar graph depicts monthly changes in each station. The historic mean (1992-2018) and min/max ranges are also displayed for comparison. The "n" value equals the number of datapoints included in the monthly historic calculations.

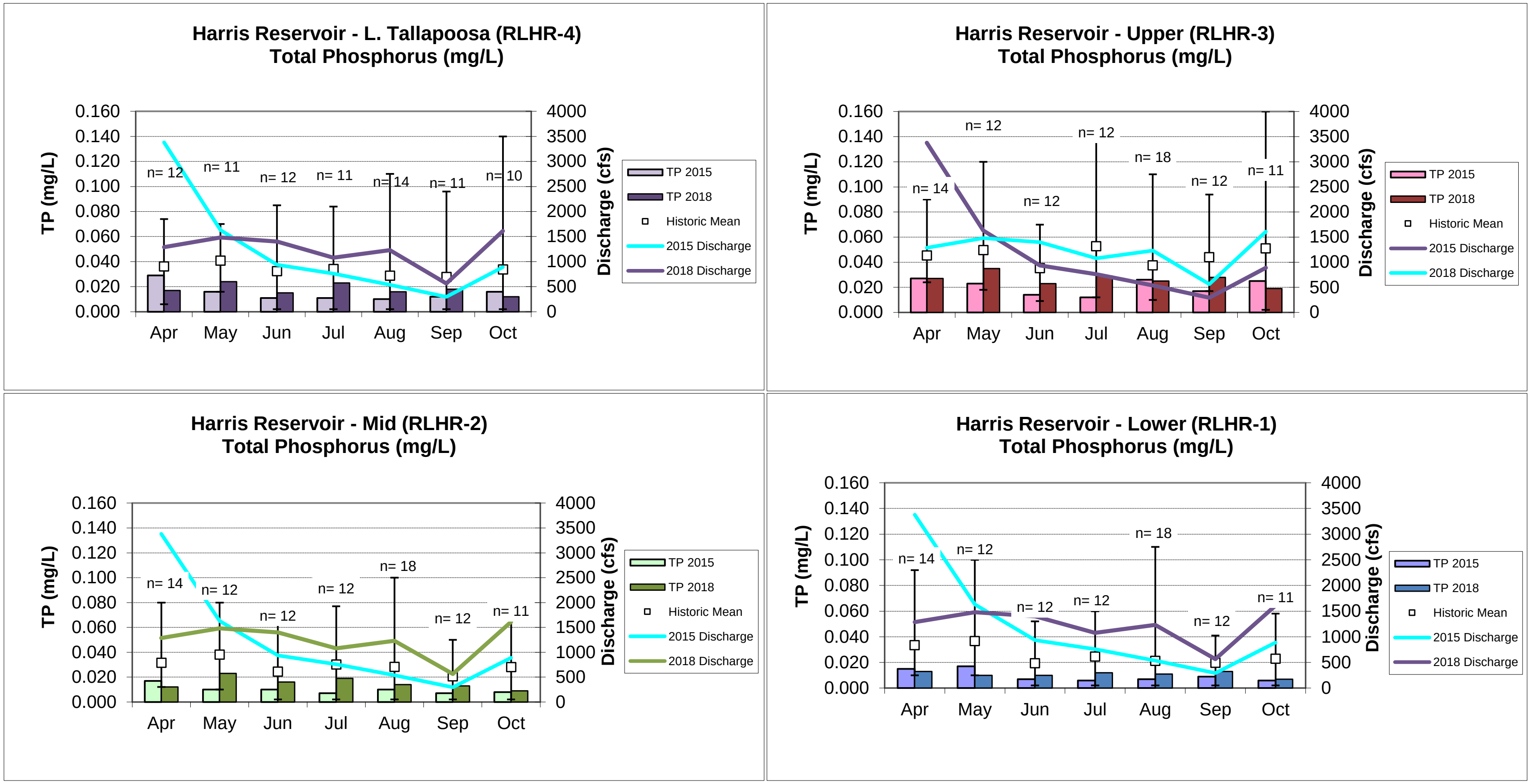


Figure 8. Monthly chl *a* concentrations measured in Harris Reservoir, April-October 2015 and 2018 vs. average monthly discharge. Monthly discharge acquired from Alabama Power at Harris Reservoir Dam. Each bar graph depicts monthly changes in each station. The historic mean (1992-2018) and min/max ranges are also displayed for comparison. The "n" value equals the number of datapoints included in the monthly historic calculations.

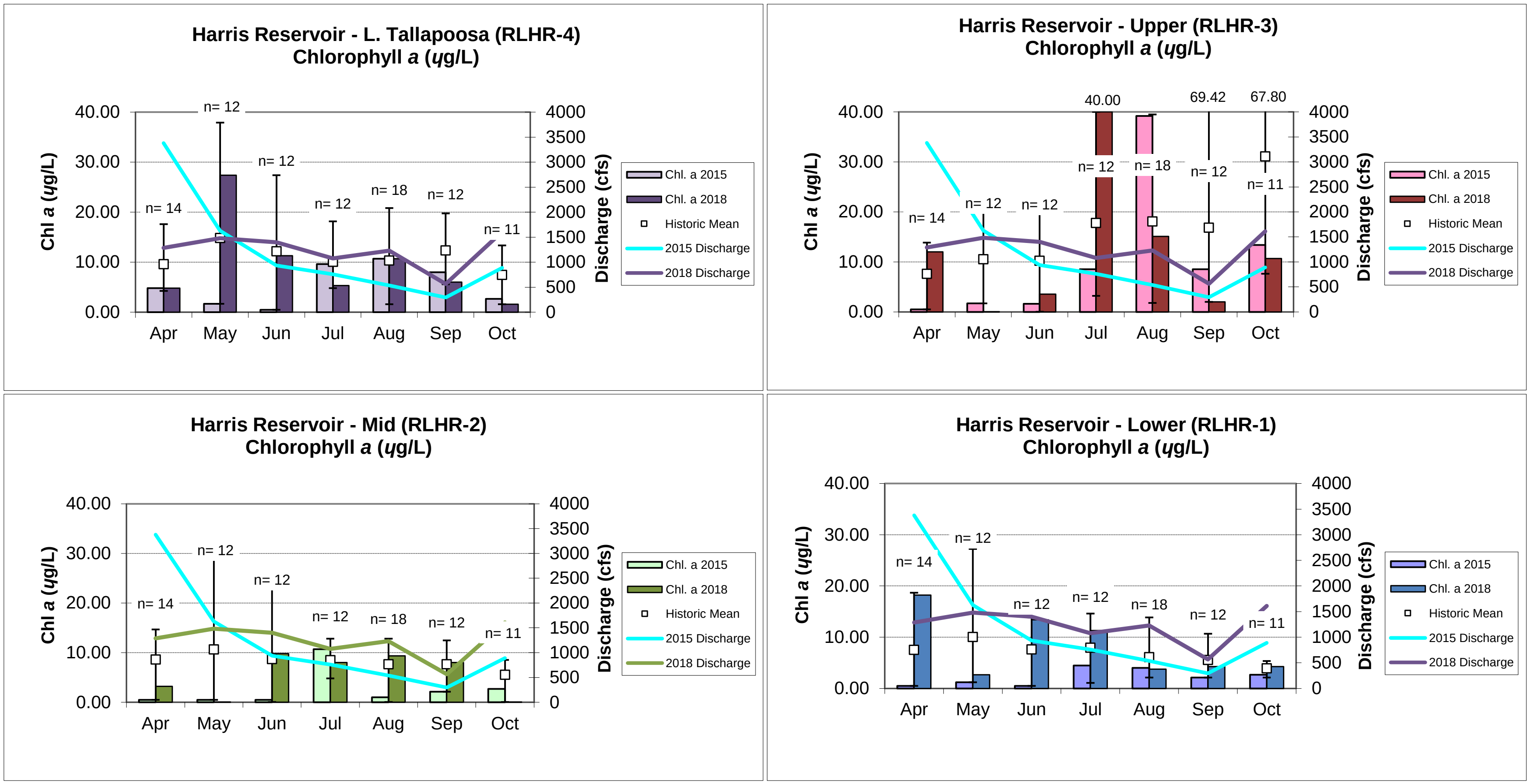


Figure 9. Monthly TSS concentrations measured in Harris Reservoir, April-October 2015 and 2018 vs. average monthly discharge. Monthly discharge acquired from Alabama Power at Harris Reservoir Dam. Each bar graph depicts monthly changes in each station. The historic mean (1992-2018) and min/max ranges are also displayed for comparison. The “n” value equals the number of datapoints included in the monthly historic calculations.

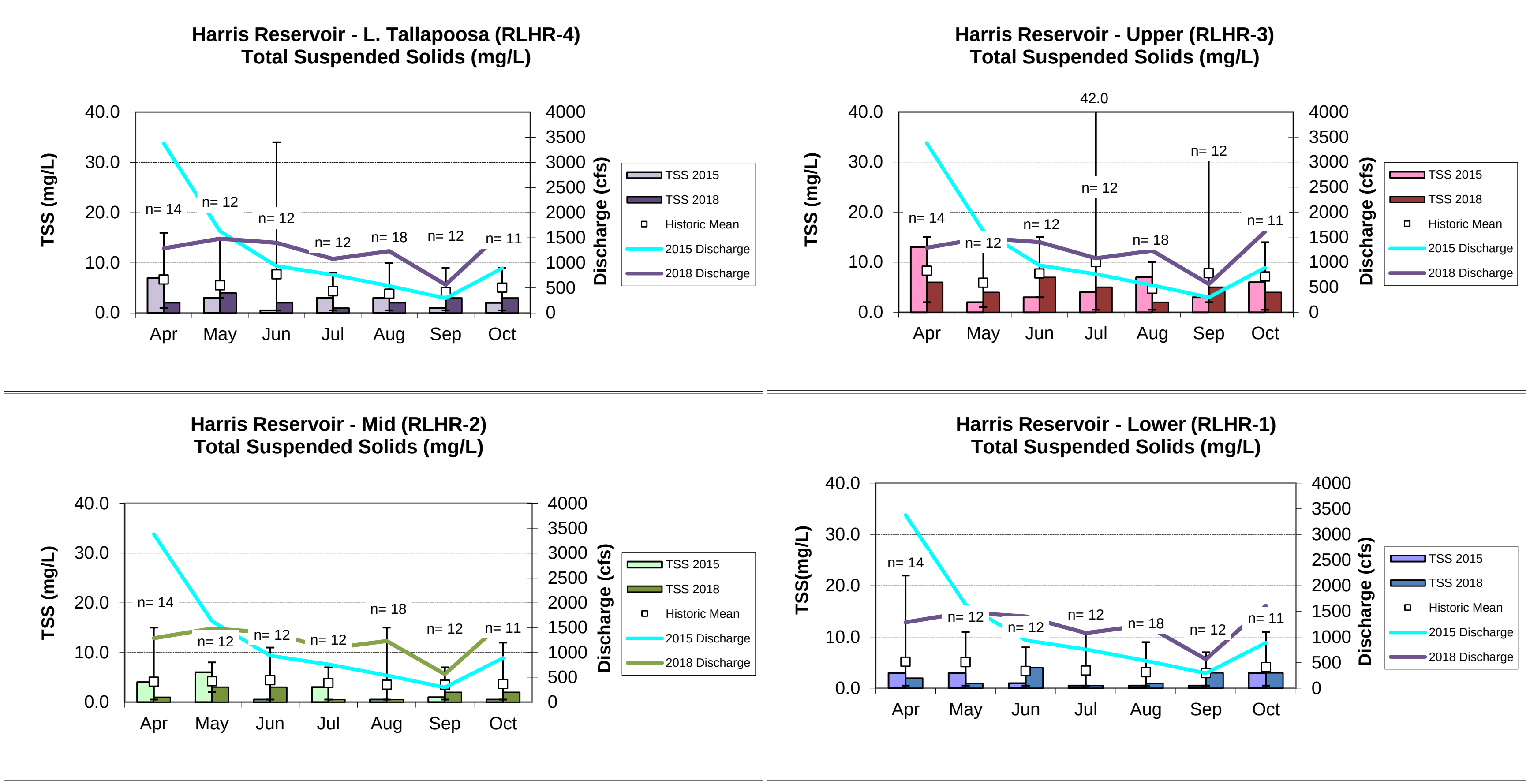
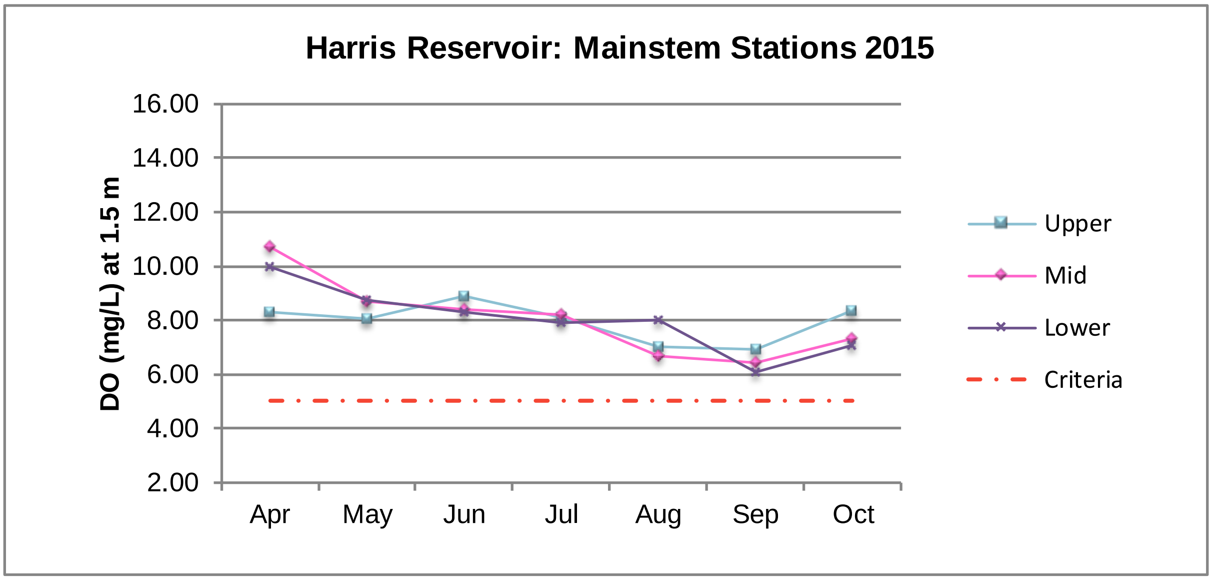


Table 2. Algal growth potential test (AGPT) results, Harris Reservoir, (expressed as mean Maximum Standing Crop (MSC) dry weights of *Selenastrum capricornutum* in mg/L) and limiting nutrient status. MSC values below 5 mg/L are considered to be protective in reservoirs and lakes (Raschke and Schultz 1987).

Station	**Mad Indian (RLHR-6)**		**Wedowee (RLHR-5)**		**L.Tallapoosa (RLHR-4)**		**Upper (RLHR-3)**		**Mid (RLHR-2)**		**Lower (RLHR-1)**	
	Control mean MSC	**Limiting Nutrient**	**Control mean MSC**	**Limiting Nutrient**	**Control mean MSC**	**Limiting Nutrient**	**Control mean MSC**	**Limiting Nutrient**	**Control mean MSC**	**Limiting Nutrient**	**Control mean MSC**	**Limiting Nutrient**
1997	---	---	---	---	3.55	Phosphorus	4.55	Phosphorus	1.82	Phosphorus	1.59	Phosphorus
2000	---	---	---	---	1.97	None	3.62	Nitrogen	1.59	Co-limiting	1.74	None
Apr 2004	---	---	---	---	3.75	Phosphorus	5.73	Phosphorus	3.16	Phosphorus	2.27	Phosphorus
May 2004	---	---	---	---	2.6	Phosphorus	3.49	Phosphorus	2.8	Phosphorus	2.33	Phosphorus
Jun 2004	---	---	---	---	3.91	Phosphorus	8.21	Phosphorus	2.99	Phosphorus	2.91	Phosphorus
Jul 2004	---	---	---	---	3.74	Phosphorus	5.48	Phosphorus	3.61	Phosphorus	2.61	Phosphorus
Aug 2004	---	---	---	---	1.1	Phosphorus	1.83	Phosphorus	0.96	Phosphorus	0.99	Phosphorus
Sep 2004	---	---	---	---	4.72	Phosphorus	7.33	Co-limiting	3.31	Phosphorus	1.32	Phosphorus
Oct 2004	---	---	---	---	3.8	Phosphorus	6.16	Phosphorus	3.03	Phosphorus	2.65	Phosphorus
2005	---	---	---	---	5.46	Phosphorus	7.46	Phosphorus	2.9	Co-limiting	2.91	Phosphorus
2010	1.51	Phosphorus	---	---	1.93	Co-limiting	---	---	---	---	---	---
2015	3.47	Phosphorus	6.21	Co-limiting	4.27	Phosphorus	5.26	Nitrogen	2.26	Co-limiting	2.32	Phosphorus

Figure 10. Monthly DO concentrations at 1.5 m (5 ft) for Harris Reservoir stations collected April-October 2015. ADEM Water Quality Criteria pertaining to reservoir waters require a minimum DO concentration of 5.0 mg/L at this depth (ADEM 2017).



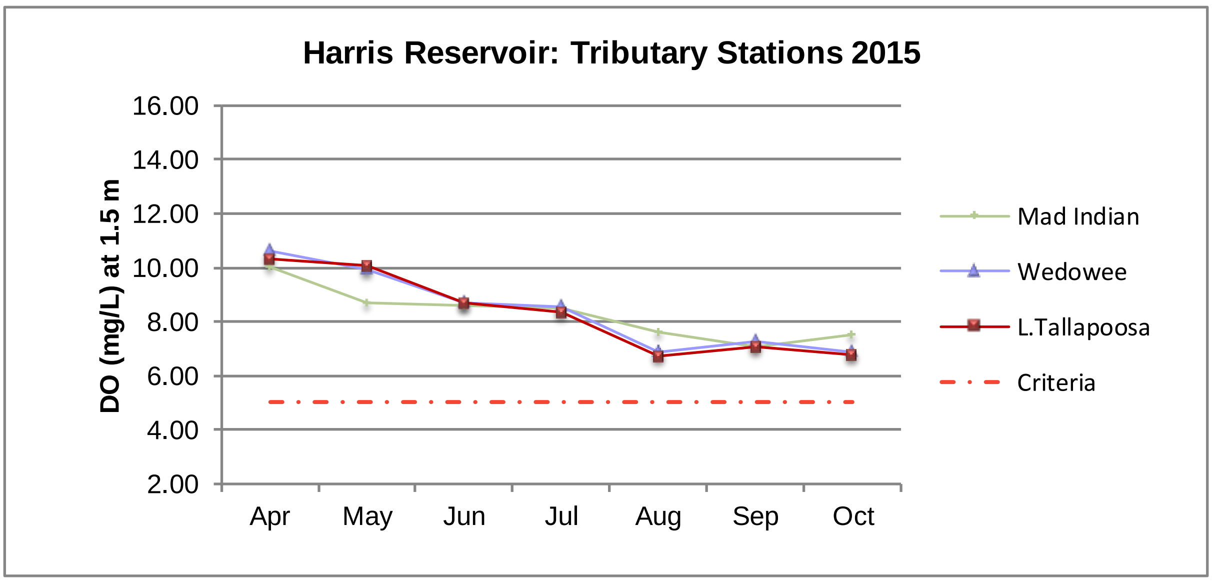
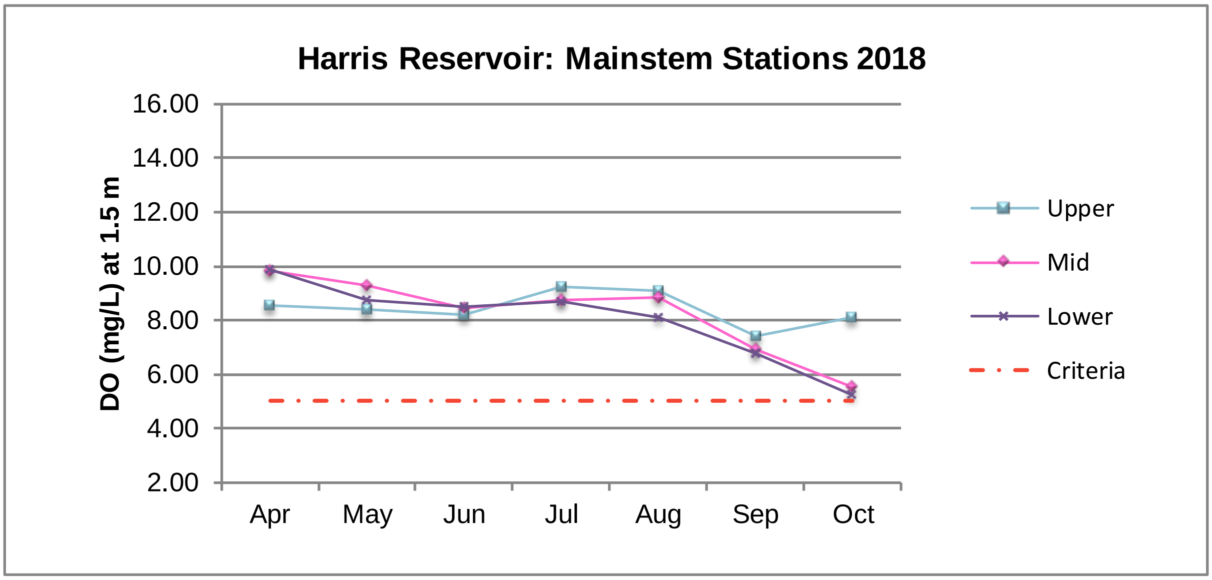


Figure 11. Monthly DO concentrations at 1.5 m (5 ft) for Harris Reservoir stations collected April-October 2018. ADEM Water Quality Criteria pertaining to reservoir waters require a minimum DO concentration of 5.0 mg/L at this depth (ADEM 2017).



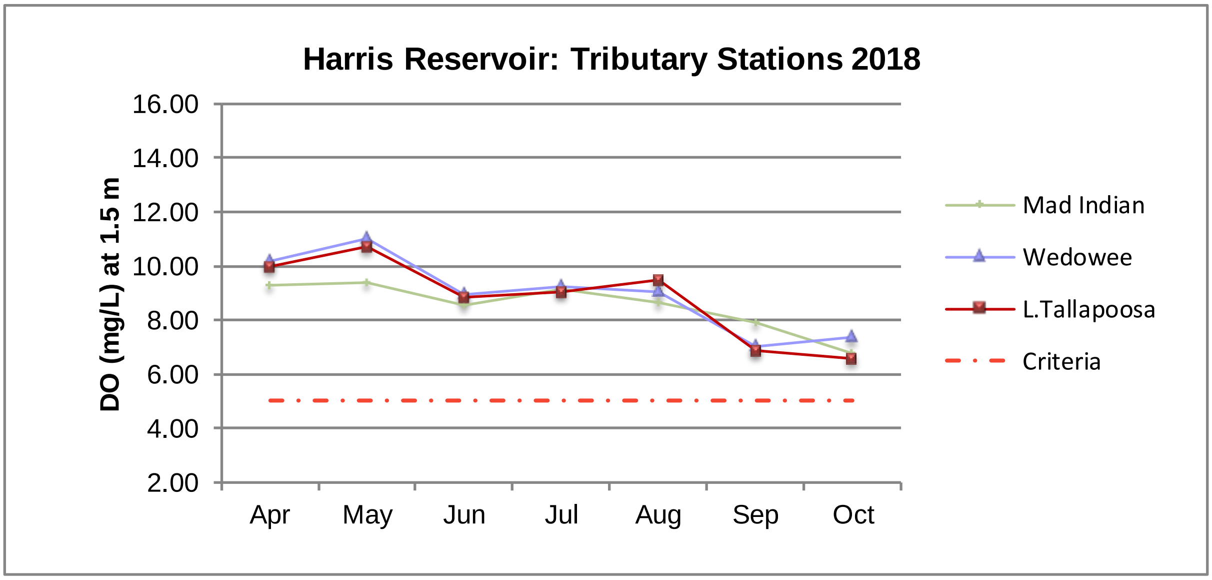


Figure 12. Monthly depth profiles of dissolved oxygen, temperature, and conductivity in the mid Harris Reservoir station, April-October 2015.

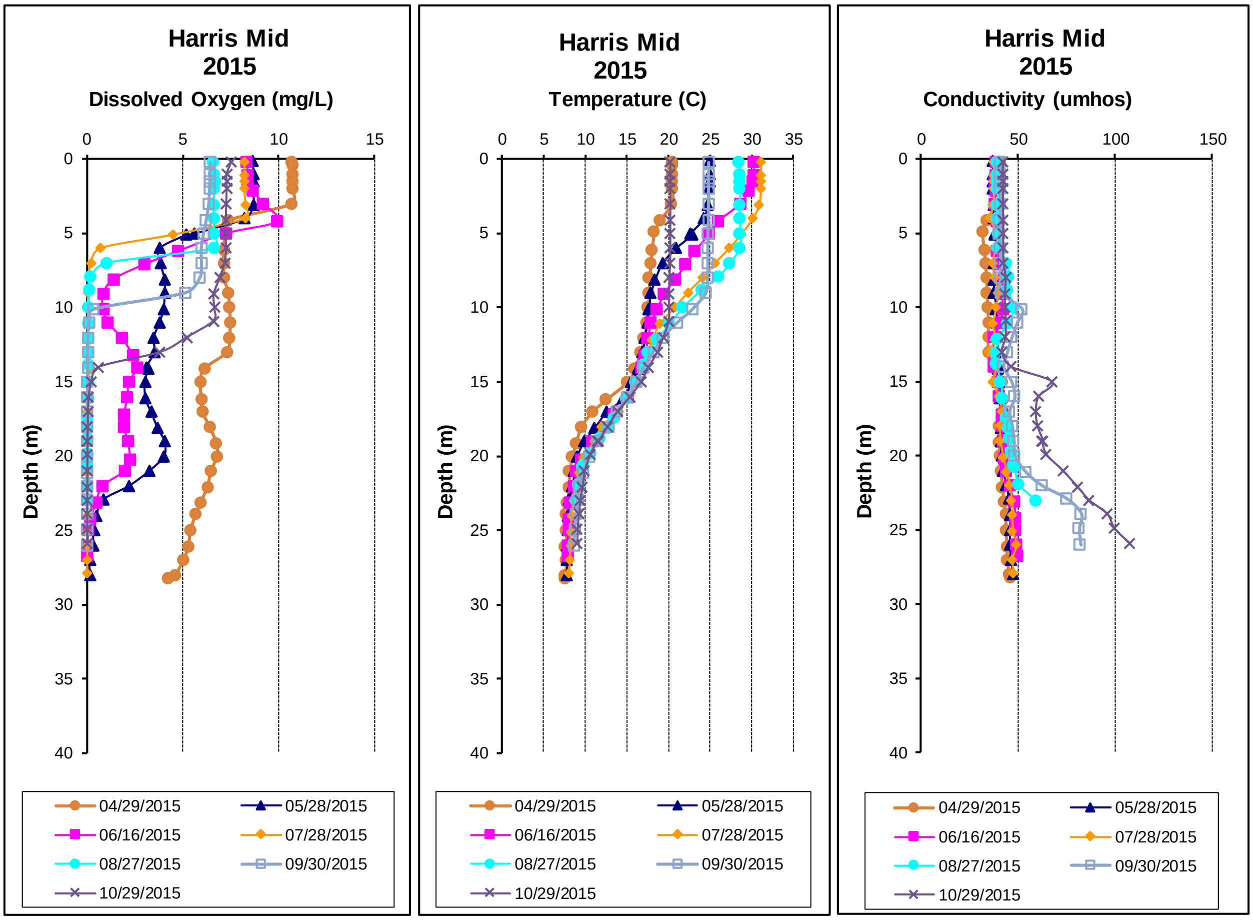


Figure 13. Monthly depth profiles of dissolved oxygen, temperature, and conductivity in the lower Harris Reservoir station, April-October 2015.

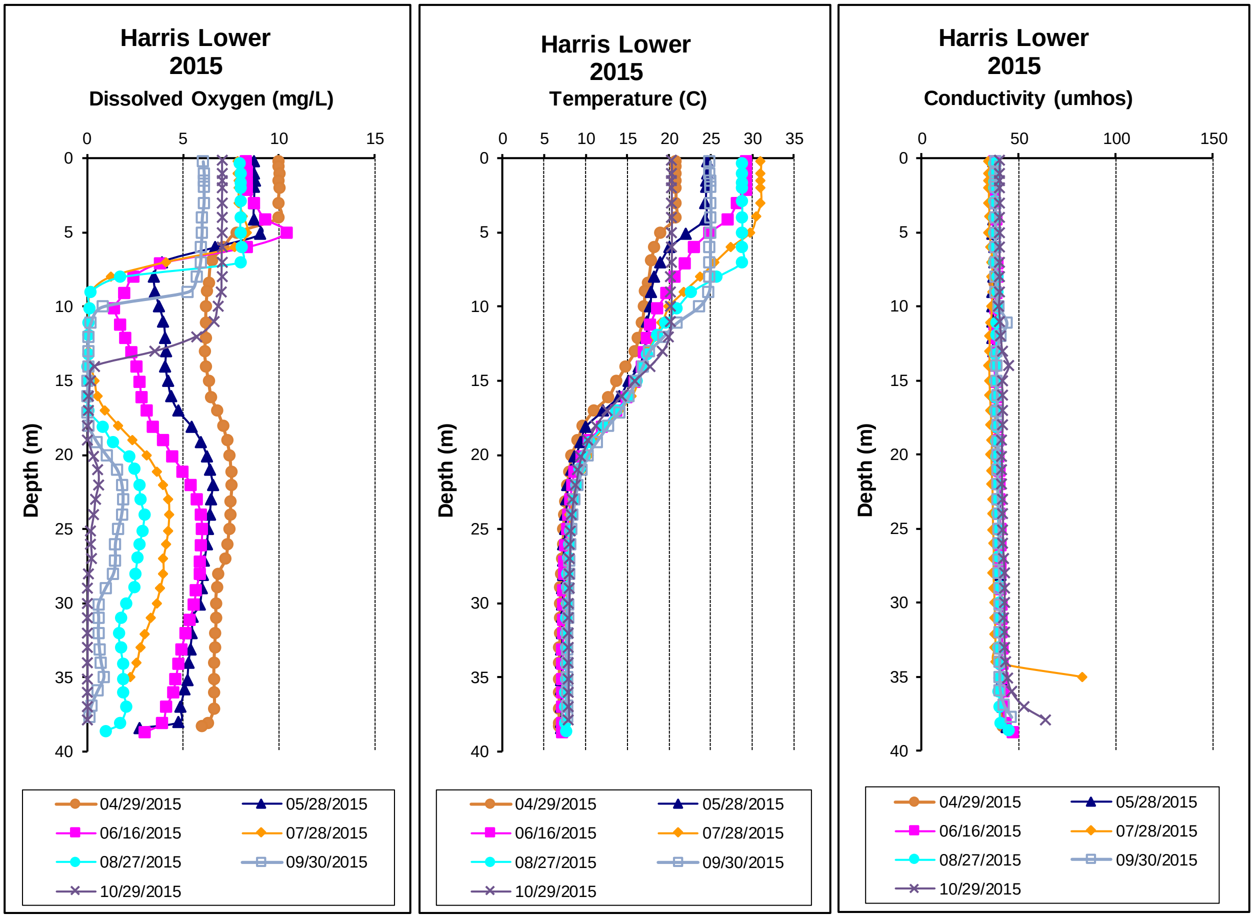


Figure 14. Monthly depth profiles of dissolved oxygen, temperature, and conductivity in the mid Harris Reservoir station, April-October 2018.

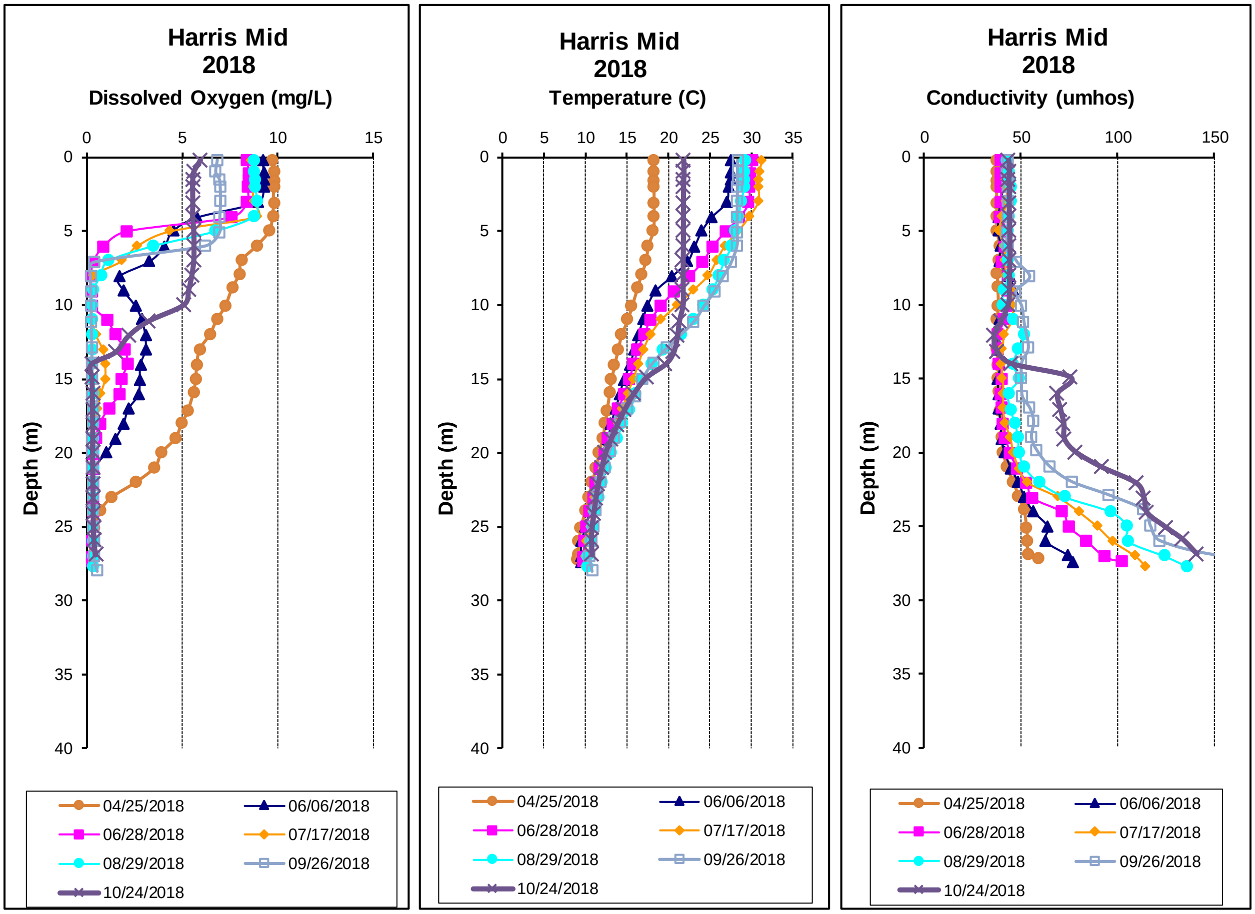


Figure 15. Monthly depth profiles of dissolved oxygen, temperature, and conductivity in the lower Harris Reservoir station, April-October 2018.

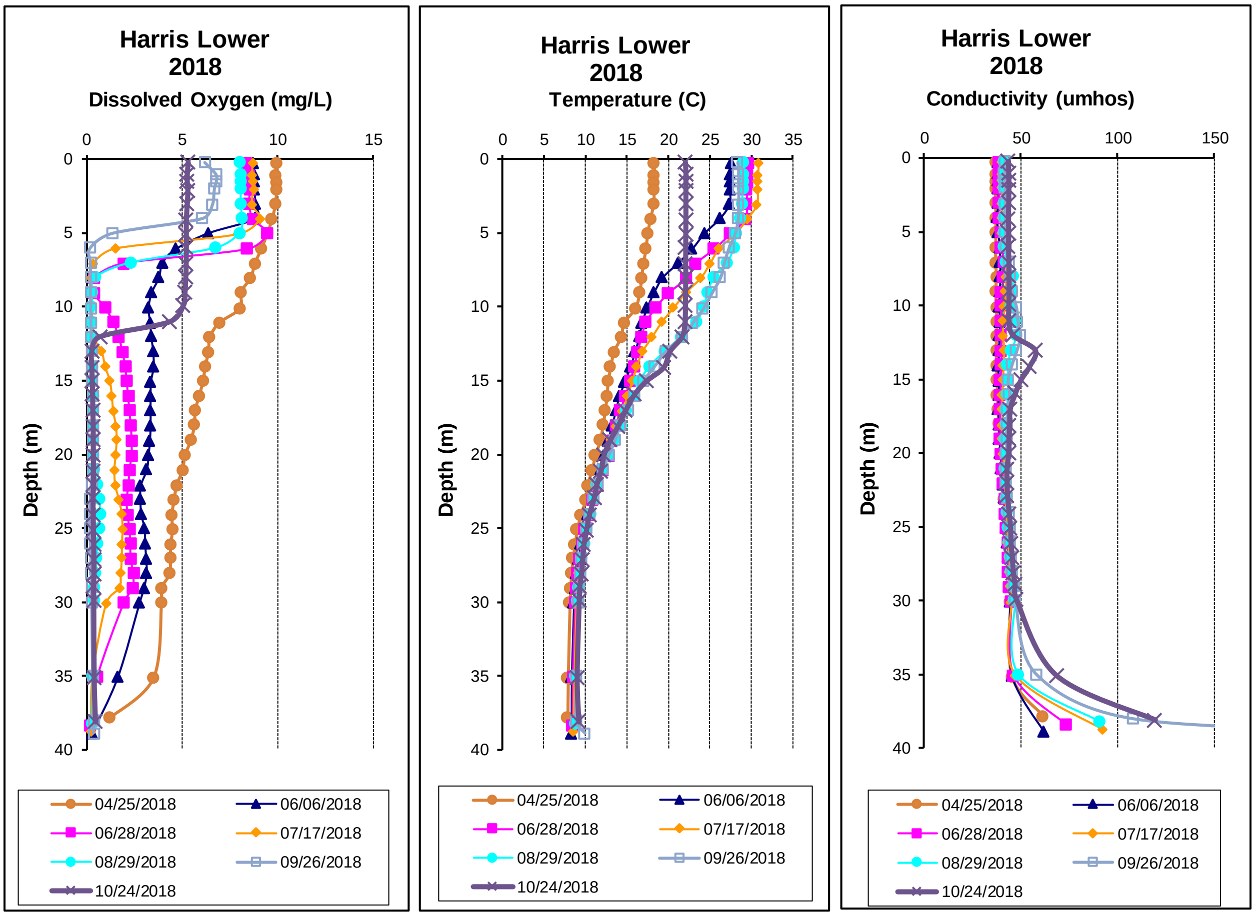
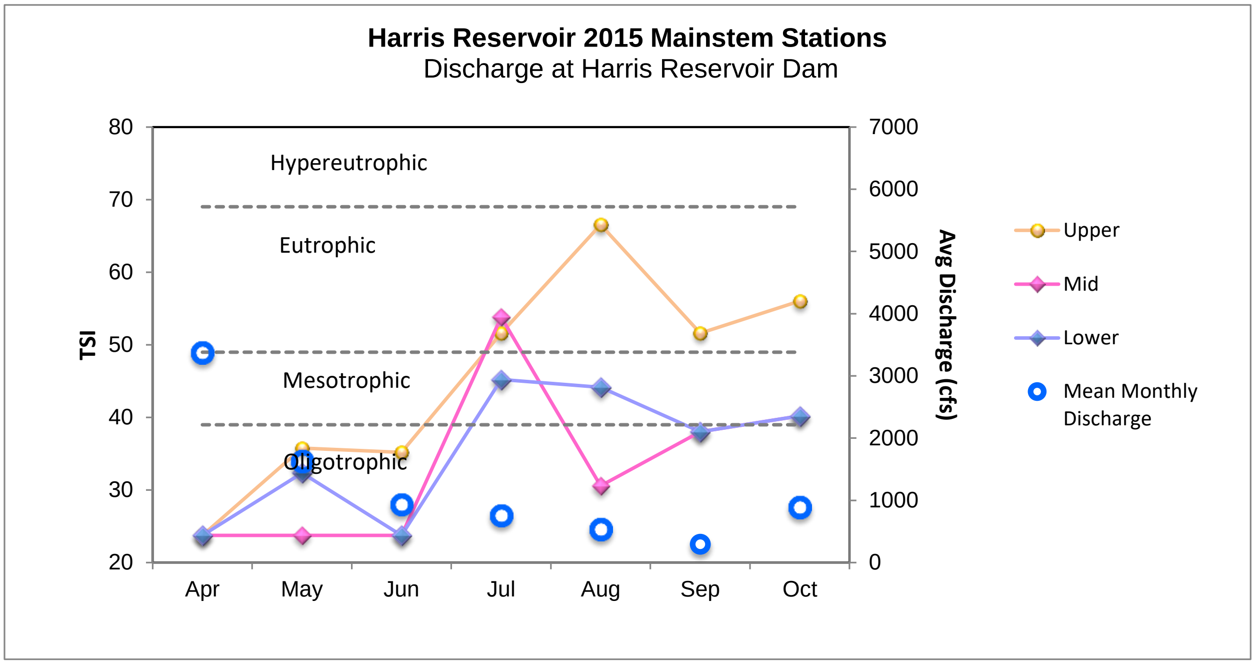


Figure 16. Monthly TSI values calculated for mainstem and tributary Harris Reservoir stations in 2015 using chl *a* concentrations and Carlson's Trophic State Index calculation. Monthly discharge acquired from Alabama Power Company at Harris Dam.



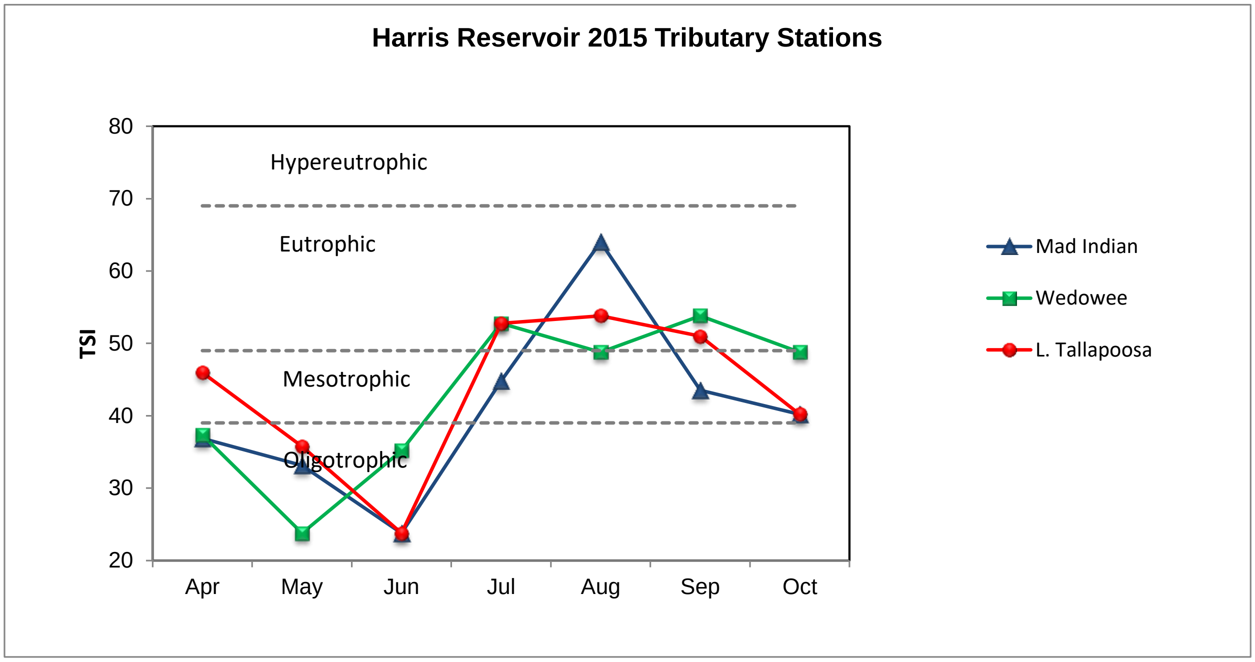
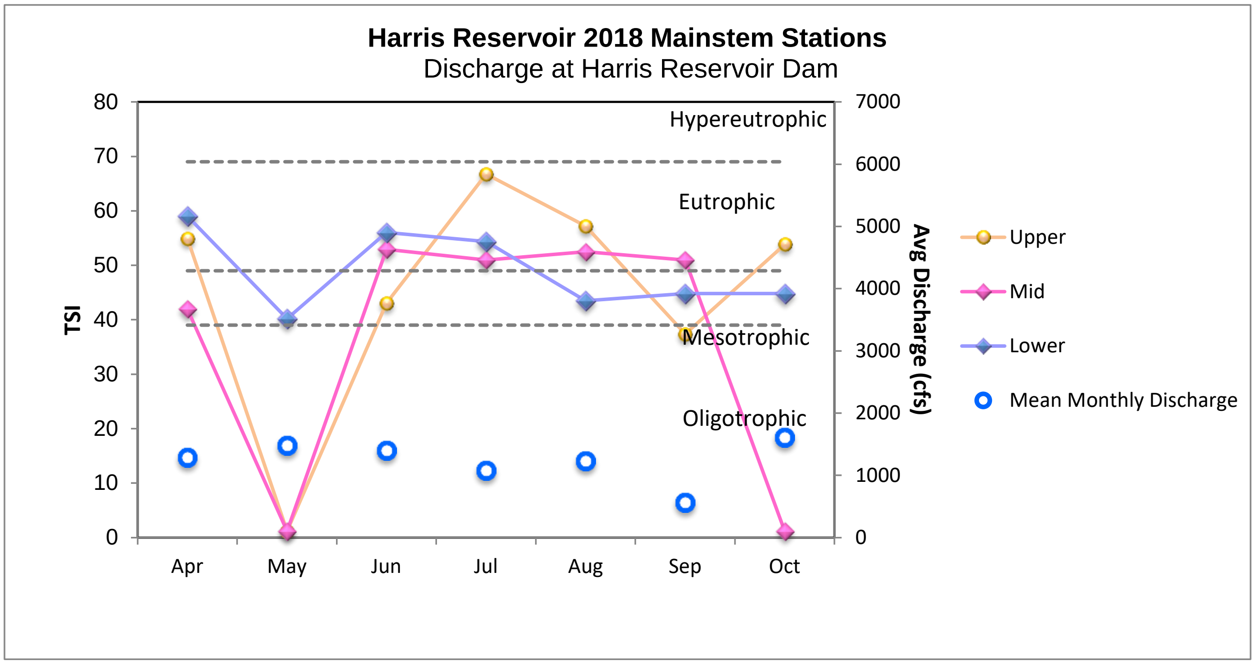
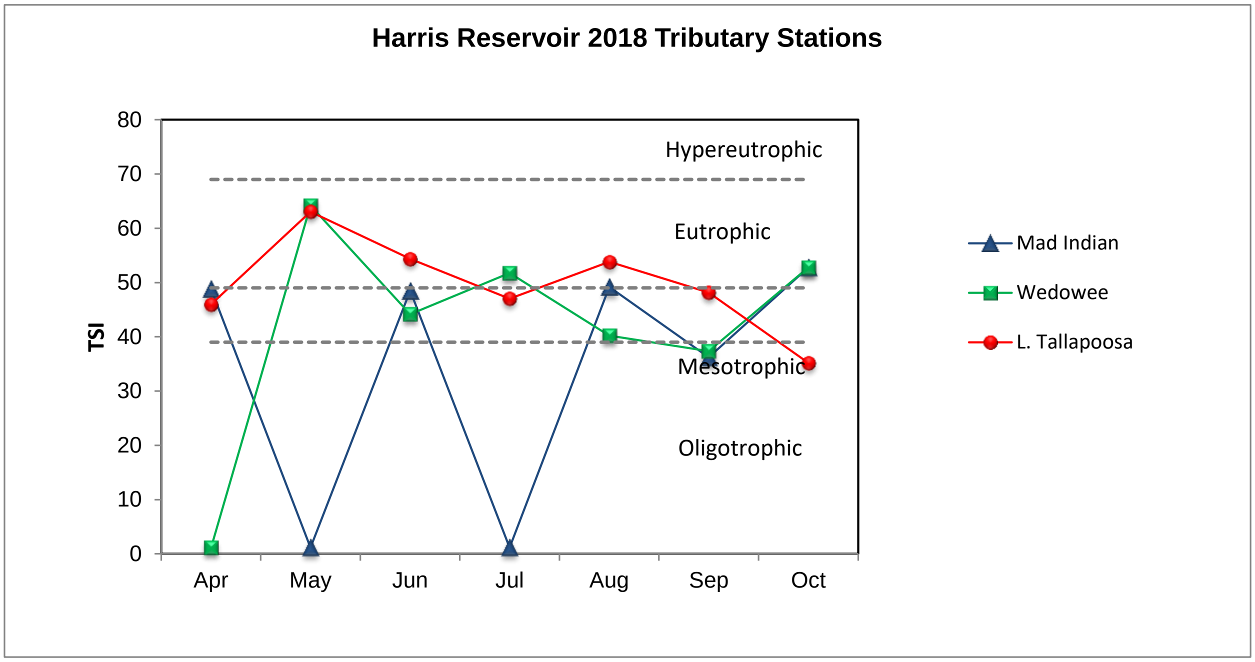


Figure 17. Monthly TSI values calculated for mainstem and tributary Harris Reservoir stations in 2018 using chl *a* concentrations and Carlson's Trophic State Index calculation. Monthly discharge acquired from Alabama Power Company at Harris Dam.





REFERENCES

ADEM. 2017. State of Alabama Water Quality Monitoring Strategy. Alabama Department of Environmental Management (ADEM), Montgomery, AL. 108 pp.

ADEM. 2018a. Standard Operating Procedures Series #2000, Alabama Department of Environmental Management (ADEM), Montgomery, AL.

ADEM. 2018b. Quality Assurance Project Plan (QAPP) for Surface Water Quality Monitoring in Alabama Rev 2. Alabama Department of Environmental Management (ADEM), Montgomery, AL. 176 pp.

ADEM. 2018c. Quality Management Plan (QMP) for the Alabama Department of Environmental Management (ADEM) Rev 5.0, Montgomery, AL. 72 pp.

Alabama Department of Environmental Management Water Division (ADEM Admin. Code R. 335-6-10-.09). 2017. Specific Water Quality Criteria. Water Quality Program. Chapter 10. Volume 1. Division 335-6.

Alabama Department of Environmental Management Water Division (ADEM Admin. Code R. 335-6-10-.11). 2017. Water Quality Criteria Applicable to Specific Lakes. Water Quality Program. Chapter 10. Volume 1. Division 335-6.

Carlson, R.E. 1977. A trophic state index. Limnology and Oceanography. 22(2):361-369.

Raschke, R.L. and D.A. Schultz. 1987. The use of the algal growth potential test for data assessment. Journal of Water Pollution Control Federation 59(4):222-227.

APPENDIX

Appendix Table 1. Summary of water quality data collected April-October, 2015. Minimum (Min) and maximum (Max) values calculated using minimum detection limits (MDL) when results were less than this value. Median (Med), mean, and standard deviations (SD) values were calculated by multiplying the MDL by 0.5 when results were less than this value.

Station	Parameter	N	Min	Max	Med	Mean	SD
RLHR-1	**Physical**						
	Turbidity (NTU)	7	1.6	3.4	1.8	2.2	0.8
	Total Dissolved Solids (mg/L)	7	2.0	40.0	17.0	19.7	13.3
	Total Suspended Solids (mg/L)	7	< 1.0	3.0	1.0	1.6	1.3
	Hardness (mg/L)	4	10.9	12.6	11.9	11.8	0.7
	Alkalinity (mg/L)	7	10.6	13.0	12.1	11.9	1.0
	Photic Zone (m)	7	5.51	9.32	6.76	6.87	1.24
	Secchi (m)	7	1.76	3.45	3.00	2.68	0.68
	Bottom Depth (m)	7	35.0	38.7	38.4	37.8	1.3
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.010	0.201	0.005	0.060	0.094
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	0.001	0.040	0.004	0.010	0.014
	Total Kjeldahl Nitrogen (mg/L)	7	< 0.064	0.625	0.225	0.248	0.207
	Total Nitrogen (mg/L)[J]	7	< 0.036	0.626	0.235	0.258	0.204
	Dis Reactive Phosphorus (mg/L)[J]	7	< 0.002	0.004	0.002	0.002	0.001
	Total Phosphorus (mg/L)[J]	7	0.006	0.017	0.007	0.010	0.004
	CBOD-5 (mg/L)[J]	7	< 2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7	2.3	2.5	2.5	2.4	0.1
	Biological						
	Chlorophyll a (mg/m^3)	7	< 1.00	4.45	2.14	2.21	1.60
	E. coli (MPN/DL)[J]	3	< 1	11	1	4	6
RLHR-2	**Physical**						
	Turbidity (NTU)	7	1.9	6.5	2.7	3.2	1.5
	Total Dissolved Solids (mg/L)	7	9.0	48.0	22.0	22.4	13.7
	Total Suspended Solids (mg/L)	7	< 1.0	6.0	1.0	2.2	2.2
	Hardness (mg/L)	4	10.7	13.3	12.8	12.4	1.2
	Alkalinity (mg/L)	7	10.9	14.2	13.3	12.7	1.4
	Photic Zone (m)	7	3.31	7.64	5.56	5.78	1.41
	Secchi (m)	7	0.88	2.54	2.18	2.05	0.57
	Bottom Depth (m)	7	25.9	28.1	27.9	27.2	0.1
	Chemical						
	Ammonia Nitrogen (mg/L)[J]	7	< 0.010	0.236	0.011	0.075	0.098
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	< 0.001	0.018	0.003	0.008	0.007
	Total Kjeldahl Nitrogen (mg/L)[J]	7	< 0.064	0.761	0.412	0.373	0.258
	Total Nitrogen (mg/L)[J]	7	< 0.050	0.777	0.412	0.381	0.260
	Dis Reactive Phosphorus (mg/L)[J]	7	< 0.002	0.005	0.002	0.003	0.001
	Total Phosphorus (mg/L)[J]	7	0.007	0.017	0.010	0.010	0.003
	CBOD-5 (mg/L)[J]	7	< 2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7	2.3	2.8	2.6	2.5	0.2
	Biological						
	Chlorophyll a (mg/m^3)	7	< 0.10	10.70	0.50	2.44	3.77
	E. coli (MPN/DL)[J]	3	< 1	1	1	1	0

Appendix Table 1. (continued)

Station	Parameter	N	Min	Max	Med	Mean	SD
RLHR-3	**Physical**						
	Turbidity (NTU)	7	5.3	21.7	8.4	10.0	5.7
	Total Dissolved Solids (mg/L)	7	< 1.0	53.0	17.0	23.1	17.7
	Total Suspended Solids (mg/L)	7	2.0	13.0	4.0	5.4	3.8
	Hardness (mg/L)	4	11.6	14.1	13.0	13.0	1.0
	Alkalinity (mg/L)	7	11.1	14.7	14.5	13.5	1.5
	Photic Zone (m)	7	2.18	4.40	3.00	3.25	0.85
	Secchi (m)	7	0.77	1.83	1.23	1.27	0.44
	Bottom Depth (m)	7	4.0	9.1	8.3	7.7	1.7
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.010	0.177	0.005	0.059	0.076
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	0.001	0.139	0.013	0.046	0.060
	Total Kjeldahl Nitrogen (mg/L)[J]	7	< 0.064	0.853	0.425	0.404	0.309
	Total Nitrogen (mg/L)[J]	7	< 0.060	0.860	0.438	0.450	0.274
	Dis Reactive Phosphorus (mg/L)[J]	7	< 0.002	0.006	0.003	0.003	0.002
	Total Phosphorus (mg/L)	7	0.012	0.027	0.023	0.021	0.006
	CBOD-5 (mg/L)[J]	7	< 2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7	1.7	2.2	2.1	2.1	0.2
	Biological						
	Chlorophyll a (mg/m^3)	7	< 1.00	39.20	8.54	10.50	13.52
	E. coli (MPN/DL)	3	1	161	2	55	92
RLHR-4	**Physical**						
	Turbidity (NTU)	7	2.4	8.7	3.1	3.9	2.2
	Total Dissolved Solids (mg/L)	7	< 1.0	48.0	22.0	19.9	16.3
	Total Suspended Solids (mg/L)	7	< 1.0	7.0	3.0	2.8	2.1
	Hardness (mg/L)	4	10.4	13.6	12.6	12.3	1.4
	Alkalinity (mg/L)	7	9.9	14.6	13.9	13.0	1.7
	Photic Zone (m)	7	2.50	6.88	4.84	4.93	1.56
	Secchi (m)	7	1.02	2.90	2.20	2.00	0.69
	Bottom Depth (m)	7	17.0	19.3	18.9	18.7	0.8
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.010	0.142	0.005	0.042	0.053
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	< 0.001	0.141	0.027	0.040	0.050
	Total Kjeldahl Nitrogen (mg/L)	7	< 0.064	0.636	0.420	0.393	0.209
	Total Nitrogen (mg/L)[J]	7	< 0.101	0.777	0.420	0.433	0.224
	Dis Reactive Phosphorus (mg/L)[J]	7	< 0.002	0.004	0.002	0.003	0.001
	Total Phosphorus (mg/L)	7	0.010	0.029	0.012	0.015	0.007
	CBOD-5 (mg/L)[J]	7	< 2.0	7.1	1.0	1.9	2.3
	Chlorides (mg/L)	7	2.6	4.0	3.7	3.6	0.5
	Biological						
	Chlorophyll a (mg/m^3)	7	< 1.00	10.70	4.80	5.43	4.04
	E. coli (MPN/DL)[J]	3	< 1	10	1	4	5

Appendix Table 1. (continued)

Station	Parameter	N	Min	Max	Med	Mean	SD
RLHR-5	**Physical**						
	Turbidity (NTU)	7	2.6	8.5	3.5	4.4	2.1
	Total Dissolved Solids (mg/L)J	7	< 1.0	41.0	28.0	22.1	15.4
	Total Suspended Solids (mg/L)J	7	< 1.0	5.0	2.0	2.4	1.5
	Hardness (mg/L)	4	9.1	13.3	12.4	11.8	2.0
	Alkalinity (mg/L)	7	8.5	14.5	13.3	12.6	2.1
	Photic Zone (m)	7	2.80	6.60	5.55	5.18	1.35
	Secchi (m)	7	1.06	2.33	2.01	1.76	0.49
	Bottom Depth (m)	7	8.1	13.5	10.5	10.6	1.8
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.010	0.113	0.005	0.042	0.048
	Nitrate+Nitrite Nitrogen (mg/L)J	7	0.002	0.162	0.034	0.050	0.058
	Total Kjeldahl Nitrogen (mg/L)J	7	0.088	0.627	0.557	0.479	0.187
	Total Nitrogen (mg/L)J	7	0.105	0.721	0.591	0.529	0.203
	Dis Reactive Phosphorus (mg/L)J	7	< 0.002	0.006	0.002	0.002	0.002
	Total Phosphorus (mg/L)	7	0.012	0.030	0.018	0.018	0.006
	CBOD-5 (mg/L)J	7	< 2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7	2.5	4.2	3.6	3.6	0.6
	Biological						
	Chlorophyll a (mg/m³)	7	< 1.00	10.70	6.41	5.32	4.04
	E. coli (MPN/DL)J	3	< 1	29	1	10	16
RLHR-6	**Physical**						
	Turbidity (NTU)	7	2.3	7.0	3.6	4.0	1.5
	Total Dissolved Solids (mg/L)	7	< 1.0	60.0	29.0	27.1	21.0
	Total Suspended Solids (mg/L)	7	< 1.0	4.0	3.0	2.1	1.5
	Hardness (mg/L)	4	10.0	12.9	11.4	11.4	1.4
	Alkalinity (mg/L)	7	10.1	13.9	12.1	12.1	1.6
	Photic Zone (m)	7	3.18	7.31	5.41	5.46	1.41
	Secchi (m)	7	0.87	2.73	2.00	1.95	0.62
	Bottom Depth (m)	7	11.7	13.5	12.5	12.5	0.6
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.010	0.241	0.005	0.067	0.095
	Nitrate+Nitrite Nitrogen (mg/L)J	7	< 0.001	0.042	0.012	0.014	0.014
	Total Kjeldahl Nitrogen (mg/L)	7	< 0.064	0.585	0.507	0.409	0.190
	Total Nitrogen (mg/L)J	7	< 0.074	0.586	0.527	0.424	0.180
	Dis Reactive Phosphorus (mg/L)J	7	< 0.002	0.004	0.004	0.003	0.001
	Total Phosphorus (mg/L)J	7	0.008	0.021	0.011	0.012	0.005
	CBOD-5 (mg/L)J	7	< 2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7	1.6	2.5	2.3	2.2	0.3
	Biological						
	Chlorophyll a (mg/m³)	7	< 1.00	30.30	2.67	6.38	10.63
	E. coli (MPN/DL)J	3	< 1	13	1	4	7

J=one or more of the values provided are estimated; < = Actual value is less than the detection limit.

Appendix Table 2. Summary of water quality data collected April-October, 2018. Minimum (Min) and maximum (Max) values calculated using minimum detection limits (MDL) when results were less than this value. Median (Med), mean, and standard deviations (SD) values were calculated by multiplying the MDL by 0.5 when results were less than this value.

Station	Parameter	N	Min	Max	Med	Mean	SD
RLHR-1	**Physical**						
	Turbidity (NTU)	7	1.9	3.2	2.1	2.4	0.5
	Total Dissolved Solids (mg/L)[J]	7	19.0	34.0	24.0	27.1	6.0
	Total Suspended Solids (mg/L)	7	< 1.0	4.0	2.0	2.1	1.3
	Hardness (mg/L)	4	1.0	13.9	11.2	9.4	5.7
	Alkalinity (mg/L)	7	10.7	14.1	12.5	12.4	1.1
	Photic Zone (m)	7	3.98	8.42	6.89	6.41	1.48
	Secchi (m)	7	1.82	3.30	2.73	2.71	0.56
	Bottom Depth (m)	7	37.8	38.9	38.4	38.4	0.4
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.007	0.077	0.004	0.020	0.029
	Nitrate+Nitrite Nitrogen (mg/L)	7	< 0.004	0.159	0.020	0.036	0.056
	Total Kjeldahl Nitrogen (mg/L)[J]	7	0.134	0.517	0.356	0.319	0.128
	Total Nitrogen (mg/L)[J]	7	< 0.156	0.560	0.368	0.355	0.153
	Dis Reactive Phosphorus (mg/L)[J]	7	< 0.004	0.005	0.002	0.002	0.001
	Total Phosphorus (mg/L)[J]	7	0.007	0.013	0.011	0.011	0.002
	CBOD-5 (mg/L)	7	< 2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7	2.4	2.8	2.5	2.6	0.1
	Biological						
	Chlorophyll a (mg/m³)	7	2.67	18.20	4.27	8.26	6.03
	E. coli (MPN/DL)[J]	4	< 1	2	2	1	1
RLHR-2	**Physical**						
	Turbidity (NTU)	7	2.3	5.2	3.2	3.3	1.0
	Total Dissolved Solids (mg/L)	7	23.0	56.0	30.0	32.1	11.2
	Total Suspended Solids (mg/L)	7	< 1.0	3.0	2.0	1.7	1.1
	Hardness (mg/L)	4	11.5	14.3	12.4	12.6	1.2
	Alkalinity (mg/L)	7	12.0	16.5	13.1	13.4	1.5
	Photic Zone (m)	7	3.75	7.77	5.92	5.81	1.20
	Secchi (m)	7	1.93	3.22	2.20	2.33	0.45
	Bottom Depth (m)	7	26.9	28.0	27.4	27.5	0.4
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.007	0.036	0.004	0.010	0.013
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	< 0.004	0.102	0.038	0.037	0.036
	Total Kjeldahl Nitrogen (mg/L)	7	0.198	0.346	0.268	0.267	0.055
	Total Nitrogen (mg/L)[J]	7	< 0.204	0.417	0.306	0.305	0.086
	Dis Reactive Phosphorus (mg/L)	7	< 0.004	0.004	0.002	0.002	0.000
	Total Phosphorus (mg/L)[J]	7	0.009	0.023	0.014	0.015	0.005
	CBOD-5 (mg/L)	7	< 2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7	2.3	3.0	2.7	2.6	0.3
	Biological						
	Chlorophyll a (mg/m³)	7	< 0.10	9.79	8.01	5.49	4.29
	E. coli (MPN/DL)[J]	4	< 1	2	1	1	1

Appendix Table 2. (continued)

Station	Parameter	N	Min	Max	Med	Mean	SD
RLHR-3	**Physical**						
	Turbidity (NTU)	7	5.2	16.3	6.2	8.7	4.5
	Total Dissolved Solids (mg/L)[J]	7	22.0	47.0	32.0	33.7	8.7
	Total Suspended Solids (mg/L)	7	2.0	7.0	5.0	4.7	1.6
	Hardness (mg/L)	4	12.0	14.9	13.6	13.5	1.3
	Alkalinity (mg/L)	7	12.5	15.6	13.7	13.9	1.0
	Photic Zone (m)	7	2.21	4.45	3.62	3.51	0.80
	Secchi (m)	7	0.93	1.86	1.36	1.35	0.31
	Bottom Depth (m)	7	6.7	9.0	8.3	8.2	0.8
	Chemical						
	Ammonia Nitrogen (mg/L)[J]	7	< 0.007	0.043	0.004	0.011	0.015
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	< 0.004	0.135	0.023	0.049	0.059
	Total Kjeldahl Nitrogen (mg/L)	7	< 0.200	0.558	0.343	0.334	0.137
	Total Nitrogen (mg/L)[J]	7	< 0.136	0.581	0.385	0.383	0.145
	Dis Reactive Phosphorus (mg/L)[J]	7	< 0.004	0.006	0.002	0.004	0.002
	Total Phosphorus (mg/L)	7	0.019	0.035	0.027	0.027	0.005
	CBOD-5 (mg/L)	7	< 2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7	1.8	2.5	2.0	2.1	0.2
	Biological						
	Chlorophyll a (mg/m^3)	7	< 0.10	40.00	10.70	11.92	13.60
	E. coli (MPN/DL)	4	1	17	9	9	8
RLHR-4	**Physical**						
	Turbidity (NTU)	7	2.4	5.4	3.3	3.6	1.1
	Total Dissolved Solids (mg/L)	7	18.0	39.0	33.0	32.3	7.0
	Total Suspended Solids (mg/L)[J]	7	1.0	4.0	2.0	2.4	1.0
	Hardness (mg/L)	4	11.9	14.5	12.8	13.0	1.1
	Alkalinity (mg/L)	7	10.9	15.1	14.1	13.6	1.4
	Photic Zone (m)	7	4.00	5.99	5.30	5.09	0.76
	Secchi (m)	7	1.68	2.42	1.97	1.98	0.22
	Bottom Depth (m)	7	18.1	19.4	18.8	18.7	0.5
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.007	0.016	0.004	0.004	0.002
	Nitrate+Nitrite Nitrogen (mg/L)	7	< 0.004	0.325	0.069	0.093	0.111
	Total Kjeldahl Nitrogen (mg/L)	7	< 0.200	0.579	0.341	0.350	0.158
	Total Nitrogen (mg/L)	7	< 0.188	0.691	0.350	0.443	0.204
	Dis Reactive Phosphorus (mg/L)[J]	7	< 0.004	0.004	0.002	0.003	0.001
	Total Phosphorus (mg/L)	7	0.012	0.024	0.017	0.018	0.004
	CBOD-5 (mg/L)	7	< 2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7	3.7	4.0	3.9	3.9	0.1
	Biological						
	Chlorophyll a (mg/m^3)	7	1.60	27.40	6.01	9.59	8.55
	E. coli (MPN/DL)[J]	4	< 1	2	2	1	1

Appendix Table 2. (continued)

Station	Parameter	N	Min	Max	Med	Mean	SD
RLHR-5	**Physical**						
	Turbidity (NTU)	7	2.8	5.6	3.3	3.7	1.0
	Total Dissolved Solids (mg/L)	7	22.0	52.0	32.0	33.9	10.8
	Total Suspended Solids (mg/L)	7	2.0	4.0	3.0	3.1	0.9
	Hardness (mg/L)	4	11.9	14.3	12.2	12.6	1.1
	Alkalinity (mg/L)	7	11.0	14.3	14.0	13.3	1.3
	Photic Zone (m)	7	3.87	7.03	4.76	4.83	1.06
	Secchi (m)	7	1.52	2.34	2.00	1.89	0.31
	Bottom Depth (m)	7	13.4	14.2	14.0	13.9	0.3
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.007	0.016	0.004	0.004	0.002
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	< 0.004	0.311	0.027	0.075	0.110
	Total Kjeldahl Nitrogen (mg/L)	7	0.252	0.741	0.314	0.384	0.176
	Total Nitrogen (mg/L)[J]	7	< 0.266	1.052	0.320	0.458	0.283
	Dis Reactive Phosphorus (mg/L)[J]	7	< 0.004	0.005	0.002	0.003	0.001
	Total Phosphorus (mg/L)	7	0.014	0.042	0.021	0.023	0.009
	CBOD-5 (mg/L)	7	< 2.0	2.7	1.0	1.4	0.8
	Chlorides (mg/L)	7	3.5	4.1	3.7	3.8	0.2
	Biological						
	Chlorophyll a (mg/m^3)	7	< 0.10	30.70	4.00	8.24	10.50
	E. coli (MPN/DL)[J]	4	< 1	2	2	1	1
RLHR-6	**Physical**						
	Turbidity (NTU)	7	3.2	5.4	4.2	4.3	0.7
	Total Dissolved Solids (mg/L)	7	22.0	30.0	27.0	26.0	3.0
	Total Suspended Solids (mg/L)	7	< 1.0	5.0	3.0	2.9	1.6
	Hardness (mg/L)	4	10.9	13.6	11.8	12.0	1.2
	Alkalinity (mg/L)	7	11.6	13.6	12.9	12.6	0.7
	Photic Zone (m)	7	4.07	6.73	4.70	5.03	0.90
	Secchi (m)	7	1.84	2.23	1.96	1.97	0.13
	Bottom Depth (m)	7	13.2	14.1	14.0	13.9	0.3
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.007	0.016	0.004	0.004	0.002
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	< 0.004	0.103	0.018	0.027	0.035
	Total Kjeldahl Nitrogen (mg/L)	7	0.180	0.439	0.316	0.299	0.086
	Total Nitrogen (mg/L)[J]	7	< 0.188	0.457	0.337	0.326	0.095
	Dis Reactive Phosphorus (mg/L)[J]	7	< 0.004	0.004	0.002	0.003	0.001
	Total Phosphorus (mg/L)	7	0.010	0.020	0.016	0.015	0.003
	CBOD-5 (mg/L)	7	< 2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7	1.9	2.8	2.4	2.4	0.3
	Biological						
	Chlorophyll a (mg/m^3)	7	< 0.10	9.61	6.23	4.40	3.75
	E. coli (MPN/DL)[J]	4	< 1	6	1	2	3

J=one or more of the values provided are estimated; < = Actual value is less than the detection limit