2010 Martin Reservoir Report

Rivers and Reservoirs Monitoring Program

Alabama Department of Environmental Management

Field Operations Division
Environmental Indicator's Section
Aquatic Assessment Unit
June 2013

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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

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INTRODUCTION

Created in the 1920's by the completion of Martin Dam, Martin Reservoir is approximately 31 miles long and contains over 40,000 acres of surface water. It is the second reservoir on the Tallapoosa River in Alabama, located downstream of Harris Reservoir.

The Alabama Department of Environmental Management (ADEM) monitored Martin Reservoir as part of the 2010 assessment of the Alabama, Coosa, and Tallapoosa (ACT) River basins 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 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, 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 2012 Monitoring Strategy (ADEM 2012).

Specific water quality criteria for nutrient management were implemented in 2002 at three locations on Martin Reservoir. These criteria represent the maximum growing season mean (April-October) chlorophyll *a* (chl *a*) concentrations allowable while still fully supporting the reservoir's Public water supply, Swimming and Fish and Wildlife [(PWS/S/F&W)] use classification as well as Martin Reservoir's designation as a Treasured Alabama Lake (TAL). Impoundments or lakes with a high quality that constitute an exceptional resource of the State of Alabama can get this special designation. In 2011, certain segments of Martin Reservoir were designated a TAL which limits new point sources by requiring them to meet a monthly average effluent limitation of 1.0 mg/l total phosphorus.

The purpose of this report is to summarize data collected at eleven stations in Martin Reservoir during the 2010 growing season 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 (Fig. 1). Specific location information can be found in Table 1. The mainstem of Martin Reservoir was sampled in the dam forebay, mid reservoir, and two locations in the upper reservoir (upper and upstream 280). Six tributary embayment stations were sampled in the upper (Hillabee and Coley Creek) and mid (Elkahatchee, Manoy, Sandy, and Blue Creek) reservoir. Kowaliga Creek constitutes a very large portion of the lower reservoir and is treated as a mainstem station in this report.

Water quality assessments were conducted at monthly intervals April-October. All samples were collected, preserved, stored, and transported according to procedures in the ADEM Field Operations Division Standard Operating Procedures (ADEM 2010), Surface Water Quality Assurance Project Plan (ADEM 2008), and Quality Management Plan (ADEM 2008).

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 discharge data and ADEM's previously collected data to help interpret the 2010 results.

Figure 1. Martin Reservoir with 2010 sampling locations. A description of each sampling location is provided in Table 1.

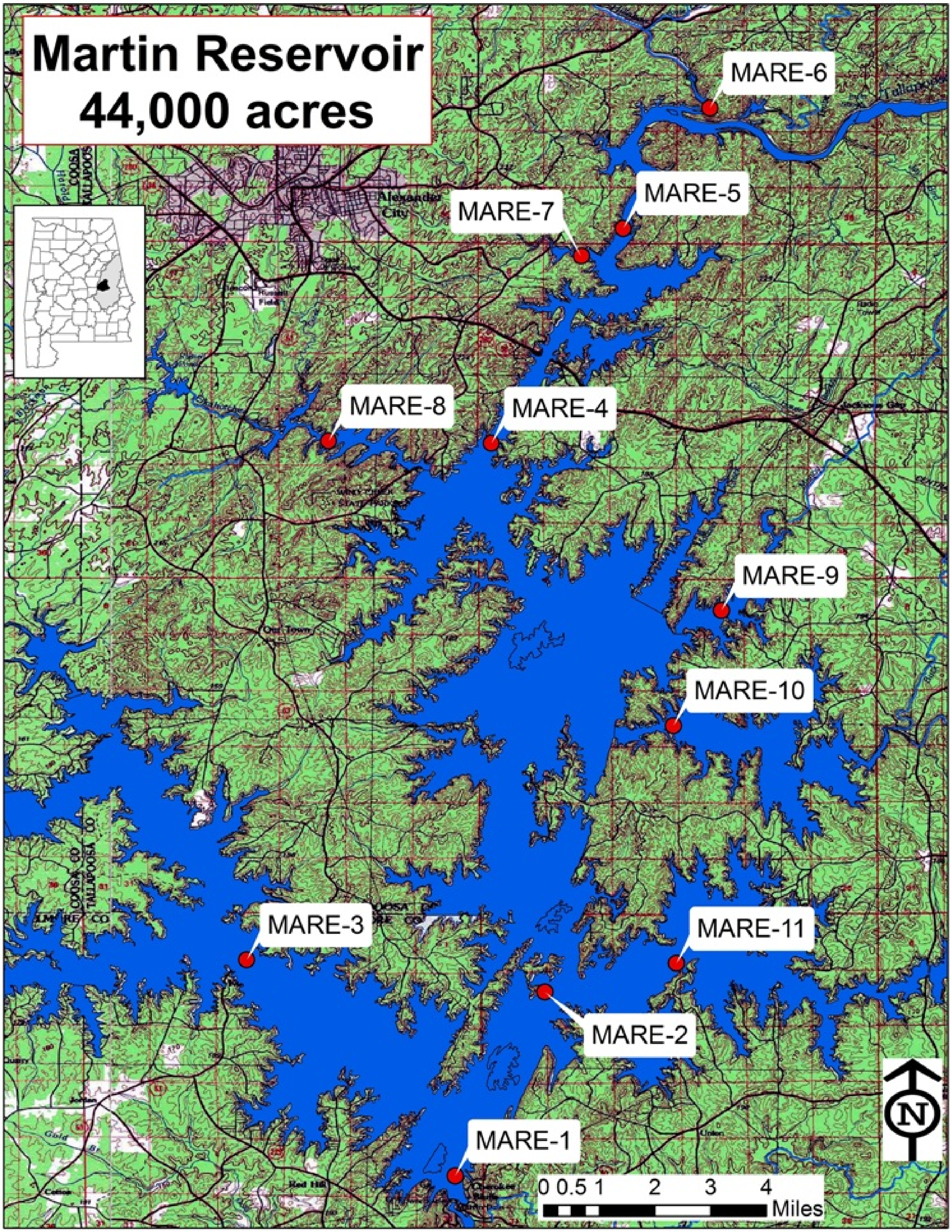


Table 1. Descriptions of the 2010 monitoring stations in Martin Reservoir.

Martin Reservoir								
HUC	**County**	**Station Number**	**Report Designation**	**Waterbody Name**	**Station Description**	**Chl *a* Criteria**	**Latitude**	**Longitude**
Middle Tallapoosa (0315-0109)								
031501090805	Elmore	MARE-1*	Lower	Tallapoosa R	Deepest point, main river channel, dam forebay .	5 µg/L	32.6865	-85.9107
031501090805	Elmore	MARE-2*	Mid	Tallapoosa R	Deepest point, main river channel, immed. upstream of Blue Creek embayment.	5 µg/L	32.7344	-85.8874
031501090703	Elmore	MARE-3*	Kowaliga	Kowaliga Cr	Deepest point, main creek channel, immed. upstream of Alabama Hwy 63 bridge.	5 µg/L	32.7428	-85.9649
031501090804	Tallapoosa	MARE-4	Upper	Tallapoosa R	Deepest point, main river channel, upstream of Wind Creek State Park.		32.8775	-85.9013
031501090802	Tallapoosa	MARE-5	Upstream 280	Tallapoosa R	Deepest point, main river channel, approx. 0.5 miles upstream of Coley Creek embayment.		32.9336	-85.8669
031501090406	Tallapoosa	MARE-6	Hillabee Cr	Hillabee Cr	Deepest point, main creek channel, Hillabee Creek embayment, approx. 0.5 miles upstream of lake confluence.		32.9650	-85.8444
031501090802	Tallapoosa	MARE-7	Coley Cr	Coley Cr	Deepest point, main creek channel, Coley Creek embayment, approx. 0.5 miles upstream of lake confluence.		32.9264	-85.8778
031501090803	Tallapoosa	MARE-8	Elkahatchee Cr	Elkahatchee Cr	Deepest point, main creek channel, Elkahatchee Creek embayment, approx. 0.5 miles downstream of Elkahatchee/Sugar Creek confluence.		32.8781	-85.9436
031501090804	Tallapoosa	MARE-9	Manoy Cr	Manoy Cr	Deepest point, main creek channel, Manoy Creek embayment, approx. 1.0 mile upstream of lake confluence.		32.8339	-85.8414
031501090504	Tallapoosa	MARE-10	Sandy Cr	Sandy Cr	Deepest point, main creek channel, Sandy Creek embayment, approx. 1.0 mile upstream of lake confluence.		32.8039	-85.8539
031501090602	Tallapoosa	MARE-11	Blue Cr	Blue Cr	Deepest point, main creek channel, Blue Creek embayment, approx. 2.0 miles upstream of lake confluence.		32.7419	-85.8531

*Growing season mean chl. *a* criteria implemented at the station in 2002

RESULTS

Growing season mean graphs for TN, TP, chl *a* and TSS are provided in this section (Figs. 2-5). Monthly graphs for TN, TP, chl *a*, TSS, DO, and TSI are also provided (Figs 6-14, & 18), 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 Figs. 15-17. Summary statistics of all data collected during 2010 are presented in Appendix Table 1. The table contains the minimum, maximum, median, mean, and standard deviation of each parameter analyzed.

Stations with the highest concentrations of nutrients, chlorophyll, 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 2010, the highest growing season mean TN was calculated for the Coley Cr station (Fig. 2). The lower, Kowaliga, and mid stations mean TN concentrations were higher in 2010 than in 2008 while mean concentration from the upper station was similar to the previous sampling. The mean TN concentration at the upstream 280 station decreased from previous sampling in 2005-2006. Mean concentrations in all tributaries except Elkahatchee Cr increased from 2005 to 2010. Highest monthly TN concentrations occurred in April and August at all mainstem stations (Figs. 6 & 7). Historic low TN concentrations occurred at all five mainstem stations in October.

In 2010, the highest growing season mean TP was calculated for the Coley Cr station (Fig. 3). Overall, growing season mean TP concentrations have decreased in recent years, with 2010 concentrations among the lowest measured. Monthly TP concentrations at all stations were at or below historic means April-October (Figs. 8 & 9).

In 2010, the highest growing season mean chl. *a* was calculated for the Coley Cr station (Fig. 4). Concentrations have increased at the upstream 280 station since 2003. All tributary stations, except the Hillabee Cr. station, decreased in mean value from 2005. In the mainstem stations, all were similar to recent sampling seasons. Specific water quality criteria for nutrient management were established for the mid, Kowaliga, and lower stations in Martin Reservoir in 2002. The growing season mean chl *a* value for all three stations in 2010 were in compliance with the criteria limit. Highest monthly concentrations were achieved in July or August for all five mainstem stations (Figs. 10 & 11). Monthly concentrations at the Kowaliga, mid and lower stations were at or below historic means April-October. Historic high monthly chl *a* concentrations were measured in July and September at the upstream 280 stations and August at the upper station.

In 2010, highest growing season mean TSS values were for the upstream 280 and Coley Cr stations (Fig. 5). All tributary station TSS mean values were lower in 2010 than in 2005. Overall, growing season mean TSS concentrations at all mainstem stations concentrations have decreased since 2004. Monthly TSS concentrations at the mainstem stations were similar to or below the mean historic values (Figs. 12 & 13). Highest values were reached in April and October at the upstream 280 station while most of the other mainstem stations peaked in August.

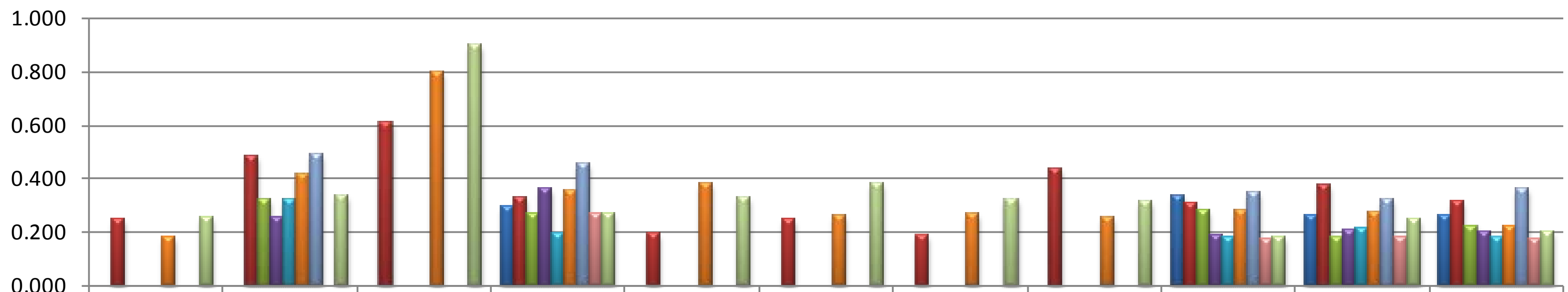
AGPT results for the Hillabee Cr station indicated nitrogen limited conditions in 2010 while the upstream 280 station was phosphorus limited (Table 2). Maximum standing crop at the upstream 280 station was the lowest to date. Due to resource constraints, AGPT samples were not collected at the upper, mid, Kowaliga, or lower stations in August. MSC values in Martin have consistently remained below 5.0 mg/L, the value that Raschke et al. (1996) defined as protective of reservoir and lake systems.

All measurements of dissolved oxygen concentrations in Martin Reservoir met the ADEM Criteria limit of 5.0 mg/L at 5.0 ft (1.5 m), though the concentration at the upper station was near 5.0 mg/L in September (ADEM Admin. Code R. 335-6-10-.09) (Fig. 14). The lower and mid reservoir stations were thermally and chemically stratified April-Oct (Figs. 15-17). The water column at the lower station had a zone of deoxygenation from 11m to 15m July-October, while the mid station was nearly deoxygenated from 7m to 15m July-October. Highest temperatures were reached June-August.

TSI values were calculated using monthly chl *a* concentrations and Carlson's Trophic State Index. The Coley Cr station had the highest trophic state, bordering hypereutrophic in August and highly eutrophic September-October (Fig. 18). TSI values varied at the mid, Kowaliga and lower stations from oligotrophic to mesotrophic April-October. The upstream 280 and upper stations were eutrophic in June, July, and August. The Hillabee Cr and Elkahatchee Cr stations were oligotrophic in April and eutrophic most of the remainder of the season. The Manoy Cr, Sandy Cr, and Blue Cr stations were oligotrophic in April, mesotrophic May-July, borderline eutrophic in Aug, and oligotrophic September-October.

Figure 2. Mean growing season TN measured in Martin Reservoir, April-October, 1997-2010. Stations are illustrated from upstream to downstream as the graph is read from left to right.

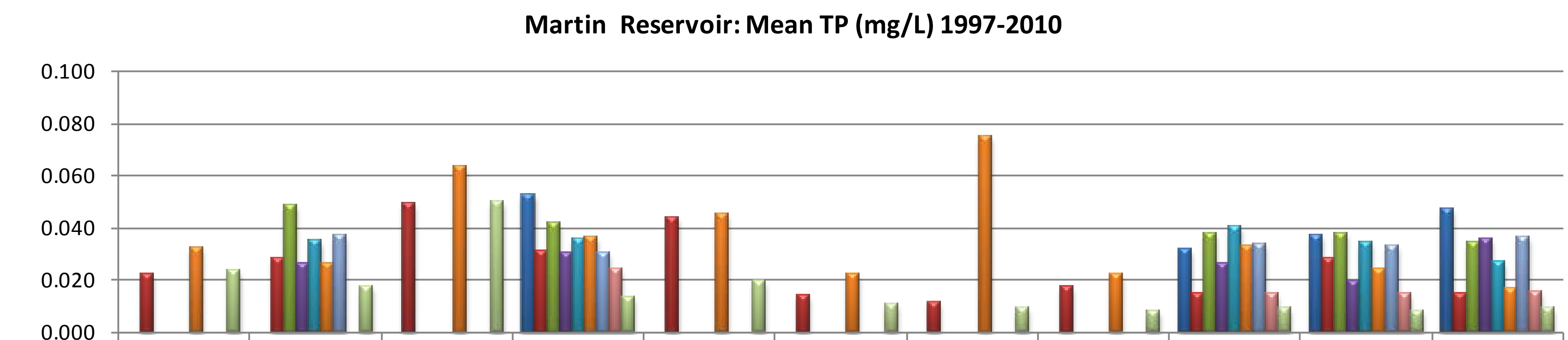
Martin Reservoir: Mean TN (mg/L) 1997-2010



	Hillabee Cr	Upstream 280	Coley Cr	Upper	Elkahatchee Cr	Manoy Cr	Sandy Cr	Blue Cr	Mid	Kowaliga	Lower
1997				0.299					0.338	0.263	0.264
2000	0.251 *	0.483	0.612 *	0.331	0.193 *	0.249 *	0.187 *	0.435 *	0.313	0.377	0.316
2002		0.322		0.270					0.282	0.181	0.226
2003		0.258		0.363					0.193	0.208	0.203
2004		0.323		0.194					0.182	0.215	0.181
2005	0.182	0.419	0.799	0.360	0.383	0.260	0.273	0.259	0.280	0.279	0.224
2006		0.492		0.456					0.351	0.326	0.361
2008				0.271					0.175	0.182	0.177
2010	0.258	0.340	0.899	0.271	0.332	0.383	0.324	0.317	0.184	0.251	0.206

*Mean of April/June/August only.

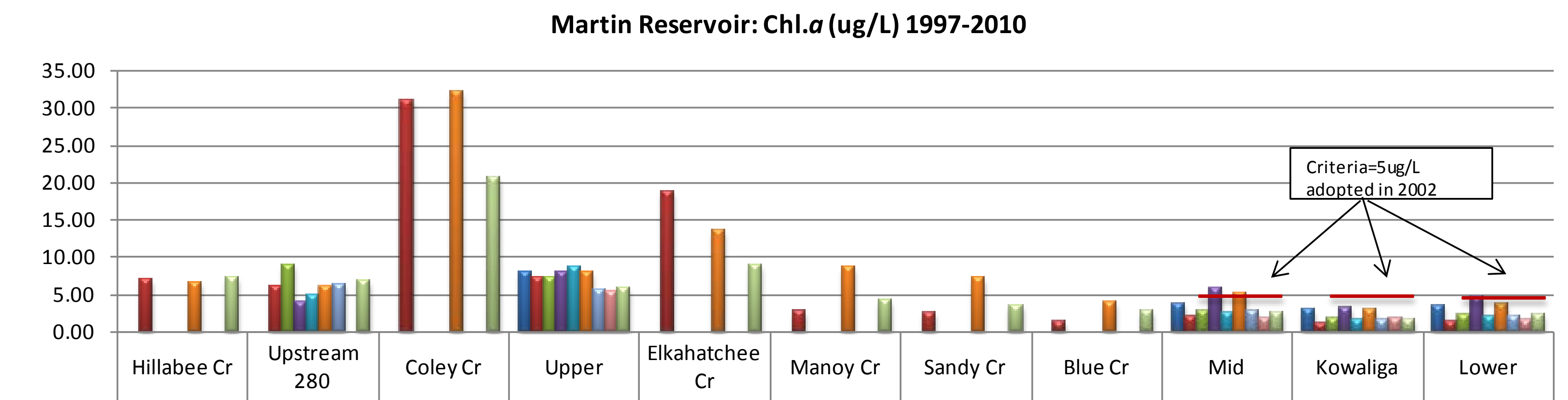
Figure 3. Mean growing season TP measured in Martin Reservoir, April-October, 1997-2010. Stations are illustrated from upstream to downstream as the graph is read from left to right.



	Hillabee Cr	Upstream 280	Coley Cr	Upper	Elkahatchee Cr	Manoy Cr	Sandy Cr	Blue Cr	Mid	Kowaliga	Lower
1997				0.053					0.032	0.037	0.048
2000	0.022 *	0.029	0.049 *	0.031	0.044 *	0.015 *	0.011 *	0.018 *	0.015	0.028	0.015
2002		0.049		0.042					0.038	0.038	0.035
2003		0.026		0.031					0.027	0.020	0.036
2004		0.035		0.036					0.041	0.035	0.027
2005	0.032	0.027	0.064	0.037	0.045	0.022	0.075	0.022	0.033	0.024	0.017
2006		0.037		0.030					0.034	0.034	0.037
2008				0.025					0.015	0.015	0.016
2010	0.024	0.017	0.050	0.014	0.019	0.011	0.010	0.009	0.009	0.008	0.010

*Mean of April/June/August only.

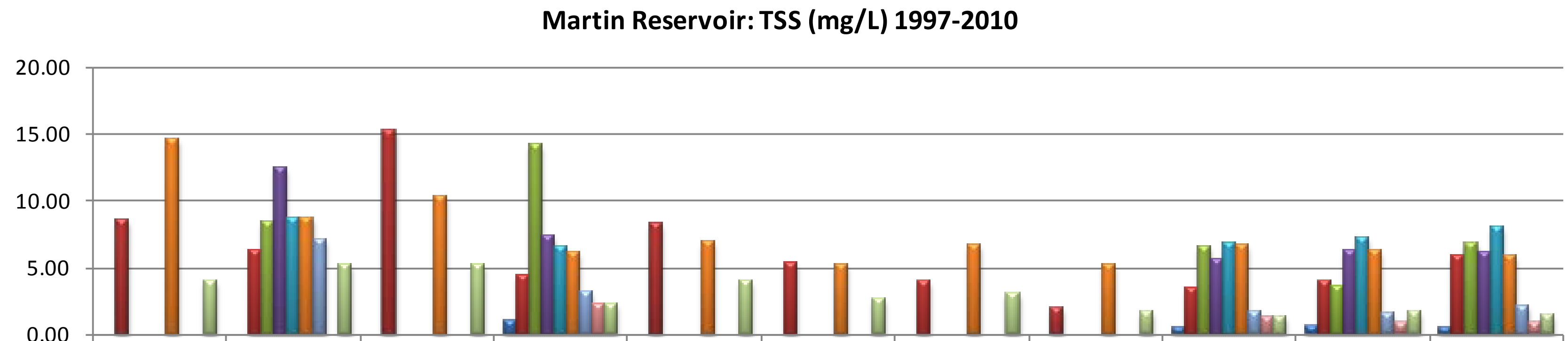
Figure 4. Mean growing season chl *a* measured in Martin Reservoir, April-October, 1997-2010. Stations are illustrated from upstream to downstream as the graph is read from left to right.



	Hillabee Cr	Upstream 280	Coley Cr	Upper	Elkahatchee Cr	Manoy Cr	Sandy Cr	Blue Cr	Mid	Kowaliga	Lower
1997				8.01					3.78	3.12	3.52
2000	7.14 *	6.24	31.15 *	7.32	18.89 *	2.94 *	2.59 *	1.44 *	2.10	1.22	1.45
2002		9.07		7.44					2.79	1.87	2.29
2003		4.02		8.12					5.88	3.28	4.69
2004		4.98		8.67					2.68	1.72	2.10
2005	6.69	6.10	32.29	8.00	13.66	8.81	7.30	3.93	5.21	3.05	3.70
2006		6.36		5.77					2.98	1.71	2.23
2008				5.34					1.97	1.91	1.60
2010	7.42	6.96	20.77	6.04	9.07	4.35	3.55	2.97	2.59	1.74	2.31

*Mean of April/June/August only.

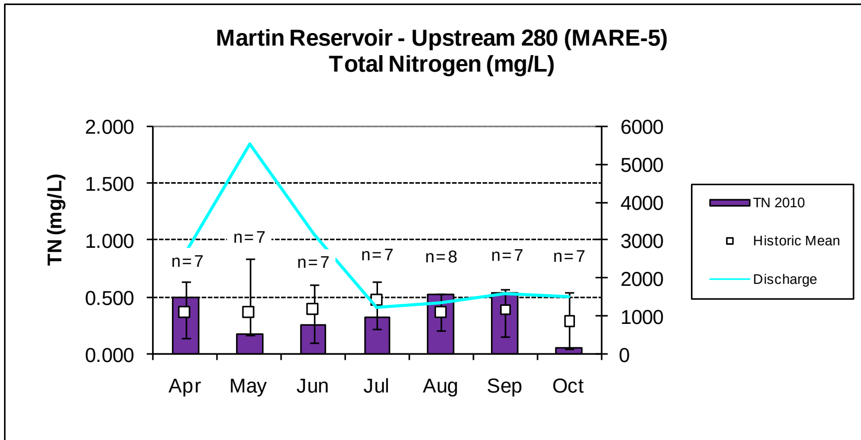
Figure 5. Mean growing season TSS measured in Martin Reservoir, April-October, 1997-2010. Stations are illustrated from upstream to downstream as the graph is read from left to right.

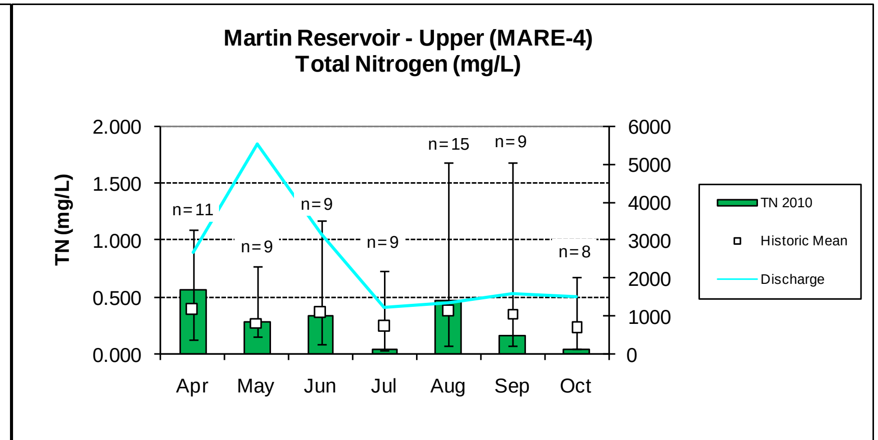


	Hillabee Cr	Upstream 280	Coley Cr	Upper	Elkahatchee Cr	Manoy Cr	Sandy Cr	Blue Cr	Mid	Kowaliga	Lower
1997				1.08					0.58	0.67	0.58
2000	8.67 *	6.29	15.33 *	4.43	8.33 *	5.33 *	4.00 *	2.00 *	3.57	4.00	6.00
2002		8.43		14.29					6.57	3.71	6.86
2003		12.57		7.43					5.71	6.29	6.14
2004		8.71		6.57					6.86	7.29	8.14
2005	14.71	8.71	10.43	6.14	7.00	5.29	6.71	5.29	6.71	6.29	6.00
2006		7.14		3.21					1.71	1.57	2.21
2008				2.36					1.36	0.93	0.93
2010	4.00	5.29	5.29	2.29	4.07	2.71	3.07	1.71	1.43	1.71	1.50

*Mean of April/June/August only.

Figure 6. Monthly TN concentrations measured at upstream 280, upper, and Kowaliga stations in Martin Reservoir, April-October 2010 vs. average monthly discharge. Monthly discharge acquired from Alabama Power at Martin Reservoir Dam. Each bar graph depicts monthly changes in each station. The historic mean (1992-2010) and min/max ranges are also displayed for comparison. The "n" value equals the number of datapoints included in the monthly historic calculations.





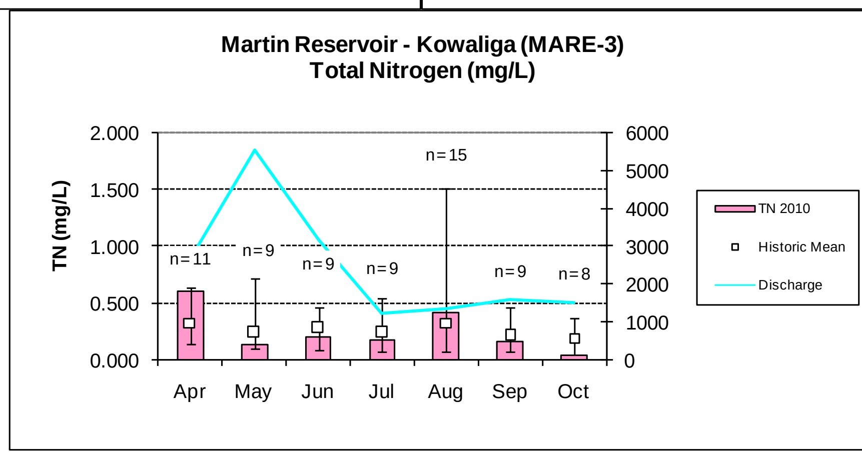
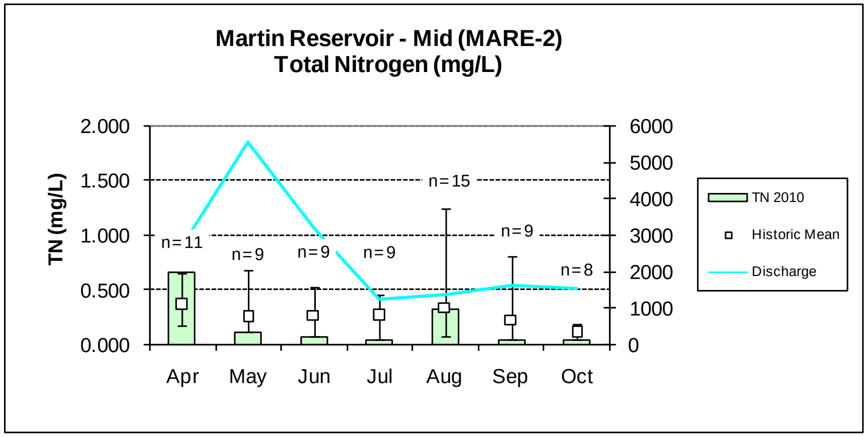


Figure 7. Monthly TN concentrations measured at mid and lower stations in Martin Reservoir, April-October 2010 vs. average monthly discharge. Monthly discharge acquired from Alabama Power at Martin Reservoir Dam. Each bar graph depicts monthly changes in each station. The historic mean (1992-2010) and min/max ranges are also displayed for comparison. The "n" value equals the number of datapoints included in the monthly historic calculations.



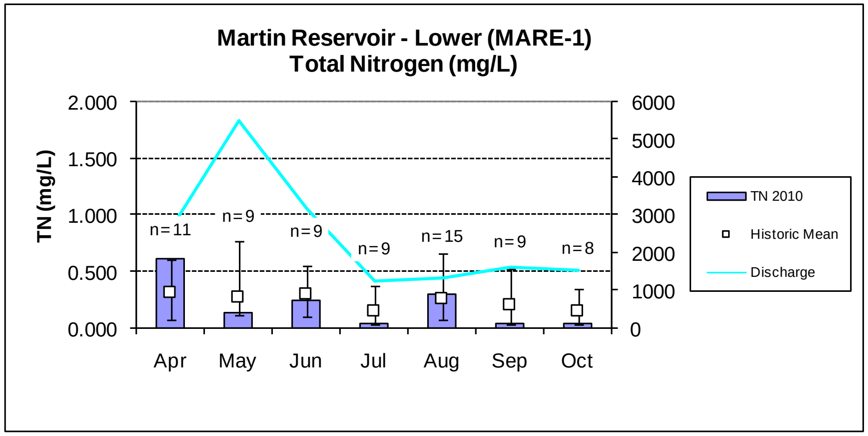


Figure 8. Monthly TP concentrations measured at upstream 280, upper, and Kowaliga stations in Martin Reservoir, April-October 2010 vs. average monthly discharge. Monthly discharge acquired from Alabama Power at Martin Reservoir Dam. Each bar graph depicts monthly changes in each station. The historic mean (1992-2010) and min/max ranges are also displayed for comparison. The “n” value equals the number of datapoints included in the monthly historic calculations.

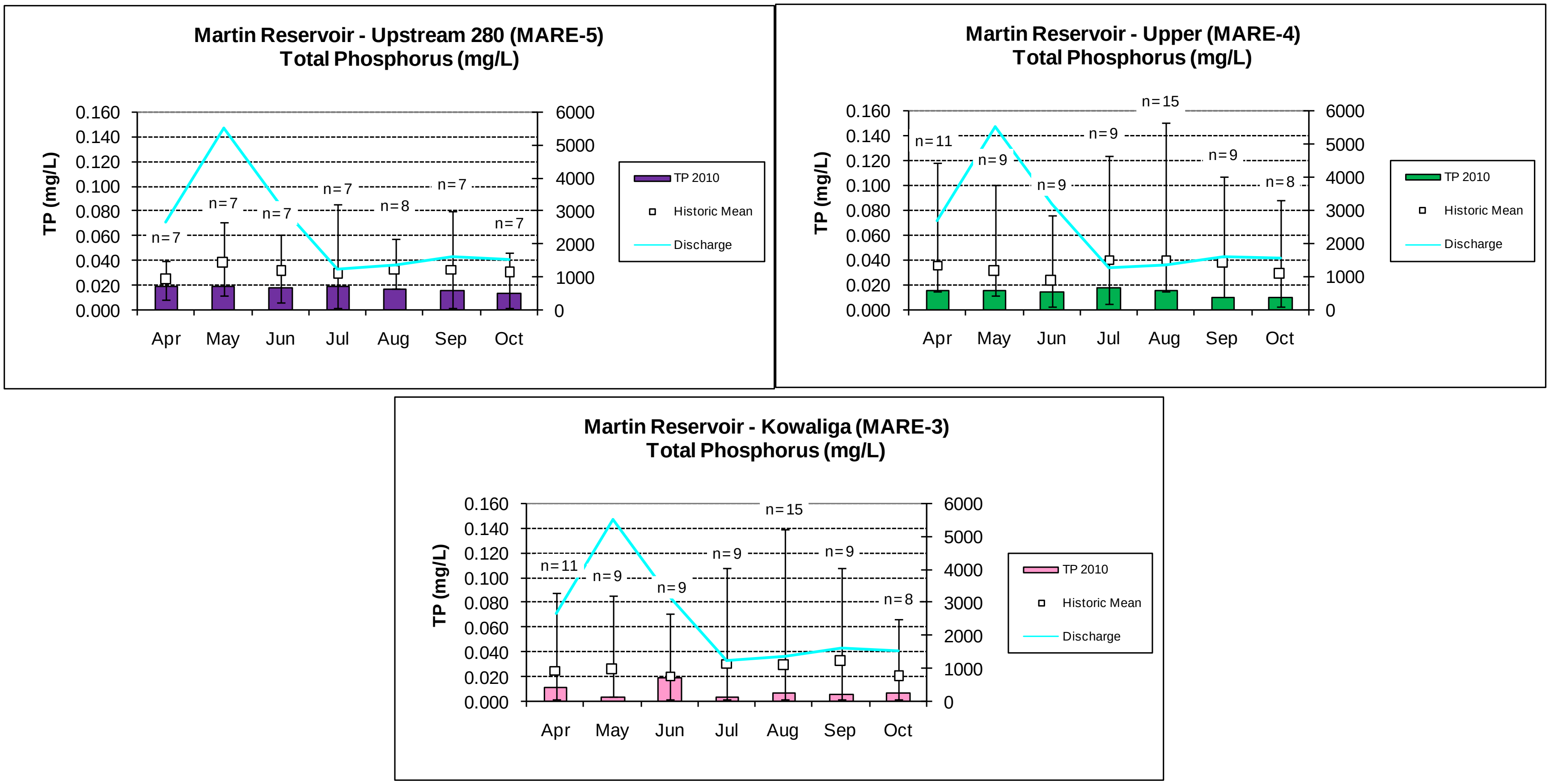
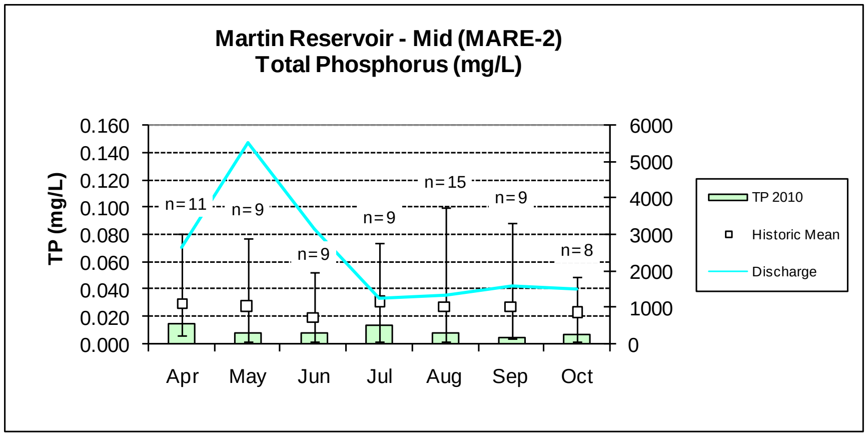


Figure 9. Monthly TP concentrations measured at mid and lower staions in Martin Reservoir, April-October 2010 vs. average monthly discharge. Monthly discharge acquired from Alabama Power at Martin Reservoir Dam. Each bar graph depicts monthly changes in each station. The historic mean (1992-2010) and min/max ranges are also displayed for comparison. The “n” value equals the number of datapoints included in the monthly historic calculations.



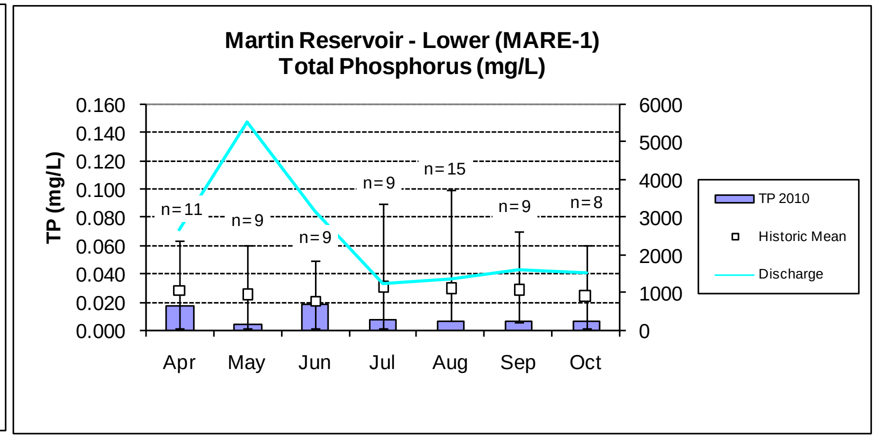
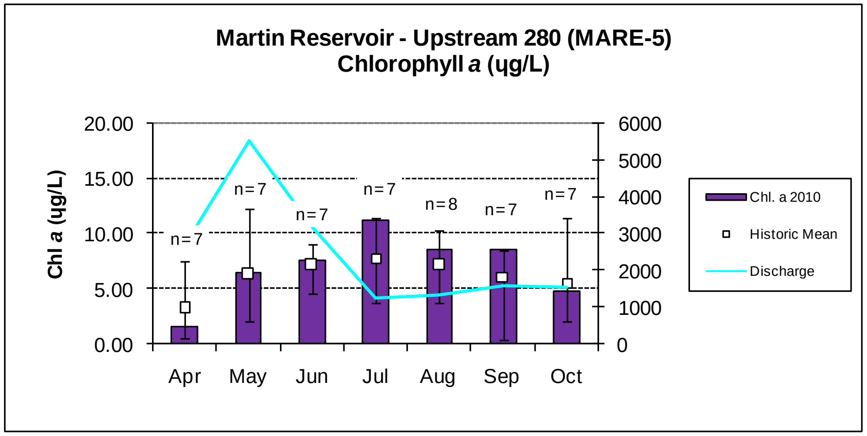
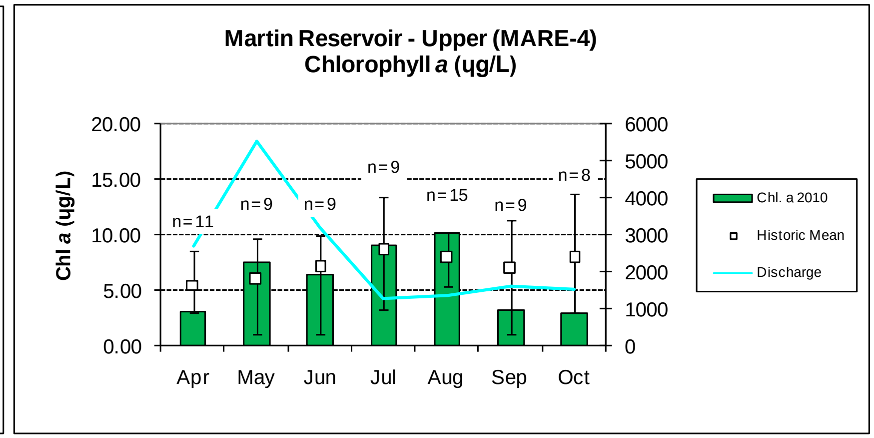


Figure 10. Monthly chlorophyll *a* concentrations measured at upstream 280, upper, and Kowaliga stations in Martin Reservoir, April-October 2010 vs. average monthly discharge. Monthly discharge acquired from Alabama Power at Martin Reservoir Dam. Each bar graph depicts monthly changes in each station. The historic mean (1992-2010) and min/max ranges are also displayed for comparison. The “n” value equals the number of datapoints included in the monthly historic calculations.





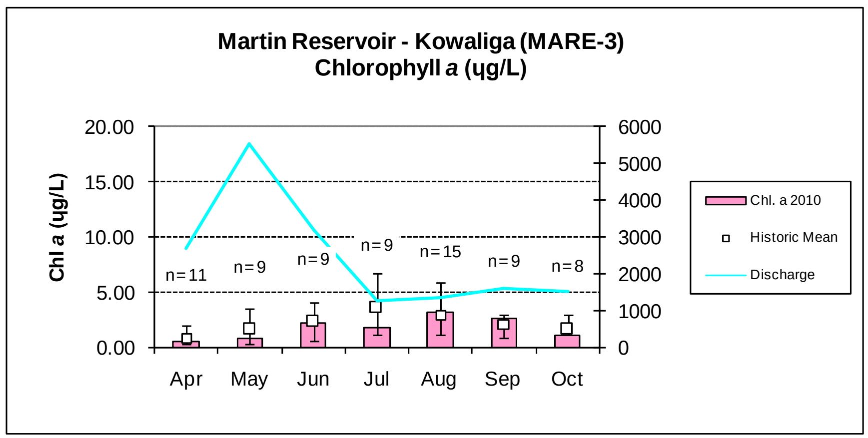
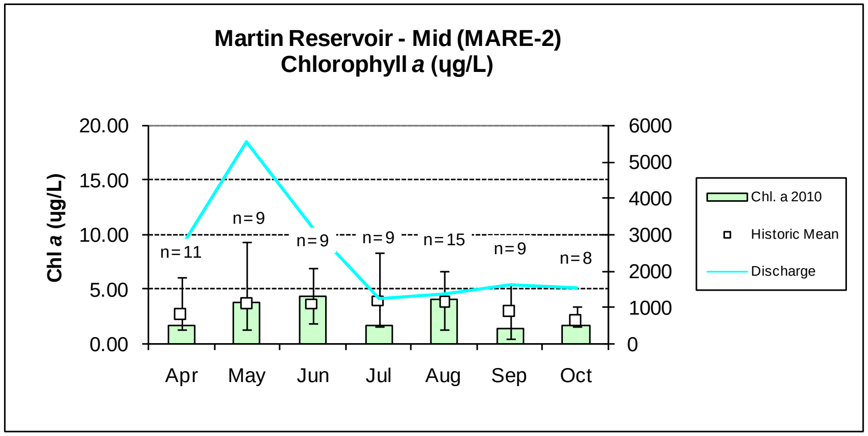


Figure 11. Monthly chlorophyll *a* concentrations measured at mid and lower stations in Martin Reservoir, April-October 2010 vs. average monthly discharge. Monthly discharge acquired from Alabama Power at Martin Reservoir Dam. Each bar graph depicts monthly changes in each station. The historic mean (1992-2010) and min/max ranges are also displayed for comparison. The "n" value equals the number of datapoints included in the monthly historic calculations.



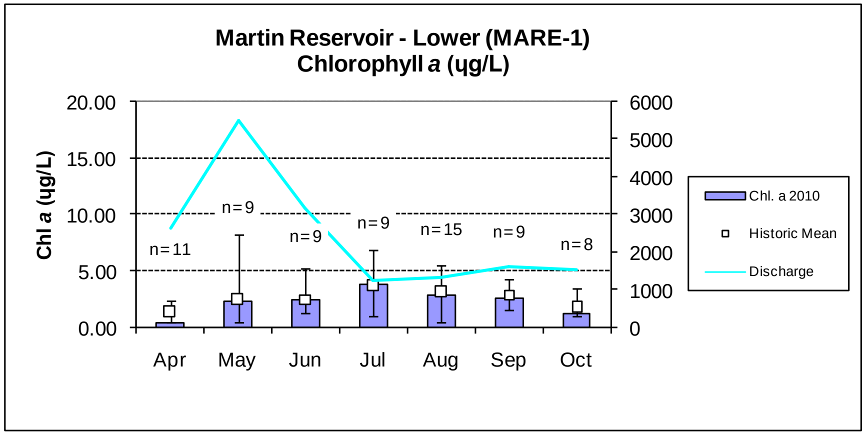


Figure 12. Monthly TSS concentrations measured at upstream 280, upper, and Kowaliga stations in Martin Reservoir, April-October 2010 vs. average monthly discharge. Monthly discharge acquired from Alabama Power at Martin Reservoir Dam. Each bar graph depicts monthly changes in each station. The historic mean (1992-2010) and min/max ranges are also displayed for comparison. The "n" value equals the number of datapoints included in the monthly historic calculations.

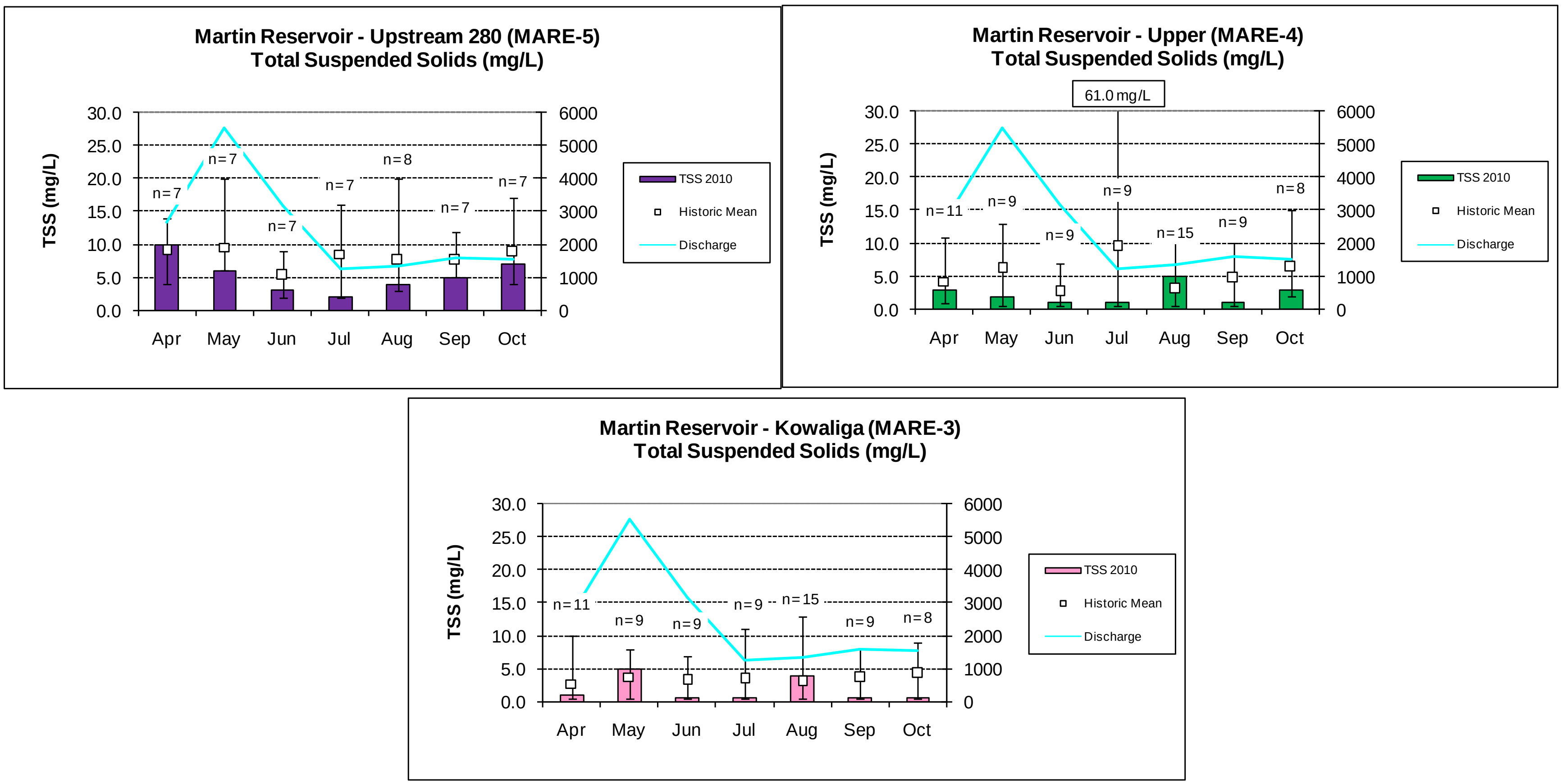
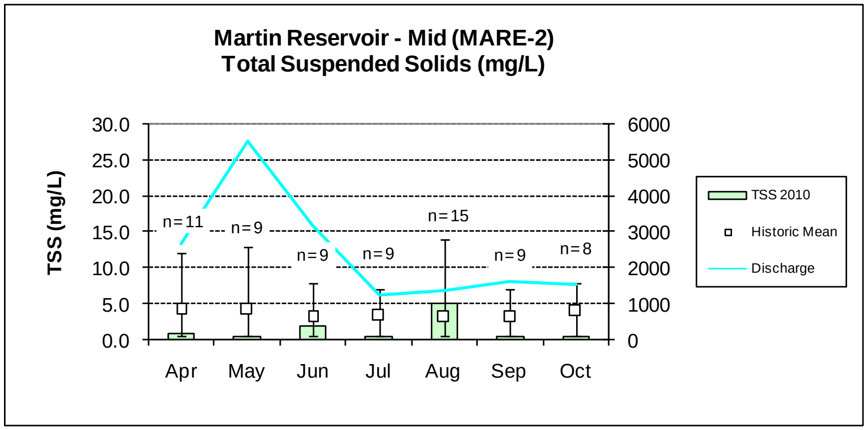


Figure 13. Monthly TSS concentrations measured at mid and lower stations in Martin Reservoir, April-October 2010 vs. average monthly discharge. Monthly discharge acquired from Alabama Power at Martin Reservoir Dam. Each bar graph depicts monthly changes in each station. The historic mean (1992-2010) and min/max ranges are also displayed for comparison. The “n” value equals the number of datapoints included in the monthly historic calculations.



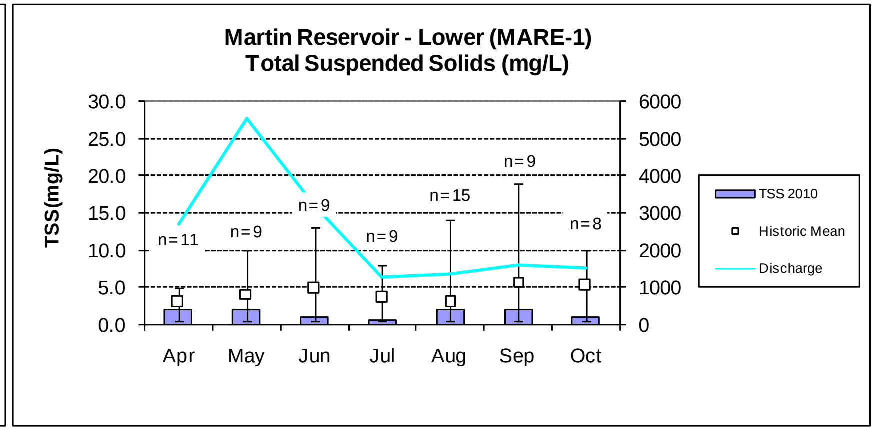


Table 2. Algal growth potential test results, Martin Reservoir, (expressed as mean Maximum Standing Crop (MSC) dry weights of *Selenastrum capricornutum* in mg/L) and limiting nutrient status. MSC values below 5 mg/L are considered to be protective in reservoirs and lakes (Raschke and Schultz 1987).

Station	Hillabee (MARE-6)		Upstream 280 (MARE-5)		Upper (MARE-4)	
	Control mean MSC	**Limiting Nutrient**	**Control mean MSC**	**Limiting Nutrient**	**Control mean MSC**	**Limiting Nutrient**
1997	---	---	---	---	2.60	PHOSPHORUS
2000	---	---	3.20	PHOSPHORUS	3.01	NITROGEN
April-04	---	---	3.63	PHOSPHORUS	3.24	PHOSPHORUS
May-04	---	---	3.79	PHOSPHORUS	3.01	PHOSPHORUS
Jun-04	---	---	3.59	PHOSPHORUS	3.38	PHOSPHORUS
Jul-04	---	---	2.70	PHOSPHORUS	1.94	PHOSPHORUS
Aug-04	---	---	4.44	PHOSPHORUS	2.97	CO-LIMITING
Sep-04	---	---	4.28	PHOSPHORUS	4.04	CO-LIMITING
Oct-04	---	---	5.40	PHOSPHORUS	4.43	CO-LIMITING
2005	---	---	4.26	PHOSPHORUS	3.50	CO-LIMITING
2010	3.47	NITROGEN	2.25	PHOSPHORUS	---	---

Station	Kowaliga (MARE-3)		Mid (MARE-2)		Lower (MARE-1)	
	Control mean MSC	**Limiting Nutrient**	**Control mean MSC**	**Limiting Nutrient**	**Control mean MSC**	**Limiting Nutrient**
1997	1.58	CO-LIMITING	1.83	CO-LIMITING	1.75	PHOSPHORUS
2000	1.63	PHOSPHORUS	*	*	1.73	PHOSPHORUS
April-04	2.05	PHOSPHORUS	2.05	PHOSPHORUS	1.92	PHOSPHORUS
May-04	1.85	PHOSPHORUS	1.97	PHOSPHORUS	1.41	PHOSPHORUS
Jun-04	2.36	PHOSPHORUS	2.39	PHOSPHORUS	2.43	PHOSPHORUS
Jul-04	1.27	PHOSPHORUS	1.56	PHOSPHORUS	1.38	PHOSPHORUS
Aug-04	1.83	CO-LIMITING	2.61	CO-LIMITING	2.43	CO-LIMITING
Sep-04	1.86	PHOSPHORUS	1.90	PHOSPHORUS	1.73	PHOSPHORUS
Oct-04	3.25	PHOSPHORUS	3.34	PHOSPHORUS	3.12	PHOSPHORUS
2005	2.78	PHOSPHORUS	2.89	PHOSPHORUS	2.99	PHOSPHORUS
2010	---	---	---	---	---	---

*Lost/damaged sample

Figure 14. Monthly DO concentrations at 1.5 m (5 ft) for Martin Reservoir stations collected April-October 2010. ADEM Water Quality Criteria pertaining to reservoir waters require a DO concentration of 5.0 mg/L at this depth (ADEM 2010).

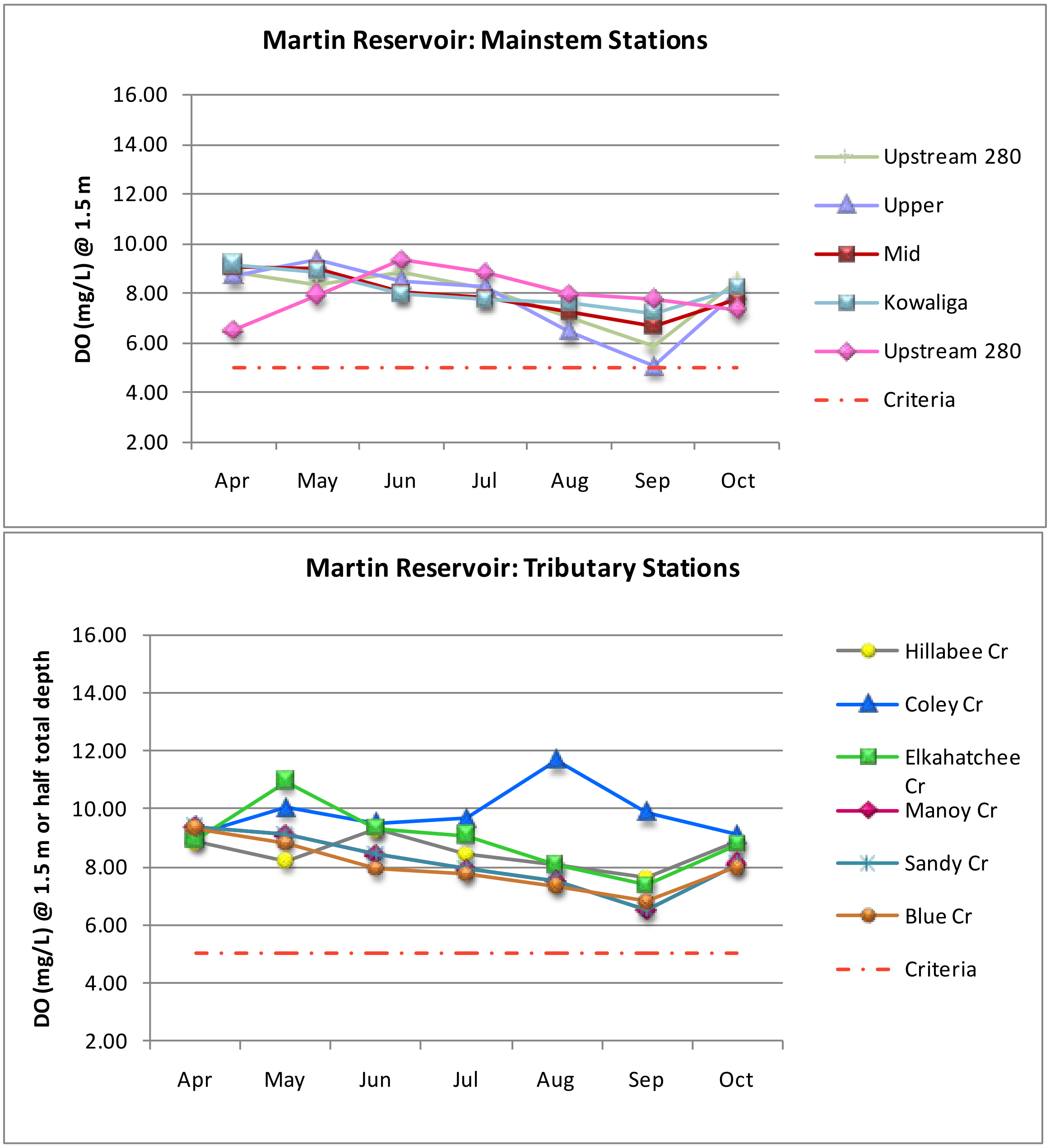


Figure 15. Monthly depth profiles of dissolved oxygen, temperature, and conductivity in the upper Martin Reservoir station, April-October 2010.

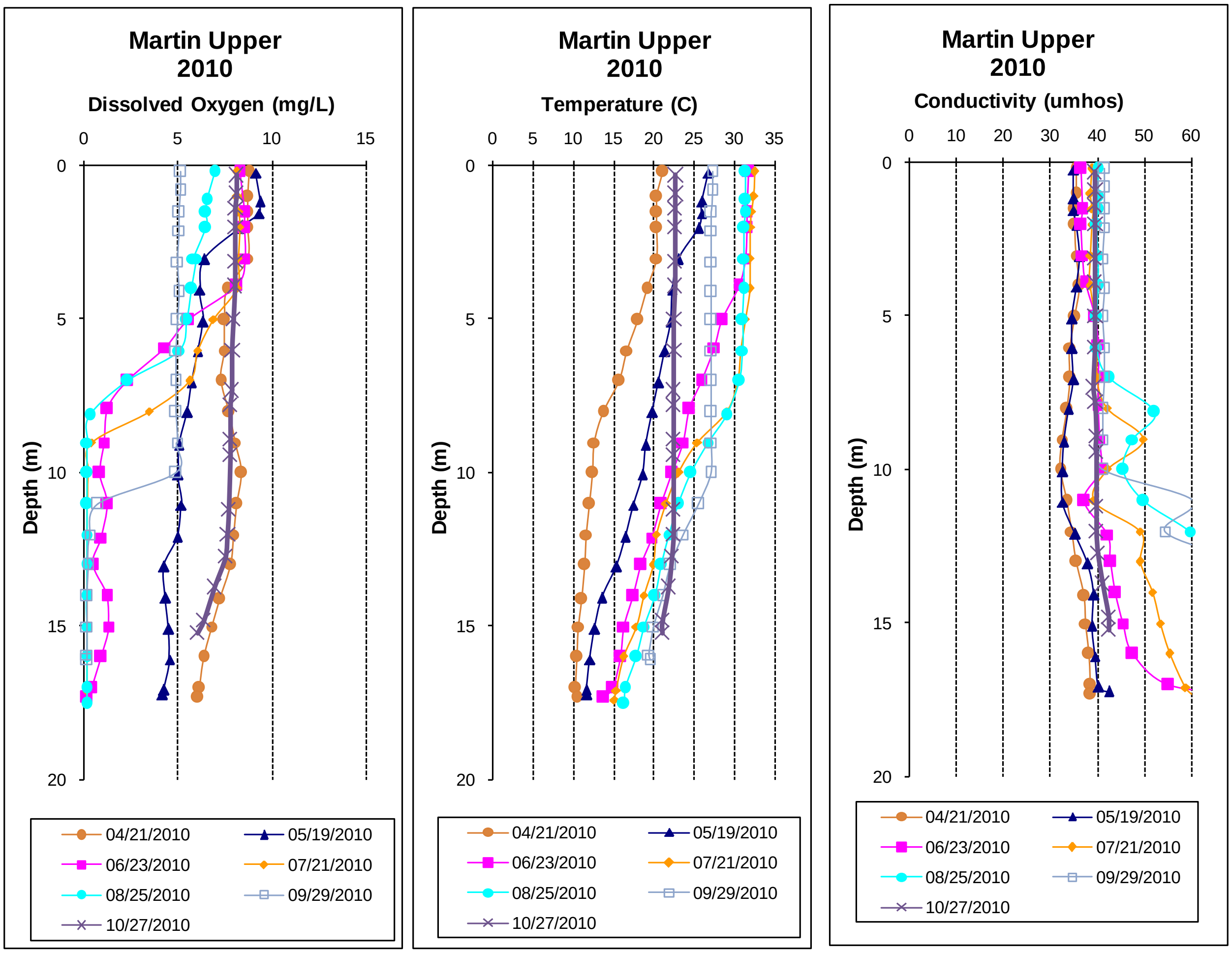


Figure 16. Monthly depth profiles of dissolved oxygen, temperature, and conductivity in the mid Martin Reservoir station, April-October 2010.

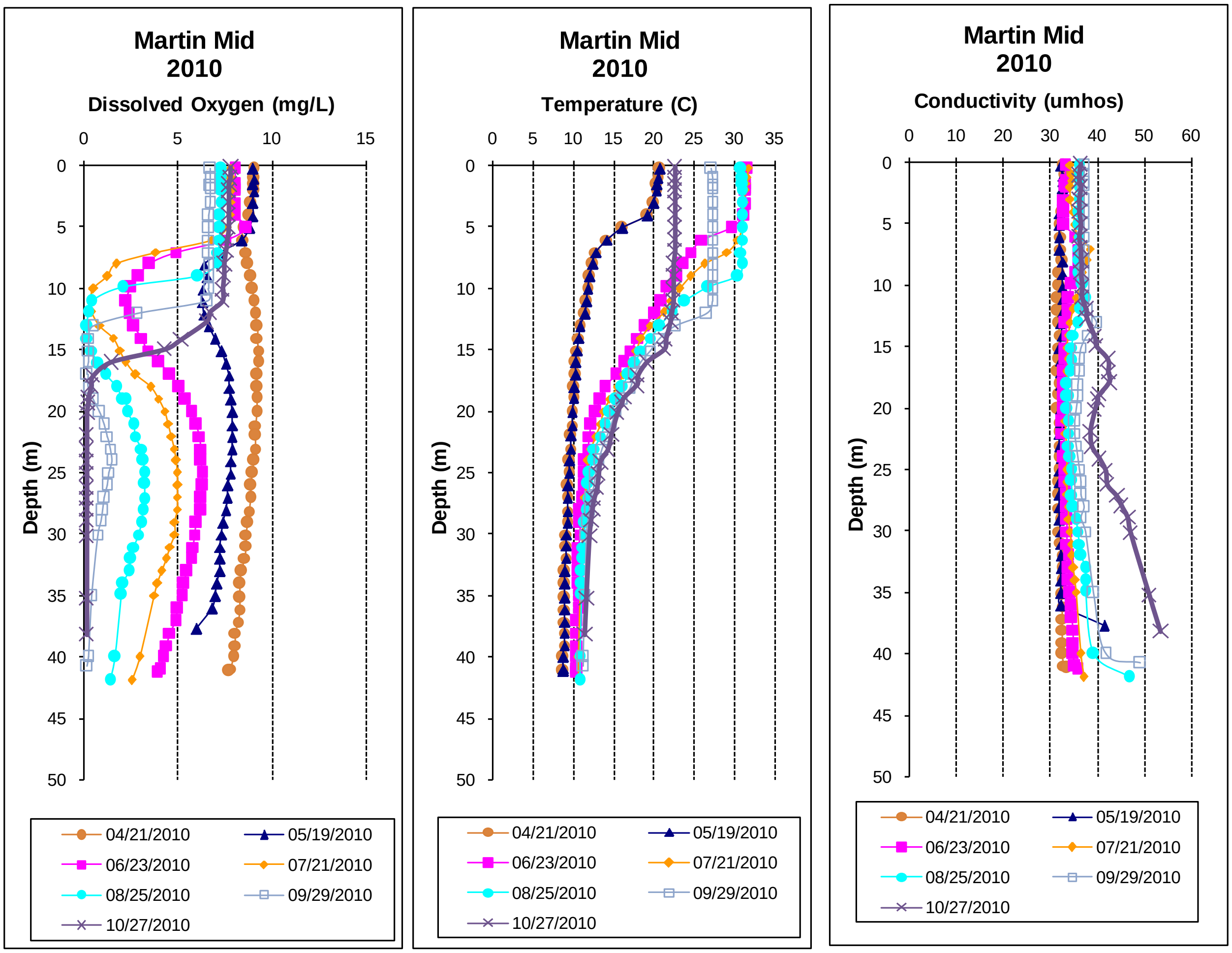


Figure 17. Monthly depth profiles of dissolved oxygen, temperature, and conductivity in the lower Martin Reservoir station, April-October 2010**.**

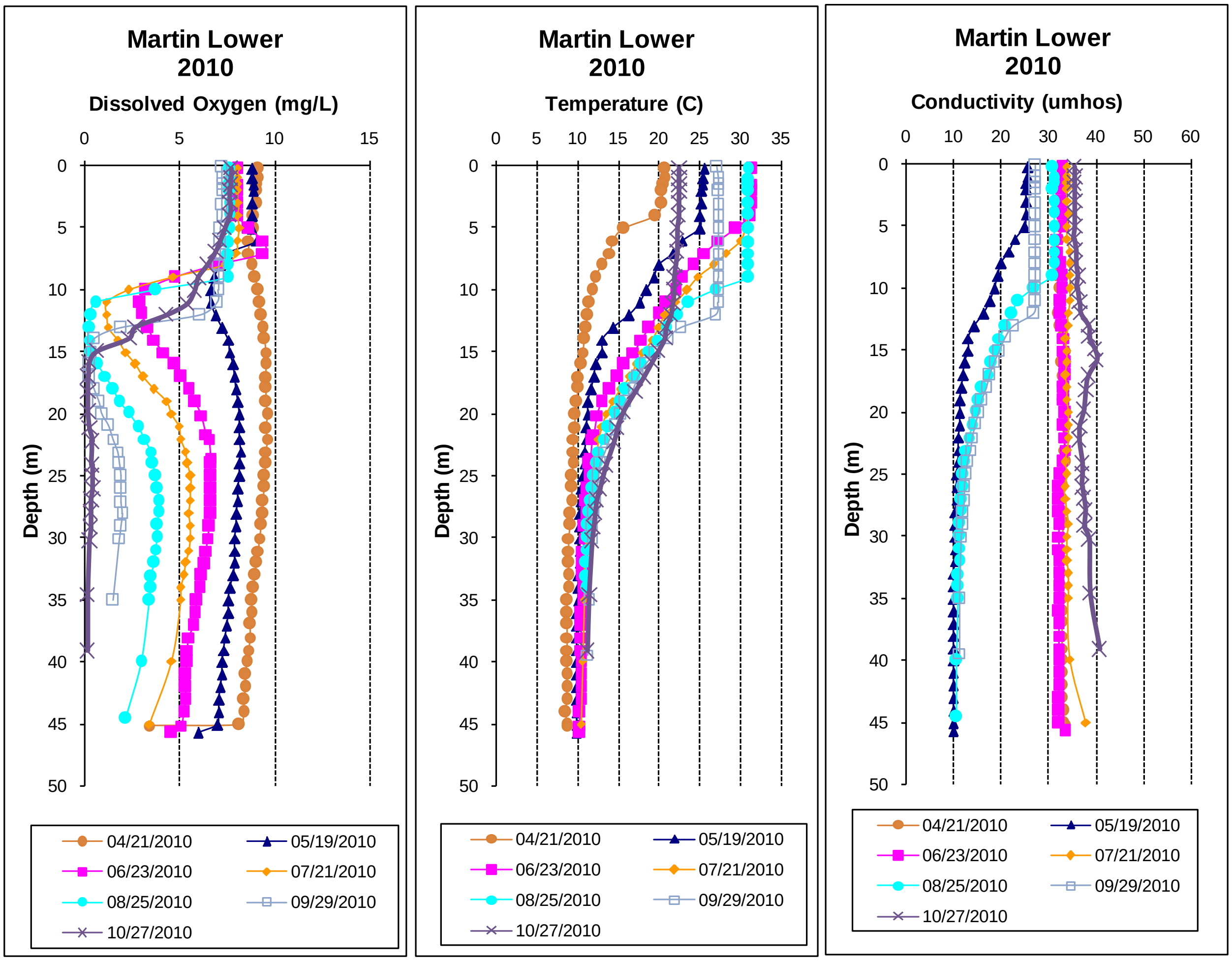
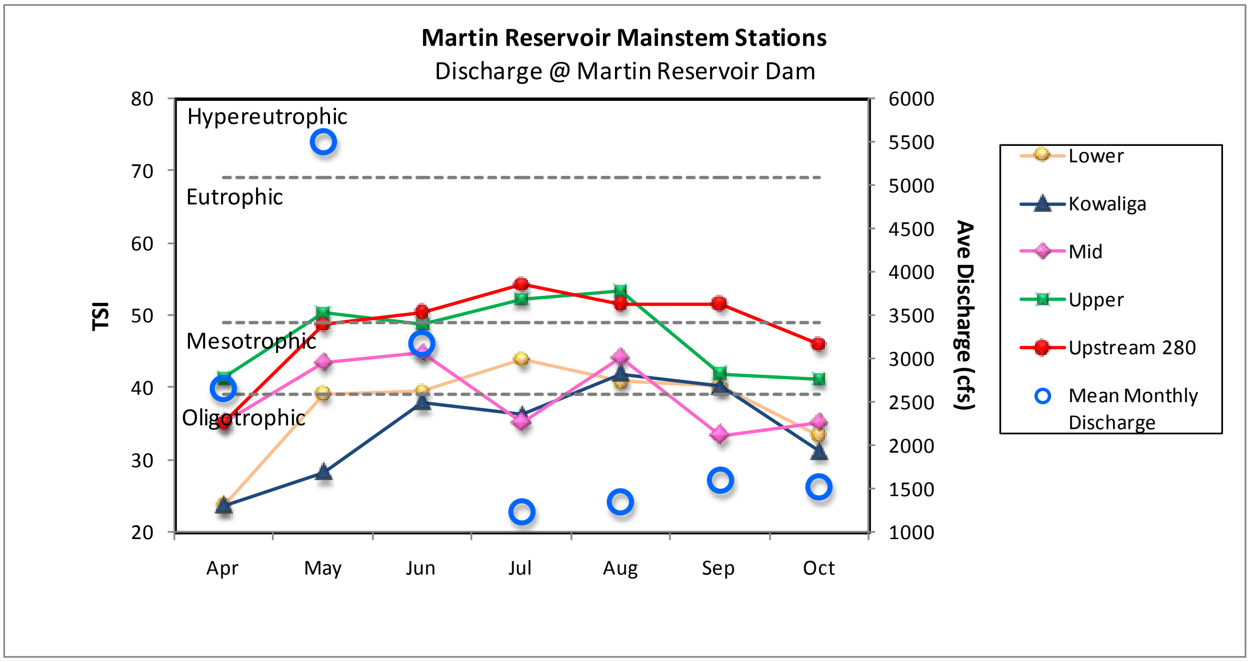
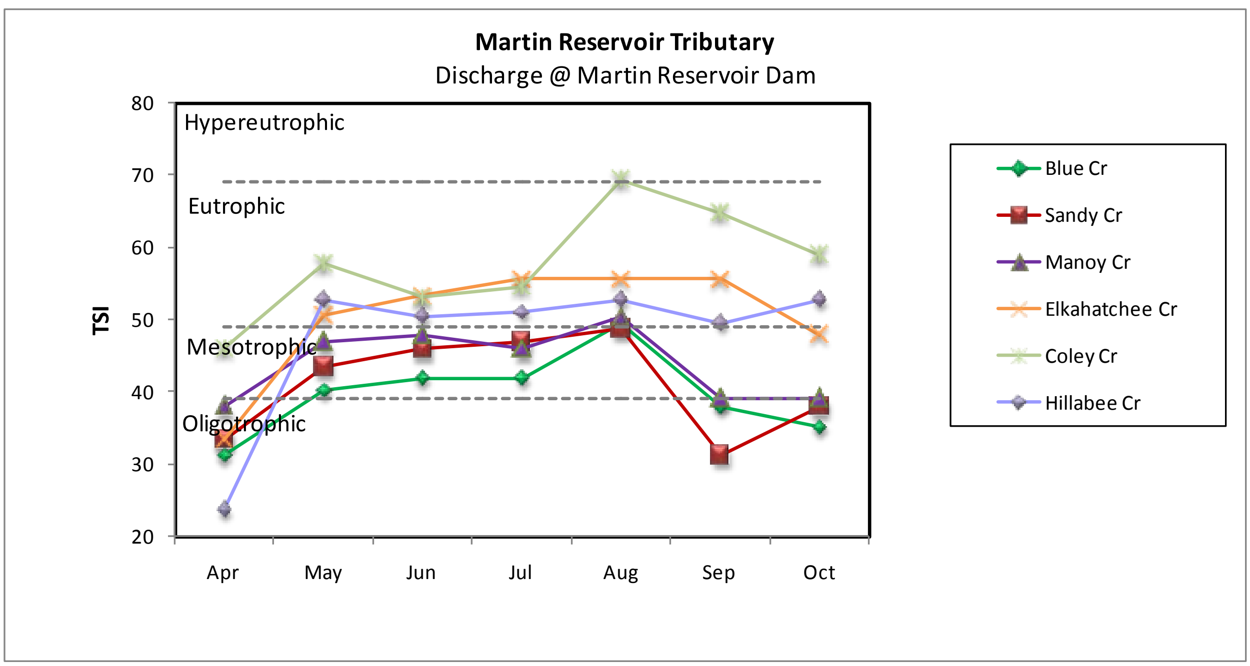


Figure 18. Monthly TSI values calculated for mainstem and tributary Martin Reservoir stations using chl *a* concentrations and Carlson's Trophic State Index calculation. Monthly discharge acquired from Alabama Power at Martin Dam.





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APPENDIX

Appendix Table 1. Summary of water quality data collected April-October, 2010. Minimum (Min) and maximum (Max) values calculated using minimum detection limits (MDL) when results were less than this value. Median (Med), average (Ave), 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
MARE-1	**Physical**						
	Turbidity (NTU)	7	1.2	5.6	1.6	2.2	1.5
	Total Dissolved Solids (mg/L) [J]	7	12.0	56.0	38.0	35.1	14.7
	Total Suspended Solids (mg/L)	7	< 1.0	2.0	2.0	1.5	0.6
	Hardness (mg/L)	4	8.1	9.6	9.0	8.9	0.6
	Alkalinity (mg/L)	7	7.7	11.5	9.3	9.7	1.4
	Photic Zone (m)	7	5.26	10.51	9.15	8.66	1.67
	Secchi (m)	7	2.17	5.64	3.83	3.95	1.12
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.021	0.021	0.010	0.010	0.000
	Nitrate+Nitrite Nitrogen (mg/L) [J]	7	0.002	0.169	0.005	0.042	0.066
	Total Kjeldahl Nitrogen (mg/L)	7	< 0.080	0.448	0.040	0.164	0.167
	Total Nitrogen (mg/L) [J]	7	< 0.043	0.617	0.138	0.206	0.210
	Dissolved Reactive Phosphorus (mg/L) [J]	7	< 0.003	0.011	0.008	0.007	0.004
	Total Phosphorus (mg/L) [J]	7	< 0.006	0.019	0.007	0.010	0.006
	CBOD-5 (mg/L)	7	< 2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7	1.8	2.1	1.9	1.9	0.1
	Biological						
	Chlorophyll a (ug/L)	7	< 1.00	3.92	2.49	2.31	1.10
	E. coli (mpn/100mL) [J]	3	< 1	7	3	4	3
MARE-2	**Physical**						
	Turbidity (NTU)	7	1.7	4.9	1.9	2.3	1.1
	Total Dissolved Solids (mg/L)	7	14.0	48.0	34.0	33.4	12.0
	Total Suspended Solids (mg/L) [J]	7	< 1.0	5.0	0.5	1.4	1.7
	Hardness (mg/L)	4	8.6	9.8	9.3	9.3	0.5
	Alkalinity (mg/L)	7	8.7	13.4	11.9	11.4	1.8
	Photic Zone (m)	7	5.25	11.23	8.37	8.49	1.90
	Secchi (m)	7	1.97	4.91	3.92	3.68	1.05
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.021	0.021	0.010	0.010	0.000
	Nitrate+Nitrite Nitrogen (mg/L) [J]	7	< 0.002	0.176	0.004	0.042	0.065
	Total Kjeldahl Nitrogen (mg/L)	7	< 0.080	0.477	0.040	0.142	0.181
	Total Nitrogen (mg/L) [J]	7	< 0.042	0.653	0.072	0.184	0.230
	Dissolved Reactive Phosphorus (mg/L) [J]	7	< 0.003	0.011	0.008	0.007	0.004
	Total Phosphorus (mg/L) [J]	7	0.005	0.015	0.008	0.009	0.004
	CBOD-5 (mg/L)	7	< 2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7	1.8	2.1	1.9	1.9	0.1
	Biological						
	Chlorophyll a (ug/L)	7	1.34	4.27	1.60	2.59	1.33
	E. coli (mpn/100mL) [J]	3	< 1	4	1	2	2

Station	Parameter	N	Min	Max	Med	Mean	SD
MARE-3	**Physical**						
	Turbidity (NTU)	6	1.4	4.8	1.6	2.1	1.3
	Total Dissolved Solids (mg/L)	7	22.0	46.0	34.0	33.7	8.9
	Total Suspended Solids (mg/L)	7	< 1.0	5.0	0.5	1.7	1.9
	Hardness (mg/L)	4	8.3	12.4	8.9	9.6	1.9
	Alkalinity (mg/L)	7	9.2	12.4	10.1	10.3	1.1
	Photic Zone (m)	7	5.91	11.78	9.95	9.20	2.20
	Secchi (m)	7	2.47	5.29	3.45	3.75	1.06
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.021	0.021	0.010	0.010	0.000
	Nitrate+Nitrite Nitrogen (mg/L) [J]	7	< 0.002	0.127	0.003	0.040	0.053
	Total Kjeldahl Nitrogen (mg/L)	7	< 0.080	0.481	0.162	0.211	0.174
	Total Nitrogen (mg/L) [J]	7	< 0.042	0.608	0.178	0.251	0.195
	Dissolved Reactive Phosphorus (mg/L) [J]	7	< 0.003	0.011	0.009	0.007	0.004
	Total Phosphorus (mg/L) [J]	7	< 0.006	0.019	0.007	0.008	0.005
	CBOD-5 (mg/L)	7	< 2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7	1.9	2.1	1.9	2.0	0.1
	Biological						
	Chlorophyll a (ug/L)	7	< 0.80	3.20	1.78	1.74	1.00
	E. coli (mpn/100mL) [J]	3	< 1	1	1	1	0
MARE-4	**Physical**						
	Turbidity (NTU)	7	2.5	6.1	3.6	3.7	1.2
	Total Dissolved Solids (mg/L) [J]	7	28.0	78.0	34.0	40.9	16.9
	Total Suspended Solids (mg/L)	7	1.0	5.0	2.0	2.3	1.5
	Hardness (mg/L)	4	9.8	13.8	10.6	11.2	1.8
	Alkalinity (mg/L)	7	10.8	20.0	12.8	13.7	3.2
	Photic Zone (m)	7	4.11	9.97	5.21	5.68	2.01
	Secchi (m)	7	1.67	3.13	2.42	2.32	0.57
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.021	0.021	0.010	0.010	0.000
	Nitrate+Nitrite Nitrogen (mg/L) [J]	7	< 0.002	0.109	0.005	0.036	0.049
	Total Kjeldahl Nitrogen (mg/L)	7	< 0.080	0.464	0.175	0.234	0.178
	Total Nitrogen (mg/L) [J]	7	< 0.042	0.563	0.278	0.271	0.201
	Dissolved Reactive Phosphorus (mg/L) [J]	7	< 0.003	0.012	0.009	0.008	0.004
	Total Phosphorus (mg/L)	7	0.010	0.017	0.015	0.014	0.003
	CBOD-5 (mg/L)	7	< 2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7	1.9	2.5	2.1	2.1	0.2
	Biological						
	Chlorophyll a (ug/L)	7	2.94	10.15	6.41	6.04	3.04
	E. coli (mpn/100mL) [J]	3	< 1	3	3	2	1

Station	Parameter	N		Min	Max	Med	Mean	SD
MARE-5	**Physical**							
	Turbidity (NTU)	7		5.2	8.0	6.9	6.7	1.1
	Total Dissolved Solids (mg/L) [J]	7		22.0	54.0	38.0	36.9	12.3
	Total Suspended Solids (mg/L)	7		2.0	10.0	5.0	5.3	2.7
	Hardness (mg/L)	4		10.3	13.4	10.8	11.4	1.4
	Alkalinity (mg/L)	7		10.8	16.3	13.1	13.1	2.1
	Photic Zone (m)	7		2.91	4.21	3.72	3.61	0.46
	Secchi (m)	7		1.06	1.94	1.36	1.33	0.30
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.021	0.021	0.010	0.010	0.000
	Nitrate+Nitrite Nitrogen (mg/L) [J]	7		0.012	0.139	0.025	0.053	0.051
	Total Kjeldahl Nitrogen (mg/L)	7	<	0.080	0.522	0.300	0.287	0.195
	Total Nitrogen (mg/L) [J]	7	<	0.052	0.535	0.325	0.340	0.190
	Dissolved Reactive Phosphorus (mg/L) [J]	7	<	0.003	0.011	0.009	0.008	0.004
	Total Phosphorus (mg/L)	7		0.014	0.019	0.018	0.017	0.002
	CBOD-5 (mg/L)	7	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7		1.9	2.6	2.3	2.3	0.2
	Biological							
	Chlorophyll a (ug/L)	7		1.60	11.21	7.63	6.96	3.09
	E. coli (mpn/100mL) [J]	3		2	5	3	3	2
MARE-6	**Physical**							
	Turbidity (NTU)	7		5.9	8.4	6.5	6.7	0.9
	Total Dissolved Solids (mg/L) [J]	7	<	1.0	74.0	38.0	37.5	21.6
	Total Suspended Solids (mg/L)	7		1.0	9.0	3.0	4.0	2.6
	Hardness (mg/L)	4		9.0	10.7	10.2	10.0	0.7
	Alkalinity (mg/L)	7		10.2	21.8	12.6	14.5	4.1
	Photic Zone (m)	7		1.90	4.00	3.20	3.08	0.85
	Secchi (m)	7		1.06	1.89	1.46	1.45	0.27
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.021	0.055	0.010	0.017	0.017
	Nitrate+Nitrite Nitrogen (mg/L) [J]	7	<	0.002	0.066	0.002	0.021	0.029
	Total Kjeldahl Nitrogen (mg/L)	7	<	0.080	0.549	0.222	0.237	0.211
	Total Nitrogen (mg/L) [J]	7	<	0.041	0.551	0.224	0.258	0.209
	Dissolved Reactive Phosphorus (mg/L) [J]	7	<	0.003	0.014	0.012	0.010	0.005
	Total Phosphorus (mg/L)	7		0.018	0.035	0.023	0.024	0.006
	CBOD-5 (mg/L)	7	<	2.0	3.1	1.0	1.7	0.9
	Chlorides (mg/L)	7		1.8	3.1	2.5	2.4	0.5
	Biological							
	Chlorophyll a (ug/L)	7	<	1.00	9.61	8.01	7.42	3.24
	E. coli (mpn/100mL) [J]	3	<	1	9	6	5	4

Station	Parameter	N		Min	Max	Med	Mean	SD
MARE-7	**Physical**							
	Turbidity (NTU)	7		3.3	11.1	8.3	7.5	3.2
	Total Dissolved Solids (mg/L) [J]	7		26.0	128.0	32.0	46.6	36.5
	Total Suspended Solids (mg/L)	7	<	1.0	11.0	5.0	5.3	3.9
	Hardness (mg/L)	4		10.2	14.9	11.6	12.1	2.0
	Alkalinity (mg/L)	7		12.2	22.7	15.6	15.8	3.5
	Photic Zone (m)	7		1.40	3.10	2.90	2.58	0.66
	Secchi (m)	7		0.75	1.90	1.44	1.39	0.38
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.021	0.021	0.010	0.010	0.000
	Nitrate+Nitrite Nitrogen (mg/L)	7	<	0.003	1.557	0.111	0.311	0.556
	Total Kjeldahl Nitrogen (mg/L)	7		0.180	0.814	0.571	0.588	0.218
	Total Nitrogen (mg/L)	7	<	0.291	2.308	0.795	0.899	0.663
	Dissolved Reactive Phosphorus (mg/L)	7	<	0.003	0.018	0.012	0.012	0.005
	Total Phosphorus (mg/L)	7		0.021	0.103	0.042	0.050	0.027
	CBOD-5 (mg/L)	7	<	2.0	4.4	1.0	1.8	1.2
	Chlorides (mg/L)	7		2.2	8.4	2.8	3.7	2.2
	Biological							
	Chlorophyll a (ug/L)	7		4.81	52.33	16.02	20.77	16.44
	E. coli (mpn/100mL) [J]	3	<	1	1	1	1	0
MARE-8	**Physical**							
	Turbidity (NTU)	7		2.6	7.1	3.7	4.2	1.5
	Total Dissolved Solids (mg/L) [J]	7		30.0	48.0	40.0	40.0	6.0
	Total Suspended Solids (mg/L)	7	<	1.0	10.0	4.0	4.1	3.2
	Hardness (mg/L)	4		10.7	13.3	11.6	11.8	1.1
	Alkalinity (mg/L)	7		10.4	15.9	14.0	13.5	1.9
	Photic Zone (m)	7		3.35	7.23	5.14	5.05	1.42
	Secchi (m)	7		1.18	2.35	2.23	1.97	0.46
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.021	0.021	0.010	0.010	0.000
	Nitrate+Nitrite Nitrogen (mg/L) [J]	7	<	0.002	0.048	0.002	0.010	0.017
	Total Kjeldahl Nitrogen (mg/L)	7	<	0.080	0.536	0.323	0.322	0.171
	Total Nitrogen (mg/L) [J]	7	<	0.052	0.537	0.324	0.332	0.175
	Dissolved Reactive Phosphorus (mg/L) [J]	7	<	0.003	0.014	0.012	0.010	0.005
	Total Phosphorus (mg/L)	7		0.012	0.024	0.021	0.019	0.004
	CBOD-5 (mg/L)	7	<	2.0	2.2	1.0	1.2	0.4
	Chlorides (mg/L)	7		1.8	2.4	2.2	2.2	0.2
	Biological							
	Chlorophyll a (ug/L)	7		1.34	12.82	10.15	9.07	4.38
	E. coli (mpn/100mL) [J]	3	<	1	2	2	2	1

Station	Parameter	N		Min	Max	Med	Mean	SD
MARE-9	**Physical**							
	Turbidity (NTU)	7		1.5	4.1	2.3	2.4	0.8
	Total Dissolved Solids (mg/L) [J]	7		2.0	32.0	26.0	22.0	11.5
	Total Suspended Solids (mg/L) [J]	7	<	1.0	10.0	1.0	2.7	3.6
	Hardness (mg/L)	3		9.9	11.3	10.9	10.7	0.7
	Alkalinity (mg/L)	7		9.9	14.9	13.2	12.6	1.9
	Photic Zone (m)	7		5.88	10.66	7.64	7.69	1.48
	Secchi (m)	7		1.75	4.30	2.96	3.06	0.92
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.021	0.021	0.010	0.010	0.000
	Nitrate+Nitrite Nitrogen (mg/L) [J]	7	<	0.002	0.142	0.003	0.028	0.052
	Total Kjeldahl Nitrogen (mg/L)	7		0.219	0.580	0.350	0.355	0.138
	Total Nitrogen (mg/L) [J]	7	<	0.222	0.583	0.394	0.383	0.151
	Dissolved Reactive Phosphorus (mg/L) [J]	7	<	0.003	0.012	0.009	0.008	0.004
	Total Phosphorus (mg/L) [J]	7		0.007	0.016	0.010	0.011	0.003
	CBOD-5 (mg/L)	7	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7		1.8	2.2	2.0	2.0	0.2
	Biological							
	Chlorophyll a (ug/L)	7		2.14	7.48	4.81	4.35	2.07
	E. coli (mpn/100mL) [J]	3	<	1	2	1	1	1
MARE-10	**Physical**							
	Turbidity (NTU)	6		1.8	5.4	1.9	2.4	1.4
	Total Dissolved Solids (mg/L) [J]	7		6.0	40.0	38.0	29.1	13.7
	Total Suspended Solids (mg/L)	7	<	1.0	10.0	3.0	3.1	3.4
	Hardness (mg/L)	4		7.1	11.9	10.4	9.9	2.3
	Alkalinity (mg/L)	7		9.8	20.6	13.9	13.4	3.8
	Photic Zone (m)	7		5.25	9.10	8.05	7.59	1.49
	Secchi (m)	7		2.25	4.57	3.15	3.34	0.83
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.021	0.021	0.010	0.010	0.000
	Nitrate+Nitrite Nitrogen (mg/L) [J]	7	<	0.002	0.169	0.006	0.039	0.063
	Total Kjeldahl Nitrogen (mg/L)	7	<	0.080	0.660	0.274	0.285	0.220
	Total Nitrogen (mg/L) [J]	7	<	0.045	0.661	0.350	0.324	0.234
	Dissolved Reactive Phosphorus (mg/L) [J]	7	<	0.003	0.012	0.009	0.008	0.004
	Total Phosphorus (mg/L) [J]	7		0.006	0.014	0.009	0.010	0.003
	CBOD-5 (mg/L)	7	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7		1.8	2.2	2.0	2.0	0.2
	Biological							
	Chlorophyll a (ug/L)	7		1.07	6.41	3.74	3.55	2.08
	E. coli (mpn/100mL) [J]	3	<	1	2	2	2	1

Station	Parameter	N		Min	Max	Med	Mean	SD
MARE-11	**Physical**							
	Turbidity (NTU)	6		1.7	5.9	2.0	2.6	1.6
	Total Dissolved Solids (mg/L)	7		6.0	46.0	30.0	24.9	13.8
	Total Suspended Solids (mg/L)	7	<	1.0	5.0	1.0	1.7	1.6
	Hardness (mg/L)	4		6.9	10.0	9.3	8.9	1.4
	Physical							
	Alkalinity (mg/L)	7		9.3	15.2	11.3	11.7	2.4
	Photic Zone (m)	7		5.41	10.76	8.52	8.42	1.62
	Secchi (m)	7		1.84	4.17	3.44	3.32	0.75
	Chemical							
	Ammonia Nitrogen (mg/L)	7	<	0.021	0.021	0.010	0.010	0.000
	Nitrate+Nitrite Nitrogen (mg/L) [J]	7	<	0.002	0.166	0.005	0.044	0.064
	Total Kjeldahl Nitrogen (mg/L)	7	<	0.080	0.528	0.309	0.272	0.182
	Total Nitrogen (mg/L) [J]	7	<	0.045	0.532	0.358	0.317	0.192
	Dissolved Reactive Phosphorus (mg/L) [J]	7		0.003	0.011	0.008	0.008	0.003
	Total Phosphorus (mg/L) [J]	7	<	0.006	0.016	0.009	0.009	0.004
	CBOD-5 (mg/L)	7	<	2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7		1.8	2.1	1.9	2.0	0.2
	Biological							
	Chlorophyll a (ug/L)	7		1.07	6.94	2.67	2.97	1.92
	E. coli (mpn/100mL) [J]	3	<	1	1	1	1	0

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