Lower Catawba River Basin – 2020 Nutrient Study

Final Report of the Field Program

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Executive Summary

During 2020, South Carolina Department of Health and Environmental Control (DHEC) collected water quality data from two stream sites and six lake sites in the Lower Catawba River Basin located in north-central South Carolina. The field sampling program spanned early April through the end of October and builds on studies conducted in previous years by DHEC and stakeholder partners. This program was designed to address specific questions that remained from studies in prior years including further resolving the seasonal cycle of physical conditions and progression in phototroph ecology in the system and to enhance chemical and physical understandings at key locations in the basin.

The 2020 program objective was achieved using a series of five monitoring systems in Lake Wateree and Fishing Creek Reservoir to continuously record physical/hydrographic parameters and biological responses (sensor-based chlorophyll-a and phycocyanin) coupled with biweekly water quality sampling at these lake sites as well as three other strategic locations (one in upper Lake Wateree and two in the Catawba River). The data collected as part of this study will provide insights into the mechanistic links between physical conditions and nutrients and algal responses such as phytoplankton biomass and toxin production.

This report discusses the successes and challenges of the field program and briefly summarizes data collected as part of the continuous monitoring and biweekly grab sample project components. Generally, all field program objectives were achieved as nearly all targeted data were successfully collected. Early in the field season, technical challenges associated with new equipment led to interruptions in the continuous records at three locations. The continuous records at these sites were more complete from early July through the end of record as issues were resolved.

Over the course of the field program:

- Surface temperatures generally exceeded 30°C by mid-July and persisted through mid-September based on vertical profile and continuous monitoring data. Apparent temperature-based stratification was variable based on the area of the lake.
- The upstream lake stations in Lake Wateree exhibited the lowest total chlorophyll-a concentrations and the dissolved oxygen concentrations and pH values in the water column in this area showed little response to algal growth.
- The highest total chlorophyll-a concentrations were measured in the Dutchman Creek arm of Lake Wateree. Elevated upper water column dissolved oxygen and pH were also observed in the lake arm.
- Generally, total chlorophyll-a concentrations were higher at 1.5 m than at the surface (0.3 m).
- Nutrient concentrations (total phosphorus and total nitrogen) in water discharged from Lake Wylie were on average lower than other sites (stream and lake) sampled as part of this project.
- Despite returning the highest total chlorophyll-a concentrations, average total phosphorus and total nitrogen in the Dutchman Creek arm were the lowest measured among the lake sites. Average total organic carbon concentration was highest in this lake arm.

Overview of the 2020 Lower Catawba Study

The Lower Catawba River Basin includes the watershed drainage from the tailrace at Lake Wylie in Fort Mill, South Carolina, to the tailrace at Lake Wateree in Kershaw County, South Carolina. The system is one of the major watersheds for the city of Charlotte, North Carolina, and its south suburbs including rapidly growing York County, South Carolina. More than 30 ambient monitoring locations in the Lower Catawba are included in the State's draft 2018 303(d) list as impaired for total phosphorus, total nitrogen, and/or chlorophyll-a. In addition, blooms of planktonic *Microcystis* and colonies of *Lyngbya wollei*, a filamentous, mat-forming algae are commonly present in Lake Wateree during the hot summer months. These cyanobacteria produce toxins known to cause swimmer's itch, respiratory problems, and taste and odor issues in drinking water.

In 2016, using an updated version of the WARMF model, South Carolina Department of Health and Environmental Control (DHEC) determined and proposed preliminary total phosphorus and total nitrogen load reductions for point and nonpoint sources as the starting point for Total Maximum Daily Loads (TMDLs). The load reductions included a 66 percent cut in phosphorus and a 55 percent cut in nitrogen from wastewater sources. Reductions from stormwater and human nonpoint sources varied by location, up to 50 percent. DHEC presented these results to stakeholders and proposed that stakeholders conduct an allocation process to determine individual allocations most effectively. DHEC provided a phosphorus allocation tool to assist the process.

In response, the dischargers in the Lower Catawba asked DHEC for time to collect additional data and develop more detailed modeling and develop site-specific numeric nutrient (total nitrogen and total phosphorus) and chlorophyll-a standards for the lakes. The standards would be used to develop TMDLs aimed at addressing water quality impairments impacting designated uses. The stakeholders and the National Council for Air and Stream Improvement (NCASI) developed an approved Quality Assurance Project Plan (QAPP) and conducted extensive monitoring in the Catawba basin in 2017 and 2018. The group also initiated a facilitated model review group to select suitable models to support criteria and TMDL development.

In 2019, DHEC Bureau of Water (BOW) 303d, TMDL and Modeling group (TMDL group) implemented the *Lower Catawba River Basin – Stream and Lake Nutrient Water Quality Study* (Nutrient Study) as well as wet-weather watershed studies to produce an enhanced suite of environmental data. The results of these studies may be found in DHEC Bureau of Water Technical Report Nos. 009-2020 (Nutrient Study) and 014-2020 (Wet Weather Studies).[1,2]

As part of the Nutrient Study, BOW collected biweekly water quality data from six stream sites and 11 lake sites from mid-April through the end of October 2019. Broadly, the objectives of the Nutrient Study were to quantify nutrient loadings from the prevalent land use types in the basin and to resolve the relationship between physical and chemical conditions and ecological responses in Fishing Creek Reservoir and Lake

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[1]South Carolina Department of Health and Environmental Control. 2020. Lower Catawba River Basin – Stream and Lake Nutrient Water Quality Study, Final Report of the 2019 Study. Bureau of Water Technical Report No. 009-2020. February 2020.

[2]South Carolina Department of Health and Environmental Control. 2020. Phase 1-Wet Weather Data Analysis. Bureau of Water Technical Report No. 014-2020. June 2020.

Wateree. Samples were collected for 18 unique chemical water quality parameters in the streams and at multiple depths in the lakes. In addition, total chlorophyll-a and photosynthetic pigment samples along with sensor-based vertical profiles for physical parameters were collected in the lakes. Monitoring systems to continuously record physical parameters at the surface were also deployed at two locations: one in the mid-lake area of Fishing Creek Reservoir and one in Lake Wateree off the Dutchman Creek lake arm. Further, DHEC partnered with EPA to 1) conduct algal growth potential tests to investigate nutrient limitation on the phytoplankton community, 2) quantify sediment oxygen demand and nutrient fluxes between sediments and the water column, and 3) install two additional continuous monitoring systems at strategic locations in Lake Wateree. DHEC also collaborated with NCASI to quantify grain size and organic carbon content in Lake Wateree sediments. Lastly, DHEC and Coastal Carolina University installed a weather station at Wateree State Park to support modelling efforts.

In 2019 and into the winter of 2020, BOW conducted two watershed studies aimed at characterizing nutrient loadings to the Catawba River and lake during wet-weather events in five watersheds of varying land use types. Nutrient loadings during storm events, particularly at the 'first flush' of the event, can be significant due to release of accumulated pollutant mass at the surface and in soil pores associated with high energy runoff of heavy rainfall. Currently, there are no nutrient loading data for the Lower Catawba associated with the wet-weather events. An understanding of these loadings during storm events enhances watershed modeling capability and robustness through verification of nutrient loading export mechanisms.

In 2020, the TMDL group conducted the *Lower Catawba River Basin – 2020 Nutrient Study* (2020 Lake Program) program to address specific questions that remained including further resolving the seasonal cycle of physical conditions and progression in phototroph ecology in the system and to enhance chemical and physical understandings at three key locations in the basin that represent important entry points into the system. The new data will be coupled with previous water quality studies by the dischargers and DHEC's ambient water quality monitoring data to develop new watershed, lake hydrodynamic, and lake water quality models to assist in informing site-specific numeric criteria for the Lower Catawba system.

The 2020 program objective was achieved using a series of five monitoring systems in Lake Wateree and Fishing Creek Reservoir to continuously record physical/hydrographic parameters and biological responses (sensor-based chlorophyll-a and phycocyanin) coupled with biweekly water quality sampling at these lake sites as well as three other strategic locations (one in upper Lake Wateree and two in the Catawba River). The data collected as part of this study will provide insights into the mechanistic links between physical conditions and nutrients and algal responses such as phytoplankton biomass and toxin production. Together with the results of the earlier studies, these links will help establish site-specific nutrient and chlorophyll-a criteria that are protective of the lakes' designated uses.

Nutrient Study Project/Task Description

Field Logistics

The 2020 Lake Program spanned 30 weeks from the end of March through the end of October 2020. The study focused on a series of eight strategic locations in the Lower Catawba River Basin to meet the objectives described above (Table 1, Figures 1,2):

1. LWT-01 – Lake Wylie tailrace immediately below dam (stream site)
2. CW-016 – Catawba River at Highway 9 bridge (stream site)
3. LCR-04 – Fishing Creek Reservoir off Bear Creek arm (lake site)
4. CW-231 – Lake Wateree headwater below Cedar Creek Reservoir dam (lake site)
5. LCR-02 – Lake Wateree upstream of Wateree Creek arm (lake site)
6. LCR-03 – Lake Wateree off Dutchman Creek arm (lake site)
7. CW-208 – Dutchman Creek arm of Lake Wateree (lake site)
8. CW-207B – Mid-lake Lake Wateree (lake site)

Table 1. Field program site coordinates and descriptions.

Station ID	Lat./Long.	County	Site Description
Stream Sites			
LWT-01	35.0213 / -81.0038	York	Lake Wylie Tailrace Boat Landing
CW-016	34.7083 / -80.8676	Chester	Catawba River at SC-9 (Fort Lawn)
Lake Sites			
LCR-04	34.6203 / -80.8862	Lancaster	Fishing Creek Reservoir off Bear Creek arm
CW-231	34.5365 / -80.8749	Lancaster	Lake Wateree headwater below Cedar Creek Reservoir dam
LCR-02	34.4882 / -80.9001	Fairfield/Lancaster	Lake Wateree upstream of Wateree Creek (near RL-11040)
LCR-03	34.4260 / -80.8460	Fairfield/Kershaw	Lake Wateree off Dutchmans Creek arm
CW-208	34.4222 / -80.8668	Fairfield	Lake Wateree at S-20-101 11 miles east northeast of Winnsboro
CW-207B	34.4039 / -80.7827	Fairfield	Mid-channel Lake Wateree at end of S-20-291

Figure 1. Grab sampling site LWT-01 at the boat ramp immediately below Lake Wylie dam.

Figure 2. Sampling sites near and within Fishing Creek Reservoir and Lake Wateree. Grab samples only were collected at river site CW-016 (purple). Continuous monitoring systems were installed and grab samples were collected at sites LCR-04, LCR-02, LCR-03, CW-208, and CW-207B (blue). Grab sampling only occurred at CW-231 (red).

Biweekly grab sampling was conducted at all sites and continuous monitoring systems were installed at five lake locations (LCR-04 in Fishing Creek Reservoir and LCR-02, LCR-03, CW-208, and CW-207B in Lake Wateree). Continuous monitoring systems were serviced every other week. Surface (nominal 0.3 m) grab sample parameters included:

- 5-day biochemical oxygen demand (BOD_5; stream sites only),
- Turbidity,
- Ammonia-nitrogen,
- Nitrate/nitrite-nitrogen,
- Total Kjeldahl Nitrogen,
- Total phosphorus,
- Orthophosphate,
- Total suspended solids,
- Total and filtered total organic carbon,
- Total chlorophyll-a (surface and 1.5 m, lake sites only), and
- Cyanotoxins (microcystins, lake site only, approximately monthly)

Field sensor measurements were recorded at each grab sample site (all sites) along with vertical profiles and photosynthetically active radiation penetration were collected at each lake site:

- Water temperature,
- Dissolved oxygen,
- pH,
- Turbidity,
- Specific conductance,
- Chlorophyll-a fluorescence (lake sites only), and
- Phycocyanin fluorescence (lake sites only)

Continuous monitoring systems recorded surface measurements (0.5-1.0 m depending on the system) at 15 to 30-minute intervals at the five lake locations. Surface measurements are the same as the field sensor measurements listed above. An attempt was made to collect continuous nitrate data at three locations (LCR-04, LCR-03, and CW-207B), however, technical issues related to Ott EcoN instrument power consumption curtailed the records for this parameter. As such, continuous nitrate data will not be presented here. Further, technical issues related to calibration and manufacturer failings of the In-Situ Aqua Troll 600 phycocyanin sensors used at the same locations limited the usefulness of these measurements and will not be presented here.

Sensor Data

Surface Parameters

Surface physical parameters were collected at a depth of 0.3 m at each stream and lake site using a calibrated Hydrolab DS5X (streams) and YSI EXO2 (lakes). Sampling was conducted from mid-morning through early afternoon (09:00-14:00). Routine physical parameters included pH (SU), optical dissolved oxygen (DO, mg/L), water temperature (°C), specific conductance (µS/cm) (Table 2)

Table 2. Range (minimum and maximum) for each primary field parameter over the 4/7/2020 – 10/20/2020 period at the stream and lake sites.

Station	Field pH (SU)	Field DO (mg/L)	Water Temp. (°C)	Spec Cond. (µS/cm)
Streams				
LWT-01	5.63 - 7.50	5.12 - 8.91	17.2 - 29.4	55.0 - 83.0
CW-016	6.85 - 7.65	6.72 - 8.43	16.8 - 30.5	68.7 - 136
Lakes				
LCR-04	6.96 - 9.22	7.27 - 11.96	19.09 - 31.30	73.0 - 115.1
CW-231	6.86 - 7.31	6.82 - 9.11	17.98 - 30.05	73.3 - 115.2
LCR-02	6.85 - 7.88	7.21 - 9.43	19.16 - 31.67	73.8 - 115.9
LCR-03	7.00 - 9.10	7.18 - 11.61	19.36 - 32.44	74.0 - 121.3
CW-208	7.44 - 9.27	7.23 - 12.12	19.78 - 32.45	79.6 - 111.3
CW-207B	7.07 - 9.23	7.03 - 11.80	20.07 - 32.33	72.4 - 116.1

An expanded suite of surface measurements was collected at each lake site including sensor-based chlorophyll-a (µg/L) and phycocyanin (µg/L) (Table 3). In addition, upper water column features were measured such as penetration depth of photosynthetically active radiation (PAR, 400-700 nm wavelength, µmol m^{-2} s^{-1}) using a LI-COR light meter and a LI-1400 data logger, water clarity expressed as secchi depth (m), and turbidity (FNU). PAR depth was determined as the depth in which PAR decays to 1% of its ambient value. The chlorophyll-a and phycocyanin maximums were determined from the vertical profile downcast and described as either a maximum depth or vertical band where pigment fluorescence was highest. YSI EXO2 sensor-based chlorophyll-a and phycocyanin measurements should be viewed relatively and compared only with 2019 Nutrient Study data. Calibration protocols for the EXO Total Algae sensors were changed to be more consistent with manufacturer recommendations prior to the upper Lake Murray field study in 2021.

Table 3. Range (surface minimum and maximum) for additional field parameters at the lake sites over the 4/7/2020 – 10/20/2020 study period.

Station	Chl-a (µg/L)	Chl-a Max Depth (m)	Phycocyanin (µg/L)	Phycocyanin Max Depth (m)	PAR Depth (m)	Secchi Depth (m)	Turbidity (FNU)
LCR-04	1.94 - 18.23	0.3 - 1.75	0 - 6.87	0.3 - 0.3	1.5 - 4.7	0.4 - 0.9	4.30 - 52.45
CW-231	0 - 5.27	0.3 - 0.3	0 - 1.50	0.3 - 0.3	1.1 - 3.0	0.3 - 0.7	7.62 - 198.09
LCR-02	0.18 - 6.69	0.3 - 1.0	0 - 1.74	0.3 - 0.3	1.3 - 2.7	0.3 - 0.7	5.71 - 154.87
LCR-03	2.60 - 18.63	0.3 - 1.75	0 - 5.03	0.3 - 1.75	1.3 - 3.1	0.4 - 0.9	5.90 - 81.37
CW-208	5.62 - 19.50	0.3 - 1.5	0 - 9.52	0.3 - 1.5	1.6 - 3.1	0.5 - 0.8	4.50 - 38.94
CW-207B	0.90 - 13.45	0.3 - 2.0	0 - 5.63	0.3 - 2.0	1.7 - 4.3	0.4 - 1.1	3.02 - 25.49

Vertical Profile

Vertical profiles were collected at each lake site visit using the YSI EXO2. The casts were conducted manually, but data were logged by the instrument every second. The sonde was gradually lowered through the water column (downcast) until contact was made with the lake bottom and then retrieved at a similar rate. An Excel tool was created to process raw vertical profile data. The tool extracts the downcast from the profile record by identifying when instrument descent was initiated and when retrieval began after contacting the lake bottom. The bottom depth for the profile could be manually adjusted to remove the effects of sediment resuspension. The program then averaged the downcast data in half meter intervals. Eight parameters were processed for each profile: water temperature, DO concentration, DO percent saturation, pH, turbidity, specific conductance, chlorophyll-a concentration, and phycocyanin concentration.

In total, 86 vertical profiles were collected as part of the 2020 Lake Program. Fifteen profiles were targeted at each site. One profile was lost at CW-231, LCR-03, CW-208, and CW-207B on 8/24/2020 due to an instrument software issue. Because profiles are collected on an approximately biweekly schedule, the data can be used to illustrate the evolution of the water column over the course of the field program, but do not capture diel variability.

Continuous Monitoring

Continuous monitoring systems were deployed at five of the six lake sites (CW-231 excluded) from 4/8/2020 through the end of October 2020. Each deployment was approximately two weeks in duration and data were recorded at 15- or 30-minute intervals depending on the instrument used. YSI EXO2s (15-minute recording interval) were deployed at sites LCR-02 and CW-208 and Hydrolab DS5Xs (30-minute recording interval) were installed at LCR-04, LCR-03, and CW-207B.

Early in the field season, technical challenges associated with new equipment led to interruptions in the continuous records, particularly at LCR-04, LCR-03, CW-207B. However, end verifications for the primary variables (DO, pH, and specific conductance) were largely successful. A complete end of deployment verification record is stored in the SharePoint Field Log. The following list summarizes end deployment verifications, equipment challenges, and lessons learned:

- There are data gaps over the first few months at LCR-04, LCR-03, and CW-207B due to battery strength and data logging/telemetry issues associated with new remote sensing buoys installed at these locations. The buoys were removed in July and the records were more complete in the second half of the field program.
- Towards the middle of the campaign, the DO sensors on Hydrolab DS5Xs occasionally began failing for periods of time (3-6 hours) midday. These failings typically occurred when DO was highest in the daily cycle and was due to flaking off of the coating on the sensor DO cap. Gentle care, frequent inspection, and replacing the DO cap as necessary is recommended to avoid data loss.
- One DO verification failed for an EXO2 at CW-208 in May (Series 2). The record was not immediately discarded as it tracked well with concurrent pH record.
- The EXO2 pH modules failed in May and replacements arrived in June. Two Series 3 pH records at LCR-02 and CW-208 were lost. In-Situ Aqua Troll 600 instruments were used to bridge the gap in pH records until EXO2 replacement modules arrived.
- A conductivity sensor failed on a Hydrolab DS5X H4472 and was replaced.

Fluorometer-Based Chlorophyll-a

A total of 165 lake samples were collected for fluorometer-based total chlorophyll-a. Samples were collected at the surface (0.3 m) and at 1.5 m at all lake sites except CW-231 where surface only samples were collected. No samples were lost.

Cyanotoxins

Samples for microcystins analysis were collected at the surface of each lake site every other field sampling event therefore on an approximately monthly schedule. A total of 48 samples were collected and no samples were lost.

Water Quality

Grab samples for water quality occurred biweekly from 4/7/2020-10/20/2020. Access Analytical and Rogers and Calcott were used for the first four sampling events (4/7, 4/21, 5/5, and 5/19). The DHEC Central Laboratory analyzed samples from 6/2 through the end of the project.

Streams

Each stream site was sampled 15 times over the course of the project. Each stream station satisfied the completeness data quality indicator (DQI) as no visits were missed because of human error. Completeness for each station, as assessed by sample opportunities, is determined to be 100%. Further, the project operated under a biweekly sampling schedule, which ensured that the samples collected at each site were evenly distributed across the study timeframe removing any bias towards a specific period of the season. All stream laboratory water quality samples were successfully analyzed except for two ammonia samples at each site due to instrument failure at the Central Laboratory.

Lakes

Each lake site was sampled 15 times during the field program. Completeness is determined to be 100% as no sample event was omitted due to field team decision or error. As with the stream component, lake sampling followed a biweekly schedule and samples were evenly distributed over the course of the study. All lake laboratory water quality samples were successfully analyzed except for two ammonia samples at each site due to instrument failure at the Central Laboratory.

Summary of Findings

The following summary represents a brief discussion of high-level observations of keystone parameters investigated as part of the 2020 Lower Catawba Nutrient Study. It is not meant to be exhaustive of all data collected during the study. The discussion centers on broad features in the vertical and continuous profile records at CW-208 in the Dutchman Creek arm of Lake Wateree and on summary statistics for grab sample total chlorophyll-a, cyanotoxins (microcystins), total phosphorus, total nitrogen, and total organic carbon for all sites.

Vertical Profile

Section graphs for temperature, dissolved oxygen, pH, temperature, specific conductance, and chlorophyll-a for each station are presented in Appendix A. The plots were interpolated from the 14 or 15 vertical profiles collected on a biweekly basis at each station. Because the plots are collected at approximately two-week intervals at roughly the same time of day, the interpolated data illustrate the seasonal, week over week, evolution of the water column at each site for physical and biological parameters.

Section plots for temperature, dissolved oxygen, and pH for station CW-208 located in the Dutchman Creek arm of Lake Wateree are presented in Figures 3-5. Surface water temperature reached a maximum of ~32.5°C in mid- to late July. At this point of the season, the water column appeared to demonstrate some thermal stratification (Figure 3), which is supported by enhanced dissolved oxygen concentrations and pH levels near the surface relative to subsurface measurements (Figures 4 and 5). Dissolved oxygen concentrations in bottom waters decreased to less than 2 mg/L during this period. These conditions persisted for at least a month; however, it is not clear if these conditions extended through late August as the 8/24/2020 profile was lost. Similar features occurred at the mid-lake stations (LCR-04, LCR-03, and CW-207B; Appendix A) and coincided with a period of low rainfall in the local area (0.11 inches (2.8 mm) for July and August, PRISM Climate Group).

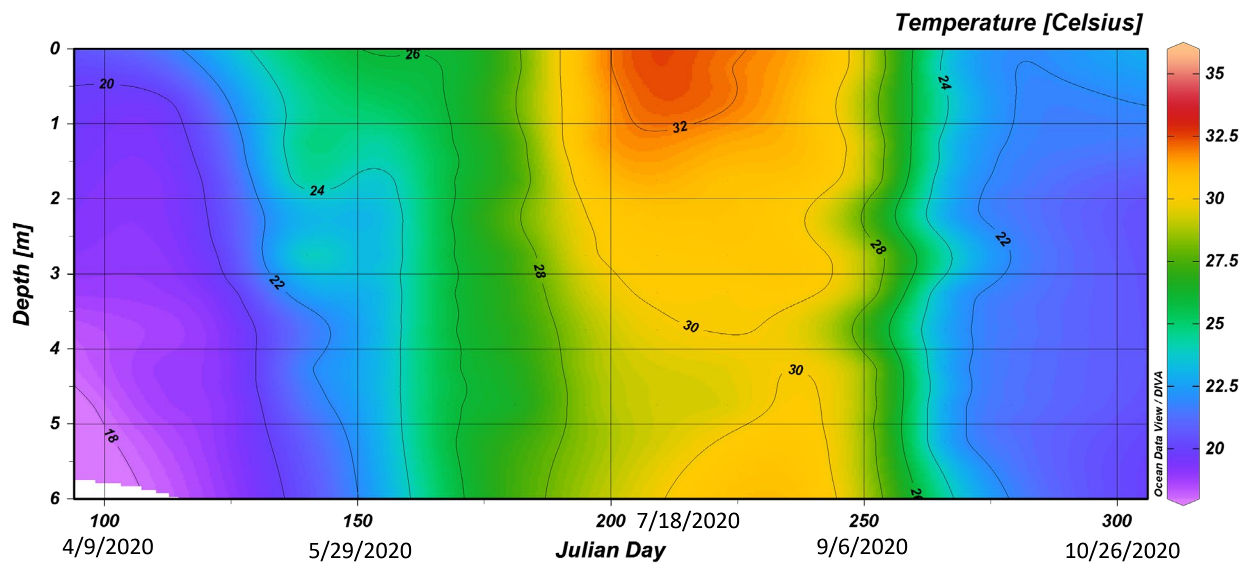

Figure 3. Temperature (°C) section plot for CW-208 in the Dutchman Creek arm of Lake Wateree. The vertical profile from 8/24/2020 (Julian Day 237) was lost due to an instrument software malfunction.

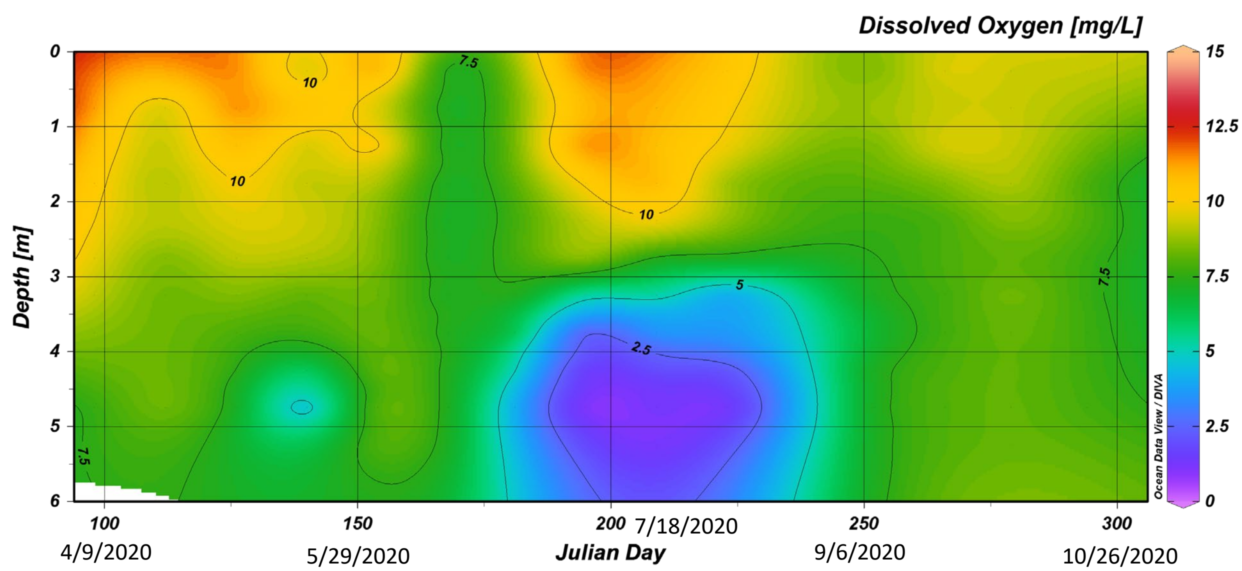

Figure 4. Dissolved oxygen (mg/L) section plot for CW-208 in the Dutchman Creek arm of Lake Wateree. The vertical profile from 8/24/2020 (Julian Day 237) was lost due to an instrument software malfunction.

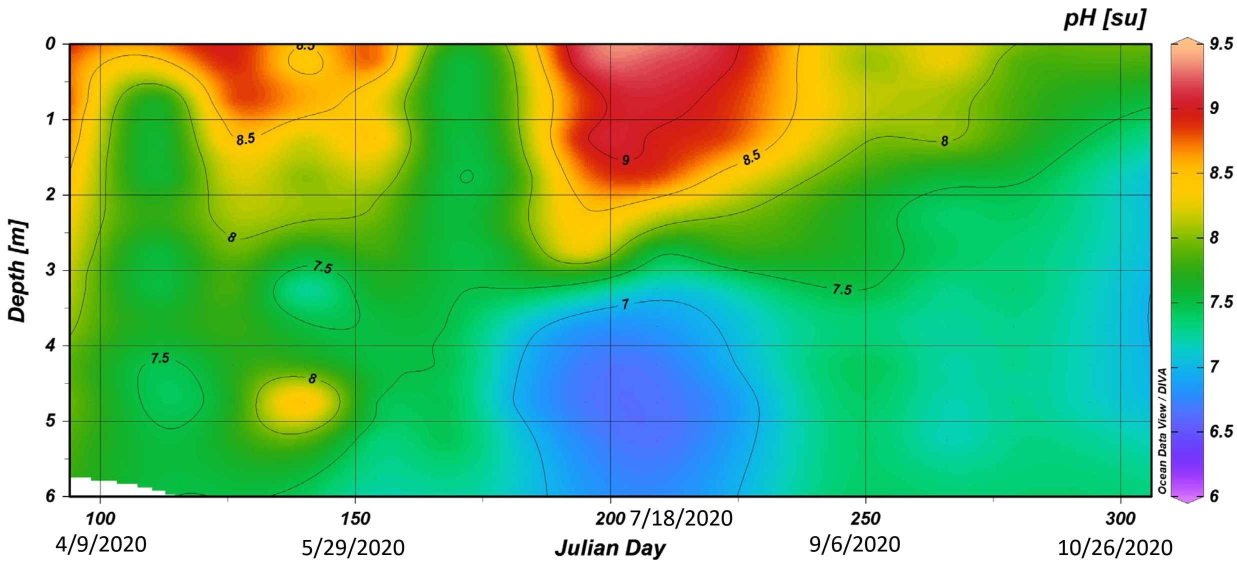

Figure 5. pH section plot for CW-208 in the Dutchman Creek arm of Lake Wateree. The vertical profile from 8/24/2020 (Julian Day 237) was lost due to an instrument software malfunction.

Continuous Monitoring

Continuous monitoring of surface temperature indicated a gradual rise from April through mid-July to a maximum daily average of 32.3°C on July 17, 2020 at CW-208 in the Dutchman Creek arm of Lake Wateree (Figure 6). Temperatures remained above 29°C until the middle of September before decreasing to 12-23°C for the remainder of the monitoring period.

During July and August, daily minimum and maximum dissolved oxygen concentrations were generally lower than in the April through June and mid-September through the end of October periods in the Dutchman Creek arm (Figure 7). The mid-summer decrease in dissolved oxygen occurred during the period of warmest ambient temperatures (Figure 6). The observed decrease in daily minimum dissolved oxygen is more pronounced than for the daily maximum concentration as daily differences (daily maximum – daily minimum) were larger during the mid-summer period. For the April through October monitoring period, dissolved oxygen appeared to mirror the pattern of daytime photosynthesis and overnight respiration (Figure 8). On average, the 0800 hour demonstrated the lowest dissolved oxygen concentration (8.54 mg/L) and 1700 produced the highest concentration (10.58 mg/L).

The Dutchman Creek arm consistently demonstrated elevated pH over the monitoring period. The maximum daily pH exceeded 8.5 on 161 of the 181-day record (89%). Further, the minimum daily pH exceeded 8.5 on 18 days, an exceedance of the standard of 10%. The average difference between daily minimum and maximum pH values was 1.42 (range: 0.13-2.52).

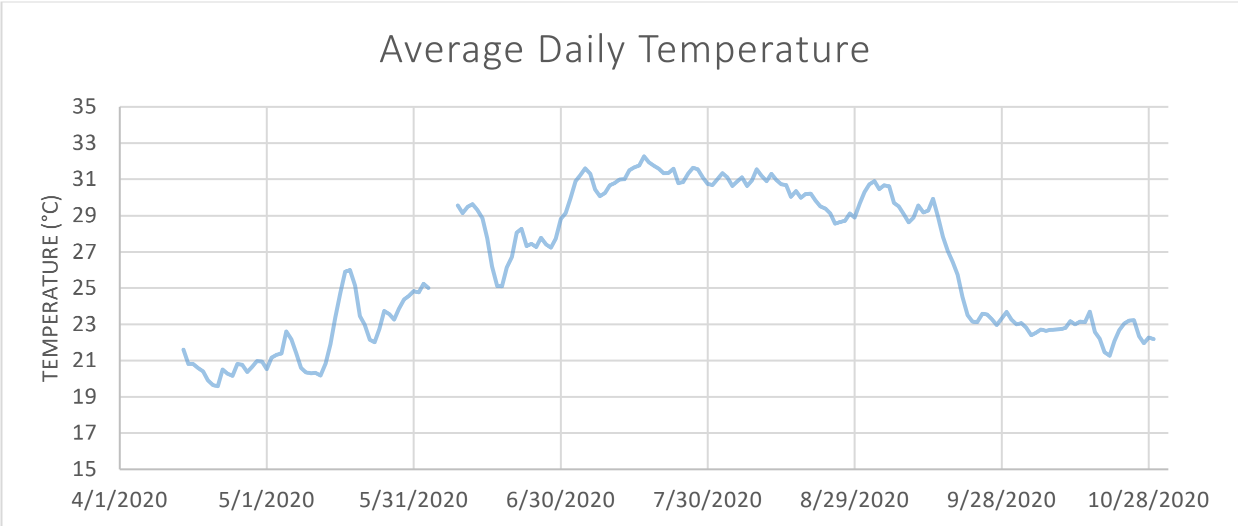

Figure 6. Average daily temperature at CW-208 in the Dutchman Creek arm of Lake Wateree. Data loss occurred for June 4-8, 2020.

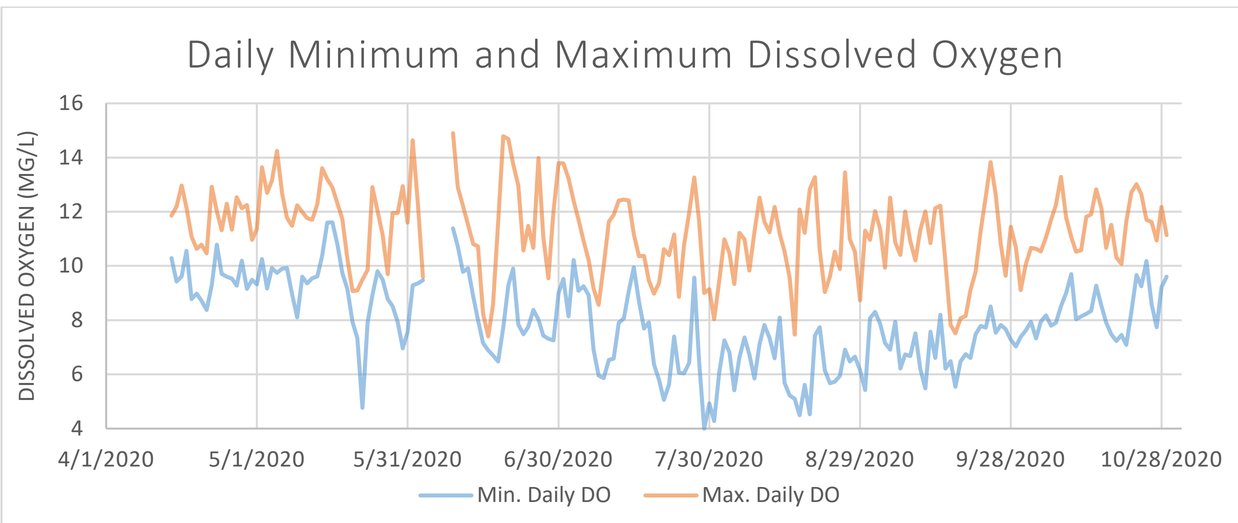

Figure 7. Daily minimum and maximum recorded dissolved oxygen concentrations (mg/L) at CW-208 in the Dutchman Creek arm of Lake Wateree. Data loss occurred for June 4-8, 2020.

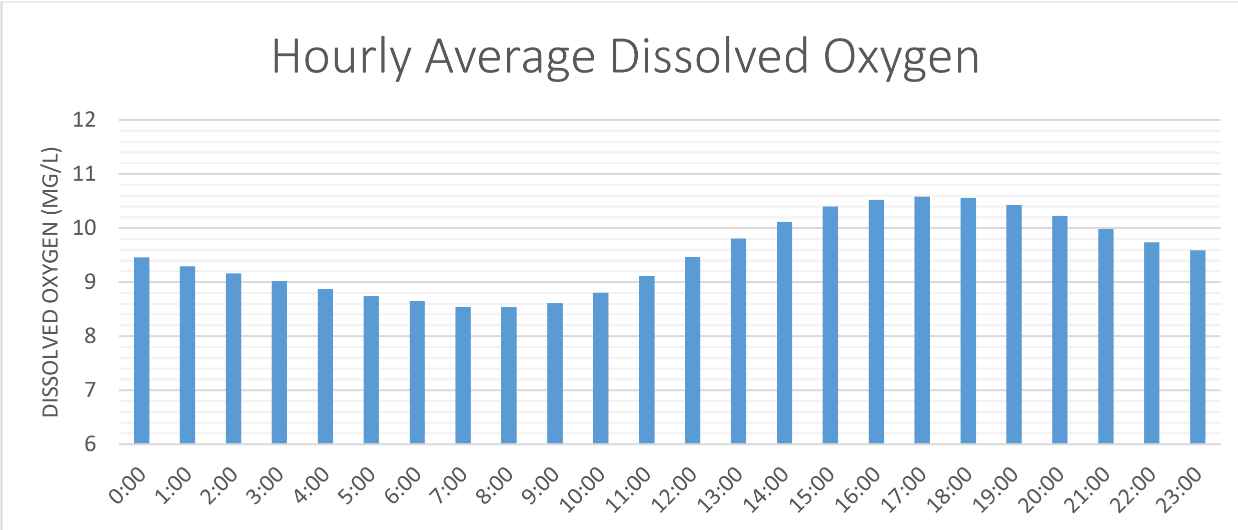

Figure 8. Hourly average dissolved oxygen concentrations (mg/L) for the April 14 through October 29, 2020, continuous monitoring record at CW-208 in the Dutchman Creek arm of Lake Wateree.

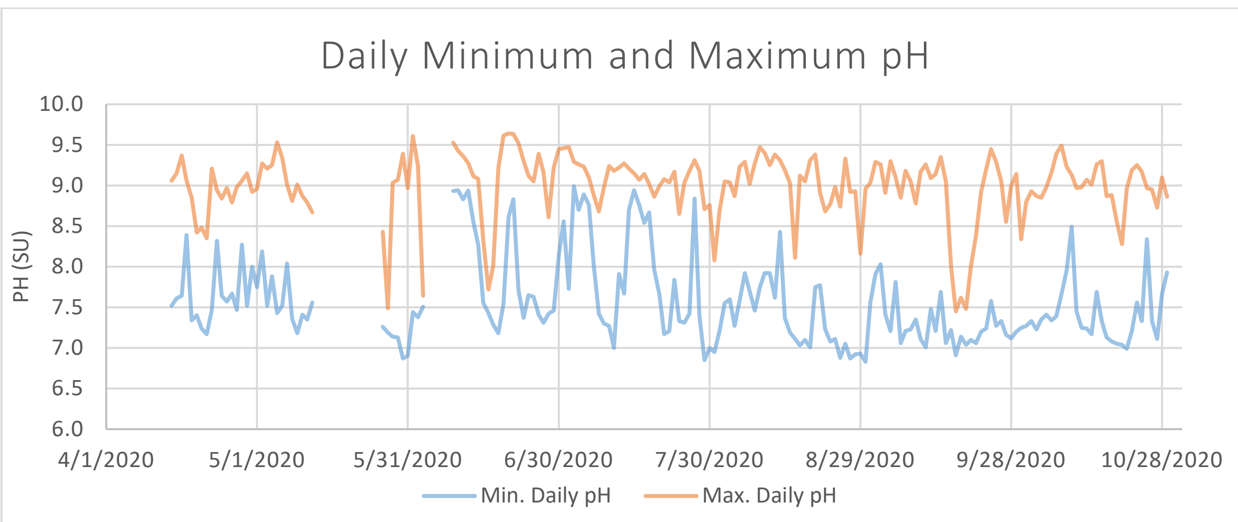

Figure 9. Daily minimum and maximum recorded dissolved pH values at CW-208 in the Dutchman Creek arm of Lake Wateree. Data loss occurred for May 13-25 and June 4-8, 2020.

Fluorometer-Based Chlorophyll-a

Grab sample total chlorophyll-a distribtions were variable across the system and throughout the study. For the mid-lake stations (LCR-03, LCR-04, CW-208, and CW-207B), the highest average surface total choloropyll-a concentration occurred in early April (31.5 µg/L on 4/7/2020). At these stations, average surface total chlorophyll-a was at least 25 µg/L for five consecutive summer sampling events (6/29, 7/13, 7/27, 8/10, and 8/24/2020). Of these stations, CW-208 demonstrated the highest field program average surface total chlorophyll-a (32.4 µg/L), followed sequentially by CW-207B (21.7 µg/L), LCR-03 (18.5 µg/L), and LCR-04 (17.7 µg/L) (Table 4). Three of the 15 (20%) surface values at CW-208 exceed the 40 µg/L ecoregional standard (Figure 10). Total chlorophyll-a concentrations were typically greater at 1.5 m compared to the 0.3 m surface value (Figure 11). Specifically, the surface concentration was greater than the 1.5 m value 27% of the time at CW-208 and LCR-03 and only 20% of the time at LCR-04 and CW-207B (Table 4).

Table 4. Total chlorophyll-a summary statistics for each lake station and depth along with the percent of observations in which the surface (0.3 m) concentration was greater than the subsurface (1.5 m) measurement. Average is presented as ± 1σ. All total chlorophyll units in µg/L.

Station	Depth (m)	Avg. T. Chl-a	Minimum	Maximum	n	Surface > 1.5 m
LCR-04	0.3	17.7 ± 8.8	4.6	32.7	15	20%
	1.5	18.1 ± 9.2	5.4	34.2	15	
CW-231	0.3	6.0 ± 2.2	2.5	11.1	15	-
LCR-02	0.3	7.4 ± 5.2	3.1	23.9	15	13%
	1.5	8.6 ± 4.5	4.2	18.1	15	
CW-208	0.3	32.4 ± 7.7	17.7	45.0	15	27%
	1.5	35.4 ± 9.2	19.8	47.1	15	
LCR-03	0.3	18.5 ± 12.1	4.6	40.7	15	27%
	1.5	20.4 ± 15.1	5.7	56.3	15	
CW-207B	0.3	21.7 ± 8.0	7.7	37.8	15	20%
	1.5	24.8 ± 10.0	8.0	48.5	15	

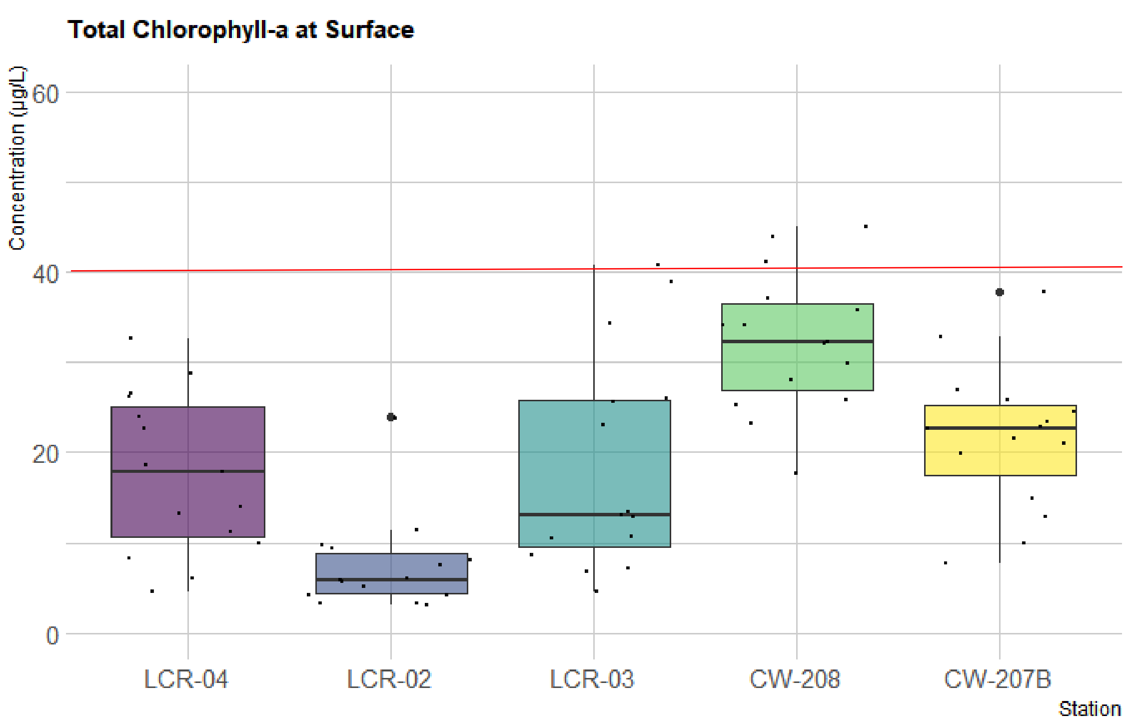

Figure 10. Box plot summary of surface (0.3 m) total chlorophyll-a concentrations (µg/L) for each lake station (n = 15). The red line denotes the 40 µg/L ecoregional total chlorophyll-a standard.

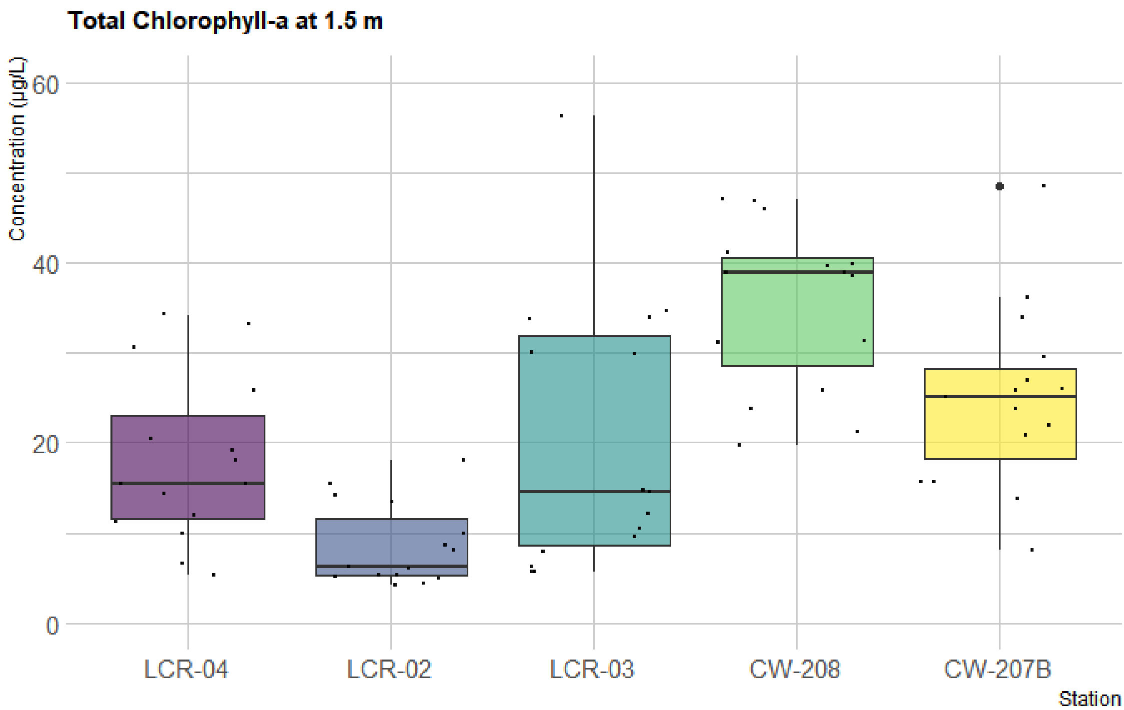

Figure 11. Box plot summary of subsurface (1.5 m) total chlorophyll-a concentrations (µg/L) for each lake station (n = 15).

Cyanotoxins

Microcystins concentrations at the open-lake stations were generally low and below the United States Environmental Protection Agency recreational health advisory value and DHEC recreational standard of 8 µg/L.[3,4] These samples were collected routinely at open water sites as part of the 2020 field program. Cyanotoxin concentrations are typically higher within blooms of toxin producing cyanobacteria and in coves or nearshore environments where macrophyte algae tend to accumulate. For more information related to cyanotoxin distributions within South Carolina waters, refer to DHEC Bureau of Water Technical Report No. 001-2021.[5]

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[3]U.S. Environmental Protection Agency. 2019. Recommended Human Health Recreational Ambient Water Quality Criteria or Swimming Advisories for Microcystins and Cylindrospermopsin. U.S. Environmental Protection Agency, Office of Water, EPA- 822-R-19-001.

[4]South Carolina Department of Health and Environmental Control. Regulations 61-68 Water Classifications and Standards.

[5]South Carolina Department of Health and Environmental Control. 2021. 2019 South Carolina Cyanotoxin Distribution Project. Bureau of Water Technical Report No. 001-2021. March 2021.

Table 5. Microcystins cyanotoxin summary statistics for each lake station. Samples for microcystins were collected every other field sampling trip at the surface (0.3 m). Average is presented as ± 1σ. All total microcystins concentrations in µg/L.

Station	Avg. Microcystins	Minimum	Maximum	n
LCR-04	0.074 ± 0.027	0.029	0.110	8
CW-231	0.080 ± 0.037	0.045	0.150	8
LCR-02	0.060 ± 0.030	0.018	0.097	8
CW-208	0.117 ± 0.063	0.062	0.253	8
LCR-03	0.066 ± 0.036	0.013	0.131	8
CW-207B	0.080 ± 0.038	0.035	0.148	8

Water Quality

The water quality data collected as part of this study will be used to support various components of the watershed loading and lake water quality models. The following discussion summarizes the results for total phosphorus (TP) and total nitrogen (TN), two nutrient parameters regulated in lakes by the State, as well as total organic carbon (TOC). Note that TN is not explicitly measured but reported as the sum of Total Kjeldahl Nitrogen (TKN, sum of ammonia/ammonium and organic nitrogen) and nitrate/nitrite. BOW also engaged with Duke Energy Company to conduct split sampling at a series of strategic locations throughout the basin as a measure of laboratory comparability as part of this project. The results of that comparison study are presented in DHEC Bureau of Water Technical Report No. 008-2021.[6]

The lowest average concentrations for TP, TN, and TOC were measured at the tailrace of Lake Wylie (LWT-01). The downstream Catawba River site, CW-014, demonstrated nutrient concentrations similar to the lake stations. At the lake stations, average surface TP concentrations range from 0.040 mg/L to 0.54 mg/L (Figure 12). Average surface TN concentrations ranged 0.69 mg/L to 1.09 mg/L (Figure 13). The lowest average concentrations for both TP and TN occurred at CW-208 in the Dutchman Creek arm where the highest average total chlorophyll-a concentation was observed. Average lake TOC concentrations ranged from2.76 mg/L to 3.55 mg/L (Figure 14) with the highest average value occuring at CW-208.

This disucssion centered on CW-208 as a case study within the project. Notable features observed at this station include:

- Surface water temperature reached of maximum of ~32.5°C in mid- to late July; possible thermal stratification at this point in the season which is supported.
- Enhanced dissolved oxygen concentrations and pH levels observed near the surface in mid-July.
- Dissolved oxygen concentrations in bottom waters decreased to less than 2 mg/L in mid-July through at least mid-August.
- Daily minimum and maximum dissolved oxygen concentrations were generally lower in July and August than in the April through June and mid-September through the end of October periods.
- The lake arm consistently demonstrated elevated pH over the monitoring period.
- Dutchman Creek demonstrated the highest field program average surface total chlorophyll-a.

[6] South Carolina Department of Health and Environmental Control. 2021. Catawba Basin Split Nutrient Study and Comparability Report. Bureau of Water Technical Report No. 008-2021. September 2021.

- Average chlorophyll-a concentration at 1.5 m was higher than at the surface.
- The lowest average TP and TN concentrations were observed at CW-208.
- Dutchman Creek arm demonstrated the highest average TOC concentration of the lake stations.

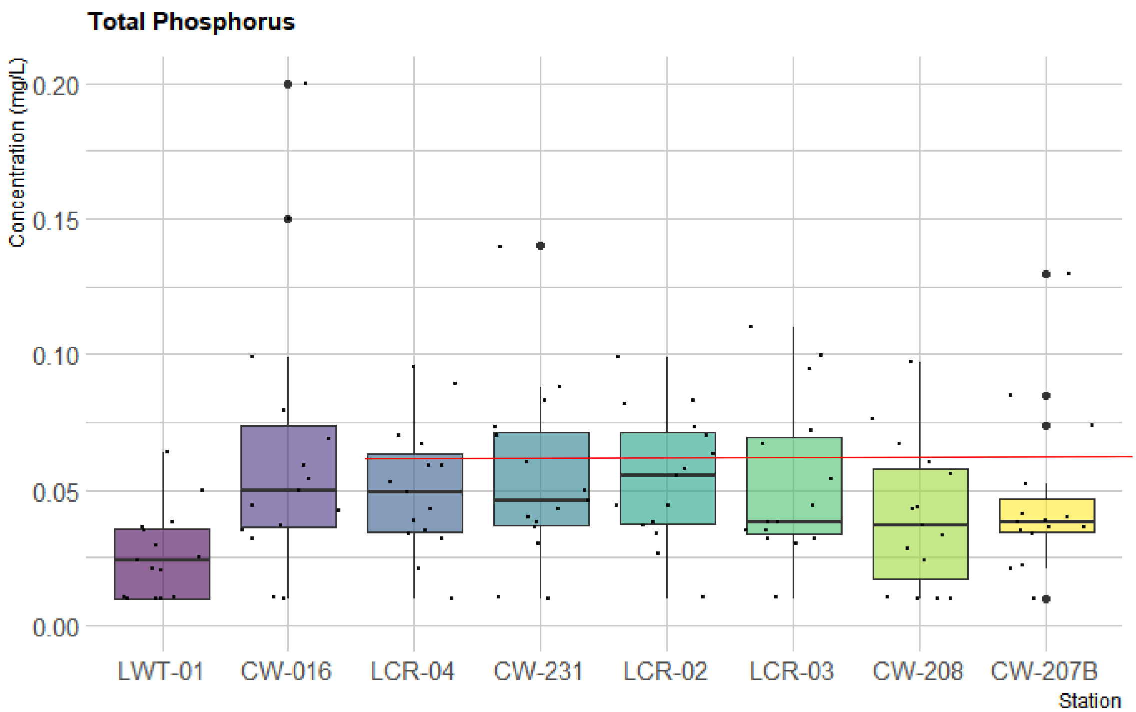


Figure 12. Box plot summary of total phosphorus concentrations (mg/L) measured at each stream and lake station. The red line denotes the 0.06 mg/L lake ecoregional total phosphorus standard.

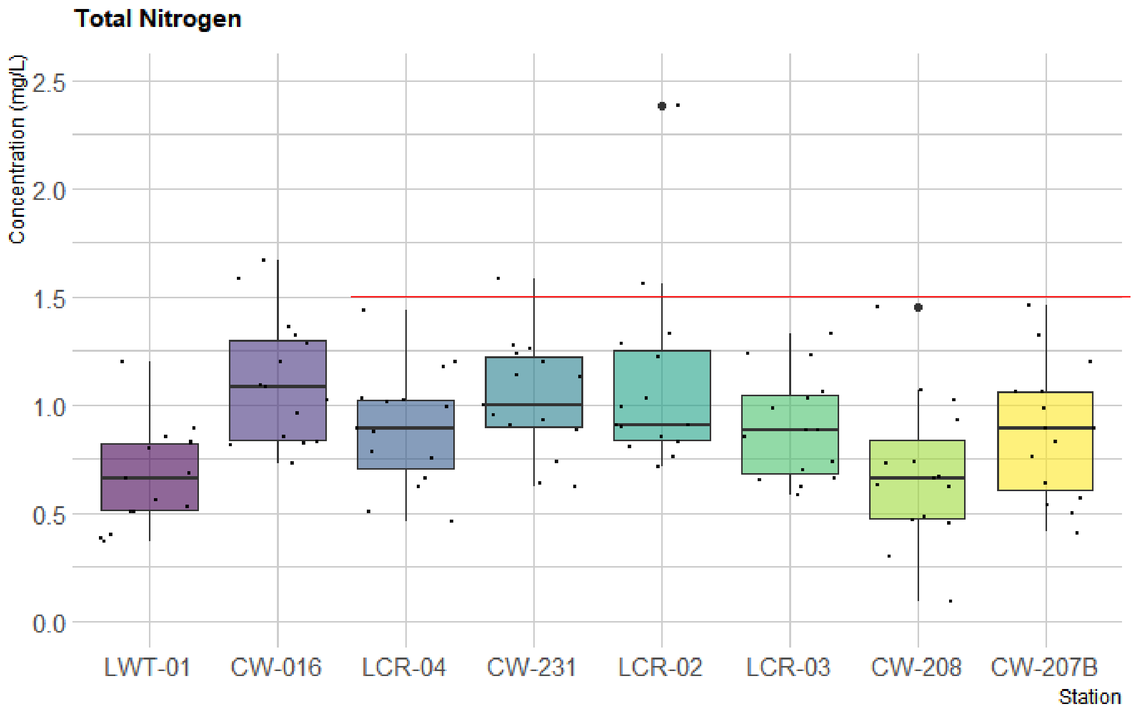


Figure 13. Box plot summary of total nitrogen concentrations (mg/L) measured at each stream and lake station. The red line denotes the 1.5 mg/L lake ecoregional total nitrogen standard.

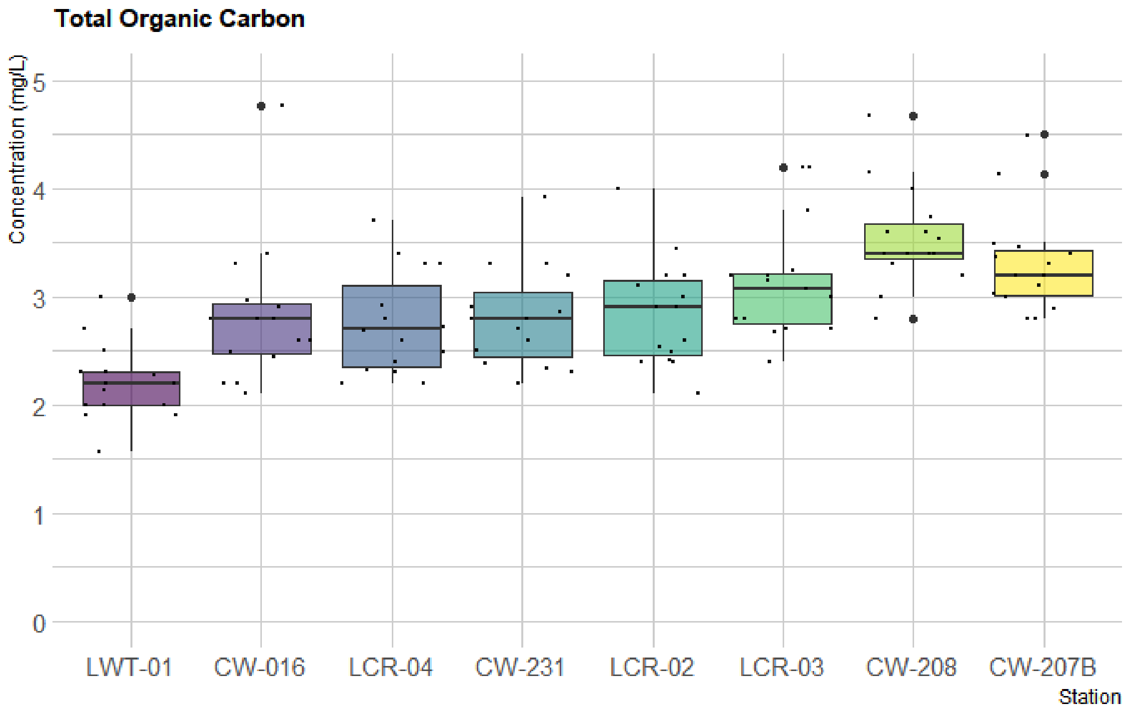


Figure 14. Box plot summary of total organic carbon concentrations (mg/L) measured at each stream and lake station.

Conclusion

As with the 2019 Nutrient Study and the other associated studies, this project is part of a comprehensive effort to resolve the relationship between physical and chemical conditions and ecological responses in the Lower Catawba Basin. Certain ecological responses impair designated uses in the system and degrade water quality as indicated by the cascade of regulatory 303(d) listings in the basin. This project builds on studies conducted in previous years by DHEC and stakeholder partners and is bolstered by years of data collected as part of DHEC's ambient monitoring program. The aggregated results of these programs fill important data gaps and provide a robust data set to develop, calibrate, and validate coupled watershed and river/lake hydrodynamic and water quality models. The calibrated models will be used in setting site-specific numeric nutrient and chlorophyll-a standards that are protective of designated uses for Lower Catawba Basin.

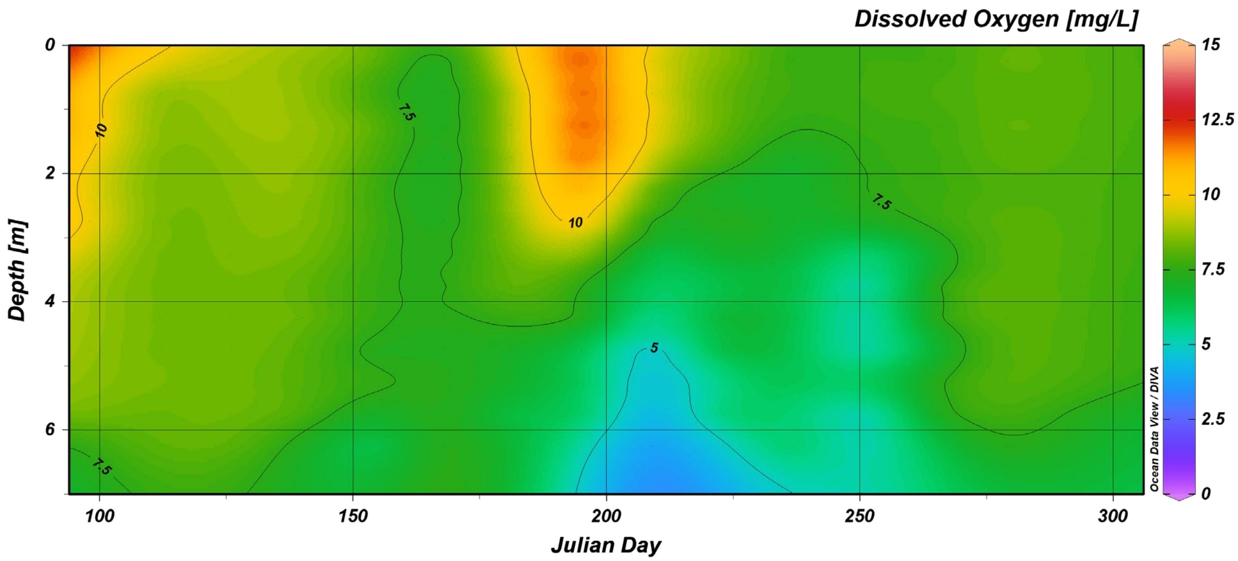
Acknowledgments

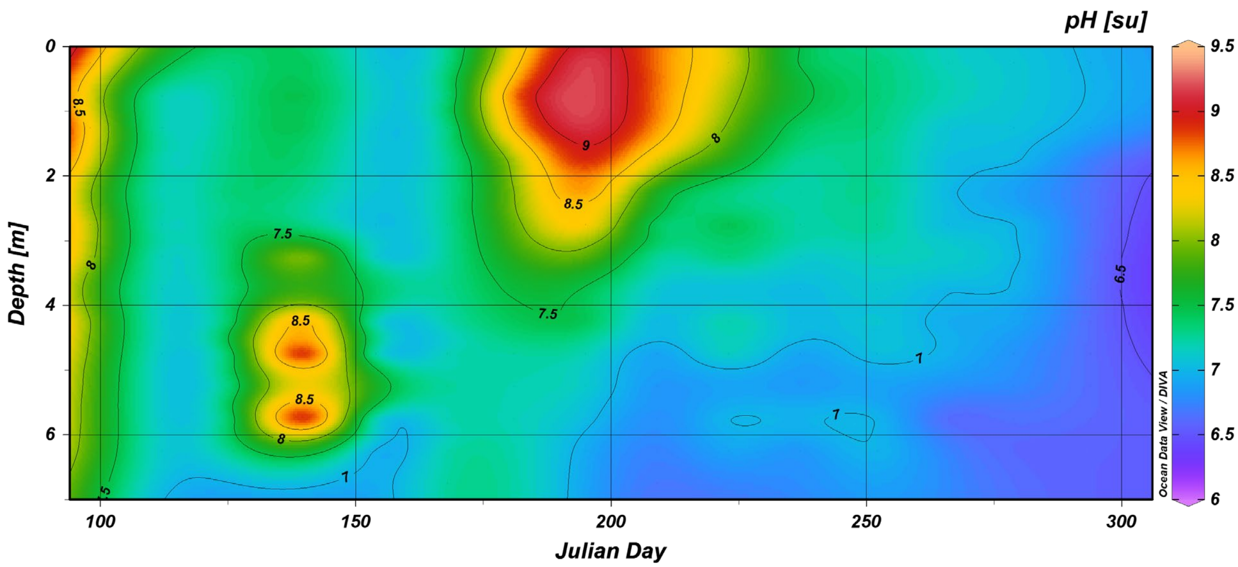
This project was made possible through support from DHEC Bureau of Water (BOW) TMDL group as well as Quality Assurance programs from the DHEC BOW and Bureau of Environmental Health Services (BEHS). The BEHS laboratory processed and analyzed water quality samples from June through the end of the project. Total chlorophyll-a and cyanotoxin samples were processed and analyzed by the BOW Aquatic Science Programs (ASP). Field sampling was conducted by personnel from the BOW TMDL and ASP groups.

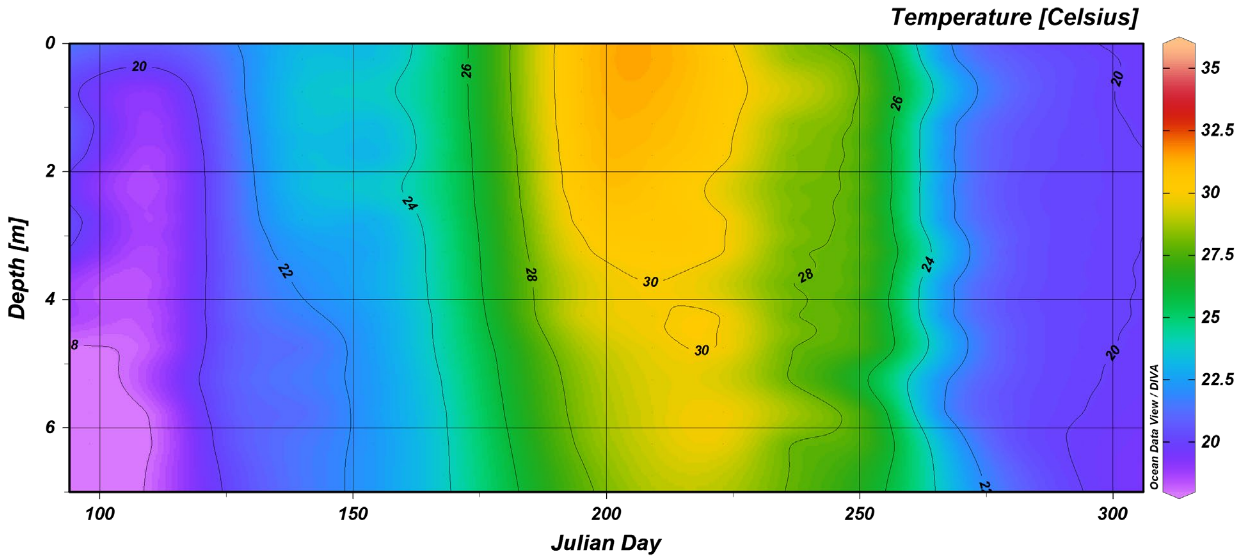
Appendix A – Vertical Profile Section Graphs

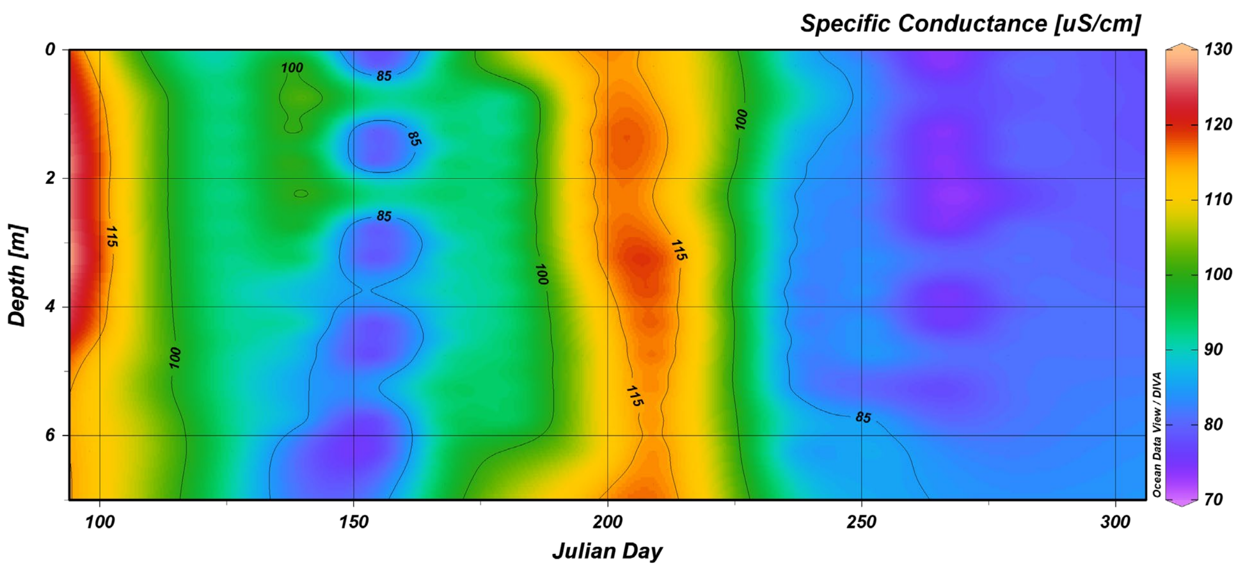
Julian Day: 100 is April 9, 2020, 150 is May 29, 2020, 200 is July 18, 2020, 250 is Sept 6, 2020, 300 is October 26, 2020

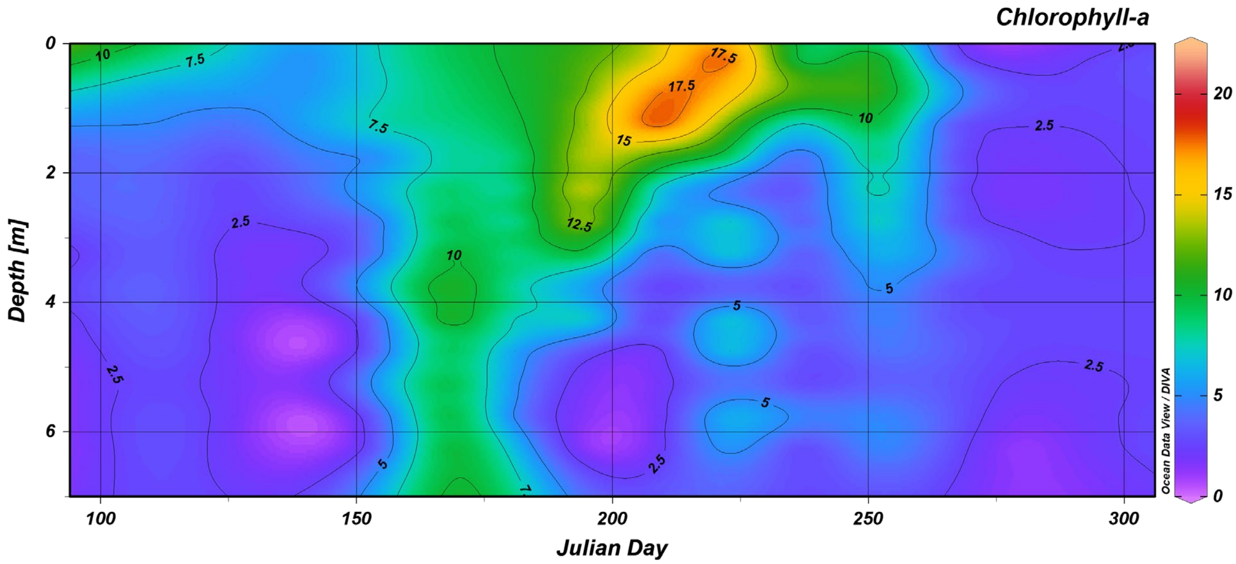
LCR-04 – Fishing Creek Reservoir off Bear Creek arm

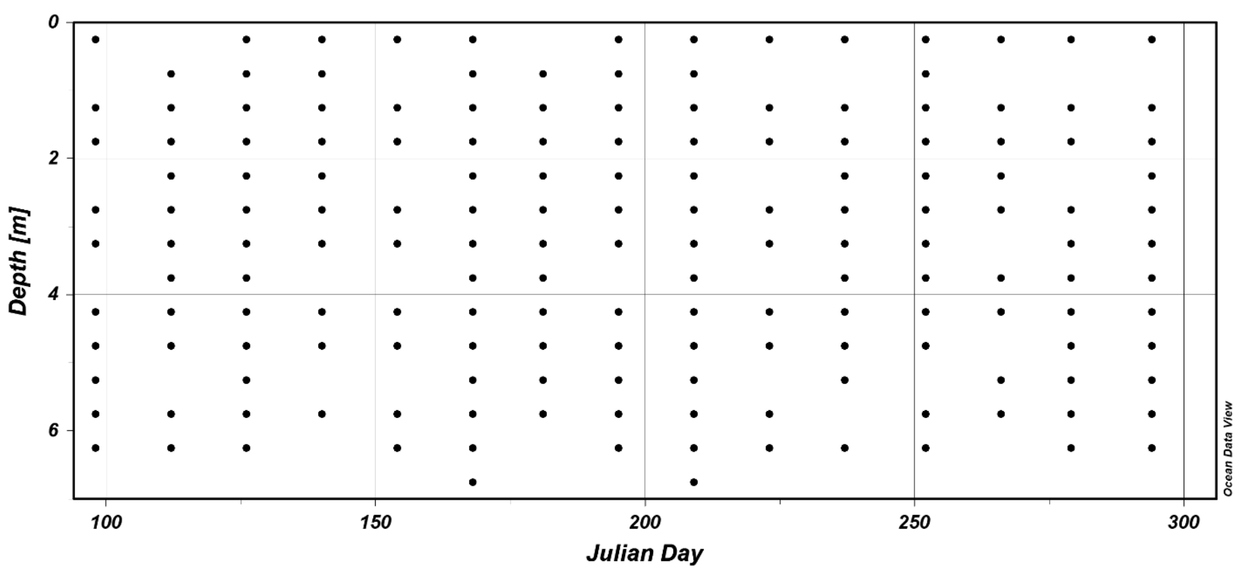





Temperature [Celsius]
Depth [m]
Julian Day
Ocean Data View / DIVA

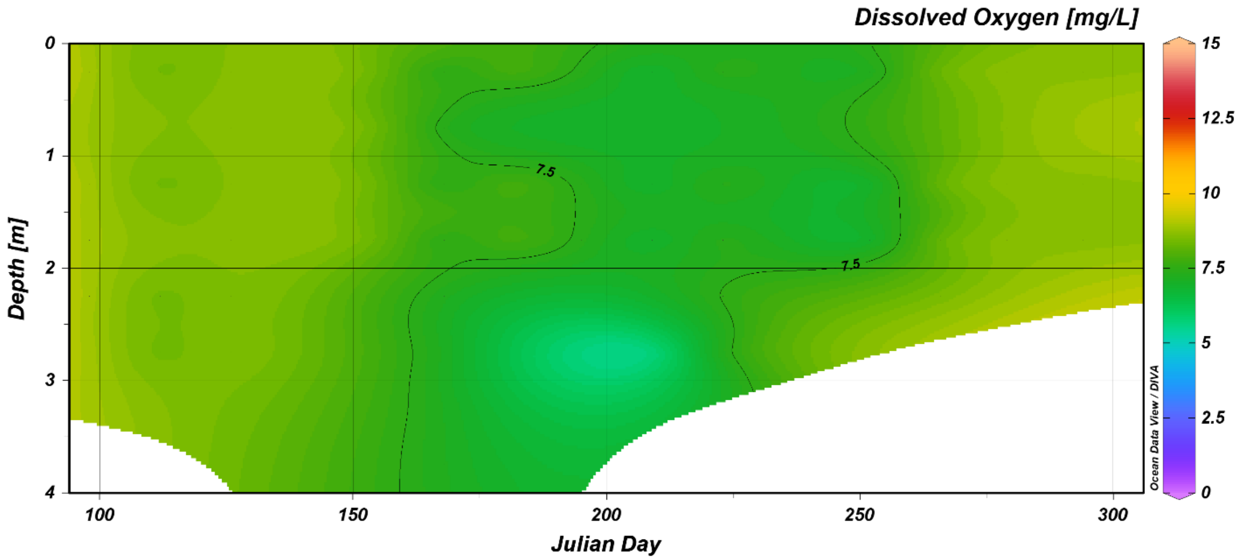

Specific Conductance [uS/cm]
Depth [m]
Julian Day
Ocean Data View / DIVA

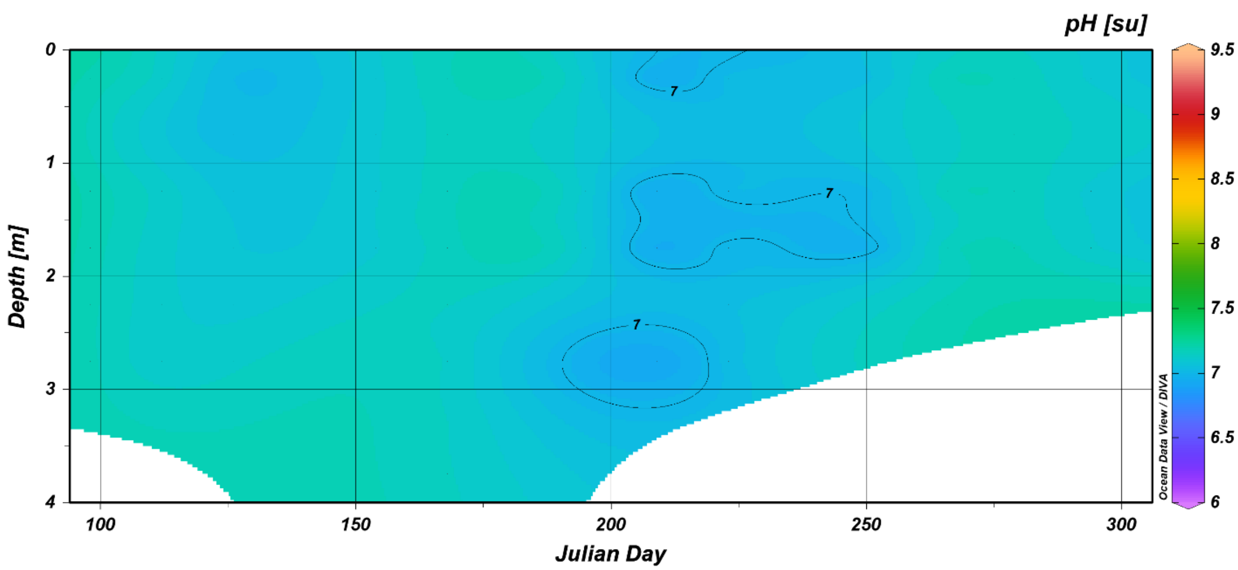

Chlorophyll-a
Depth [m]
Julian Day
Ocean Data View / DIVA

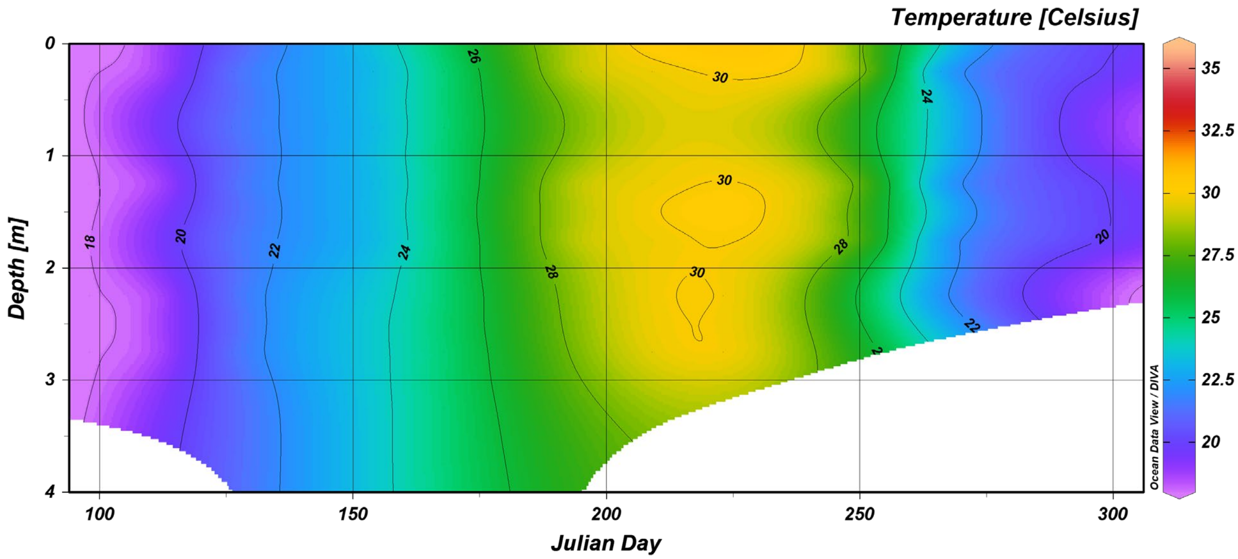

Depth [m]
Julian Day
Ocean Data View

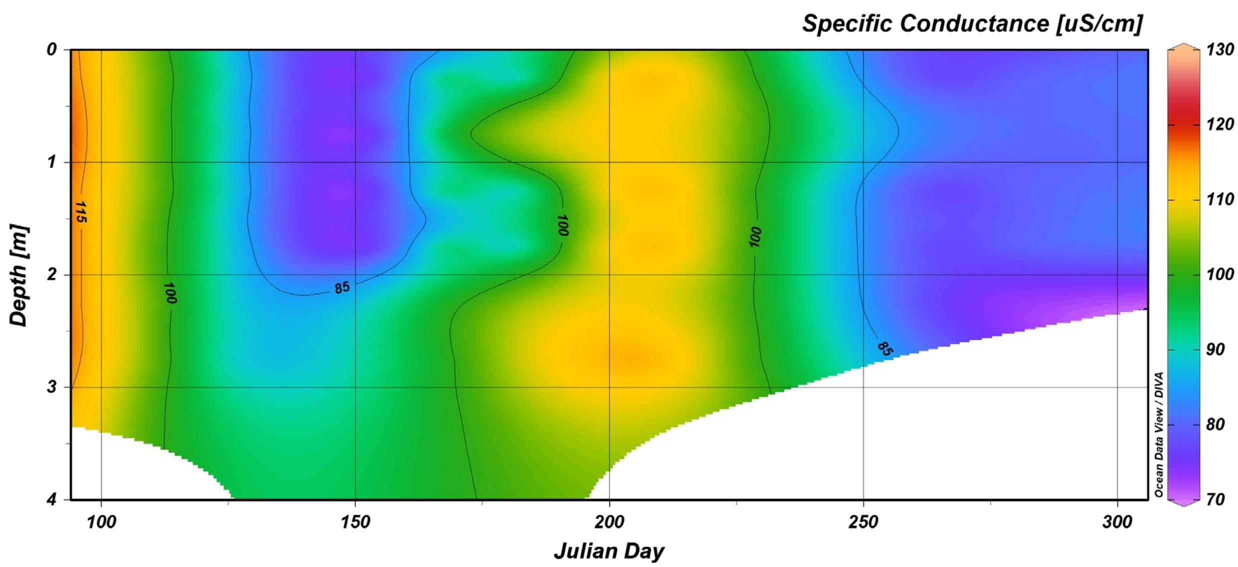
CW-231 – Upstream Lake Wateree Headwater, below Cedar Creek Dam

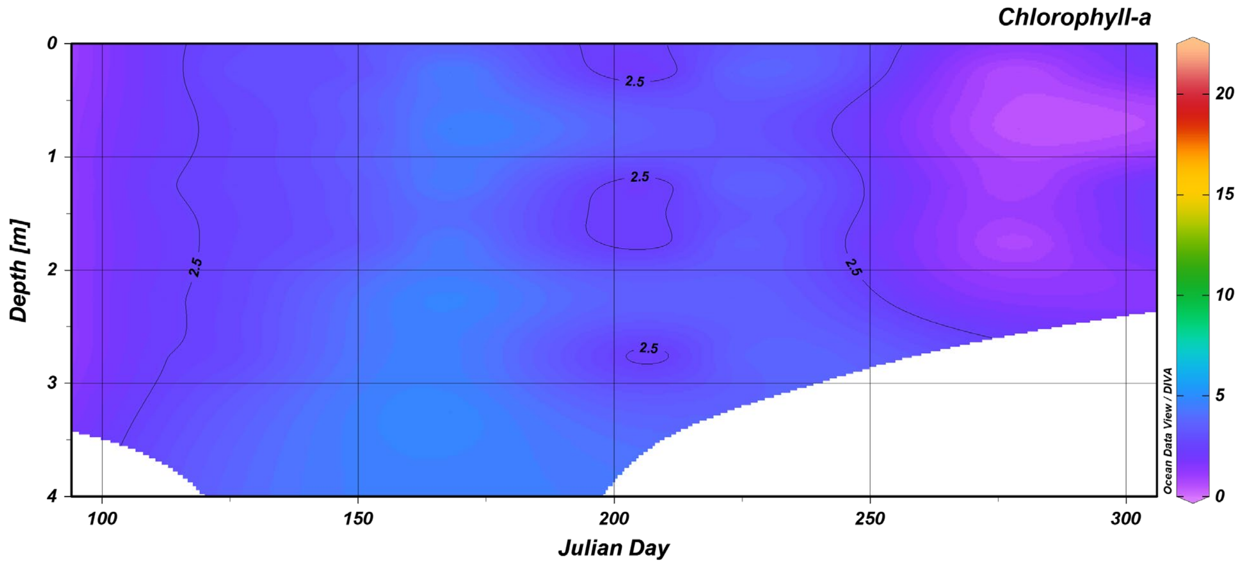
Missing 8/24/2020

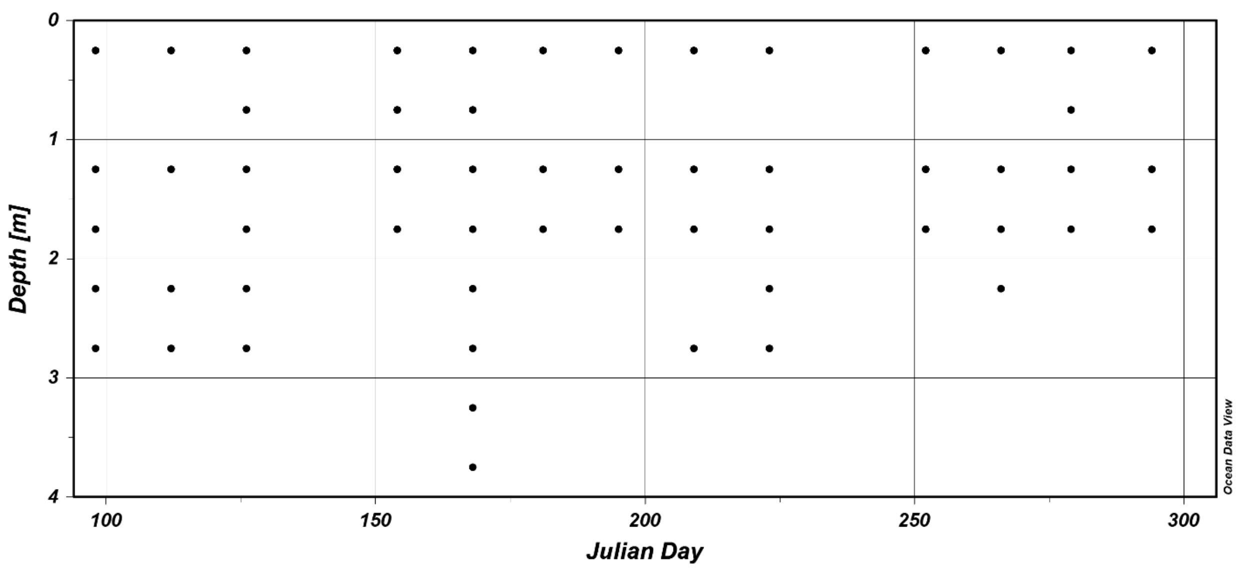





Temperature [Celsius]
Depth [m]
Julian Day
Ocean Data View / DIVA

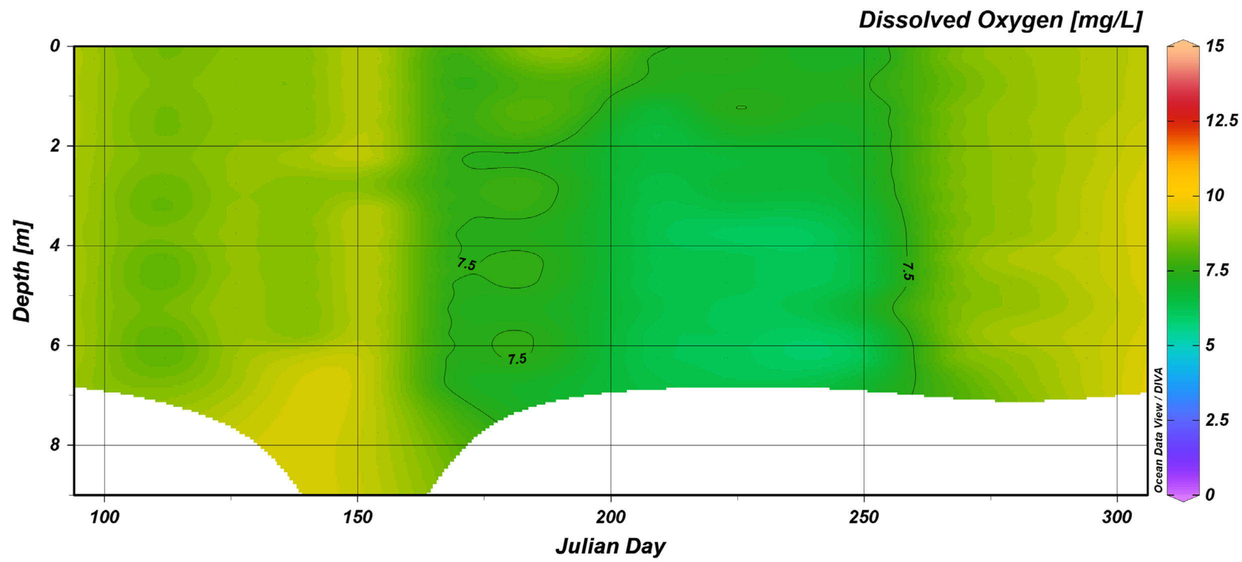

Specific Conductance [uS/cm]
Depth [m]
Julian Day
Ocean Data View / DIVA

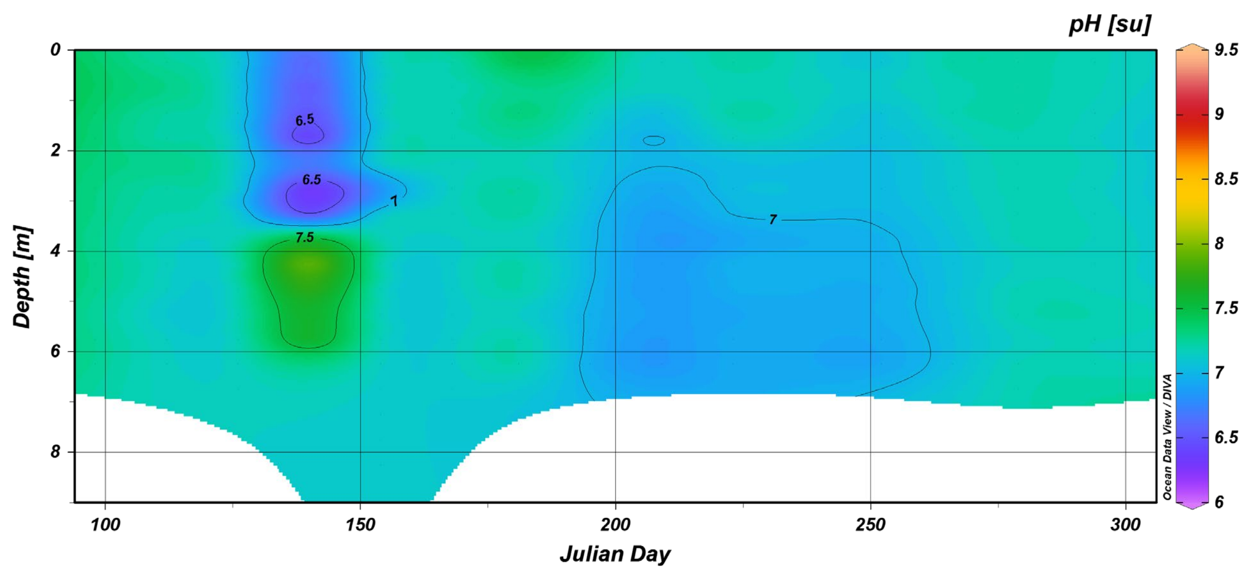

Chlorophyll-a
Depth [m]
Julian Day
Ocean Data View / DIVA

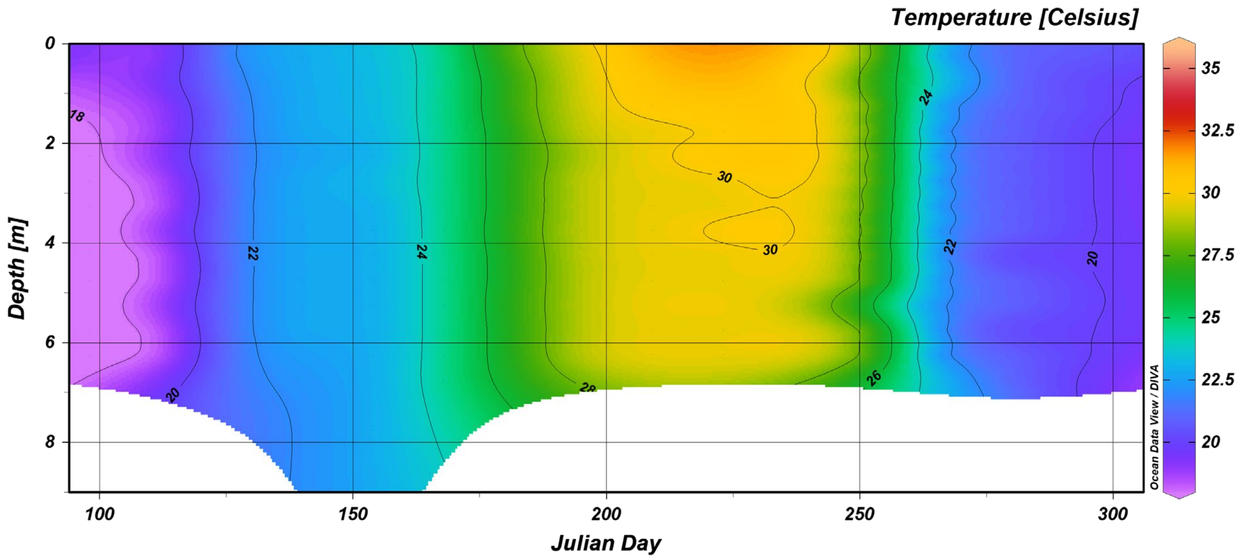

Depth [m]
Julian Day
Ocean Data View

LCR-02 – Lake Wateree upstream of Wateree Creek arm

Missing 8/24/2020






Temperature [Celsius]
Depth [m]
Julian Day
Ocean Data View / DIVA
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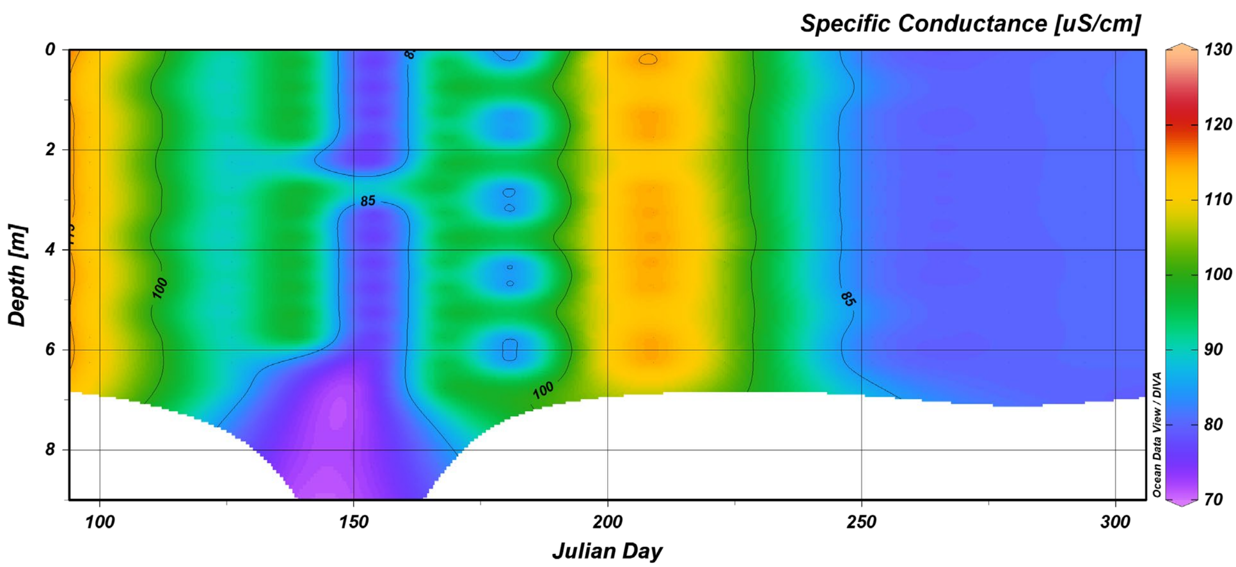
Specific Conductance [uS/cm]
Depth [m]
Julian Day
Ocean Data View / DIVA
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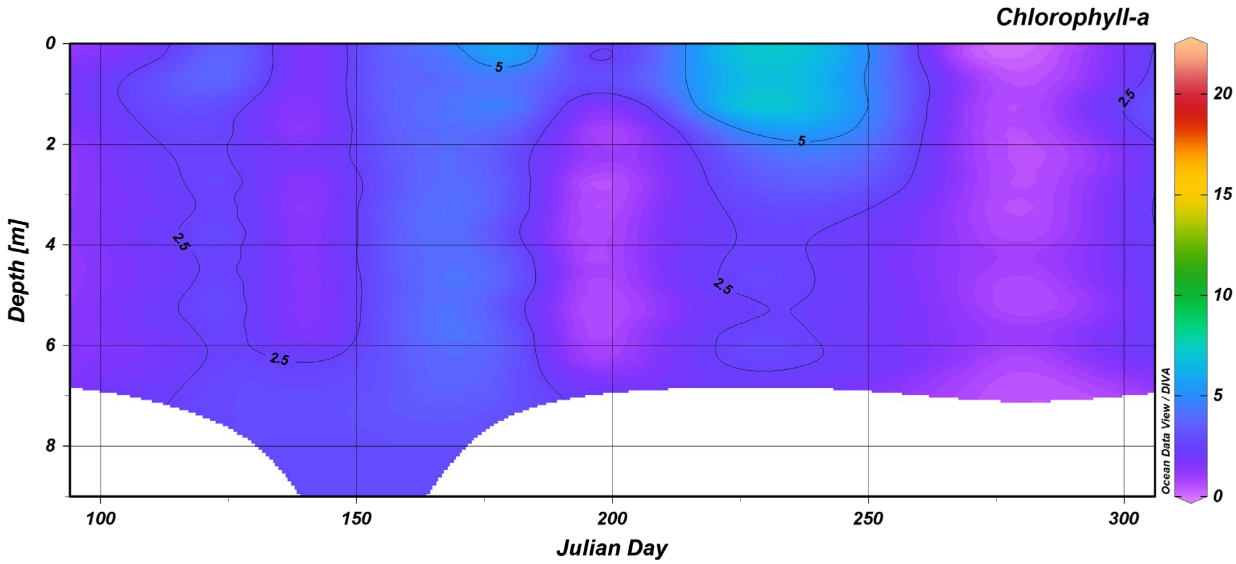
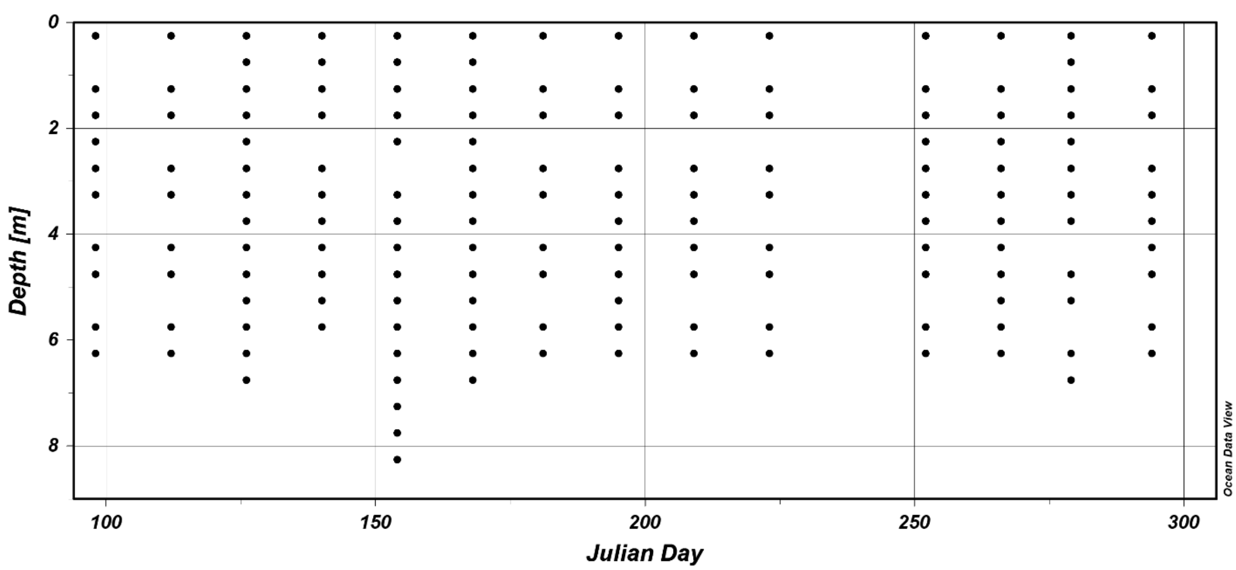
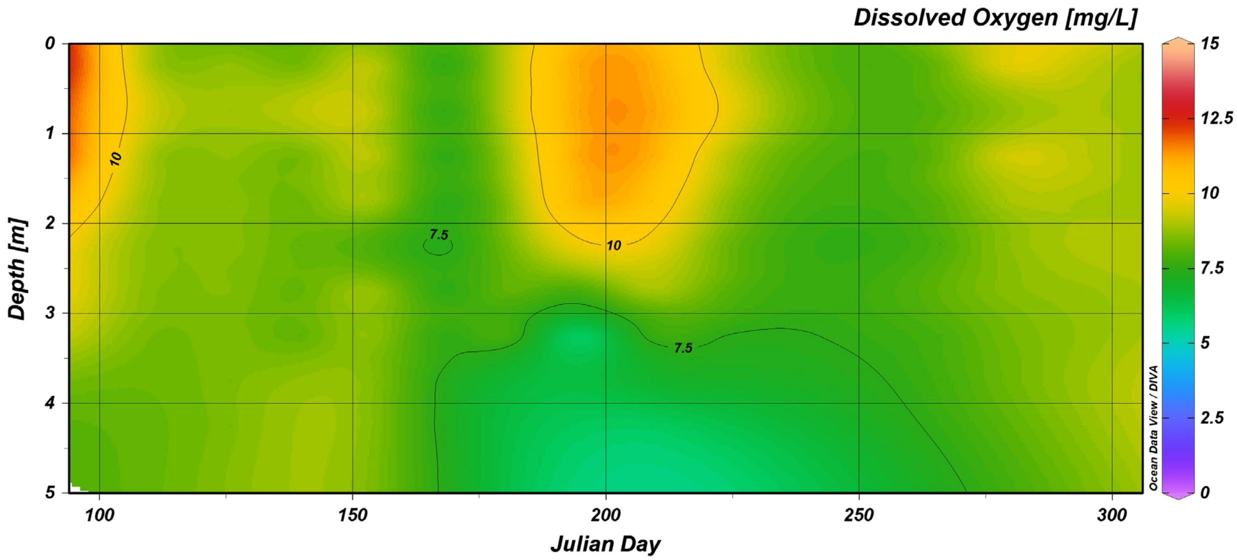
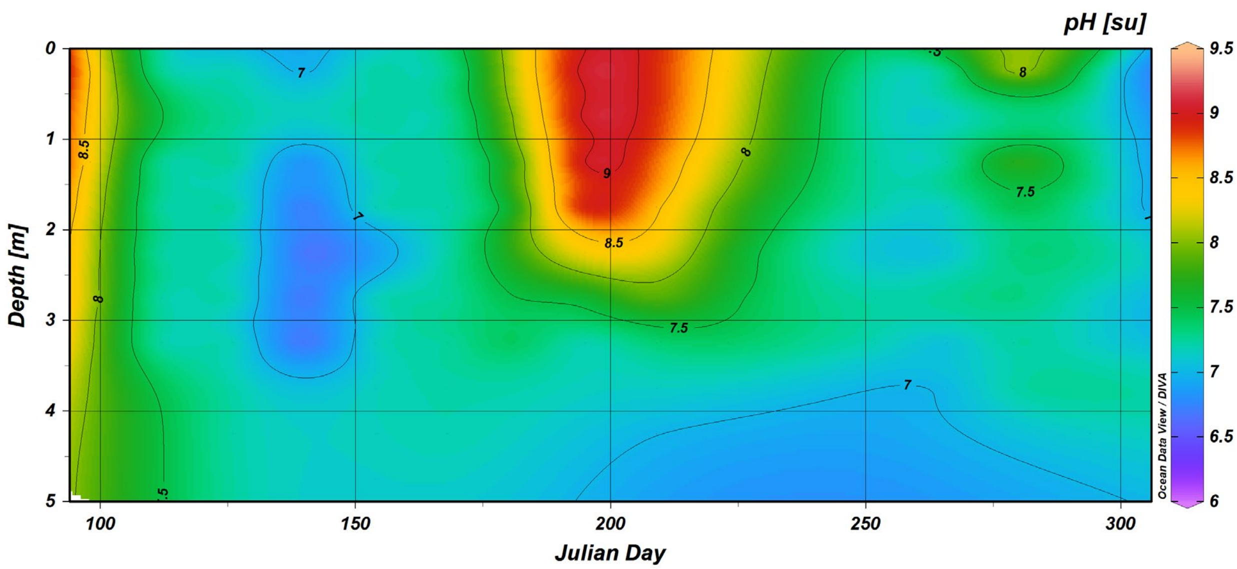

Chlorophyll-a
Depth [m]
Julian Day
Ocean Data View / DIVA

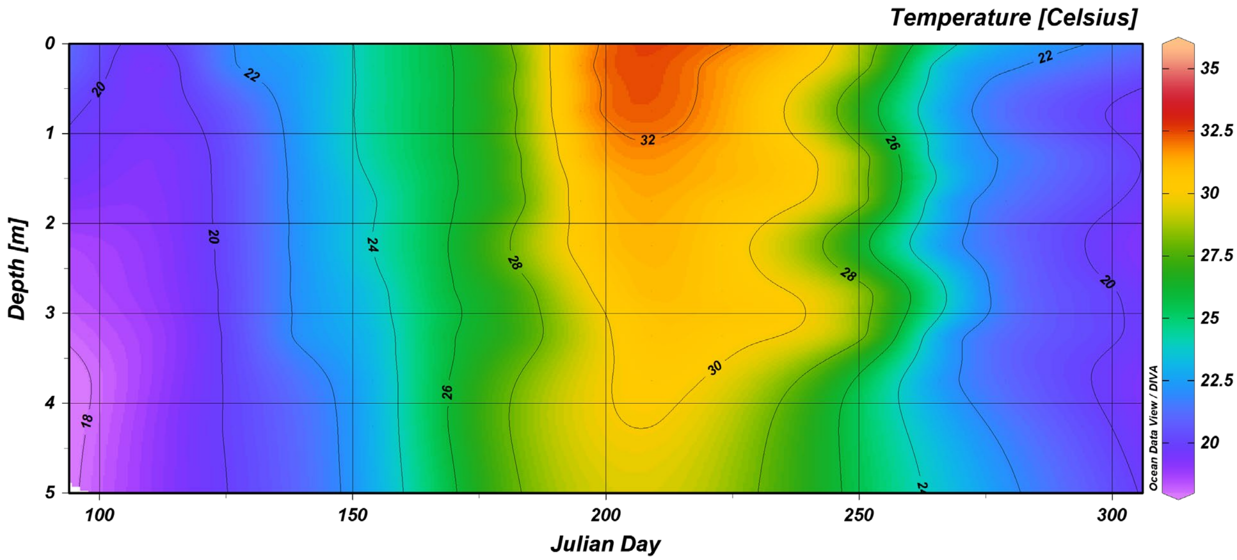

Depth [m]
Julian Day
Ocean Data View

LCR-03 – Lake Wateree off Dutchmans Creek arm

Missing 8/24/2020







Temperature [Celsius]
Depth [m]
Julian Day
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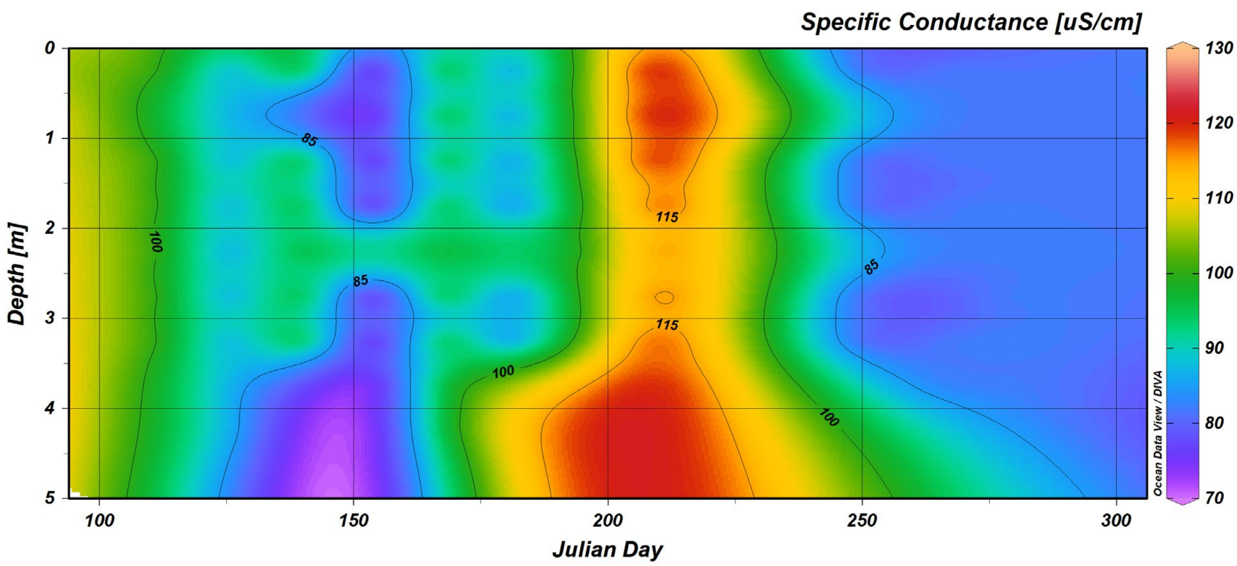
28
32
Ocean Data View / DIVA



Specific Conductance [uS/cm]
Depth [m]
Julian Day
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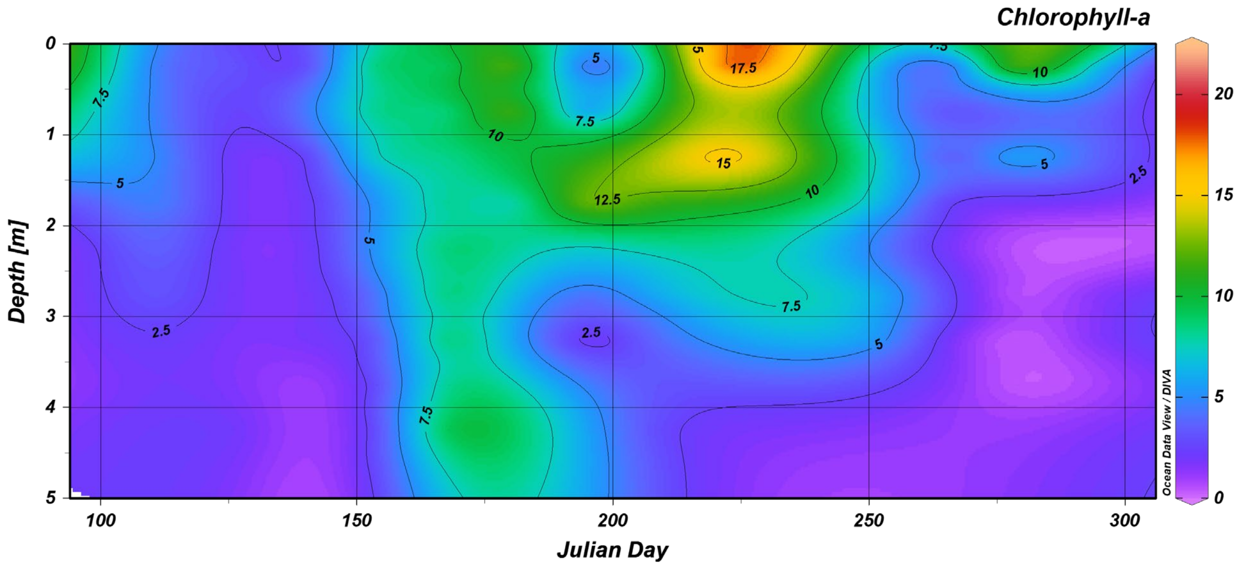
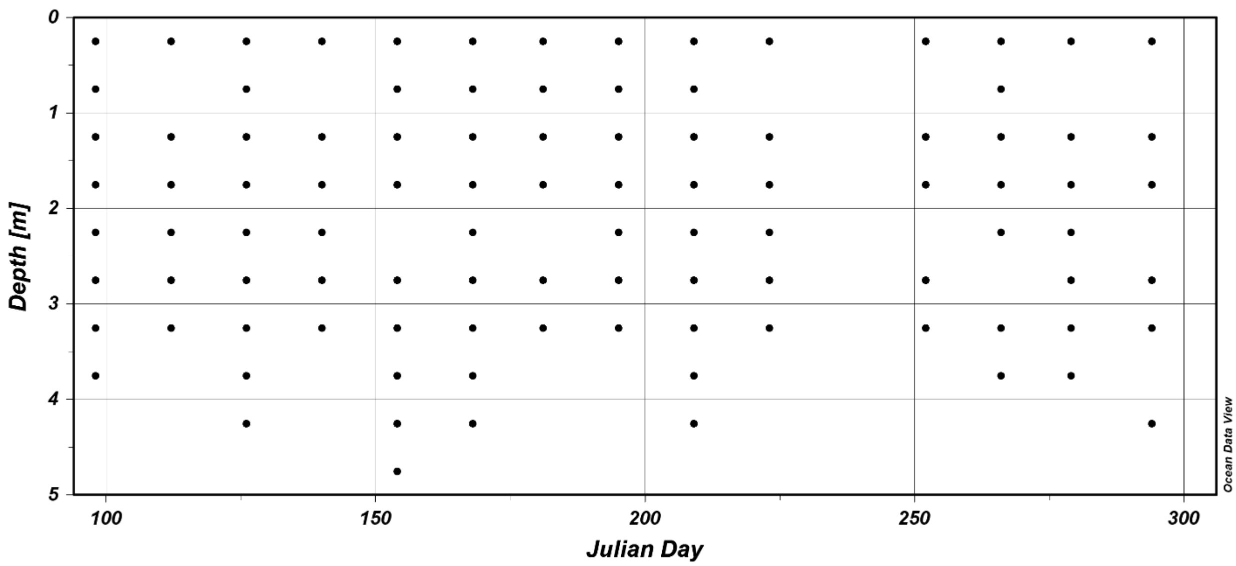
115
Ocean Data View / DIVA

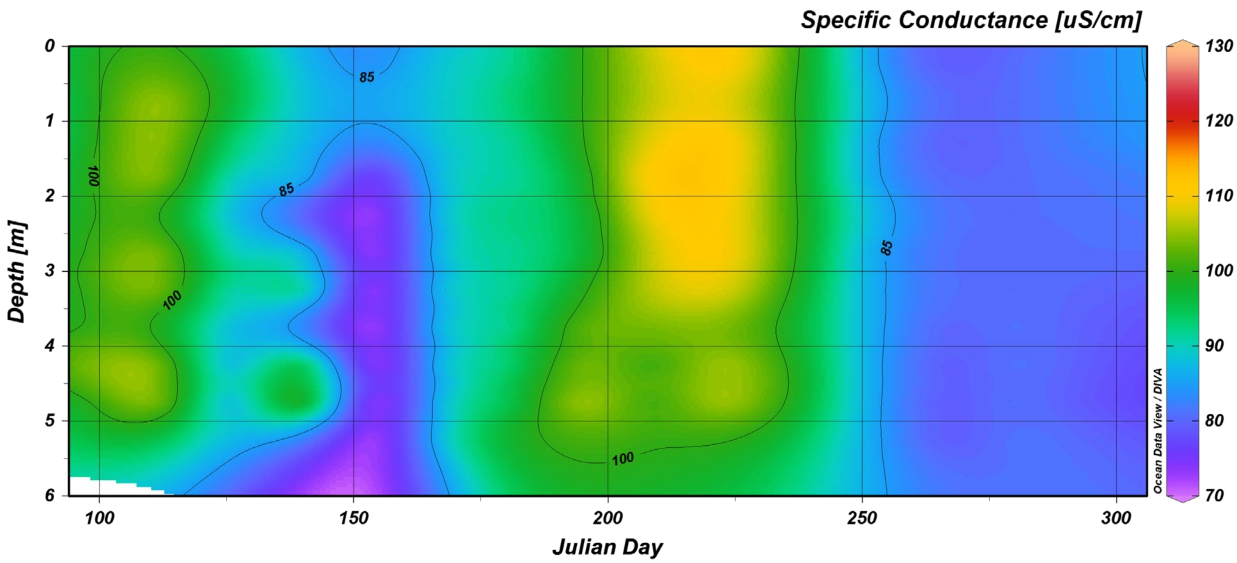

Chlorophyll-a
Depth [m]
Julian Day
Ocean Data View / DIVA

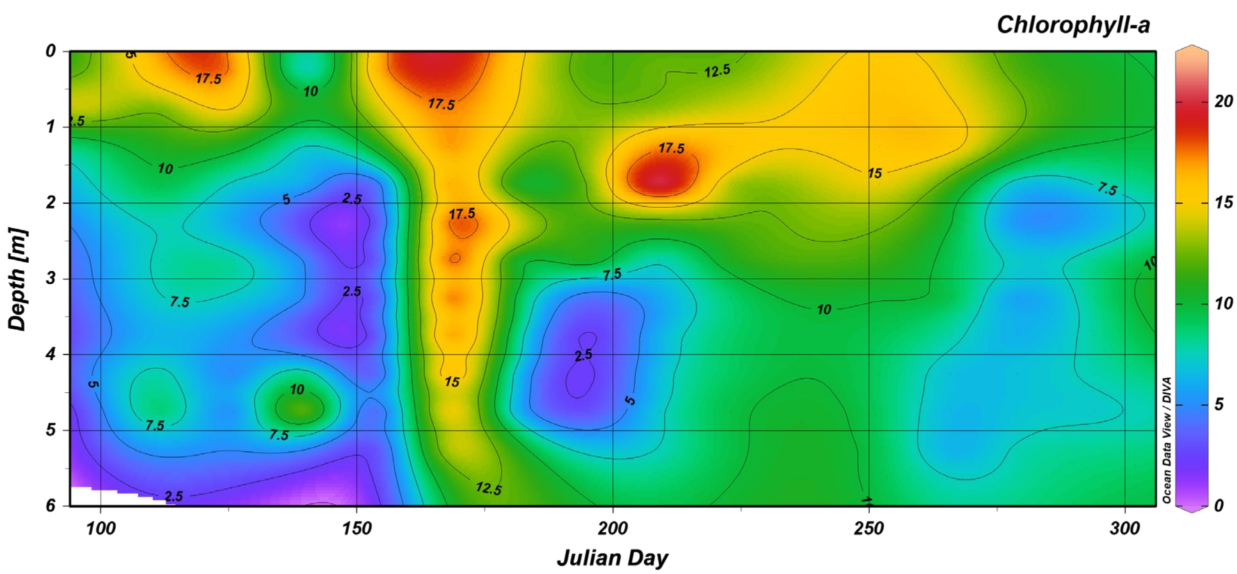

Depth [m]
Julian Day
Ocean Data View

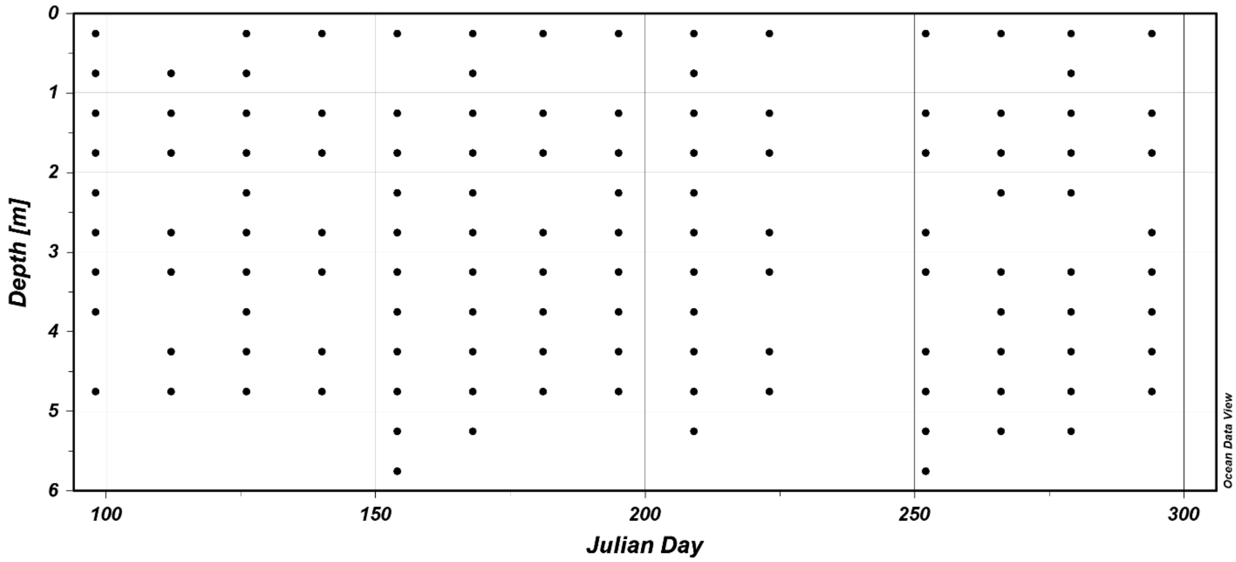
CW-208 – Lake Wateree at S-20-101 (Dutchman Creek arm)

Missing 8/24/2020

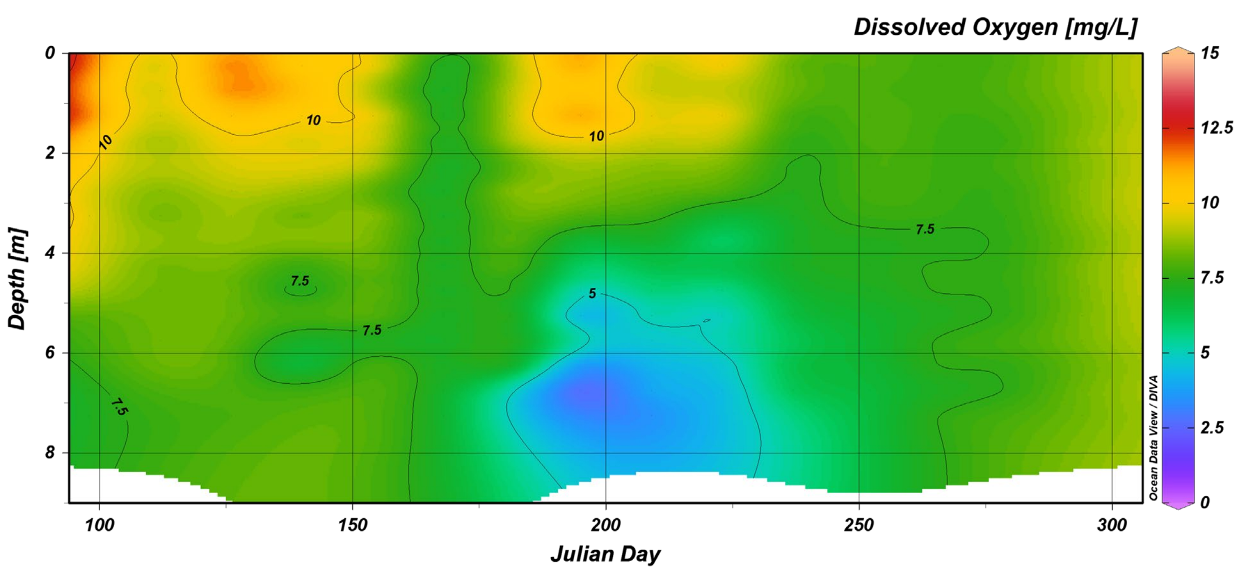
Dissolved oxygen, pH and temperature section plots included above in main body of report

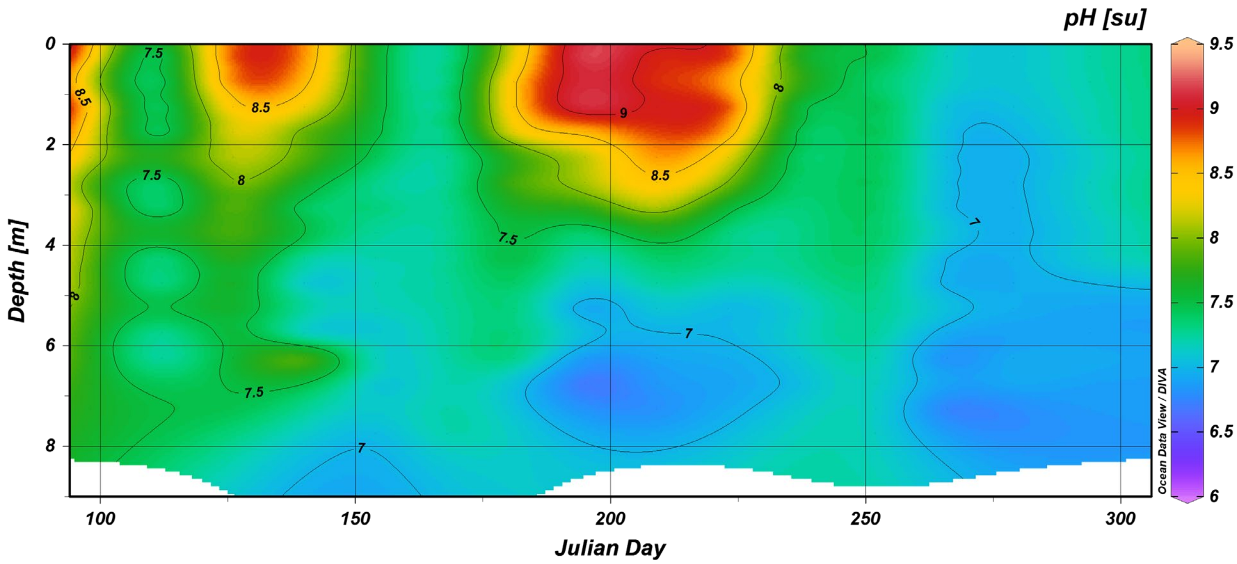


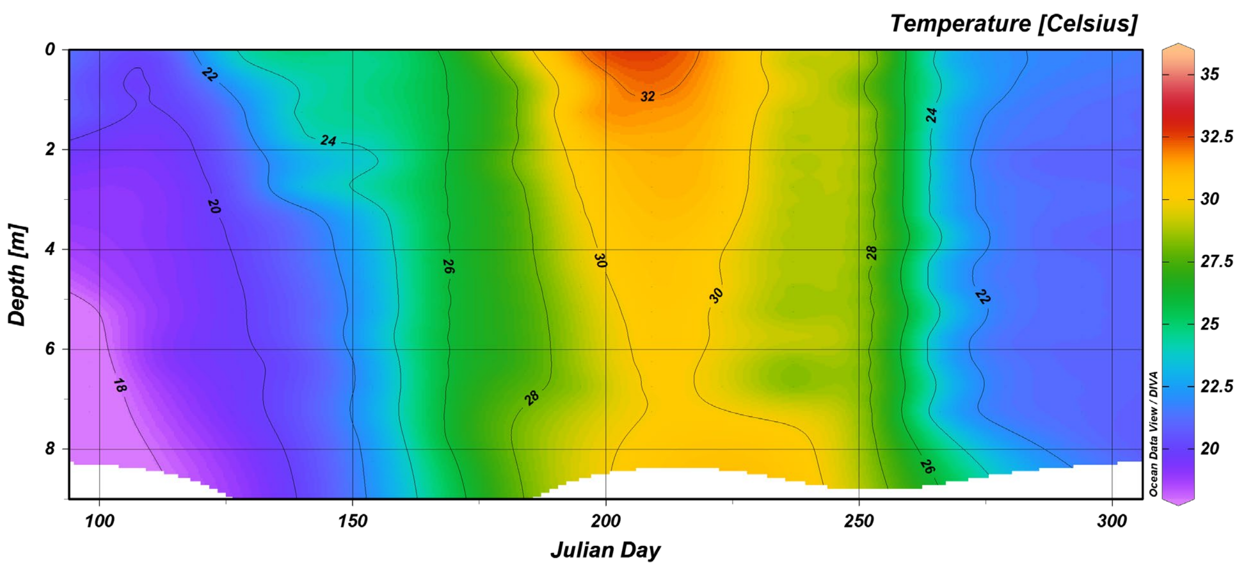




CW-207B – Mid-channel Lake Wateree at end of S-20-291




pH [su]
Depth [m]
Julian Day
Ocean Data View / DIVA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Depth [m]
Julian Day
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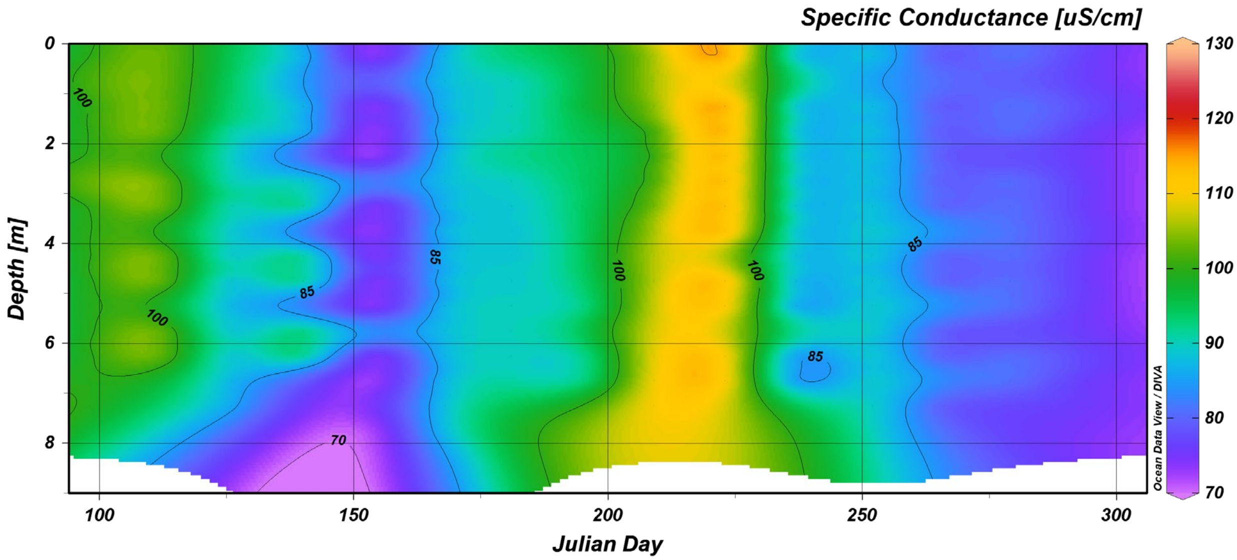
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Depth [m]
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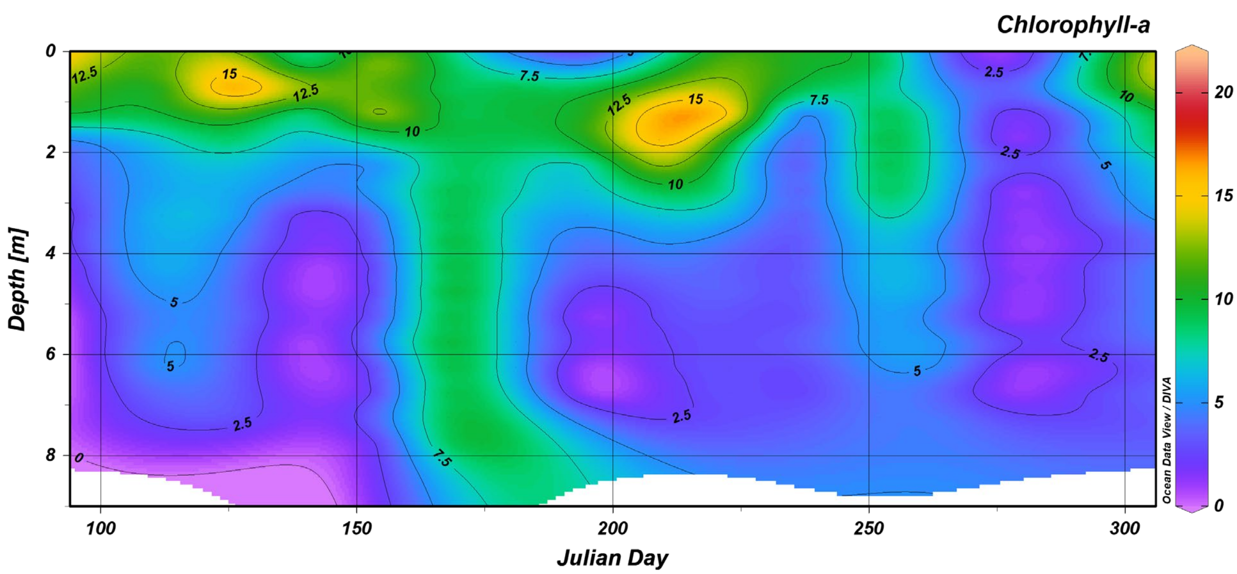
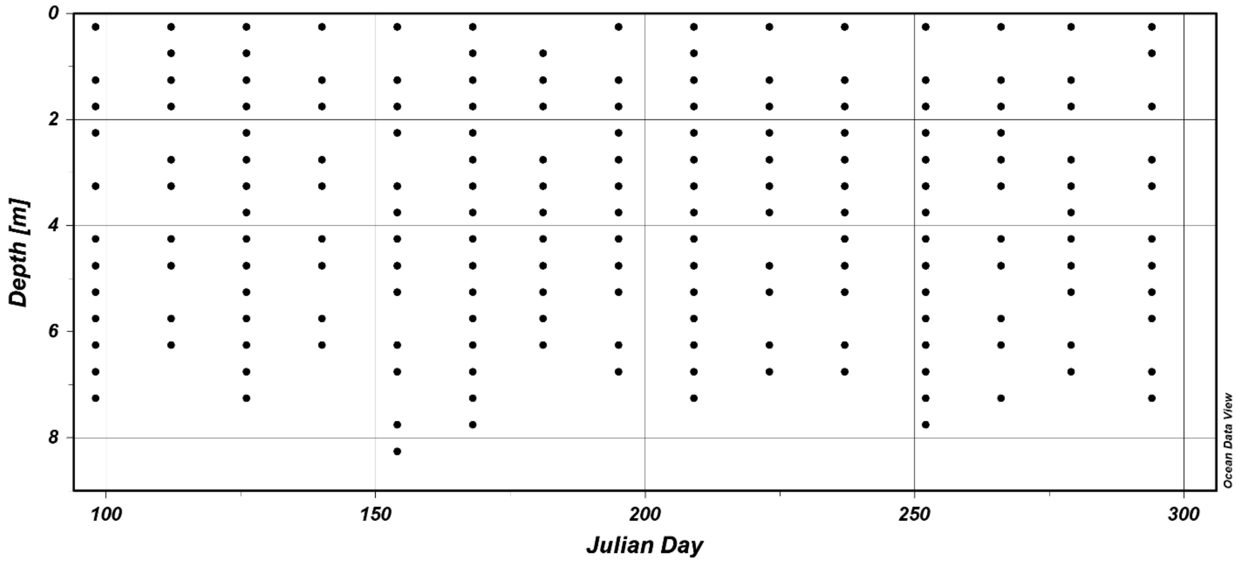

Chlorophyll-a
Depth [m]
Julian Day
Ocean Data View / DIVA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Julian Day
Ocean Data View