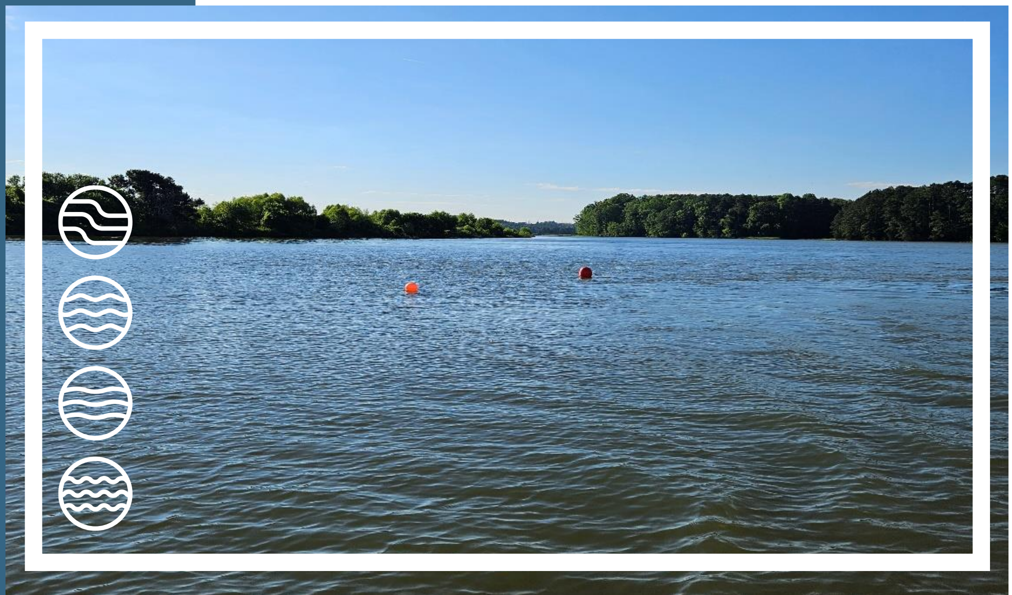

2024 Parr Shoals and Monticello Reservoirs Nutrient Study

SC DEPARTMENT of ENVIRONMENTAL SERVICES

Bureau of Water – 303d Modeling TMDL Section & Aquatic Science Division

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Cover Photo: Parr Shoals Reservoir (Fairfield County, South Carolina)

On July 1, 2024, the South Carolina Department of Health and Environmental Control dissolved into two separate agencies, the South Carolina Department of Environmental Services and the South Carolina Department of Public Health.

Parr Shoals and Monticello Reservoirs 2024 Nutrient Study

Final Report of the Field Program

February 2025

Prepared by Eric Lachenmyer & Matthew S. Baumann, Ph.D.

SC DEPARTMENT *of* ENVIRONMENTAL SERVICES

Bureau of Water
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Columbia, SC 29201

Technical Report No. 004-2025

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Executive Summary

In 2024, the South Carolina Department of Environmental Services (SCDES) Bureau of Water completed a field study on Parr Shoals (or Parr) Reservoir and Monticello Reservoir to support future watershed and lake water quality nutrient total maximum daily load (TMDL) model development. These reservoirs are designated priority restoration areas in the State of South Carolina's 2020-2022 Integrated Report due to total phosphorus impairments in Parr Reservoir and pH impairments in Monticello Reservoir. A TMDL for Parr and Monticello reservoirs is required to adequately evaluate any new or requests for expanded wastewater discharges.

The Parr and Monticello study focused on three existing SCDES ambient monitoring sites and established two new sites to enhance spatial resolution. Of the three existing sites only one (B-327) is a current fixed ambient surface water site. The project's objectives were achieved through biweekly (every other week) water quality (nutrients, physical parameters, and total chlorophyll-a) sampling and vertical hydrographic profiling at routine reservoir sites. Further, three continuous monitoring systems (one on Parr, two on Monticello) were used to provide diurnal data of physical/hydrographic parameters and biological responses in Parr and Monticello Reservoirs. The comprehensive dataset provided insights into the links between hydrographic conditions, nutrients fluctuations, and algal responses such as phytoplankton biomass and toxin production.

This report summarizes data collected as part of the biweekly sampling and continuous monitoring project components. Generally, all field program objectives were achieved In Monticello Reservoir; however, there were summertime data gaps in the Parr Reservoir dataset due to rapid lake draw down by Dominion Energy pump storage operations that resulted in lake levels insufficient to access the sampling locations.

Summary of observations:

- Chl-*a* and phycocyanin fluorescence were considerably higher in Hellers Creek (B-889) than the main channel of Parr Reservoir (B-346)
- Chl-*a* and phycocyanin mirror each other in the Parr main channel but decouple in Hellers Creek lake arm
- Hellers Creek had the highest Chl-*a* fluorescence of all five program sites
- pH was higher in Hellers Creek than the Parr main channel but lower than Monticello, despite high Chl-*a* fluorescence
- Monticello Reservoir had higher average pH than Parr Reservoir at all sample sites consistent with historical data
- Monticello Reservoir demonstrated moderate Chl-*a* and phycocyanin fluorescence
- A link between pH and Chl-*a* fluorescence was observed in field and continuous data; higher Chl-a values generally coincided with higher pH levels
- Low to anoxic dissolved oxygen concentrations observed in deeper waters of Monticello Reservoir

Overview of the 2024 Parr and Monticello Reservoir Study

Parr Shoals Reservoir (or Parr Reservoir) and Monticello Reservoir are designated priority restoration areas in the State of South Carolina's 2020-2022 Integrated Report due to total phosphorus impairments in Parr and pH impairments in Monticello. Specifically, South Carolina Department of Environmental Services (SCDES) monitoring sites RL-12049, B-346 and RL-16047 in Parr Reservoir are listed as impaired for total phosphorus on the 2020-2022 303(d) list. Additionally, sites RL-04370, RL-15009, B-327, RL-13089, RL-04374, RL-19170, and RL-17067 in Monticello Reservoir are listed as impaired for pH on the 2020-2022 303(d) list. Two fixed water quality monitoring sites B-345 on Parr Reservoir and B-327 on Monticello Reservoir were established years ago to further characterize and monitor water quality trends in these waterbodies.

Parr Reservoir receives treated wastewater from multiple upstream major dischargers from the Enoree, Tyger, and Upper Broad basins. The reservoir also receives treated wastewater effluent from a permitted municipal discharger in the Cannons Creek watershed.

Parr Reservoir is a 4,400 acre hydroelectric facility impoundment of the Broad River near Pomaria, South Carolina, along the border of Newberry and Fairfield counties. The Parr Development is a modified run of the river operation generating energy as a baseload facility. Parr Reservoir is the last significant impoundment of the Broad River above the confluence with the Saluda River near Columbia.

Monticello Reservoir (6,700 acres) is adjacent to Parr Reservoir in Fairfield County. Parr and Monticello reservoirs operate in tandem to supply cooling water for the Virgil C. Summer Nuclear Station. The reservoirs also operate as a pumped storage facility (Fairfield Development) to provide peaking energy and emergency energy reserve capabilities. As such, water is pumped back and forth from the reservoirs on a nearly daily basis leading to daily rises and drops in lake levels.

Parr and Monticello reservoirs are located in the Lower Broad River 8-digit hydrologic unit (HU, HUC-8) 03050106. This HUC-8 receives drainage from three HUC-8 watersheds: Upper Broad River (03050105), Tyger River (03050107), and Enoree River (03050108). The two Reservoirs are contained within the Cannons Creek-Broad River 10-digit hydrologic unit (HUC-10) watershed 03050106-04 (146310 acres). This watershed is subdivided into six 12-digit subwatersheds (HUC-12): Rocky Creek-Broad River (03050106-04-06; 37,895 acres), Beaver Creek-Broad River (3050106-04-01; 27,926 acres), Hellers Creek (03050106-04-02; 26,112 acres), Upper Cannons Creek (03050106-04-04; 17,833 acres), Lower Cannons Creek (03050106-04-05; 25,192 acres) and Monticello Reservoir (030501060-4-03; 11,234 acres).

In 2024, SCDES Bureau of Water (BOW) completed the Parr Shoals and Monticello Reservoirs nutrient study. The study focused on two ambient monitoring sites located on Parr Reservoir and three sites on Monticello to provide key temporal and spatial data. The objectives of the project were to:

- Support updated nutrient evaluation of the Parr and Monticello Reservoirs and better define the spatial distribution of nutrients and nutrient-related parameters across the lakes,
- Understand bottom water dynamics through oxygen demand and nutrient flux from the sediments in the reservoirs,
- Develop a continuous record of key physical and biological parameters in the reservoirs
- Understand vertical hydrographic structure and light availability in the water column, and

- Support future watershed nutrient loading and nutrient TMDL determinations.

This study is one component of a comprehensive plan to investigate the Parr and Monticello watershed. Other aspects include: (1) increased watershed monitoring, reactivation of lake monitoring at RL-16031, and ongoing monitoring at B-345 conducted by the SCDES regional office, (2) a United States Environmental Protection Agency led sediment oxygen demand and nutrient flux study, (3) and forthcoming wet-weather synoptic sampling. Taken together, these studies will provide important insights into the relationships and spatial/temporal variations among nutrient inputs and watershed loading, physical conditions (e.g., temperature, total suspend solids, turbidity, etc.), algal activity, and metabolically driven water column response variables (e.g., dissolved oxygen and pH). The comprehensive results of these studies will provide guidance and source data for future system modeling/TMDL development. This report summarizes the results of the 2024 Parr and Monticello Reservoir study.

Nutrient Study Project/Task Description

Field Logistics

The Parr and Monticello field study spanned 31 weeks from the beginning of April through the end of October 2024. The study focused on a series of five strategic locations in the lakes to meet the objectives described above (Table 1, Figures 1,2):

1. B-346 – Parr Reservoir upper lake area
2. B-889 – Hellers Creek arm of Parr Reservoir
3. B-327 – Monticello Reservoir mid-lake area
4. RL-04370 – Monticello Reservoir upper lake area
5. B-890 – Monticello Reservoir lower lake area

Site coordinates are provided in Table 1 and site locations are presented in Figure 1.

Table 1. Field program site coordinates and descriptions.

Site	Lat., Long.	County	Site Description
B-346	34.304872, -81.355222	Fairfield	Parr Reservoir upper lake area
B-889	34.321780, -81.378630	Newberry	Hellers Creek arm of Parr Reservoir
B-327	34.329669, -81.302637	Fairfield	Monticello Reservoir between large islands
RL-04370[a]	34.365606, -81.322863	Fairfield	Monticello Reservoir 1.7 mi NW of Monticello
B-890	34.31591, - 81.317800	Fairfield	Monticello Reservoir 0.5 mi NW of lower island

a: Site also identified as RL-11031

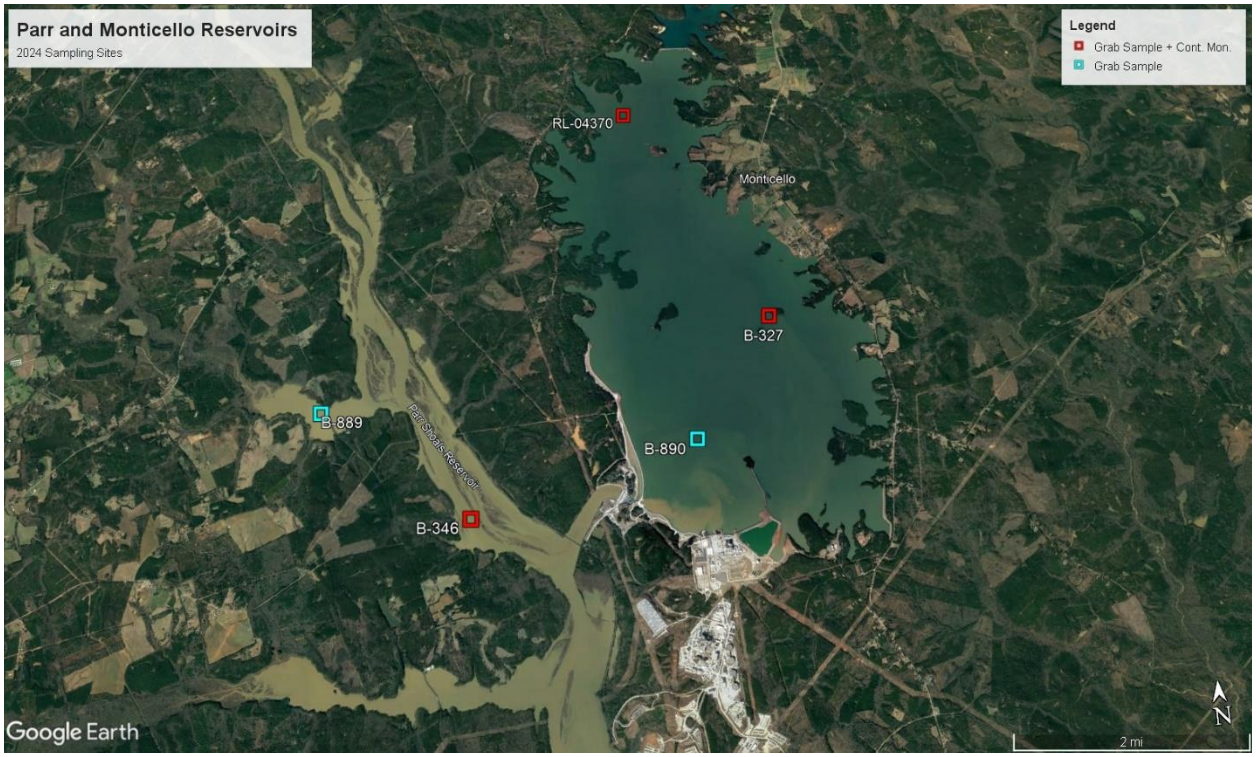


Figure 1. Site locations in Parr and Monticello Reservoirs. Blue squares indicate routine sampling sites and red squares indicate routine sampling sites with continuous monitoring systems.

Biweekly (every other week) surface (0.3 m) grab sampling was conducted at all sites. Continuous monitoring systems were installed at B-346, B-327, and RL-04370 and were serviced every other week. Low lake levels prevented routine sampling at B-889 and B-346 and servicing of the continuous monitoring system at B-346 in Parr Reservoir on multiple occasions in mid-summer. Routine surface grab sample parameters included:

- 5-day biochemical oxygen demand,
- Turbidity,
- Ammonia-nitrogen,
- Nitrate/nitrite-nitrogen,
- Total Kjeldahl Nitrogen,
- Total phosphorus,
- Orthophosphate,
- Total suspended solids,
- Total and filtered total organic carbon,
- Total chlorophyll-*a*,
- Cyanotoxins (microcystins)

Field surface sensor measurements were recorded at each grab sample site along with vertical profiles using a YSI EXO2 and photosynthetically active radiation (PAR) penetration using a LI-COR light meter:

- Water temperature,
- Dissolved oxygen (DO),
- pH,
- Turbidity,
- Specific conductivity,
- Chlorophyll-*a* fluorescence,
- Phycocyanin fluorescence.

Continuous monitoring systems on Monticello Reservoir recorded surface measurements (~0.5 m) at 30-minute intervals at B-327 and RL-04370. Monitored parameters are the same as the field sensor measurements listed above.

Continuous monitoring systems on Parr Reservoir recorded surface measurements (~0.5 m depth) at 30-minute intervals at B-346. Monitored parameters are the same as the field sensor measurements; however, phycocyanin, pH, and Turbidity were not monitored due to instrument limitations.

Sensor Data

Surface Parameters

Surface physical parameters were collected at a depth of 0.3 m at each site using a calibrated YSI EXO2. These measurements accompany routine grab sampling. Sampling was conducted from mid-morning through early afternoon (0930-1300). Routine physical parameters included pH (SU), optical dissolved oxygen (DO, mg/L), water temperature (°C), specific conductivity (µS/cm), and turbidity (FNU) (Table 2).

Table 2. Range (surface minimum and surface maximum) for each primary field parameter over the 4/2/2024 – 10/29/2024 period at the lake sites. Each range for Monticello sites consists of 16 sampling events while sites on Parr Reservoir consisted of 13 sampling events.

Site	Field pH (SU)	Field DO (mg/L)	Water Temp. (°C)	Spec Cond. (µS/cm)	Turbidity (FNU)
B-346	6.82 – 7.48	6.00 – 9.45	17.28 – 30.0	82.3 – 147.0	5.29 – 95.68
B-889	6.85 – 8.79	6.05 – 11.74	17.48 – 21.18	73.1 – 131.1	8.38 – 43.06
B-890	7.13 – 9.27	6.57 – 10.78	16.98 – 31.82	92.8 – 105.2	1.27 – 8.94
B-327	6.95 – 9.30	5.55 – 11.19	19.35 – 33.8	93.5 – 105.9	1.43 – 6.98
RL-04370	6.90 – 9.31	5.30 – 11.05	18.92 – 32.89	94.9 – 104.6	1.72 – 3.64

An expanded suite of surface measurements was also collected at each site, which included sensor-based chlorophyll-a (RFU) and phycocyanin (RFU) (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 and water clarity expressed as secchi depth (m). 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 discrete depth or vertical band where pigment fluorescence was highest.

Table 3. Range (minimum and maximum) for additional field parameters at the lake sites over the 4/2/2024 – 10/29/2024 study period. Each range for Monticello sites consists of 16 sampling events while sites on Parr Reservoir consisted of 13 sampling events.

Site	Chl-a (RFU)	Chl-a Max Depth (m)	Phycocyanin (RFU)	Phycocyanin Max Depth (m)	PAR Depth (m)	Secchi Depth (m)
B-346	0.26 – 1.28	0.3 – 2.8	0.00 – 0.44	0.3 – 1.5	0.73 – 3.30	0.25 – 1.55
B-889	0.80 – 7.00	0.3 – 1.2	0.10 – 2.29	0.3 – 2.0	0.80 – 2.45	0.35 – 0.85
B-890	0.50 – 2.45	0.3 – 4.0	0.07 – 1.36	0.3 – 3.2	2.55 – 5.80	0.90 – 2.20
B-327	0.55 – 3.78	0.3 – 3.0	0.04 – 0.93	0.3 – 3.9	3.00 – 5.95	1.0 – 2.1
RL-04370	0.71 – 3.09	0.3 – 5.5	0.06 – 0.76	0.3 – 5.6	3.30 – 5.15	1.10 – 1.95

Vertical Profile

Vertical profiles were collected at each sampling site visit using a 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 of ascent. An Excel tool was used 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 was manually adjusted, if necessary, to remove the effects of sediment resuspension on the sensor measurements. Subsequently, the program averages the downcast data in half meter intervals. Eight parameters were processed for each profile: water temperature, DO concentration, DO percent saturation, pH, turbidity, specific conductivity, chlorophyll-a fluorescence, and phycocyanin fluorescence.

In total, 74 vertical profiles were collected as part of the 2024 Lake Program: 16 biweekly profiles at each routine site on Lake Monticello and 13 biweekly profiles in Parr Reservoir. 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.

Continuous Monitoring

Continuous monitoring systems were deployed at B-346, B-327, and RL-04370 from 4/2/2024 through 11/5/2024. Each deployment was two weeks in duration with data recorded at 30-minutes intervals. At site B-346 there are data gaps from 5/15 - 6/11 and from 8/21 to the end of the field program due to low water levels on Parr Reservoir. End of deployment verifications for all variables were largely successful (Table 4).

Table 4. Percent of continuous monitoring deployments passing end of deployment verifications for each sensor. Assessment criteria are identified in the column headers. Note: 10% criterion for phycocyanin is not an approved accuracy rating but provides basic interpretation of sensor performance.

Station	Dissolved Oxygen (0.2 mg/L)	pH (0.2 SU)	Specific Conductivity (10%)	EXO2 Chlorophyll-a (10%)	EXO2 Phycocyanin (10%)	Turbidity (10%)
B-346	100%	55.6%	100%	100%	N/A	66.7%
B-327	93.8%	100%	100%	100%	100%	100%
RL-04370	93.8%	93.8%	100%	100%	100%	100%

The following list summarizes deployment notes:

B-346

- The pH verification for the 4/16/2024 record showed severe drift. Verification was over 10.21 (for 7 pH). The drift is noticeable in the dataset and a drift corrected dataset was used.
- The pH verification for the 4/30/2024 record showed severe drift. The drift is noticeable in the dataset and a drift corrected dataset was used. An In-situ sonde was used for subsequent deployments.
- During the 4/30/2024 - 5/15/2024 deployment, the buoy was dragged ~600 meters downstream, likely from a large log/tree.
- The field team was unable to locate the buoy and instruments on 5/29/2024.
- Gear and buoy were redeployed on 5/31/2024. During instrument verification on 6/11/2024, the turbidity record failed starting on ~6/9 likely due to battery depletion. The buoy was dragged downstream prior to 8/21/2024. Gear was not reset following this instance due to recurring issues with system mooring.

RL-04370

- Monticello 8/5/2024 – 8/20/2024: Failed DO verification was apparent in the record.

Fluorometer-Based Chlorophyll-a

A total of 90 samples were collected for fluorometer-based total chlorophyll-a. Samples were collected at the surface (0.3 m) at all sites during all visits. All samples were successfully analyzed.

Cyanotoxins

Samples for microcystins analysis were collected at the surface as part of every other site visit. A total of 33 samples were collected. One analyzed sample did not pass laboratory quality control (B-890 on 7/23/2024).

Water Quality

Grab samples for water quality occurred biweekly from 4/2/2024-10/29/2024. Each site on Monticello was sampled 16 times over the course of the field program while Parr Reservoir was sampled 13 times due to low water levels preventing lake access. Completeness of the water quality grab sampling component was 100% as no sample event was omitted due to field team decision or error. In total, 90 grab samples at 74 site visits were successfully collected. The total includes 16 subsurface grab samples collected at B-890 (one subsurface sample per visit). Lake sampling followed a biweekly schedule and samples were evenly distributed over the course of the study.

Water quality sampling notes:

- 4/2/2024 – B-890: Lots of drag on instrument and Niskin, D2 estimated at 20 m.
- 8/5/2024 – B-890: Vertical profile collected 500 m from site towards dam due to wind.
- 8/20/2024 – B-890: Parr influence/dam operations at site, wind drift on deep cast

- Parr too shallow on 8/20, sampled on 8/21
- 9/4/2024 – B-890: Wind drag on Niskin during D2 sample collection
- Parr not sampled due to low water levels: 9/4, 9/17, & 10/1

Summary of Findings

The following discussion presents observations of key parameters investigated as part of the 2024 Parr and Monticello reservoirs study. The discussion is not meant to be exhaustive of all data collected during the study but highlights seasonal trends and features of the system. The vertical profile data discussion centers on the structure of the water column over the course of the field program at B-890. Continuous monitoring data focuses on key features at RL-04370, B-327, and B-346. Summary statistics for total chlorophyll-a, microcystins, total phosphorus, total nitrogen, and total organic carbon are presented for all sites and all available depths. Additional site figures are presented in Appendix A (vertical profile) and B (continuous monitoring).

Vertical Profile

Section plots for temperature, dissolved oxygen, pH, chlorophyll-a fluorescence, and turbidity for B-890 are presented in Figures 2-6. Phycocyanin fluorescence, and specific conductivity plots for B-890 along with section plots for RL-04370, B-327, B-346, B-889 are presented in Appendix A. The section plots were interpolated from the 13 (Parr) – 16 (Monticello) vertical profiles collected on a biweekly basis at each station. Because the profiles were collected at approximately two-week intervals at roughly the same time of day, the interpolated data illustrate the seasonal evolution of water column physical and biological parameters at each site.

In April, the average water column temperature at B-890 (average total depth = 40.4 m) was 16.1°C with the average difference between surface and bottom of 6.2°C. Specifically, surface temperatures at this point in the season were 17.1 – 21.6°C and bottom temperatures were 12.8 – 14.3°C (Figure 2). Average water column temperatures increased to 26.6°C in August before decreasing to 22.3°C in mid-October. Surface temperatures in August were ~31°C with bottom temperatures of 15.8 - 16.6°C. The highest temperature differences between surface and bottom were ~17°C and observed at the end of June and early July. By late July, warmer temperatures were present in the deeper reaches of the water column. Vertical mixing of the water column occurred at the end of October as surface temperatures cooled to 20°C (Figure 2).

Throughout the project, DO at the surface ranged from 7.3 - 10.8 mg/L (Figure 3). Higher surface water DO concentrations were observed early in the project (April and May) and decreased through the summer and early fall. Bottom water DO concentrations of <2.0 mg/L were observed at the end of May and gradually expanded to encompass the water column below 20 m by early June. After July, this low DO feature gradually contracted. By mid-September, minimum water column DO concentrations were >4 mg/L. Vertical mixing in October largely homogenized DO concentrations throughout the water column resulting in ~0.5 mg/L differences between the surface and bottom waters (Figure 3).

Surface water pH was highest from the end of April through mid-July with relatively lower values in early April and after late July (Figure 4). Measured pH in surface waters throughout the project largely mirrored DO which suggests that DO and pH may be influenced by phytoplankton growth more than physical processes in this area of the lake. Surface water chlorophyll-a fluorescence patterns support this observation as higher values were measured from the end of April through June (Figure 5). Mid-water column turbidity spikes were observed on multiple occasions throughout the project (Figure 6).

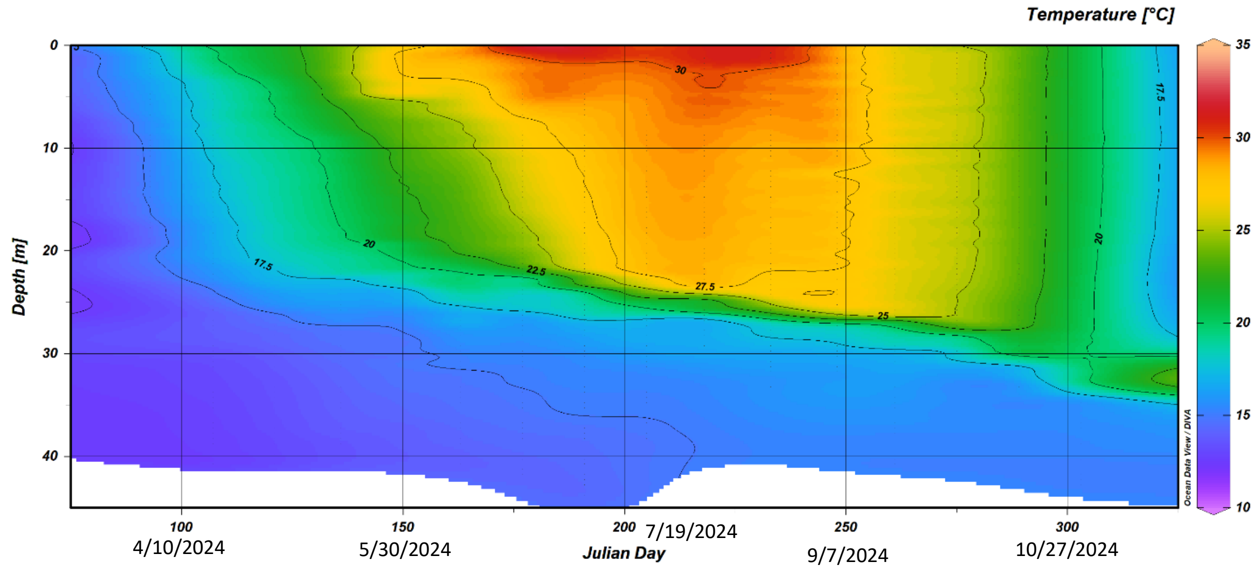


Figure 2. Temperature (°C) section plot for B-890*. Corresponding calendar dates are listed next to Julian Day labels.*

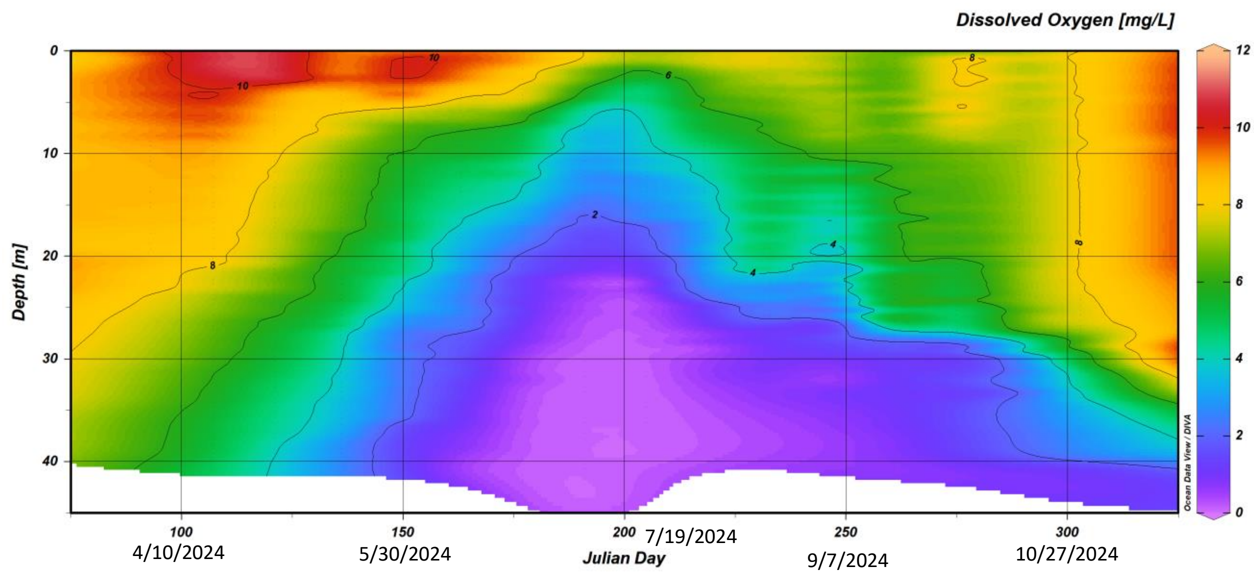


Figure 3. Dissolved oxygen (mg/L) section plot for B-890*. Corresponding calendar dates are listed next to Julian Day labels.*

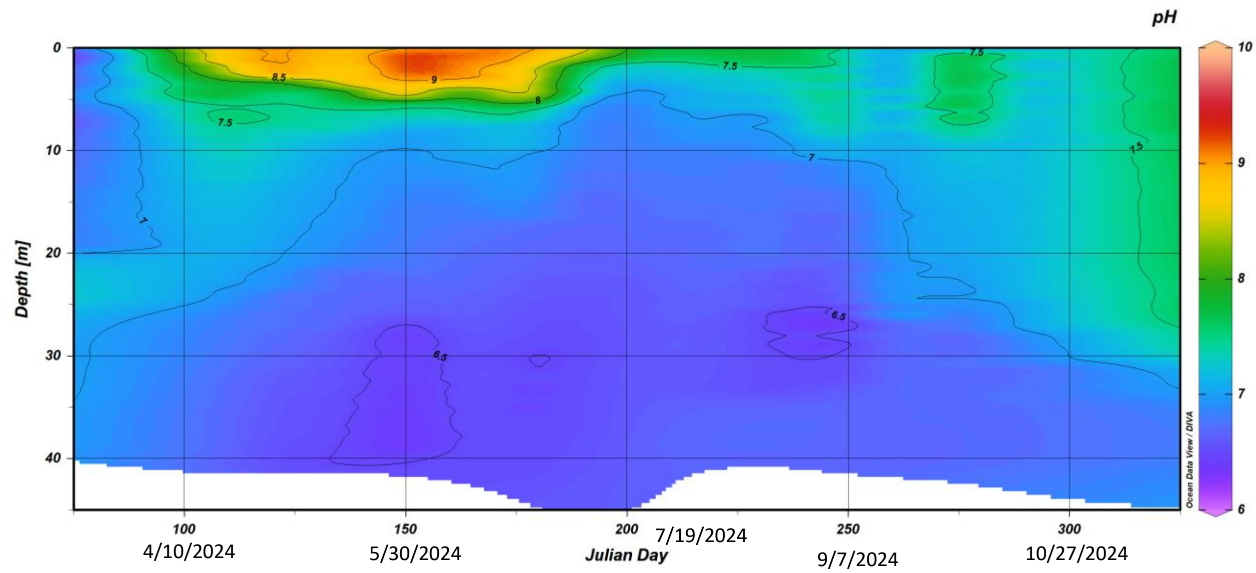


Figure 4. pH (SU) section plot for B-890. Corresponding calendar dates are listed next to Julian Day labels.

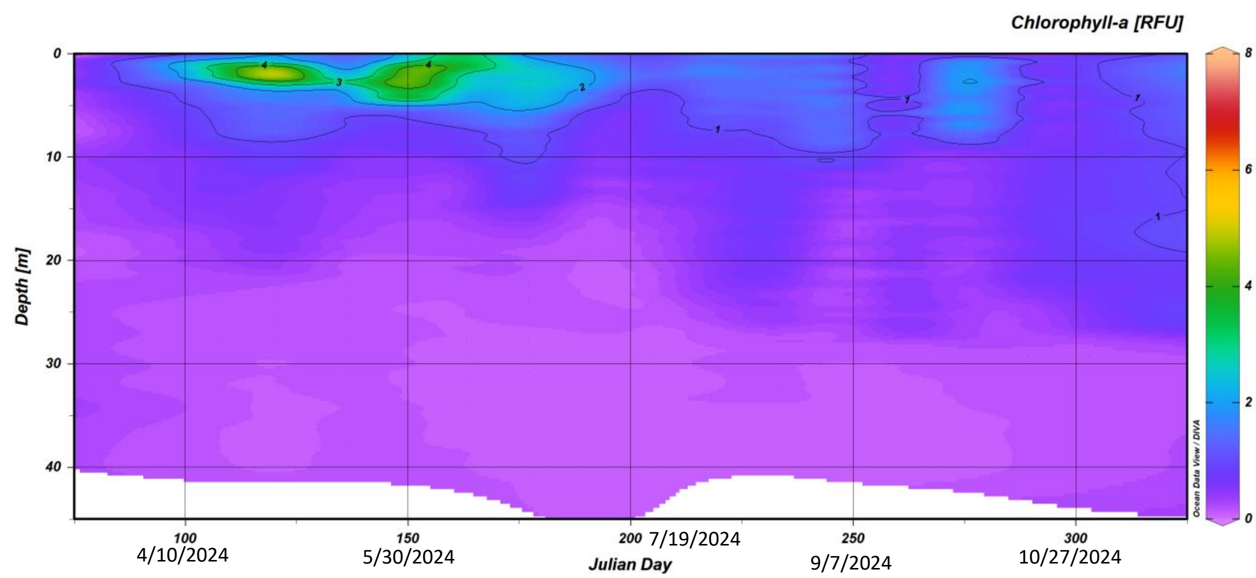


Figure 5. Chlorophyll-a fluorescence (RFU) for B-890*. Corresponding calendar dates are listed next to Julian Day labels.*

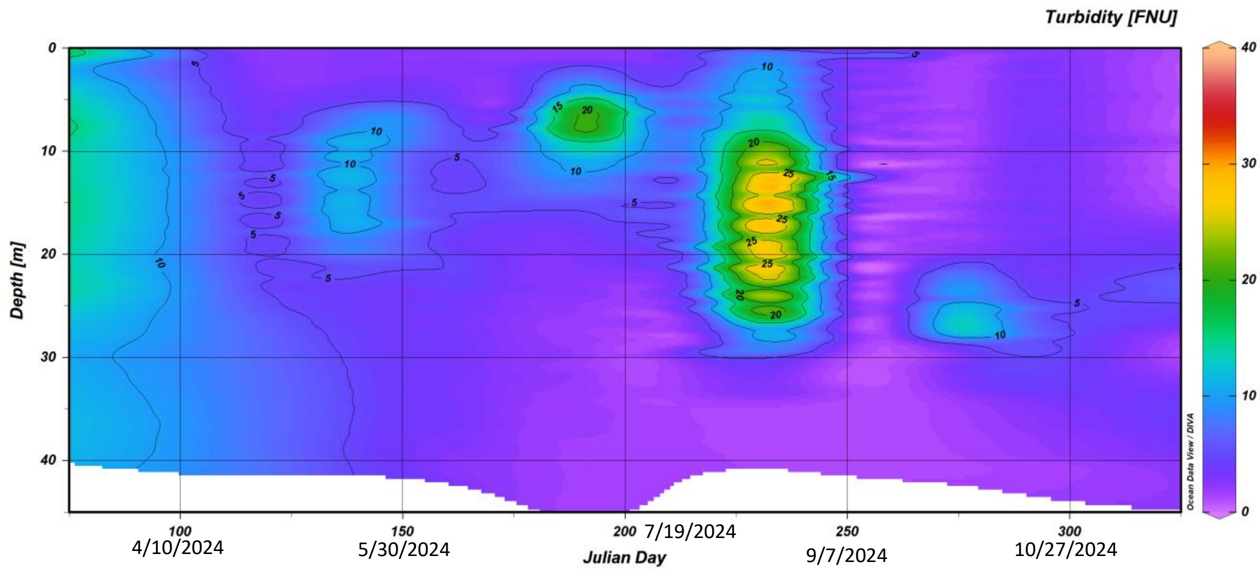


Figure 6. Turbidity (FNU) for B-890. Corresponding calendar dates are listed next to Julian Day labels.

Continuous Monitoring

Continuous monitoring in the surface water environment filled data gaps between biweekly surface measurements and vertical profiles. The following discussion focuses on the temperature, DO, pH and chlorophyll-a fluorescence time-series for RL-04370 and B-327 in Monticello and B-346 in Parr Reservoir. This timeseries data along with hourly average histograms of DO, pH, and chlorophyll-a fluorescence provide insights into daily patterns for these parameters. Additional continuous monitoring plots are presented in Appendix B.

Generally, Monticello Reservoir continuous monitoring parameters at stations RL-04370 and B-327 mirrored each other but with different magnitudes.

In April, surface water temperatures at RL-04370 and B-327 (Figure 7) averaged 20.5 & 21.1°C, respectively, consistent with the surface component of the vertical profiles collected at these sites (Appendix A). These values were higher than station B-890 (Figure 2) which has a much greater depth (~40m) compared to RL-04370 and B-327 (~10-12m). The average percent difference in temperatures between stations RL-04370 and B-327 was 2.6%. Temperature fluctuations tended to mirror each other. Minor differences occurred in the spring with B-327 having slightly higher temperatures while in the fall RL-04370 had slightly higher temperatures. Station B-346 in Parr was on average 2.2°C cooler than RL-04370 and B-327. Temperature differences could be attributed to a number of factors including shorter residence time in Parr compared to Monticello, smaller waterbody size, less heat retention ability, larger area of shading, and Dam pumping operations. Daily maximum average temperatures at station RL-04370 (32.9°C) on 8/2/2024 and stations B-327 (33.5°C) and B-346 (30.5°C) occurred on 7/14/2024.

Seasonal cooling of surface water began in mid-September at sites RL-04370 and B-327. Stations RL-04370 and B-327 cooled at a similar rate from mid-September to the data end of sample recording. Both stations reached minimum temperatures of ~21°C near the conclusion of the time-series at the beginning of November (Figure 7).

Dissolved oxygen concentrations were consistently higher at Monticello site RL-04370 than B-327 with maximum daily concentrations occurring in the 1800 hour at both sites (Figure 8). Daily minimum DO concentrations typically occurred in the morning at 0800 hour at both sites. Surface DO concentrations were lower in the main channel of Parr Reservoir compared to Monticello Reservoir. Specifically, surface DO concentration at B-346 were on average ~1-3mg/L lower than the Monticello stations. On a monthly basis, the average daily maximum DO concentration at RL-04370 occurred in April (11.72 mg/L) while the B-327 maximum was in May (12.02 mg/L). The maximum monthly DO concentration at B-346 in Parr occurred in June (9.73 mg/L). The lowest DO month at RL-04370 was October for both minimum (7.06 mg/L) and maximum (8.91 mg/L) daily average concentrations. At B-327, DO was lowest in September for daily average minimum (6.28 mg/L) and maximum (8.31 mg/L) concentrations.

As with DO, pH exhibited a diel cycle with higher values in the early evening and lower values mid-morning (Figure 8). In Monticello hour-by-hour average pH was generally higher at RL-04370 than B-327. Station B-346 in Parr had a narrow range of (0.2 SU) over the course of the diel cycle. B-346 was also on average ~1 SU less than both Monticello stations over the diel cycle. June had the highest average daily maximum pH for all stations: RL-04370 (9.43 SU), B-327 (9.33 SU) and B-327 (7.93 SU) (Table 5). For RL-04370 and B-327, during the 218-day time-series maximum daily pH exceeded the state standard of 8.5 on 167 and 155 days (daily exceedance rate: 77% and 71%), respectively. Significantly fewer exceedances were observed in Parr Reservoir at B-346. At this site, pH exceeded 8.5 on 7 days of the 125-day record (5.6%).

In Monticello, continuous chlorophyll-a fluorescence was on average slightly higher (0.34 RFU) at RL-04370 than B-327 (Figures 10 – 12). While magnitudes of fluorescence were different, both sites exhibited similar features. Moderately high fluorescence values (3-5 RFU) were observed from April through mid-June. Lower chlorophyll-a fluorescence values (1-3 RFU) were characteristic of the July through mid-September period. The highest fluorescence values occurred in early October in a sharp increase before declining to its lowest values at the end of October through the rest of the time-series. Maximum average chlorophyll-*a* fluorescence occurred in the 2000 hour for both sites in Monticello, RL-04370 and B-327 (Figure 11), an approximate 2-hour delay from maximum average DO and pH. Minimum average fluorescence occurred at 0800 for both sites. Due to differences in the instrumentation used and sensor limitations between Monticello and Parr, lake-to-lake chlorophyll-a comparisons cannot be directly made.

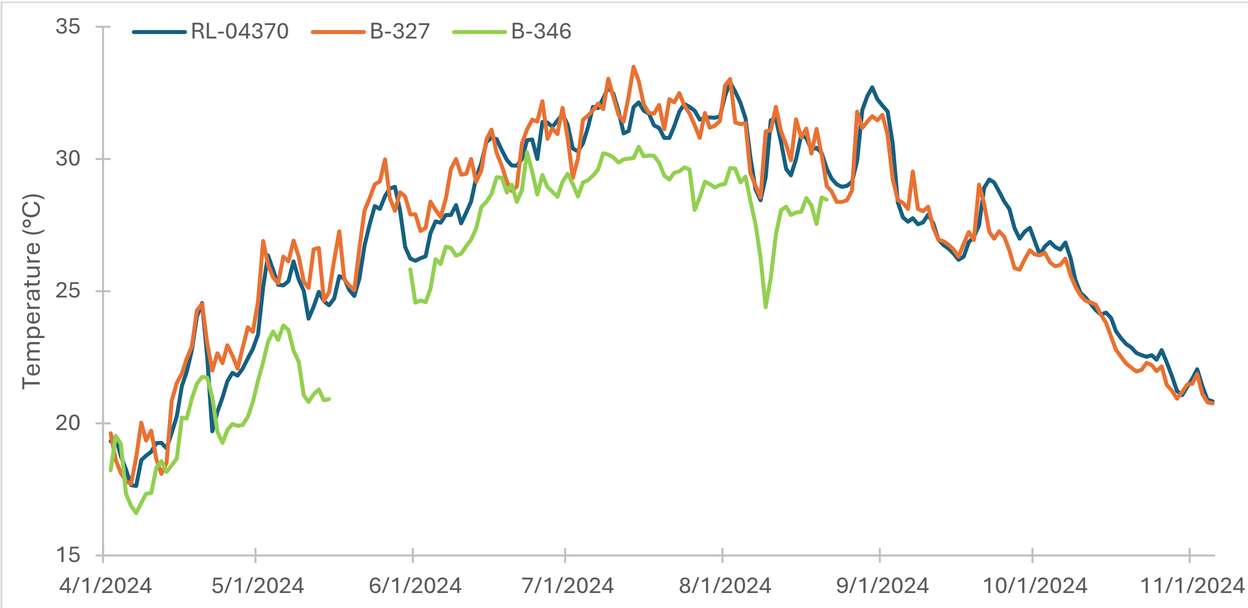


Figure 7. Average daily surface water temperature at RL-04370, B-327, and B-346*. Note: The record for* B-346 *ends on* 8/21/2024 due to low lake levels.

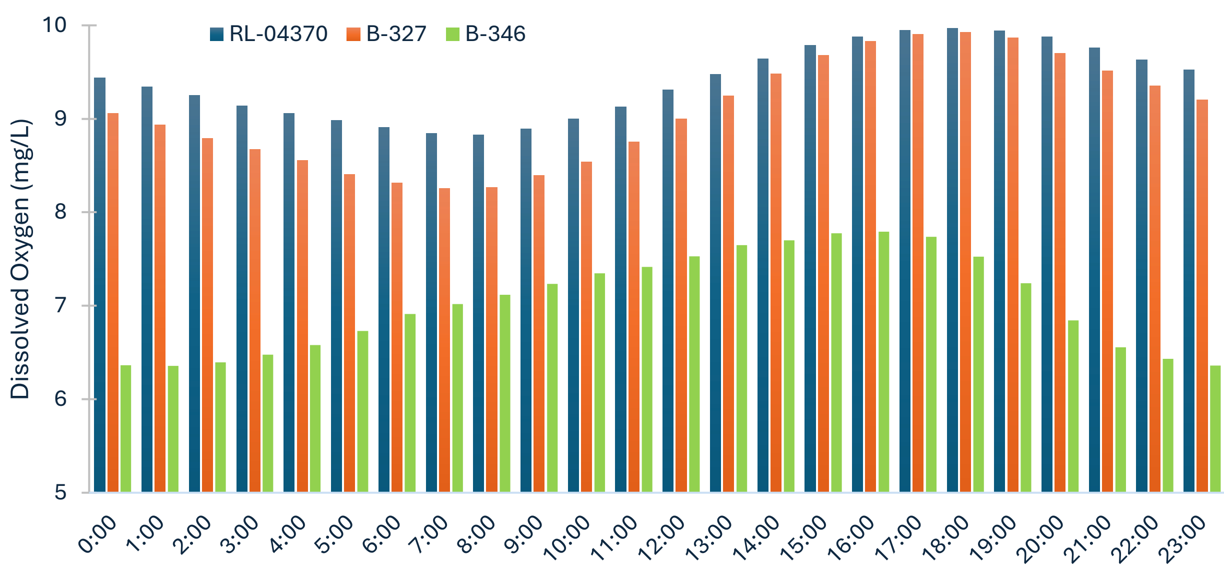


Figure 8. Hourly average dissolved oxygen concentrations (mg/L) at RL-04370, B-327, and B-346*. Note: The record for* B-346 *ends on* 8/21/2024 due to low lake levels.

Table 5. Month by month average minimum and maximum dissolved oxygen concentration along with average daily range in recorded values RL-04370, B-327, and B-346. The period of record begins on 4/2/2024 for all sites. The record for B-346 ends on 8/21/2024 and the records for RL-04370, B-327 end on 11/5/2024. All units in mg/L.

Month	Site	Avg Daily Min DO	Avg Daily Max DO	Avg Δ DO	n
April	B-346	8.26	9.19	0.93	29
	B-327	9.75	11.49	1.74	29
	RL-04370	10.59	11.72	1.13	29
May	B-346	7.52	8.33	0.81	16
	B-327	9.57	12.02	2.45	31
	RL-04370	10.14	11.71	1.58	31
June	B-346	5.77	9.73	3.99	29
	B-327	8.83	11.19	2.37	30
	RL-04370	9.51	11.05	1.54	30
July	B-346	3.67	7.71	4.05	31
	B-327	7.11	9.89	2.78	31
	RL-04370	8.19	9.76	1.57	31
August	B-346	5.05	6.71	1.66	21
	B-327	6.42	9.54	3.11	17
	RL-04370	7.60	9.35	1.75	17
September	B-346	-	-	-	-
	B-327	6.28	8.31	2.03	30
	RL-04370	7.47	8.97	1.50	30
October	B-346	-	-	-	-
	B-327	7.64	9.22	1.58	31
	RL-04370	7.06	8.91	1.85	31

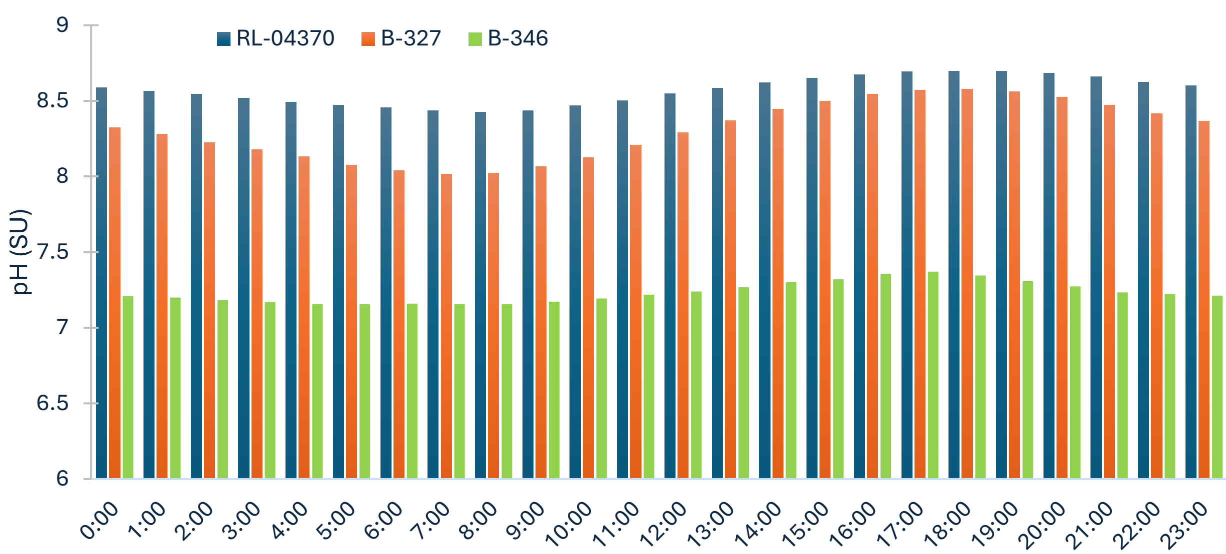


Figure 9. Hourly average pH (SU) at RL-04370, B-327, and B-346. *Note: The record for* B-346 *ends on* 8/21/2024 due to low lake levels.

Table 6. Month by month average minimum and maximum pH (SU) along with average daily range in recorded values and the number of daily maximum values that exceeded 8.5 for RL-04370, B-327, and B-346. *The period of record begins on 4/2/2024* for all *sites. The record for* B-346 *ends on* 8/21/2024 *and the records for* RL-04370, B-327 *end on 11/5/2024.*

Month	Site	Avg Daily Min pH	Avg Daily Max pH	Avg Δ pH	Max > 8.5	n
April	B-346	7.47	7.79	0.33	0	29
	B-327	8.01	8.85	0.84	23	29
	RL-04370	8.66	9.07	0.41	29	29
May	B-346	6.97	7.36	0.39	0	16
	B-327	8.68	9.24	0.56	31	31
	RL-04370	9.09	9.35	0.26	31	31
June	B-346	7.08	7.93	0.85	7	30
	B-327	8.81	9.33	0.52	30	30
	RL-04370	9.25	9.43	0.19	30	30
July	B-346	6.74	7.23	0.49	0	31
	B-327	7.73	8.86	1.13	30	31
	RL-04370	8.75	9.10	0.36	31	31
August	B-346	6.90	7.14	0.24	0	19
	B-327	7.29	8.62	1.33	22	31
	RL-04370	7.97	8.64	0.67	22	31
September	B-346	-	-	-	-	0
	B-327	7.29	8.04	0.75	9	30
	RL-04370	7.56	8.18	0.62	14	30
October	B-346	-	-	-	-	0
	B-327	7.48	8.10	0.61	9	31
	RL-04370	7.32	7.93	0.61	9	31

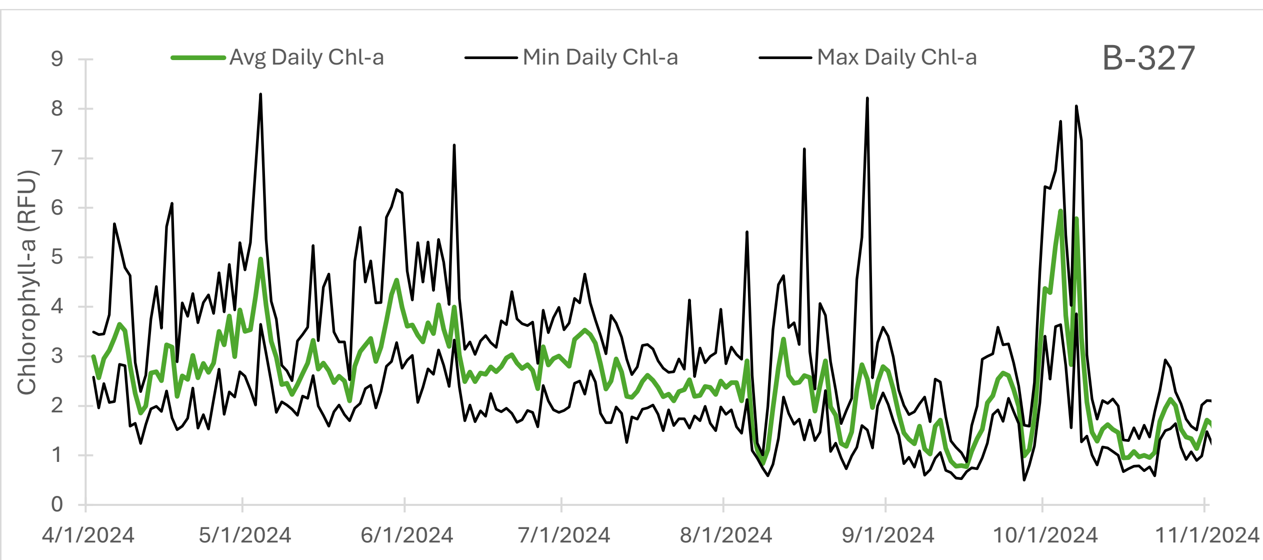


Figure 10. Daily average, daily minimum, and daily maximum YSI EXO2 chlorophyll-a fluorescence (RFU) at B-327. Note: Y-axis scaled to dataset.

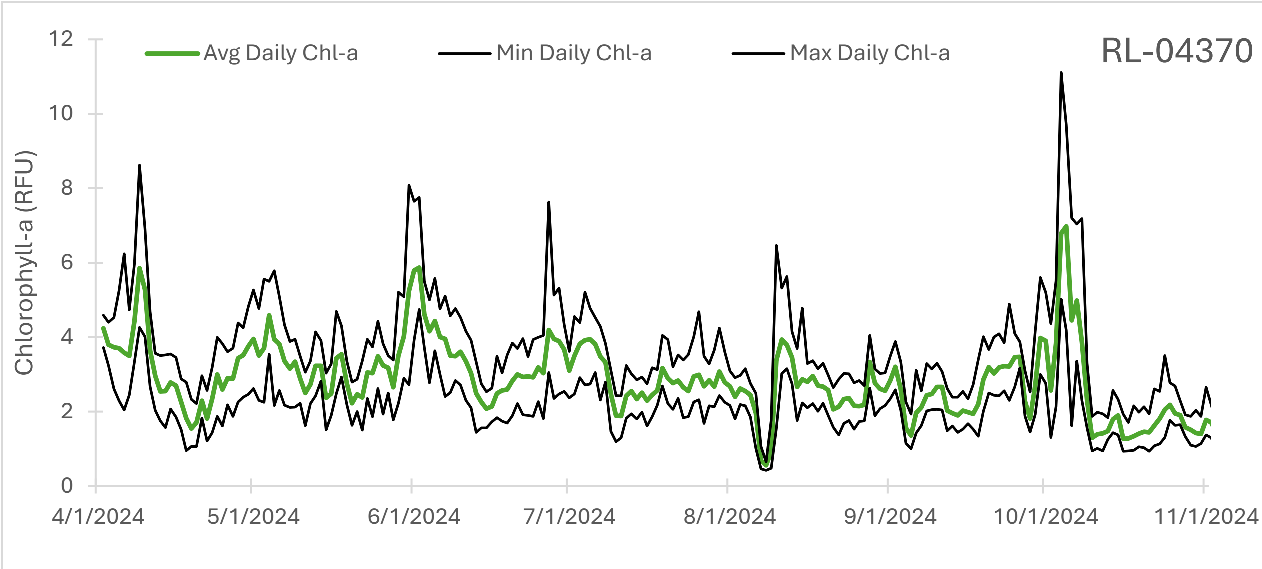


Figure 11. Daily average, daily minimum, and daily maximum YSI EXO2 chlorophyll-a fluorescence (RFU) at RL-04370. Note: Y-axis scaled to dataset.

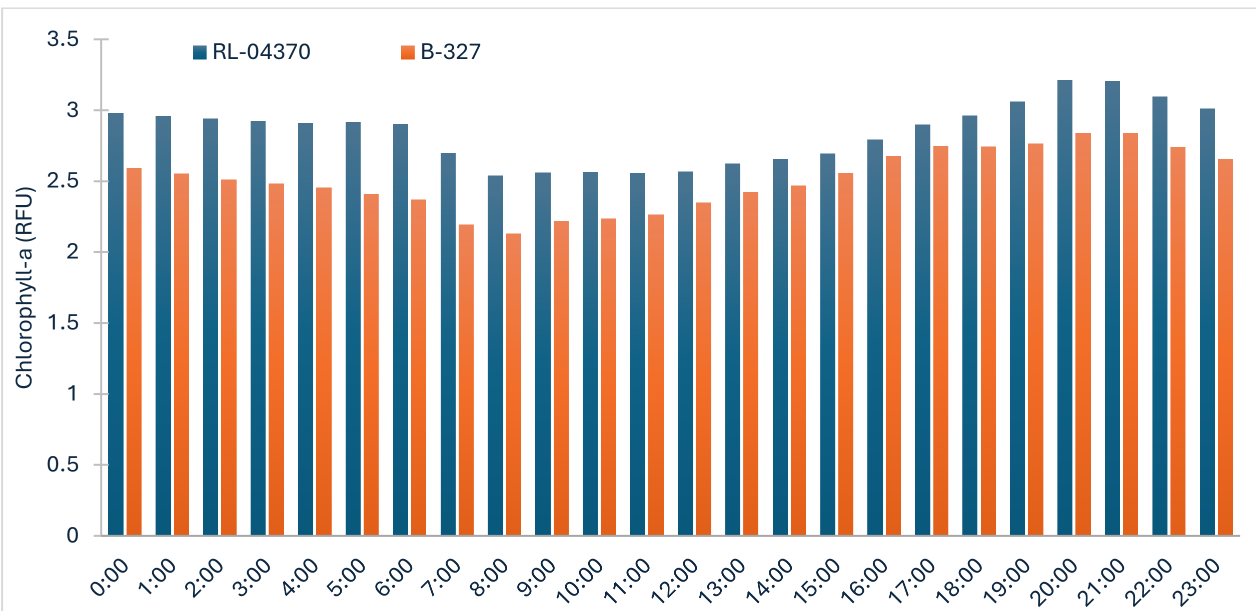


Figure 12. Hourly average chlorophyll-a fluorescence (RFU) at RL-04370, and B-327*. Note: chlorophyll-a is collected using a YSI EXO2 (RFU).*

Fluorometer-Based Chlorophyll-a

In Monticello Reservoir, average total chlorophyll-a (µg/L) was similar among all three stations (RL-04370, B-327 and B-890). The stations demonstrated similar total chlorophyll-a trends over the time-series. (Table 7, Figure 14). Generally, from April through mid-August chlorophyll-a concentrations were near the station's respective time-series average., Concentrations decreased in late summer before increasing in the beginning of October (Figure 15). Total chlorophyll-a concentrations then decreased to the lowest values of the time-series from mid-October through the end of the time-series.

There were no exceedances of the State 40 µg/L ecoregional standard for chlorophyll-a at any site. The highest chlorophyll-a values occurred in the Hellers Creek lake arm of Parr Reservoir (B-889), with a program maximum of 39.5 µg/L on 4/16/2024. The seasonal pattern in total chlorophyll-a at B-889 was similar to the Monticello Reservoir sites with higher observed values early in the program followed by a decrease in concentration late in the summer through the end of the program. Average total chlorophyll-a was lowest at B-346 (3.0 ± 1.7). B-346 was located in the Broad River channel of Parr Reservoir and demonstrated more riverine characteristics than the Hellers Creek lake arm. Chlorophyll-a remained low at B-346 (<5 µg/L) except for a small increase at the end of June through mid-July (Avg. 5.7 ± 1.4), before decreasing for the rest of the time-series.

In general, higher total chlorophyll-a concentrations were observed early in the time-series followed by a progressive decrease later in the summer (Figure 15). Similar features including the October chlorophyll-a increase were observed in the continuous chlorophyll-a fluorescence time-series as noted above (Figure 11 and 12). Further, fluorometric total-chlorophyll-a concentrations and corresponding surface water field measurements of chlorophyll-a fluorescence indicate good agreement (Figure 16). This relationship provides insights into the ranges and magnitudes of total chlorophyll-a over the daily cycle at RL-04370, B-327, and B-346.

Table 7. Surface (0.3 m) total chlorophyll-a summary statistics for each sample site. Average is presented as ± 1σ. All total chlorophyll-a units in µg/L.

Site	Avg. Chlorophyll a	Minimum	Maximum	n
B-346	3.0 ± 1.7	0.81	7.29	17
B-889	20.5 ± 8.8	2.94	39.49	13
B-890	13.4 ± 5.8	2.15	23.20	16
B-327	13.5 ± 6.2	4.13	26.19	20
RL-04370	12.5 ± 4.5	5.13	21.57	16

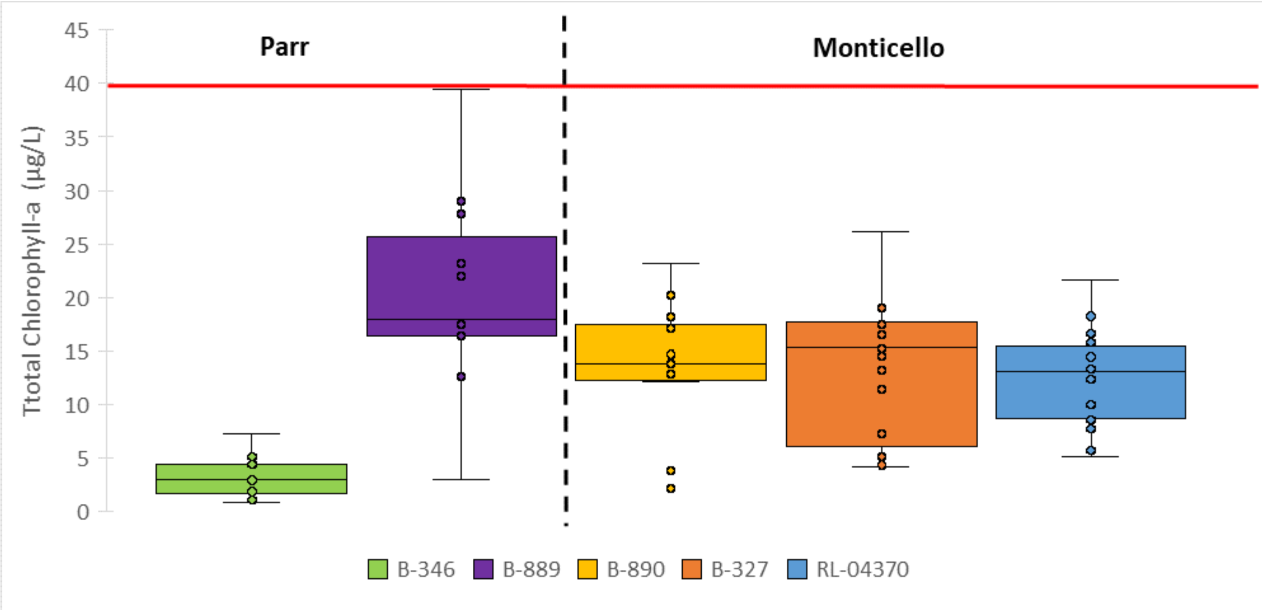


Figure 13. Box plot summary of surface (0.3 m) total chlorophyll-a concentrations (µg/L) for each lake site. Box plots include median, first (lower) and third (upper) quartiles, and ranges (minimum and maximum) for the data. The red line denotes the 40 ug/L *lake ecoregional total* Chlorophyll-a *standard.*

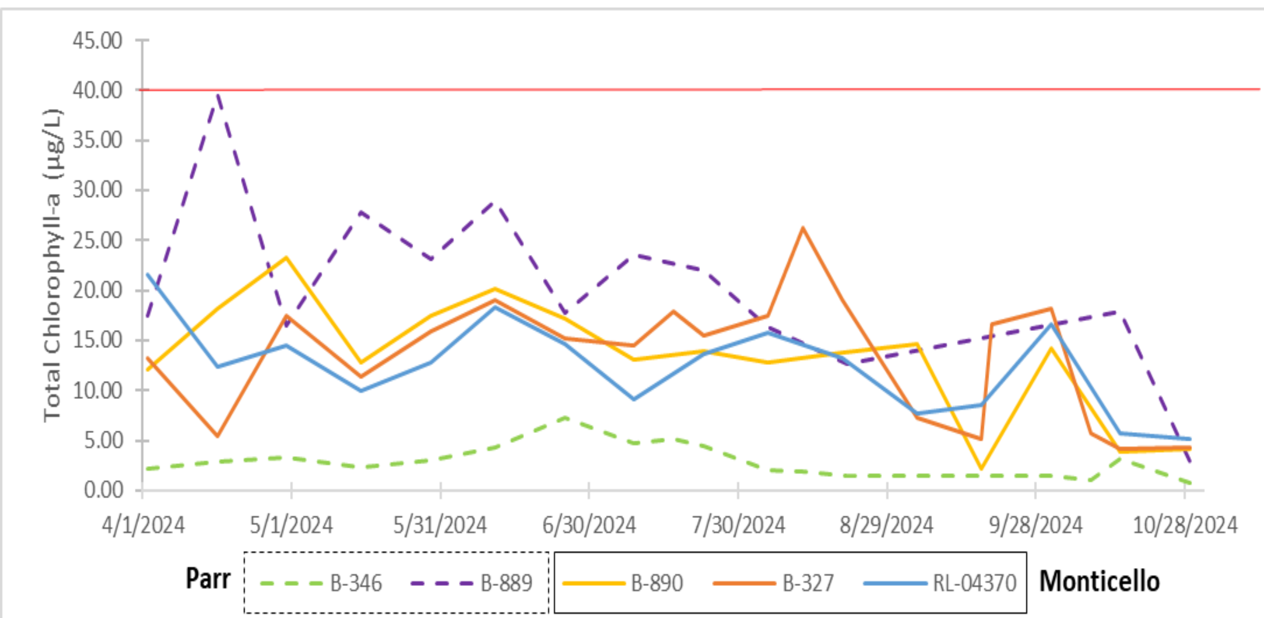


Figure 14. Total chlorophyll-a measurements (µg/L) at the biweekly lake stations. All values are surface samples (0.3 m).

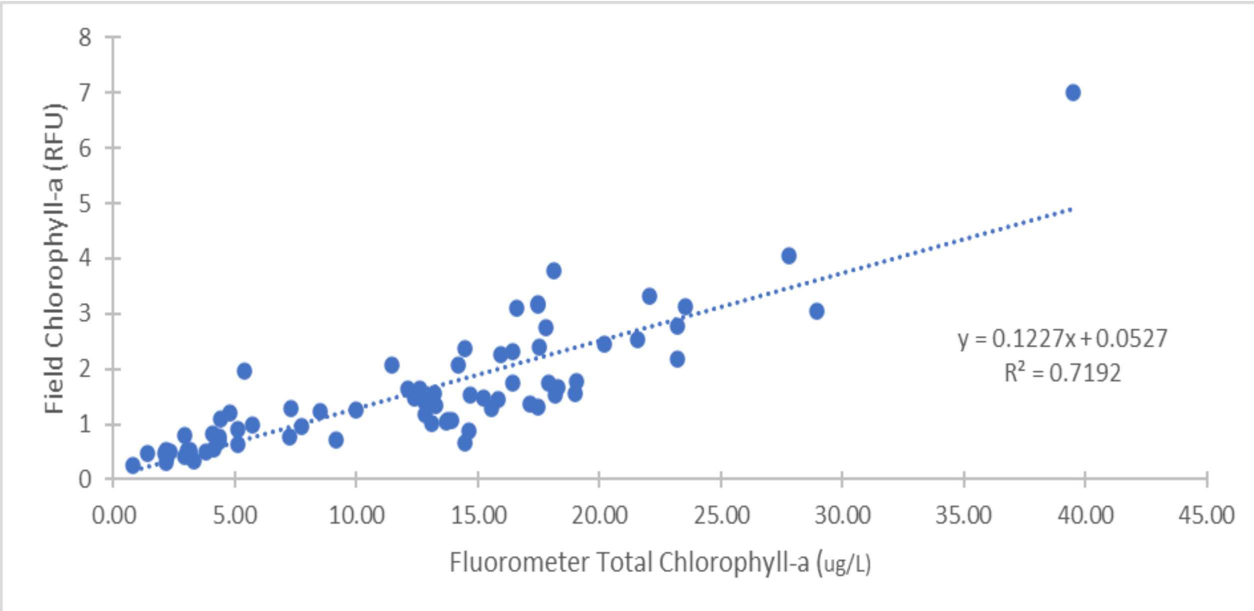


Figure 15. Relationship between laboratory fluorometer total chlorophyll-a (µg/L) and corresponding surface water chlorophyll-a fluorescence (RFU).

Cyanotoxins

Concentrations of microcystins were generally low at all sites and below the United States Environmental Protection Agency recreational health advisory value and SCDES recreational standard of 8 µg/L.[1,2] For more information related to cyanotoxin distributions within South Carolina waters, refer to DES Bureau of Water Technical Report No. 001-2025.[3]

Table 8. Surface (0.3 m) microcystins summary statistics for each lake site. Average is presented as ± 1σ. Dashes (-) indicate a concentration below analytical detection limit (0.016 µg/L). Values below detection limit are assumed ½ detection limit (0.008 µg/L) for the site average. All total concentrations in µg/L.

Site	Avg. Microcystins	Minimum	Maximum	n
B-346	0.073 ± 0.065	-	0.205	11
B-889	0.048 ± 0.044	-	0.118	7
B-890	0.109 ± 0.134	-	0.330	7
B-327	0.133 ± 0.092	-	0.294	12
RL-04370	0.191 ± 0.147	-	0.437	8

[1] 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.

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

[3] South Carolina Department of Health and Environmental Control. 2023. 2023 South Carolina Cyanotoxin Distribution Project. Bureau of Water Technical Report No. 001-2025. June 2025.

Water Quality - Nutrients

The following discussion summarizes grab sample 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). This section also includes subsurface grab samples from site B-890. Regulatory assessment of these parameters occurs only for surface samples. 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.

Total phosphorus and total nitrogen concentrations were on average highest In Parr Reservoir at stations B-346 and B-889 (Tables 9 and 10, Figures 17 and 18). Nutrient concentrations In Monticello Reservoir were relatively stable (0.04 ± 0.01mg/L) with lower average total phosphorus compared to Parr. There were two exceedances of the ecoregional TP water quality standard (0.06 mg/L) in Monticello Reservoir over the study: stations B-327 and B-890 on 5/29/2024. At B-890, subsurface TP and TN concentrations were generally higher than surface values. There were no exceedances of the 1.5 mg/L ecoregional standard for total nitrogen in either reservoir (Figure 18). Total phosphorus concentrations in Parr Reservoir were higher than observed in Monticello Reservoir, with all samples at B-889 and 85% of B-346 samples (11 of 13) exceeding the ecoregional water quality standard (Table 9, Figure 17). TOC concentrations were largely similar site-by-site in both reservoirs with average and median values of ~2-3 mg/L (Table 11).

*Table 9. Total phosphorus summary statistics for all sites and depths. '*B-890 Bottom*' sample depths* were ~27 *m depending on* wind/surface current*. All units in mg/L.* ***Bolded*** *values exceed the ecoregional water quality standard for Total Phosphorus (0.06 mg/L)*

Site	Avg Total Phosphorus	Min	Max	n
B-346	**0.09 ± 0.04**	0.05	**0.16**	13
B-889	**0.09 ± 0.02**	**0.06**	**0.13**	13
B-890 Surface	0.04 ± 0.01	0.03	**0.06**	16
B-890 Bottom	0.04 ± 0.01	0.03	**0.06**	16
B-327	0.04 ± 0.01	0.03	**0.06**	16
RL-04370	0.04 ± 0.01	0.03	0.05	16

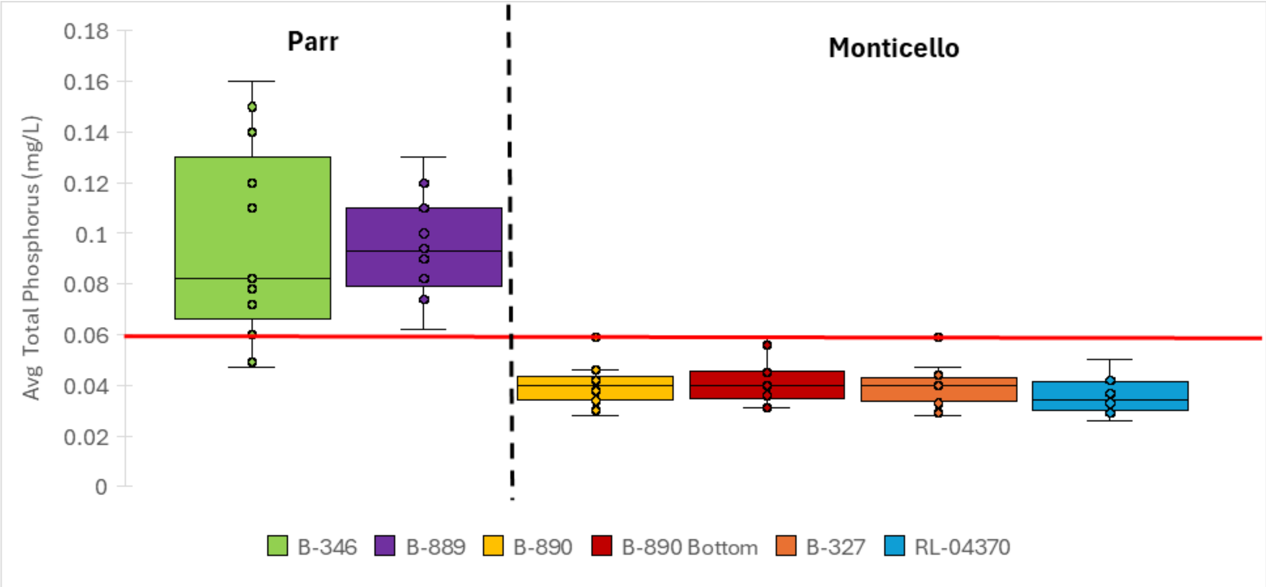


Figure 16. Box plot summary of total phosphorus concentrations (mg/L) measured at each lake site. 'B-890 Bottom' sample depths were ~27 m depending on wind/surface current. Box plots include median, first (lower) and third (upper) quartiles, and ranges (minimum and maximum) for the data. The red line denotes the 0.06 mg/L lake ecoregional total phosphorus standard.

Table 10. Total Nitrogen summary statistics for all sites and depths. 'B-890 Bottom' sample depths were ~27 m depending on wind/surface current. For concentrations below the analytical detection limit (0.1 mg/L for TKN and 0.02 mg/L for nitrate/nitrite), a value of one-half the detection limit was substituted (0.05 mg/L for TKN and 0.01 mg/L for nitrate-nitrite). All units in mg/L.

Site	Avg Total Nitrogen	Min	Max	n
B-346	0.71 ± 0.28	0.45	1.23	13
B-889	0.61 ± 0.26	0.31	0.98	13
B-890 Surface	0.41 ± 0.12	0.17	0.68	16
B-890 Bottom	0.53 ± 0.13	0.36	0.86	16
B-327	0.40 ± 0.14	0.19	0.67	16
RL-04370	0.38 ± 0.10	0.27	0.57	16

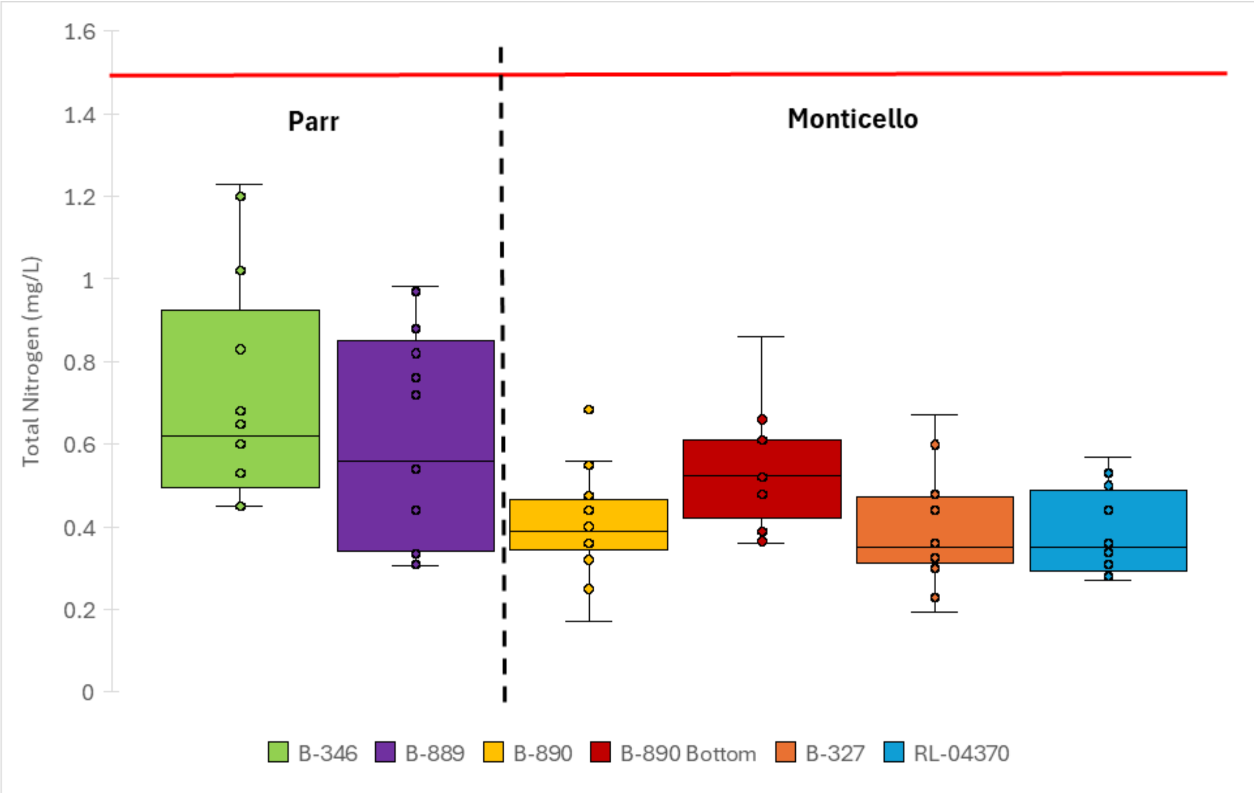


Figure 17. Box plot summary of total nitrogen concentrations (mg/L) measured at each lake site. Total nitrogen is reported as the sum of Total Kjeldahl Nitrogen and nitrate-nitrite. 'B-890 Bottom' sample depths were ~27 *m depending on* wind/surface current. *For concentrations below the analytical detection limit (0.1 mg/L for TKN and 0.02 mg/L for nitrate/nitrite), a value of* one-half *the detection limit was substituted (0.05 mg/L for TKN and 0.01 mg/L for nitrate-nitrite). Box plots include median, first (lower) and third (upper) quartiles, and ranges (minimum and maximum) for the data. The red line denotes the 1.5 mg/L lake ecoregional total nitrogen standard.*

Table 11. Total Organic Carbon *summary statistics for all sites and depths.* Total *organic carbon concentrations (mg/L) measured at* each site. *'*B-890 Bottom*' sample depths* were ~27 *m depending on* wind/surface current.

Site	Avg Total Organic Carbon	Min	Max	Median	n
B-346	2.4 ± 0.8	1.6	4.2	2.2	13
B-889	3.0 ± 1.0	1.9	5.3	2.8	13
B-890 Surface	2.7 ± 0.3	2.3	3.1	2.7	16
B-890 Bottom	2.4 ± 0.2	2.2	3.0	2.3	16
B-327	2.8 ± 0.3	2.3	3.3	2.8	16
RL-04370	2.8 ± 0.3	2.4	3.4	2.8	16

Additional Sampling

The following discussion summarizes grab sample results from sampling conducted on Parr Reservoir by the BOW project staff and Regional staff for total phosphorus, total nitrogen, and chlorophyll-*a*. Station B-327 in Monticello Reservoir and Parr Reservoir stations B-345 (forebay) and RL-16031 (Cannons Creek lake arm) we concurrently sampled in 2024 as part of the SCDES's Ambient Surface Water Monitoring Program. These data provided valuable insights into longitudinal variances on Parr and potential influences of a wastewater discharge on lake arm nutrient dynamics.

Parr Longitudinal Pattern

Average chlorophyll-*a* concentrations were higher at downstream station B-345 (8.51 ± 6.5 µg/L, n = 4) compared to upstream B-346 (3.0 ± 1.7 µg/L, n = 17) (Figure 18). Total phosphorus concentrations were on average higher at station B-346 (0.09 ± 0.04 mg/L, n = 13) compared to B-345 (0.06 ± 0.02 mg/L, n = 9) (Figure 19). Average total nitrogen concentrations were similar between the stations, however in July and August upstream station B-346 concentrations were higher than downstream (B-345) (Figure 20). Taken together, the upstream area of Parr Reservoir is characterized by higher nutrient concentrations and lower chlorophyll-a while the forebay area demonstrated lower nutrient concentrations but high chlorophyll-a.

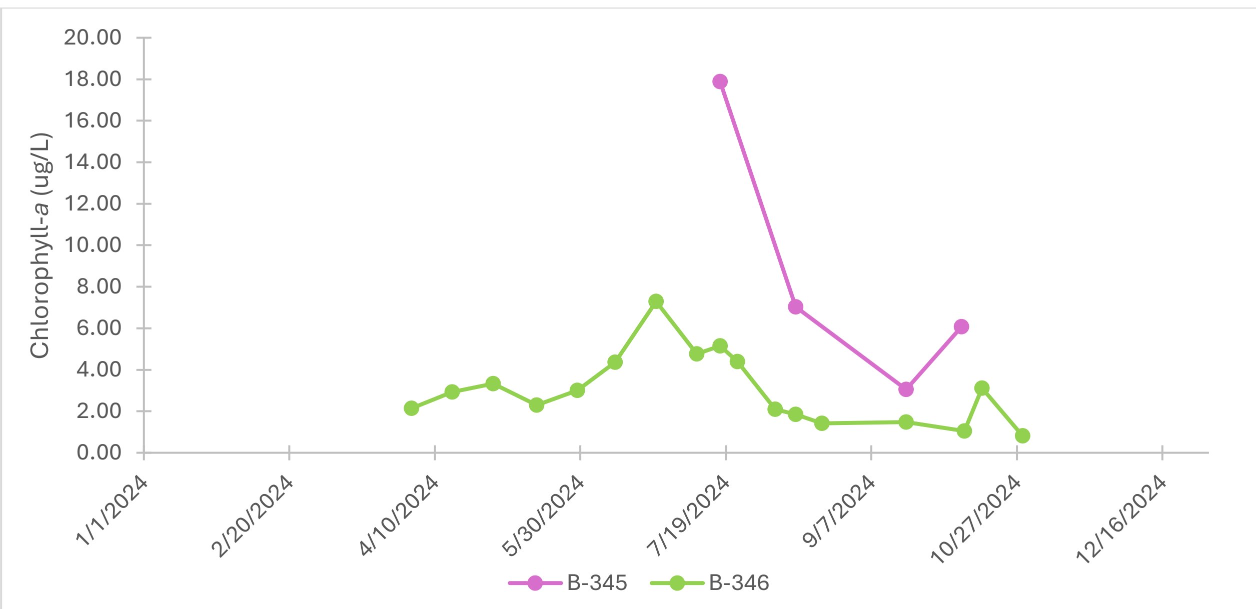


Figure 18. Total chlorophyll-a measurements (µg/L) at the lake stations. All values are surface samples (0.3 m).

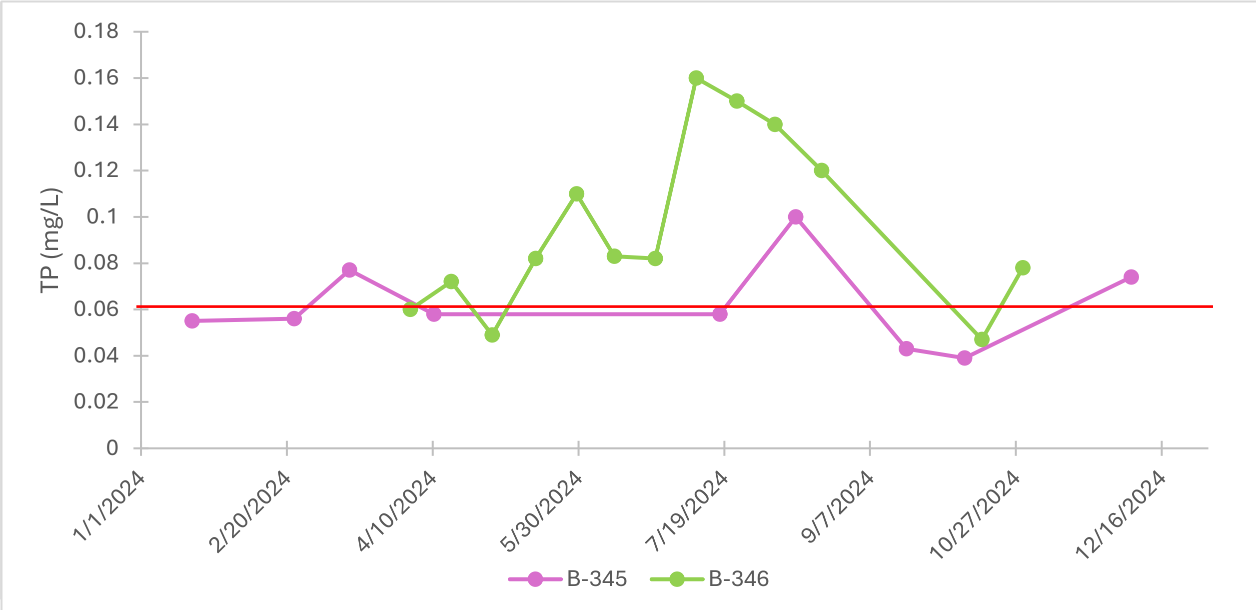


Figure 19. Total phosphorus concentrations (mg/L) measured at sites. The red line denotes the 0.06 mg/L lake ecoregional total phosphorus standard.

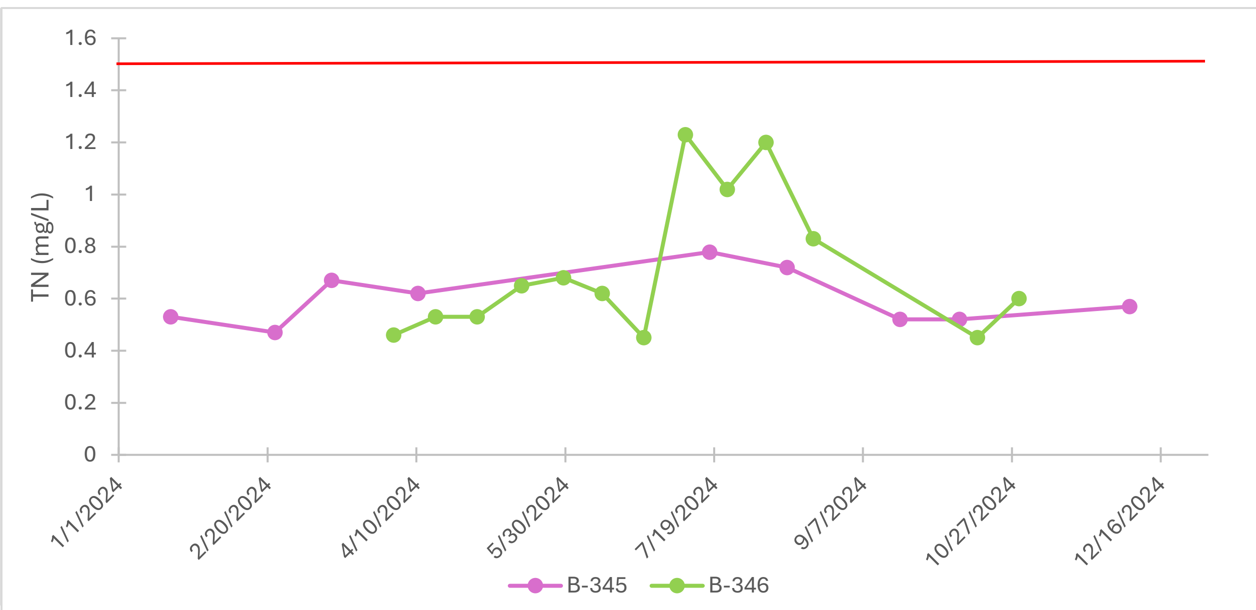


Figure 20. Box plot summary of total nitrogen concentrations (mg/L). Total nitrogen is reported as the sum of Total Kjeldahl Nitrogen and nitrate-nitrite. For concentrations below the analytical detection limit (0.1 mg/L for TKN and 0.02 mg/L for nitrate/nitrite), a value of one-half *the detection limit was substituted (0.05 mg/L for TKN and 0.01 mg/L for nitrate-nitrite). The red line denotes the 1.5 mg/L lake ecoregional total nitrogen standard.*

Lake Arm Discharge Comparison

Two lake arms are located on the west side of Parr Reservoir: Hellers Creek (station B-889) and Cannons Creek (station RL-16031). A 0.95 MGD maximum design flow wastewater treatment facility (WWTF) is located upstream on Cannons Creek. Hellers Creek does not have a WWTF facility which allows for the investigation of the potential impact of the WWTF on Parr Reservoir and its lake arms. Over the course of the study average TP, TN, and chlorophyll-*a* did varied little between the lake arms (Table 12).

Table 12. Average Total phosphorus concentrations (mg/L), Total nitrogen concentrations (mg/L), and Chlorophyll-a (µg/L) summary statistics for sites B-889 and RL-16031.

Site	Total Phosphorus	Total Nitrogen	Chlorophyll-a
B-889	0.09 ± 0.02	0.61 ± 0.26	20.50 ± 8.81
RL-16031	0.08 ± 0.02	0.54 ± 0.18	21.23 ± 6.10

Monthly sampling results show very similar trends over the course of the study. Hellers Creek lake arm had at times slightly higher TN and TP concentrations than RL-16031 (Appendix C). These results illustrate that the wastewater facility's discharge did not greatly elevate nutrient concentrations in the Cannons Creek lake arm.

B-327 BOW & Regional Sampling Comparison

Regional ambient monitoring sampling at sample site B-327 was not conducted on concurrent days as lake project sampling; direct comparison of monthly data can't be made but general trends are evaluated. Average TP, TN, and chlorophyll-*a* results were similar between BOW and regional ambient sampling over the course of the study (Table 13).

Table 13. Average Total phosphorus concentrations (mg/L), Total nitrogen concentrations (mg/L), and Chlorophyll-a (µg/L) summary statistics for site B-327 samples by BOW and Regional staff.

Sampler	Total Phosphorus	Total Nitrogen	Chlorophyll-a
BOW	0.04 ± 0.01	0.40 ± 0.14	12.70 ± 5.59
Region	0.04 ± 0.01	0.48 ± 0.17	16.56 ± 8.43

Conclusion

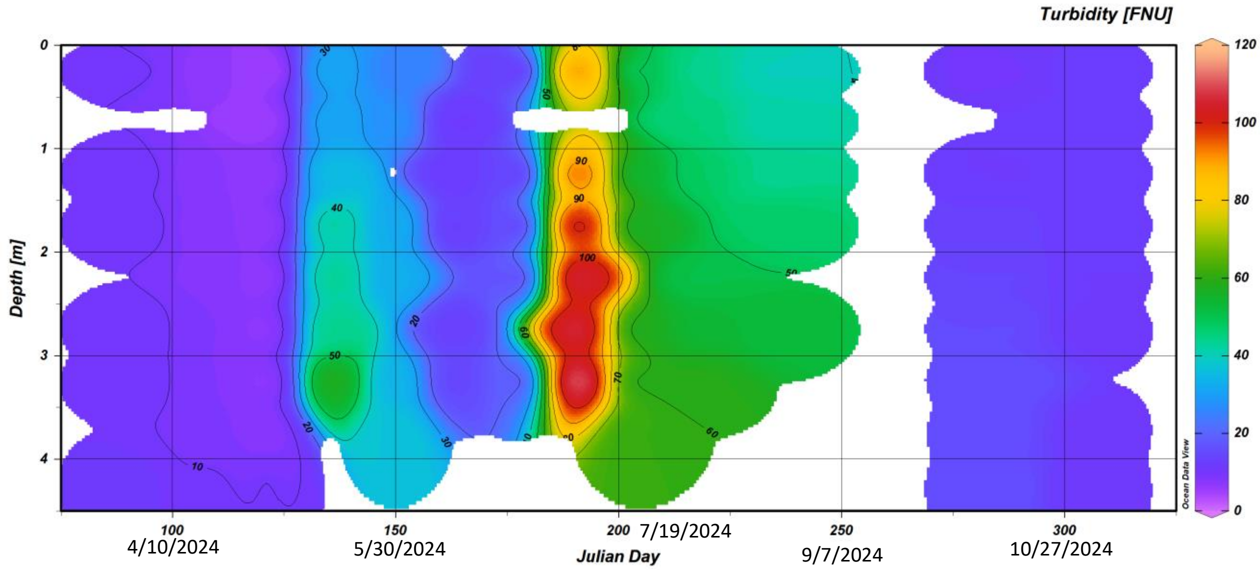
The results of this project revealed important features in the vertical structure of the water column in the Parr and Monticello reservoirs. Response parameters such as dissolved oxygen and pH may be influenced by both phytoplankton growth and physical conditions. Key differences were observed between Parr and Monticello reservoirs. Nutrients and turbidity were higher in Parr Reservoir, while DO, pH, and temperature were higher in Monticello. Parr displayed both lake-like conditions at B-889 and riverine-like conditions at B-346. The reservoirs also demonstrated different diel cycles for temperature, DO and turbidity with minimum and maximum values occurring at differing hours. The aggregated results of this study and accompanying watershed nutrient loading studies will provide a robust data set to develop, calibrate, and validate coupled watershed loading and lake water quality models to inform TMDLs for this area of the Broad River at Parr Reservoir and Monticello Reservoir.

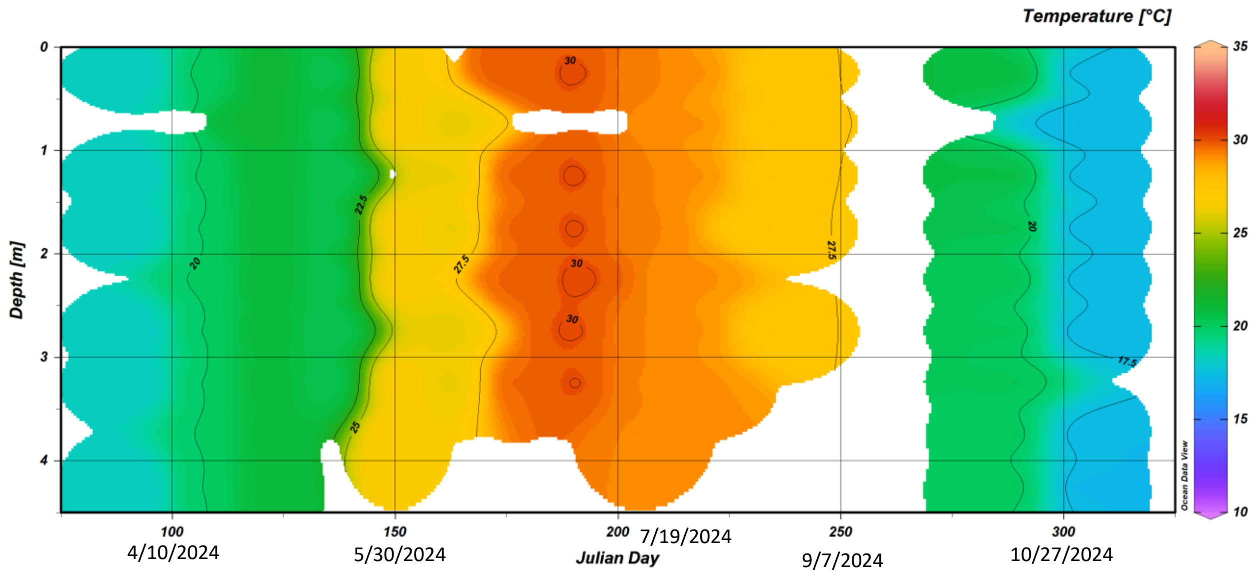
Acknowledgments

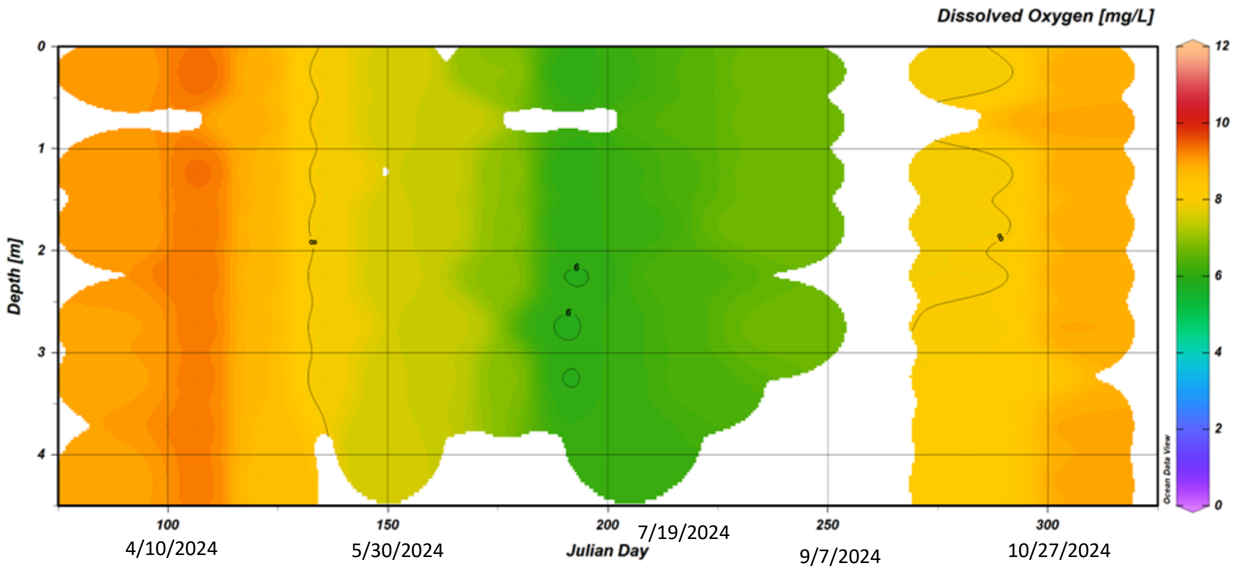
This project was made possible through support from SCDES Bureau of Water (BOW) TMDL section and Aquatic Science Division as well as Bureau of Regional and Laboratory Services (BRLS). The BRLS laboratory processed and analyzed water quality samples. Total chlorophyll-a and cyanotoxin samples were processed and analyzed by the Aquatic Science Division. Field sampling was conducted by personnel from the BOW TMDL and Aquatic Science Division groups.

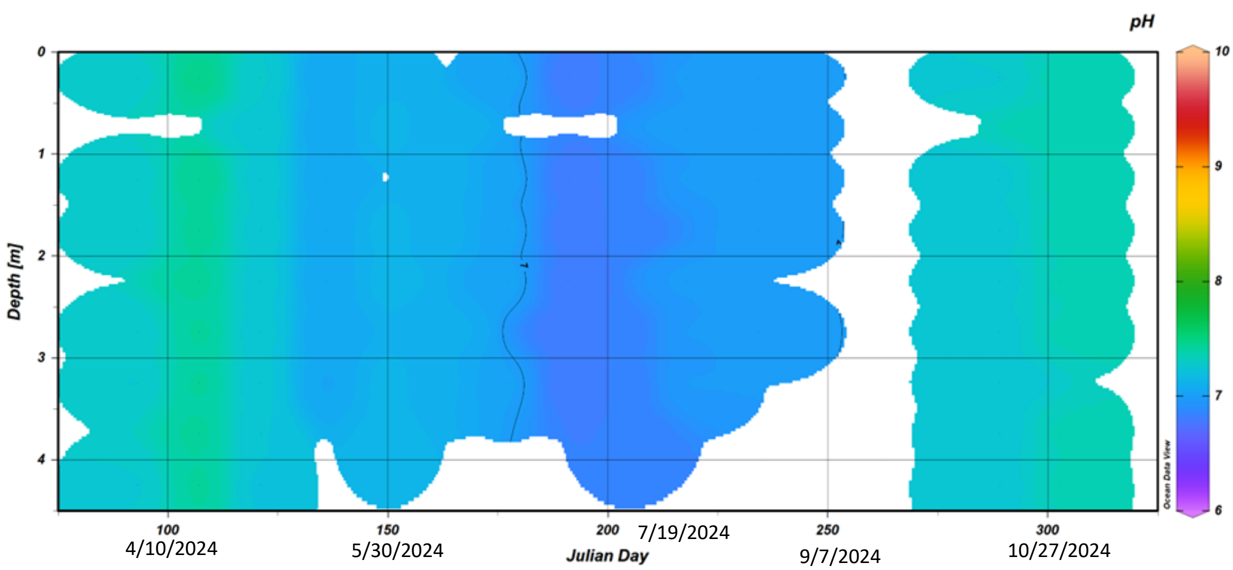
Appendix A – Vertical Profile Section Graphs

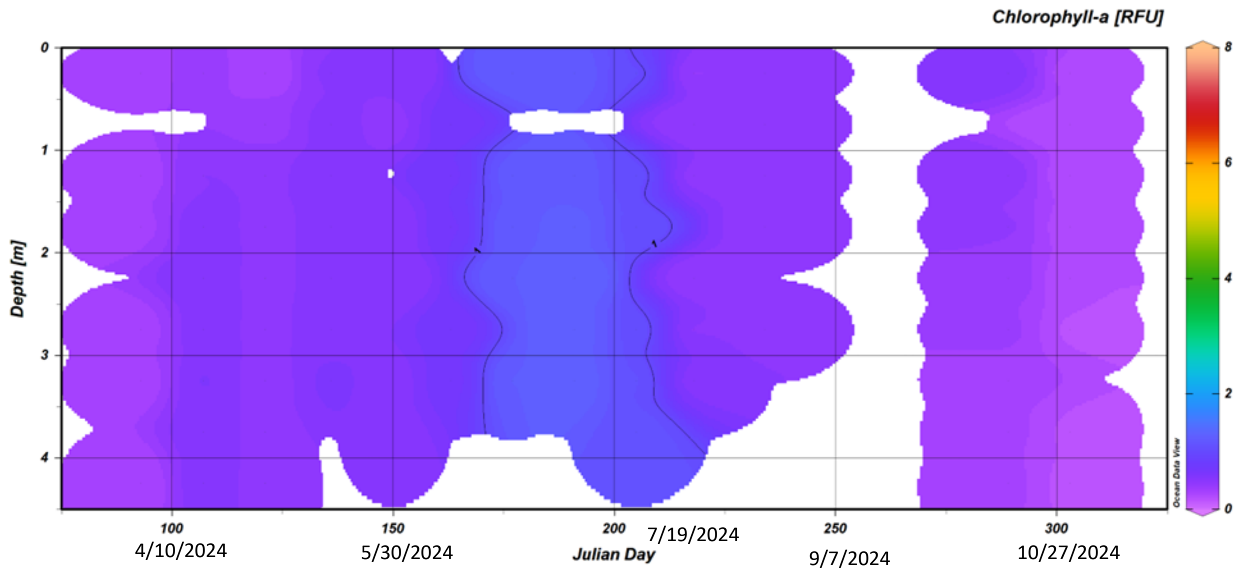
B-346 – additional section plots – average total depth = 3.7m



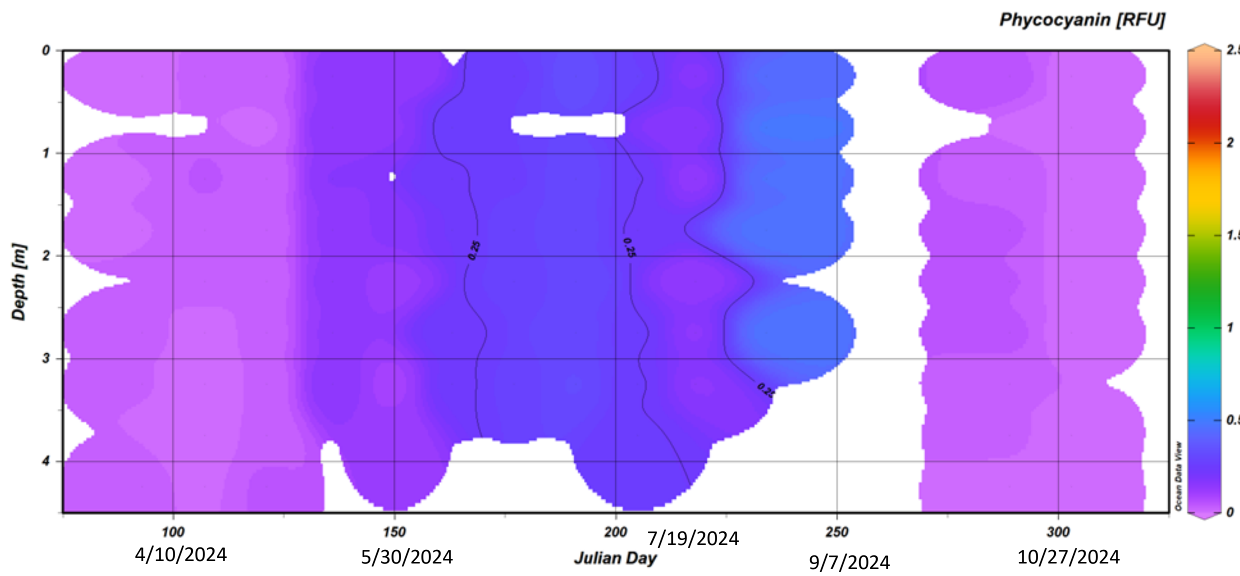



Dissolved Oxygen [mg/L]
Depth [m]
Julian Day
4/10/2024
5/30/2024
7/19/2024
9/7/2024
10/27/2024
Ocean Data View


pH
Depth [m]
Julian Day
4/10/2024
5/30/2024
7/19/2024
9/7/2024
10/27/2024
Ocean Data View

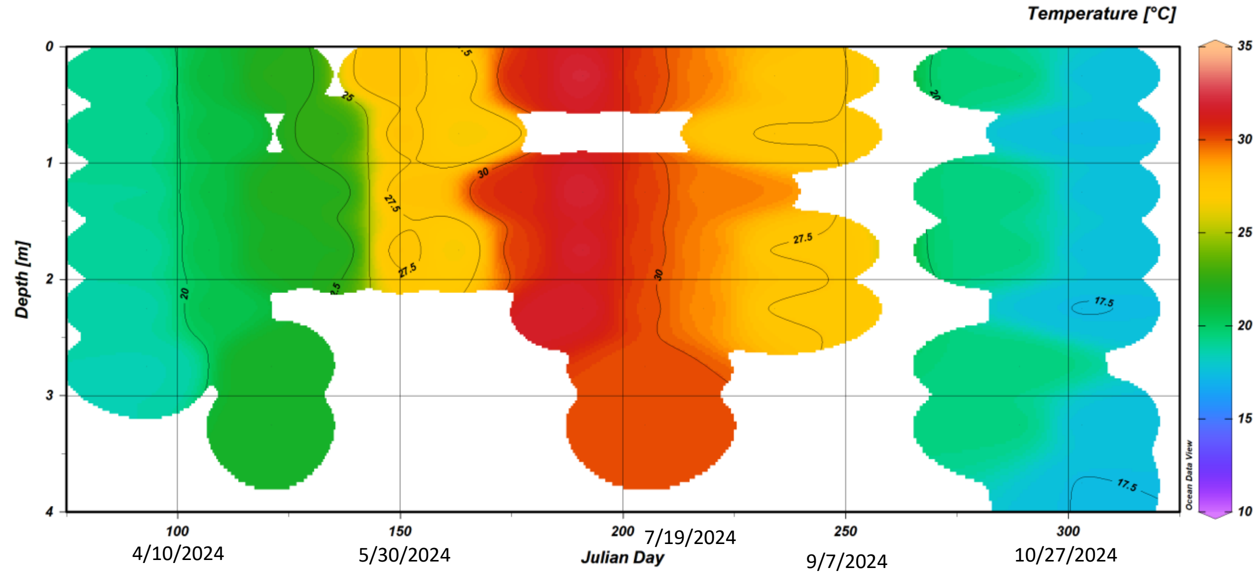


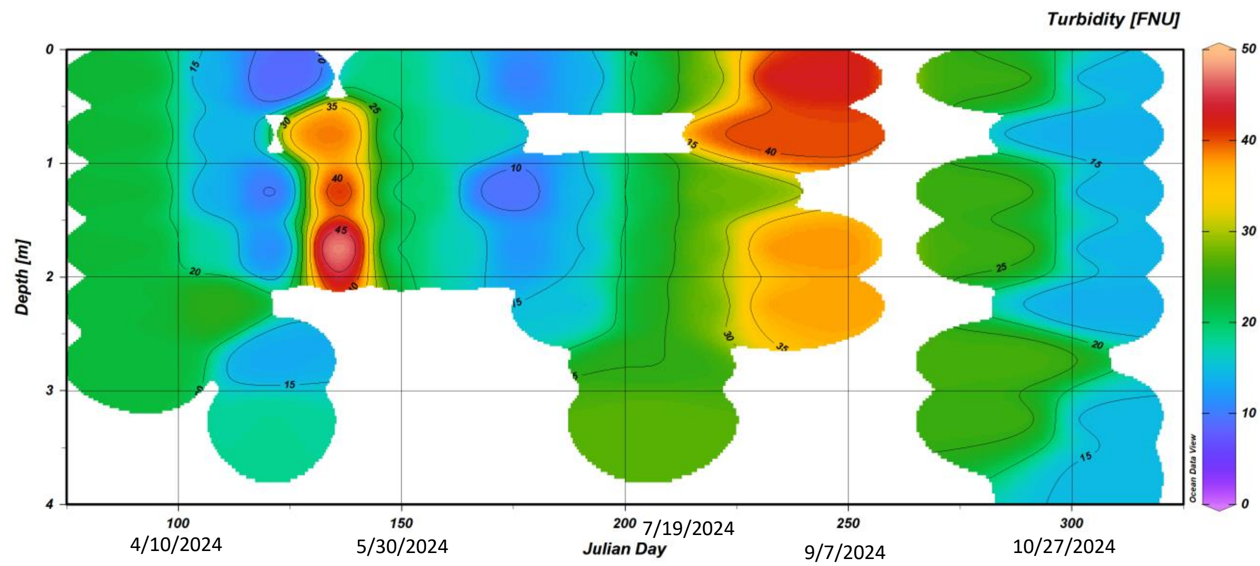
Chlorophyll-a [RFU]
Depth [m]
Julian Day
4/10/2024
5/30/2024
7/19/2024
9/7/2024
10/27/2024
Ocean Data View

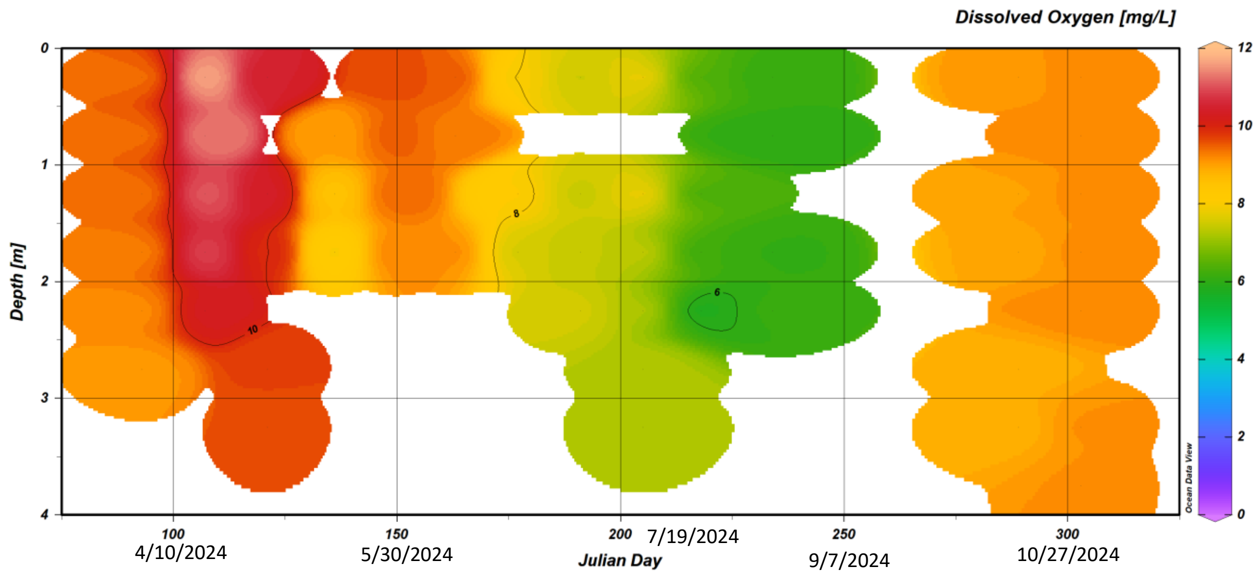


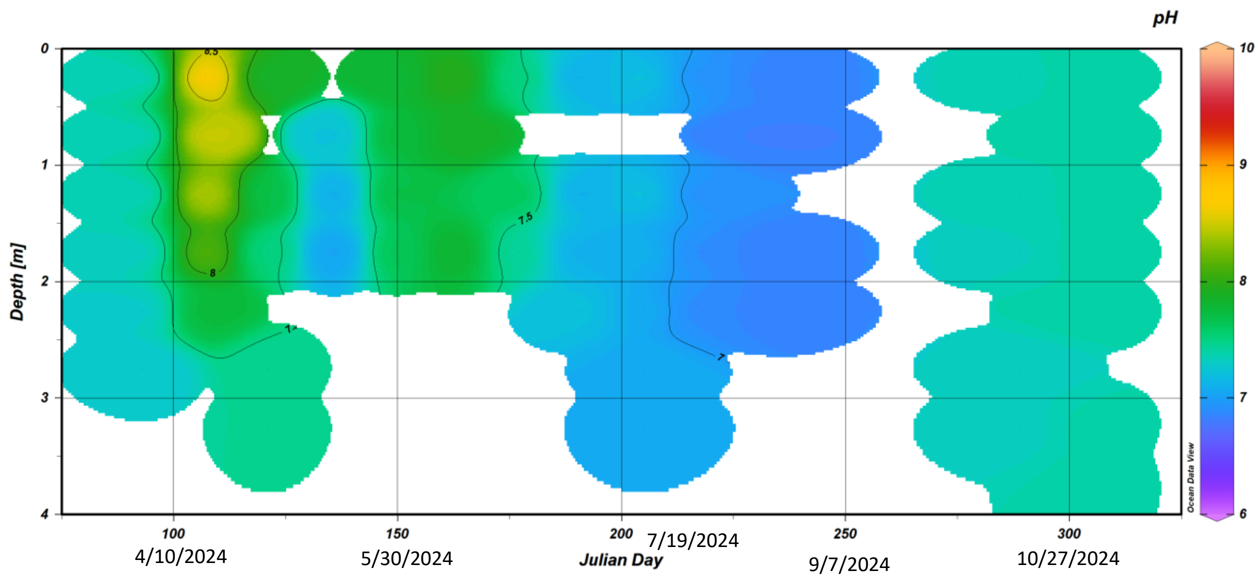
Phycocyanin [RFU]
Depth [m]
Julian Day
4/10/2024
5/30/2024
7/19/2024
9/7/2024
10/27/2024
Ocean Data View

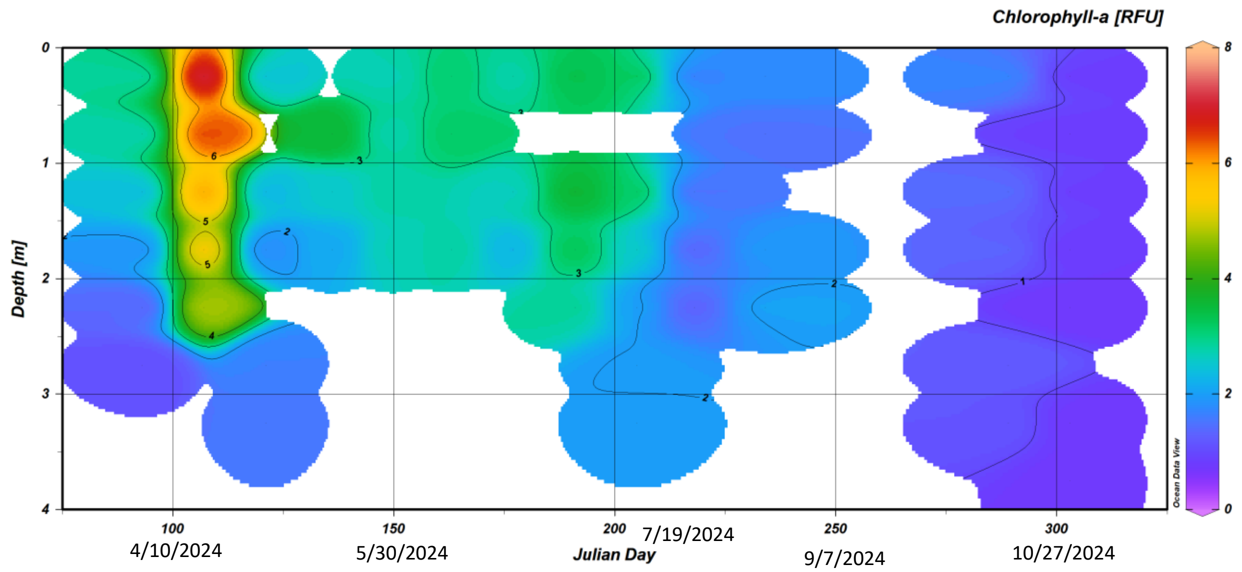
B-889 – average total depth = 2.6 m



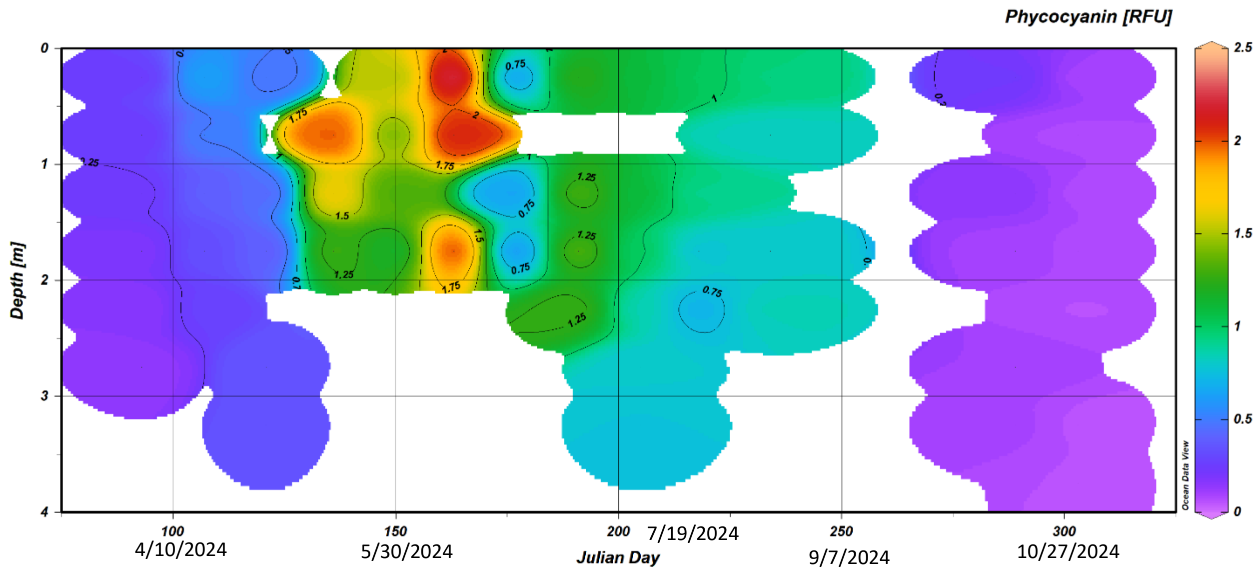



Dissolved Oxygen [mg/L]
Depth [m]
Julian Day
100
150
200
250
300
4/10/2024
5/30/2024
7/19/2024
9/7/2024
10/27/2024
Ocean Data View


pH
Depth [m]
Julian Day
100
150
200
250
300
4/10/2024
5/30/2024
7/19/2024
9/7/2024
10/27/2024
Ocean Data View

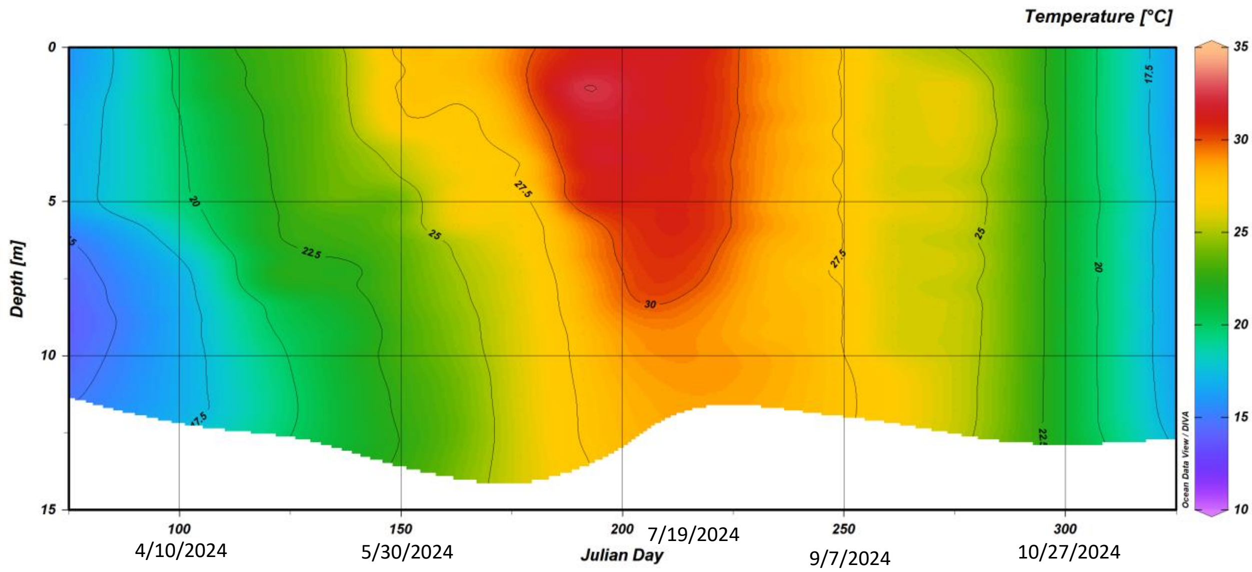


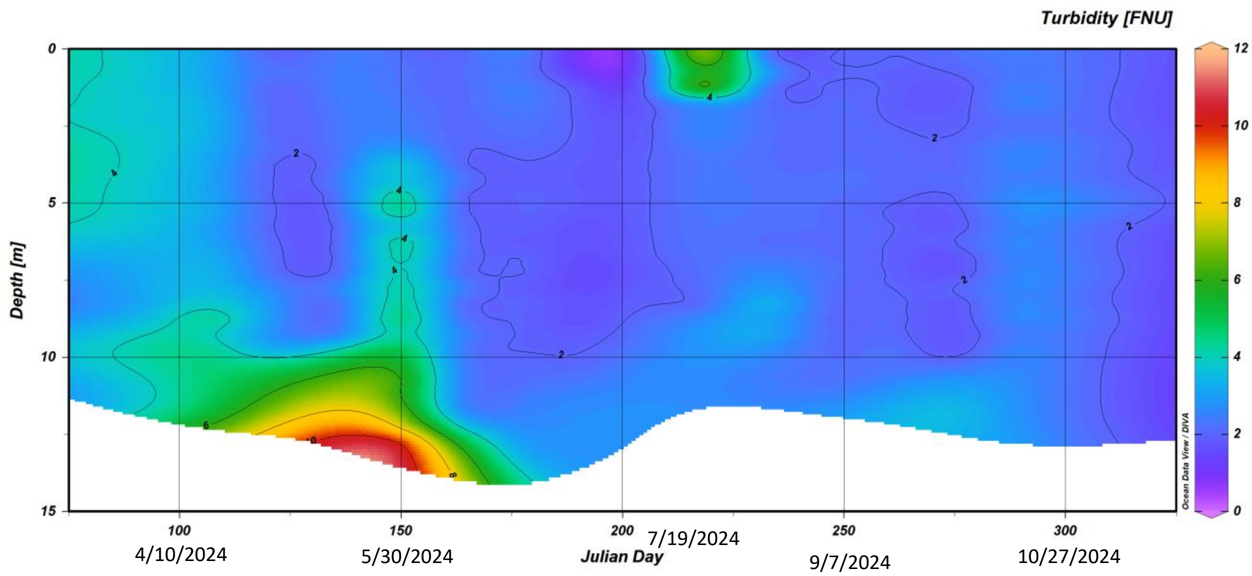
Chlorophyll-a [RFU]
Depth [m]
Julian Day
100
150
200
250
300
4/10/2024
5/30/2024
7/19/2024
9/7/2024
10/27/2024
Ocean Data View

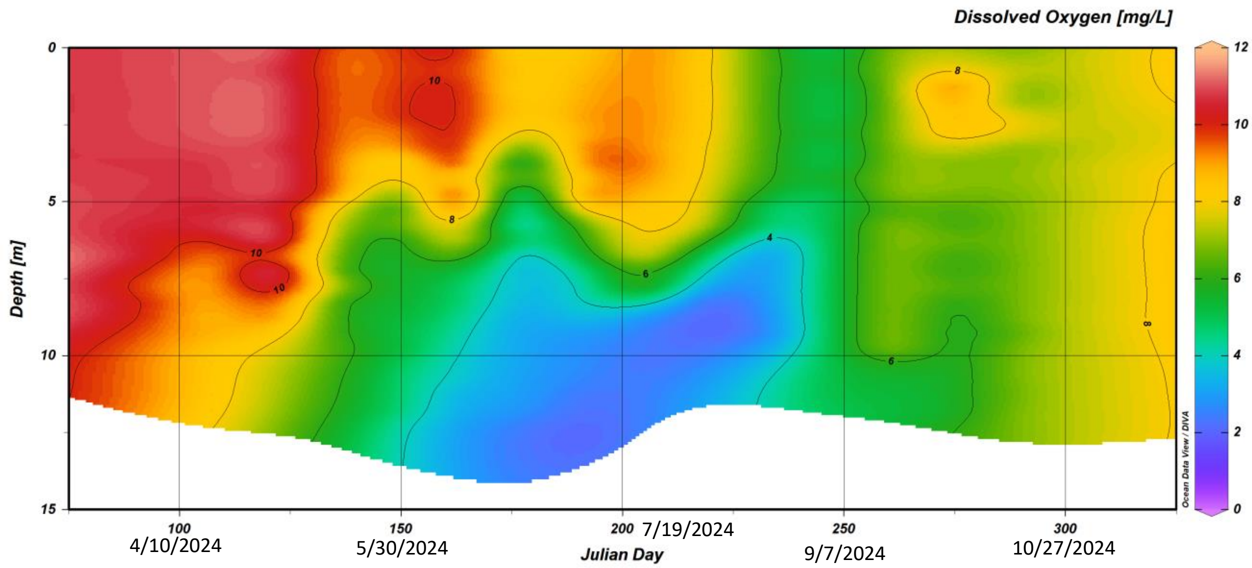


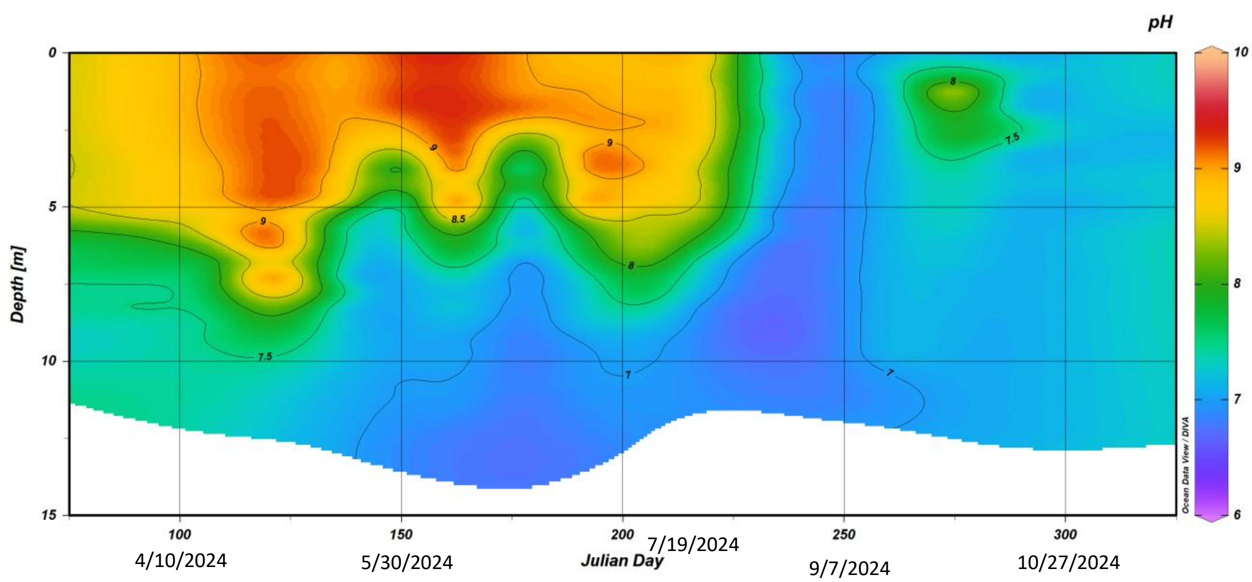
Phycocyanin [RFU]
Depth [m]
Julian Day
100
150
200
250
300
4/10/2024
5/30/2024
7/19/2024
9/7/2024
10/27/2024
Ocean Data View

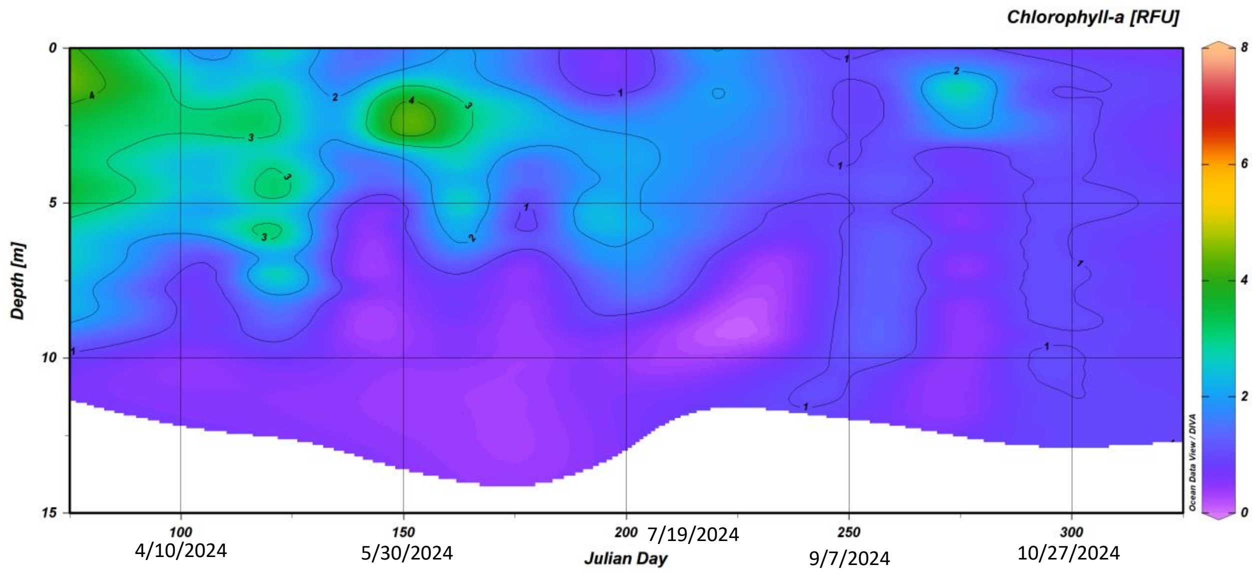
RL-04370 – average total depth = 11.3 m

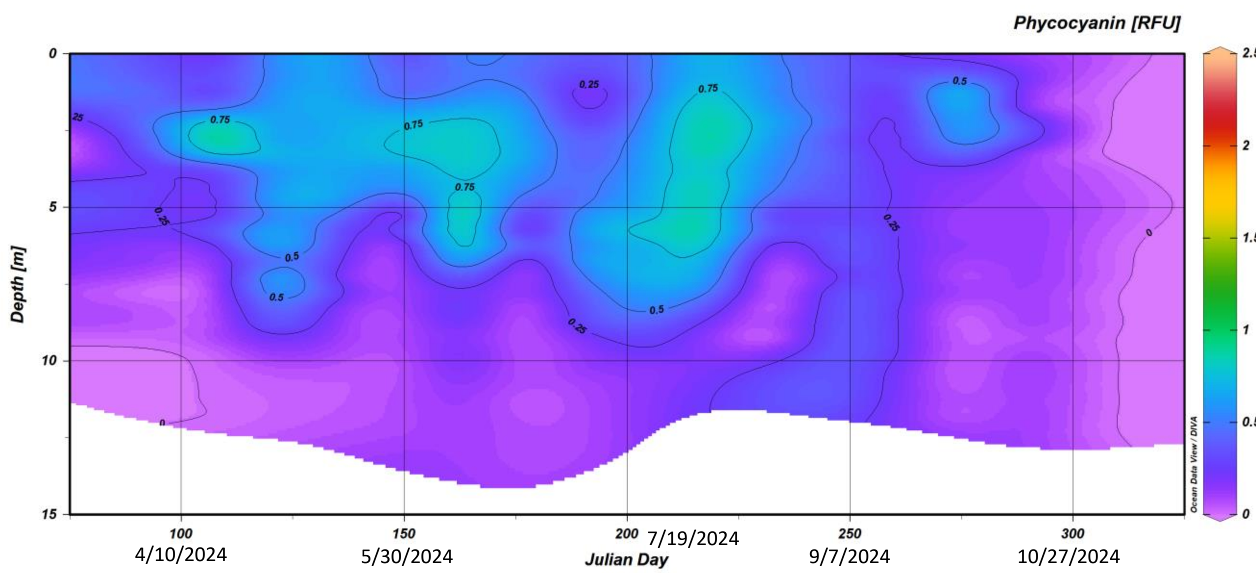




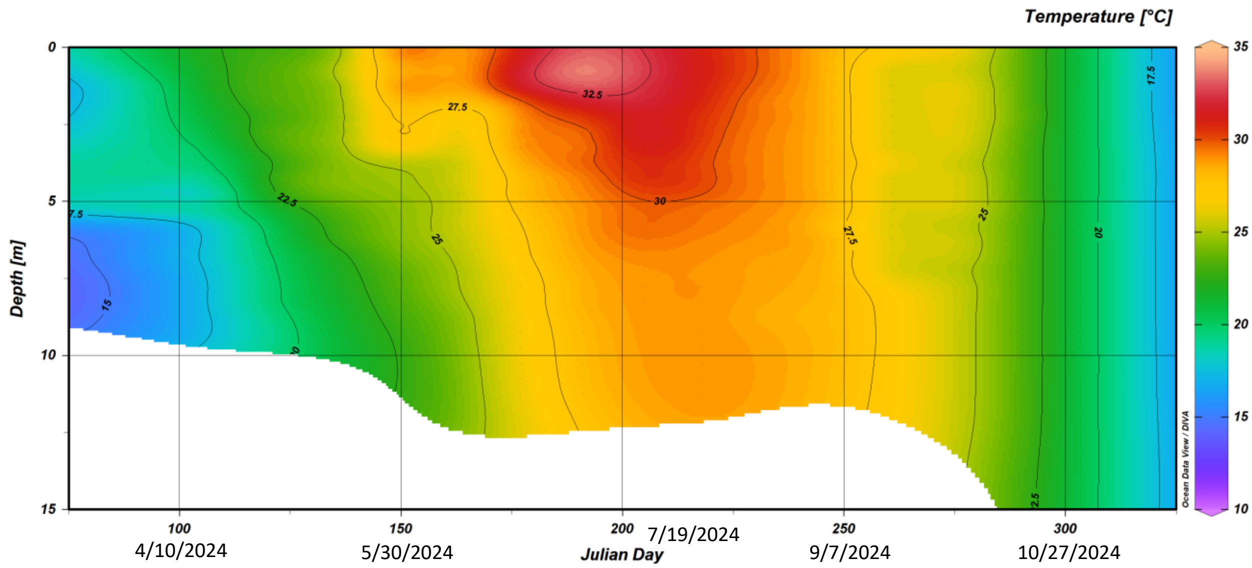

Dissolved Oxygen [mg/L]
Depth [m]
Julian Day
4/10/2024
5/30/2024
7/19/2024
9/7/2024
10/27/2024
Ocean Data View / DIVA

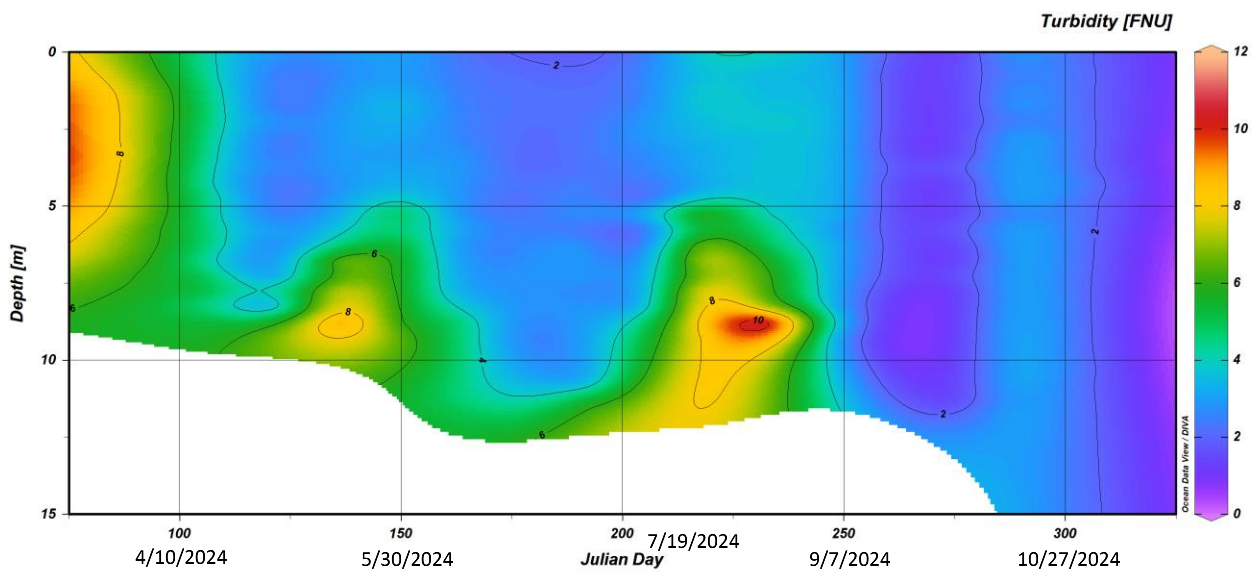

pH
Depth [m]
Julian Day
4/10/2024
5/30/2024
7/19/2024
9/7/2024
10/27/2024
Ocean Data View / DIVA

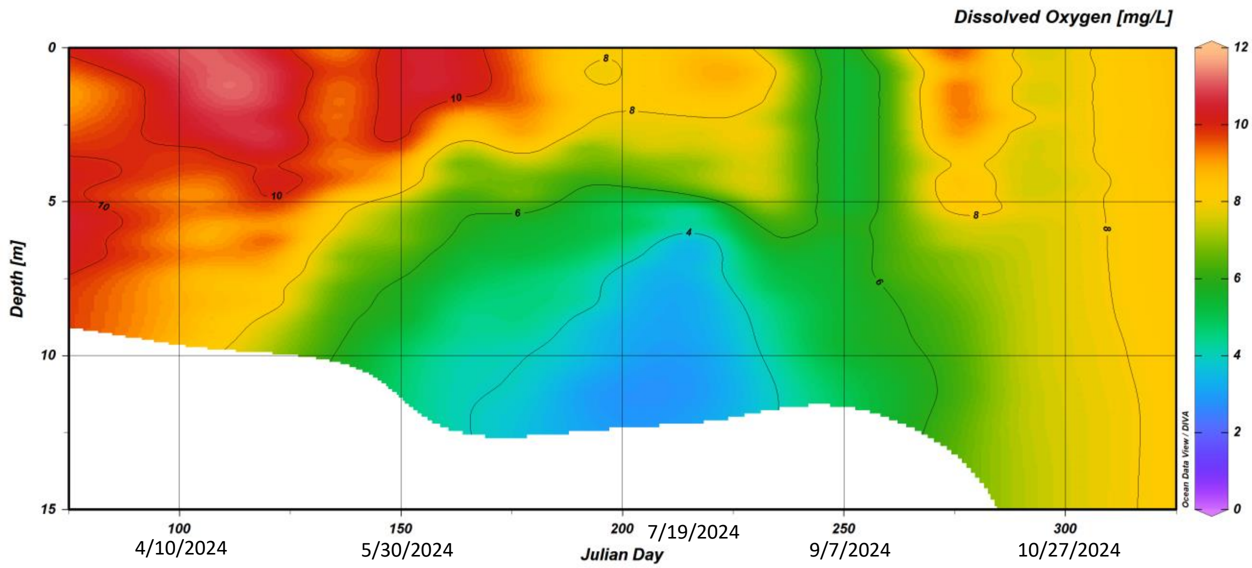

Chlorophyll-a [RFU]
Depth [m]
Julian Day
4/10/2024
5/30/2024
7/19/2024
9/7/2024
10/27/2024
Ocean Data View / DIVA

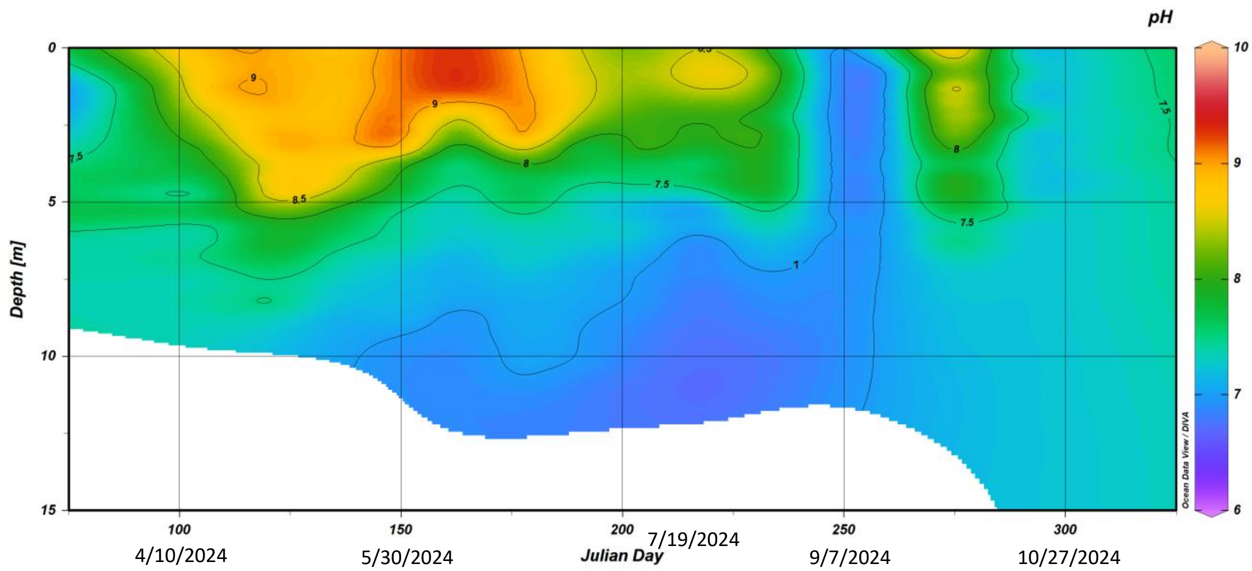

Phycocyanin [RFU]
Depth [m]
Julian Day
4/10/2024
5/30/2024
7/19/2024
9/7/2024
10/27/2024
Ocean Data View / DIVA

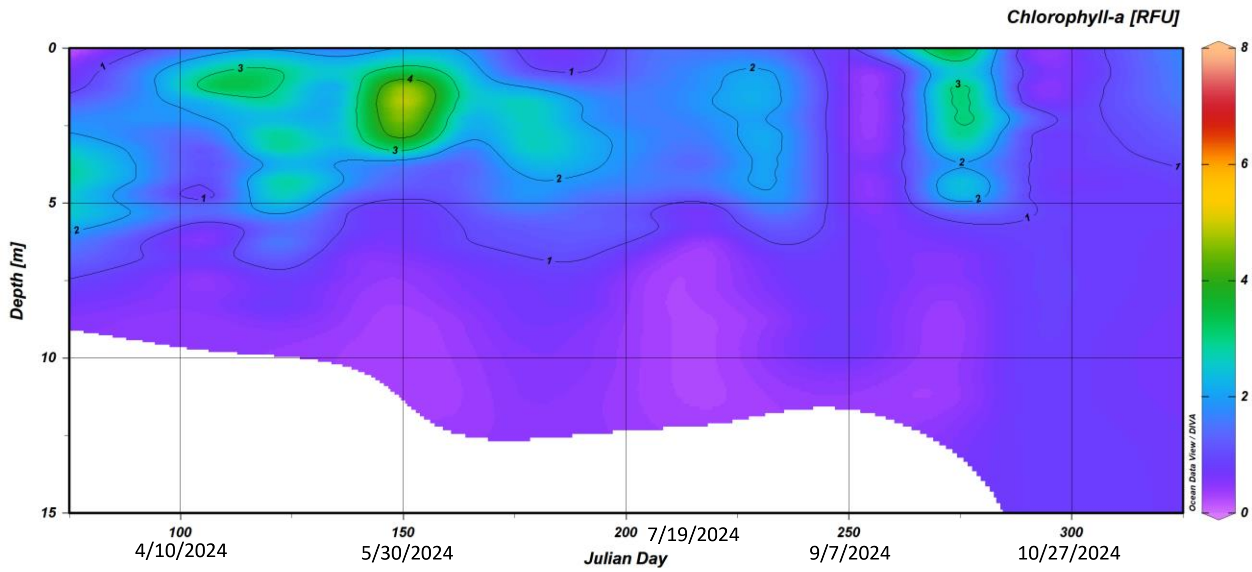
B-327 – average total depth = 10.8 m

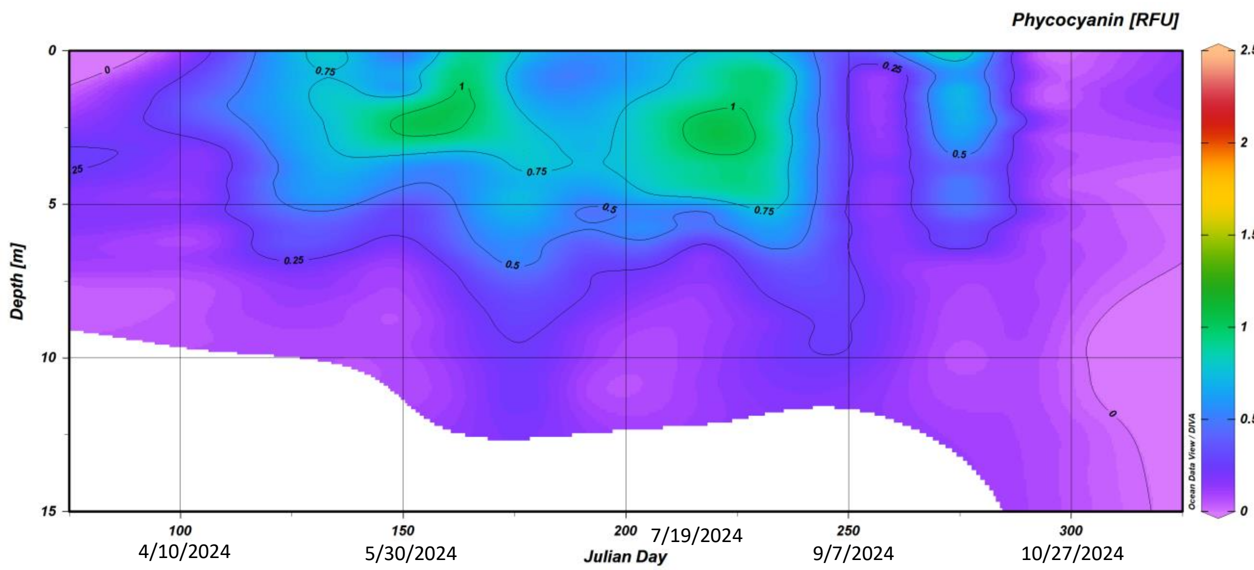




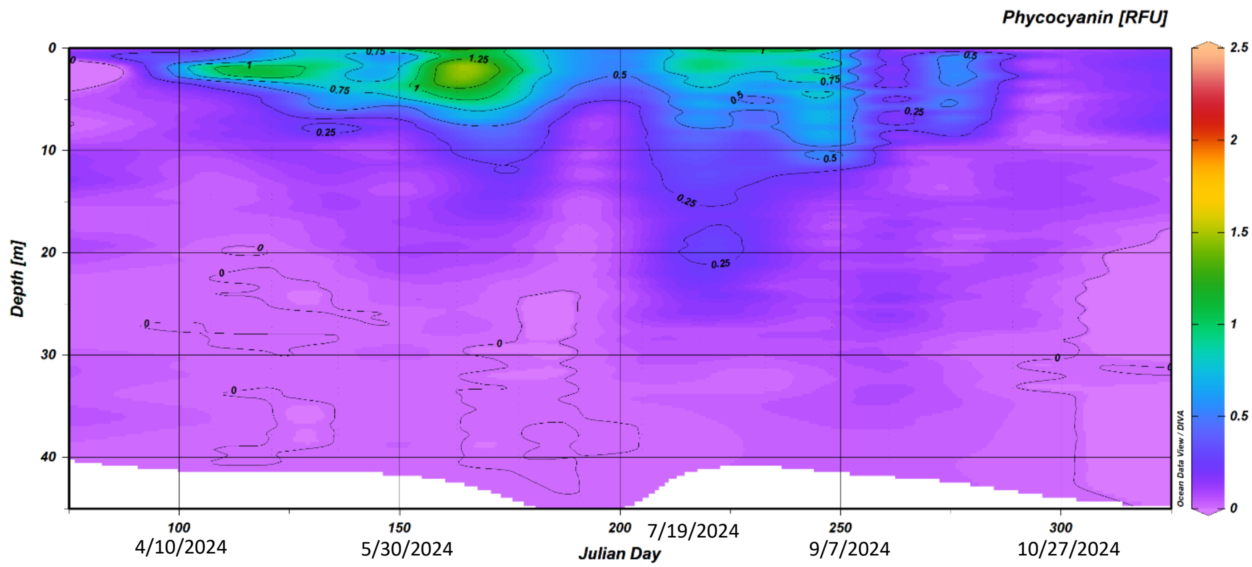

Dissolved Oxygen [mg/L]
Depth [m]
Julian Day
4/10/2024
5/30/2024
7/19/2024
9/7/2024
10/27/2024
Ocean Data View / DIVA


pH
Depth [m]
Julian Day
4/10/2024
5/30/2024
7/19/2024
9/7/2024
10/27/2024
Ocean Data View / DIVA


Chlorophyll-a [RFU]
Depth [m]
Julian Day
4/10/2024
5/30/2024
7/19/2024
9/7/2024
10/27/2024
Ocean Data View / DIVA

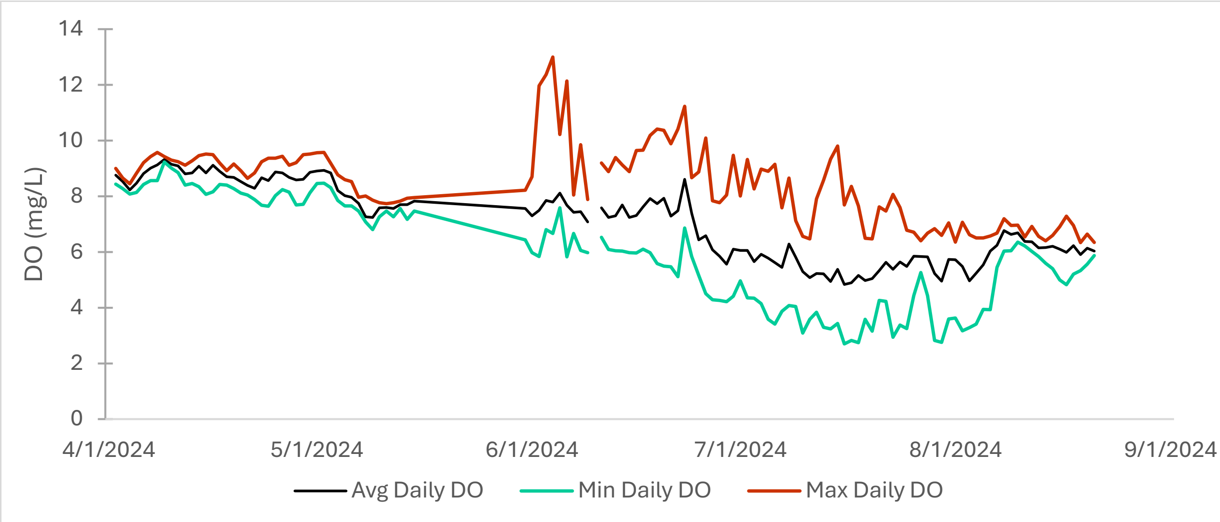

Phycocyanin [RFU]
Depth [m]
Julian Day
4/10/2024
5/30/2024
7/19/2024
9/7/2024
10/27/2024
Ocean Data View / DIVA

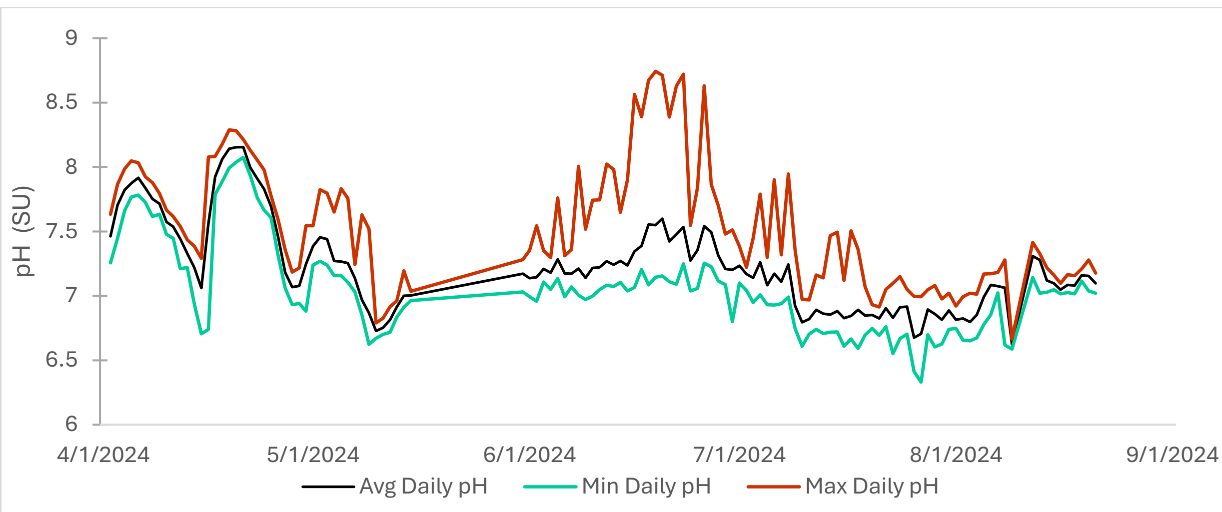
B-890 – average total depth = 40.8 m

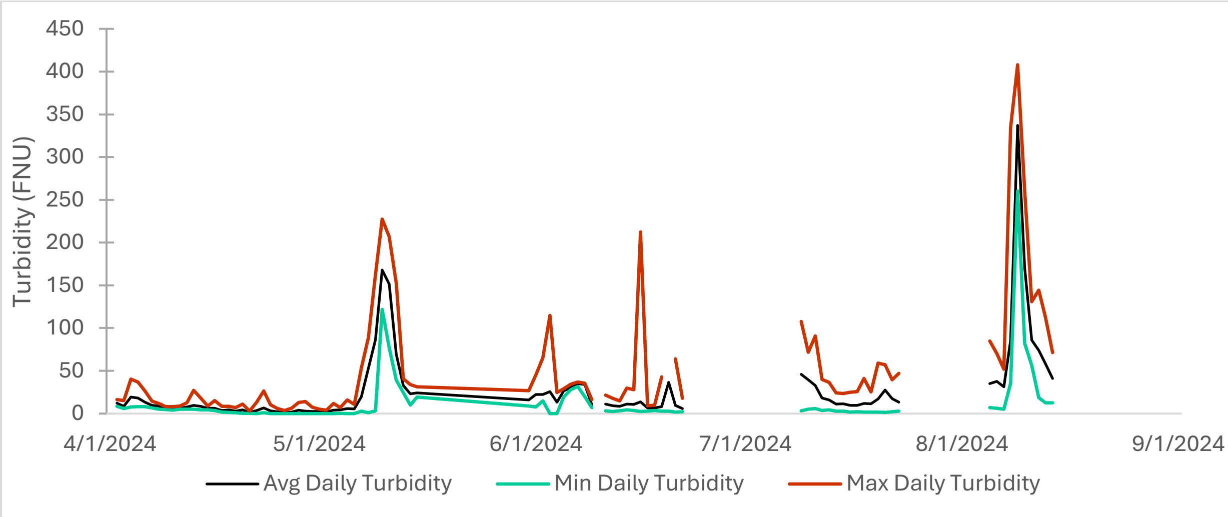


Appendix B – Surface Continuous Monitoring Time-series Plots

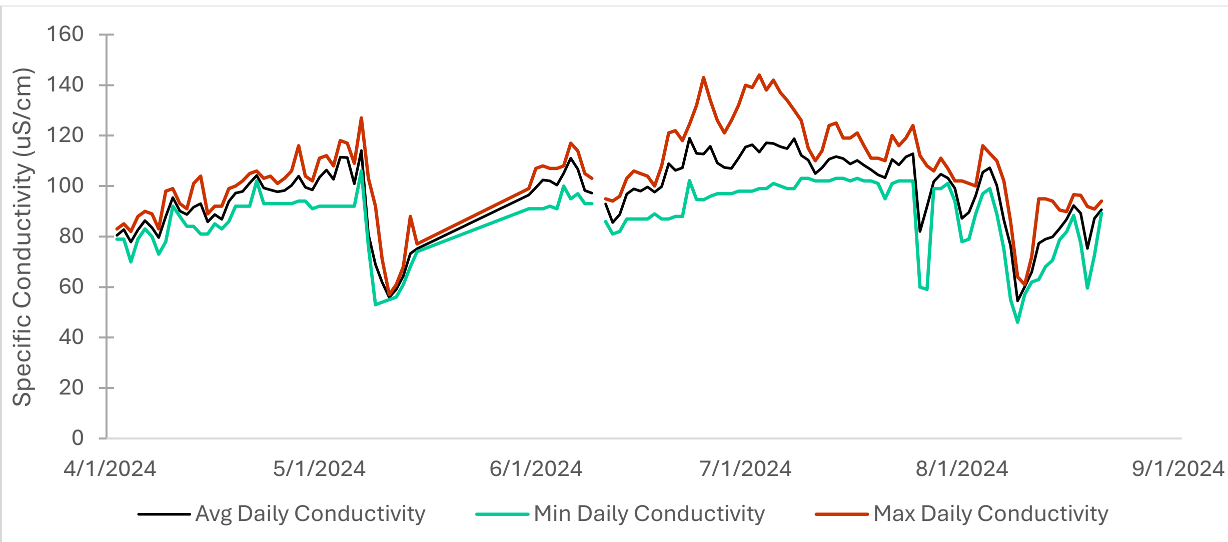
B-346 – additional continuous monitoring plots





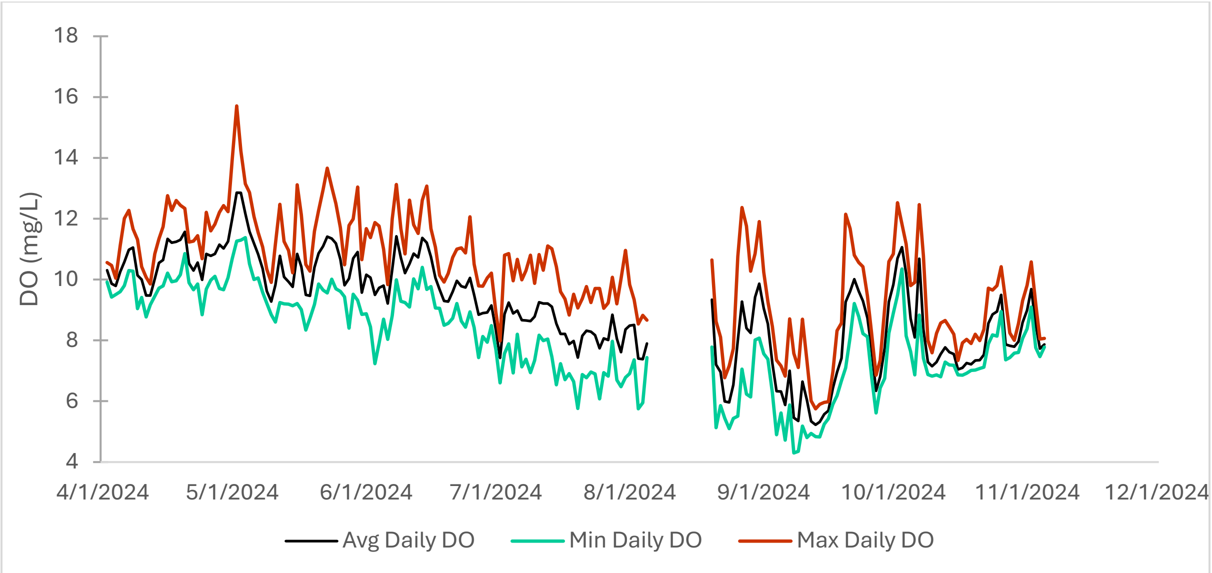


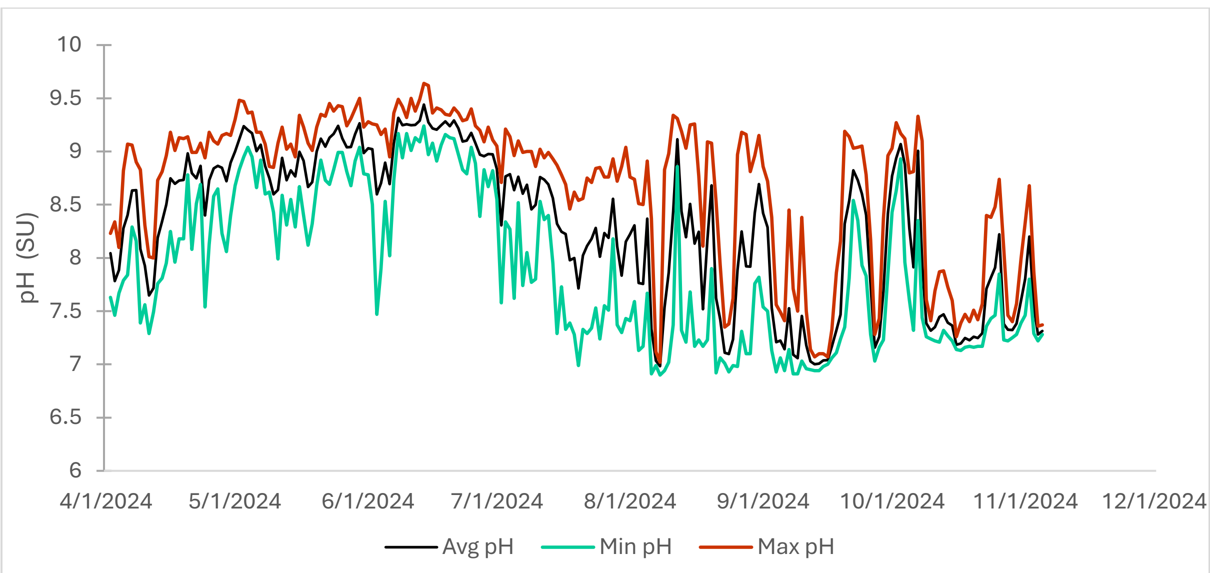
450
400
350
300
250
200
150
100
50
0
Turbidity (FNU)
4/1/2024
5/1/2024
6/1/2024
7/1/2024
8/1/2024
9/1/2024
Avg Daily Turbidity
Min Daily Turbidity
Max Daily Turbidity

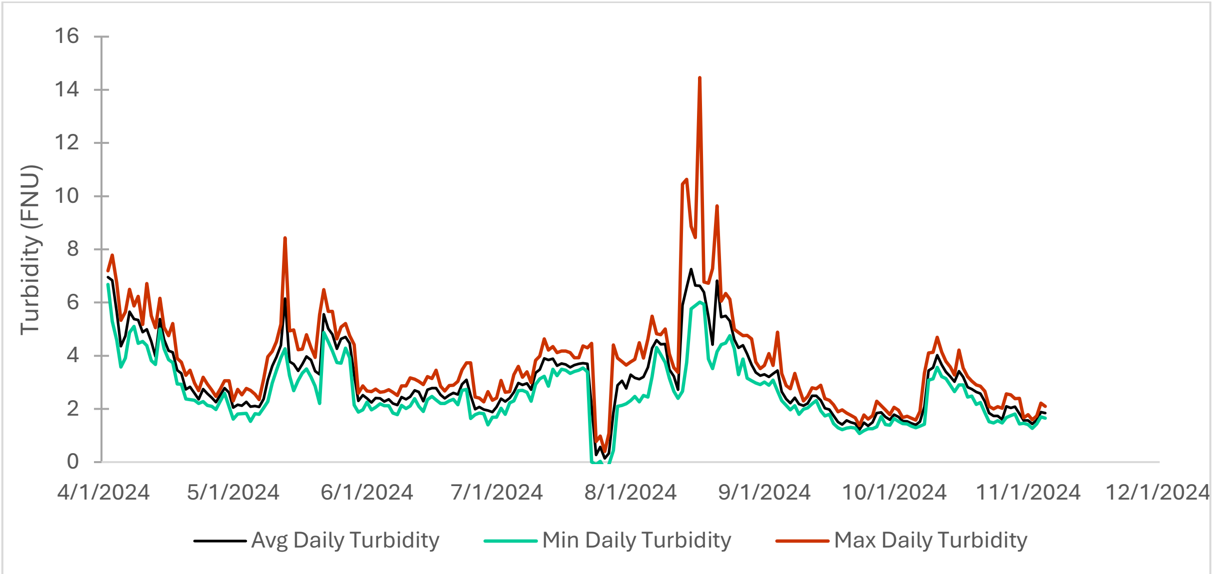


160
140
120
100
80
60
40
20
0
Specific Conductivity (uS/cm)
4/1/2024
5/1/2024
6/1/2024
7/1/2024
8/1/2024
9/1/2024
Avg Daily Conductivity
Min Daily Conductivity
Max Daily Conductivity

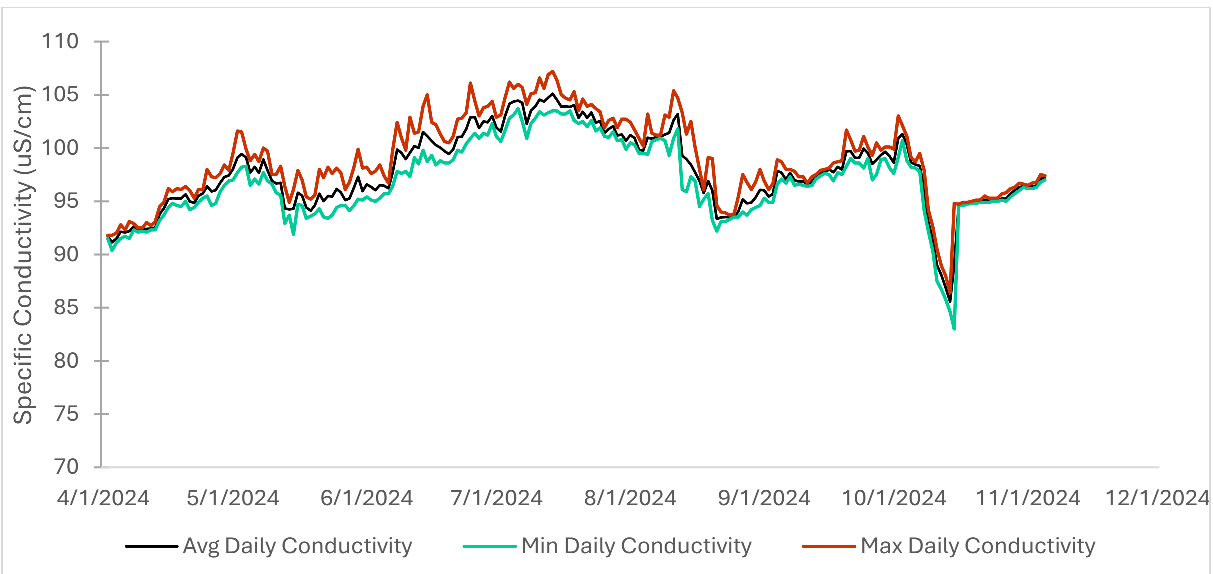
B-327 – additional continuous monitoring plots



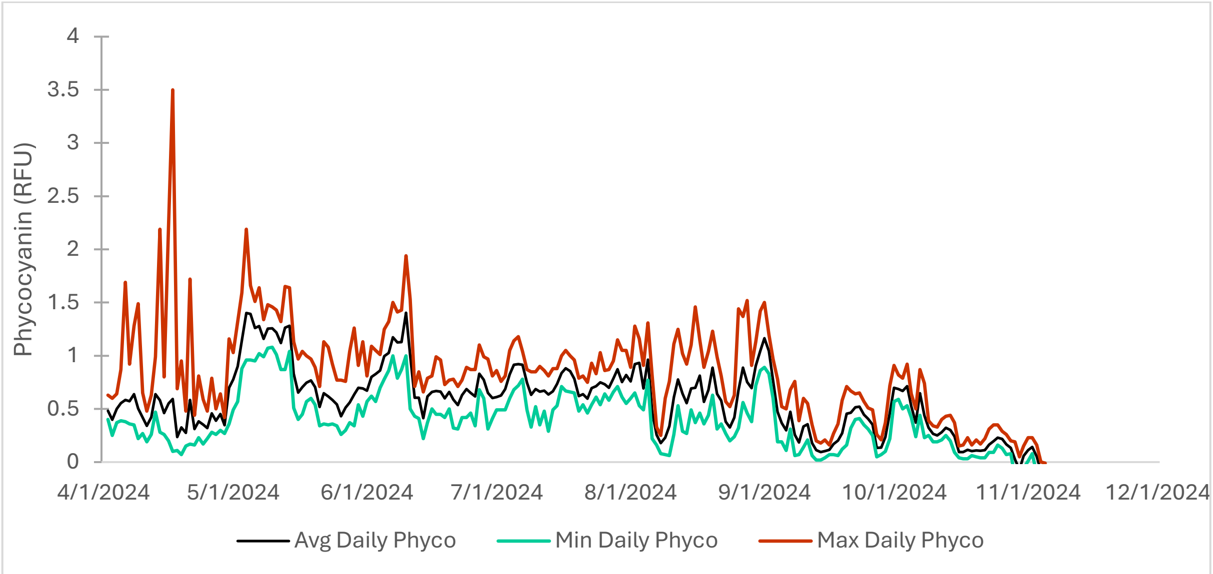




16
14
12
10
8
6
4
2
0
Turbidity (FNU)
4/1/2024
5/1/2024
6/1/2024
7/1/2024
8/1/2024
9/1/2024
10/1/2024
11/1/2024
12/1/2024
Avg Daily Turbidity
Min Daily Turbidity
Max Daily Turbidity

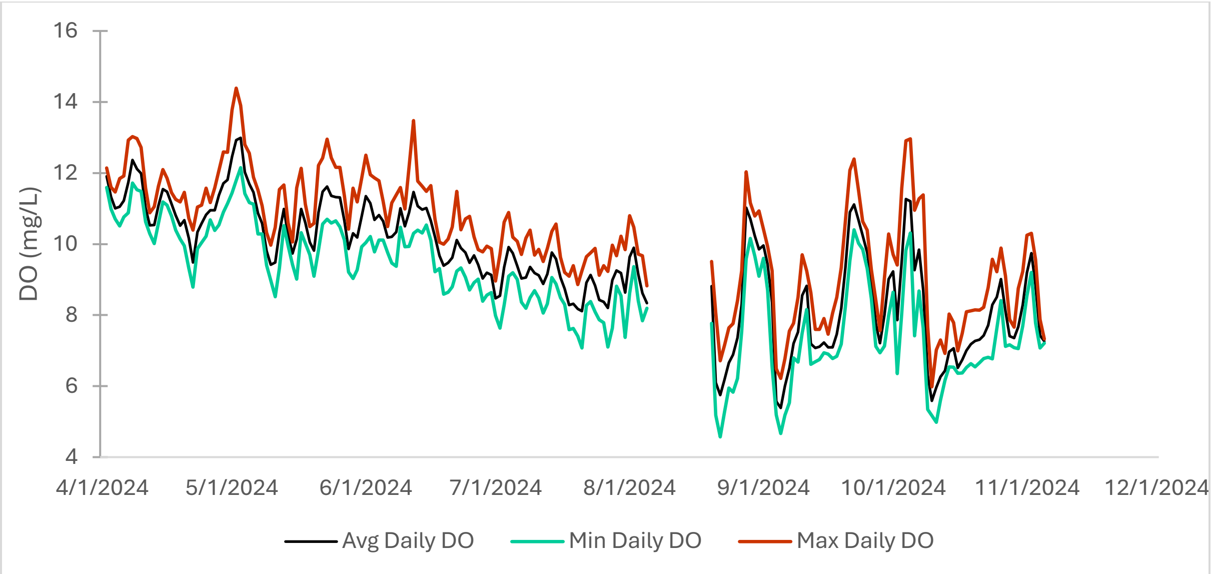


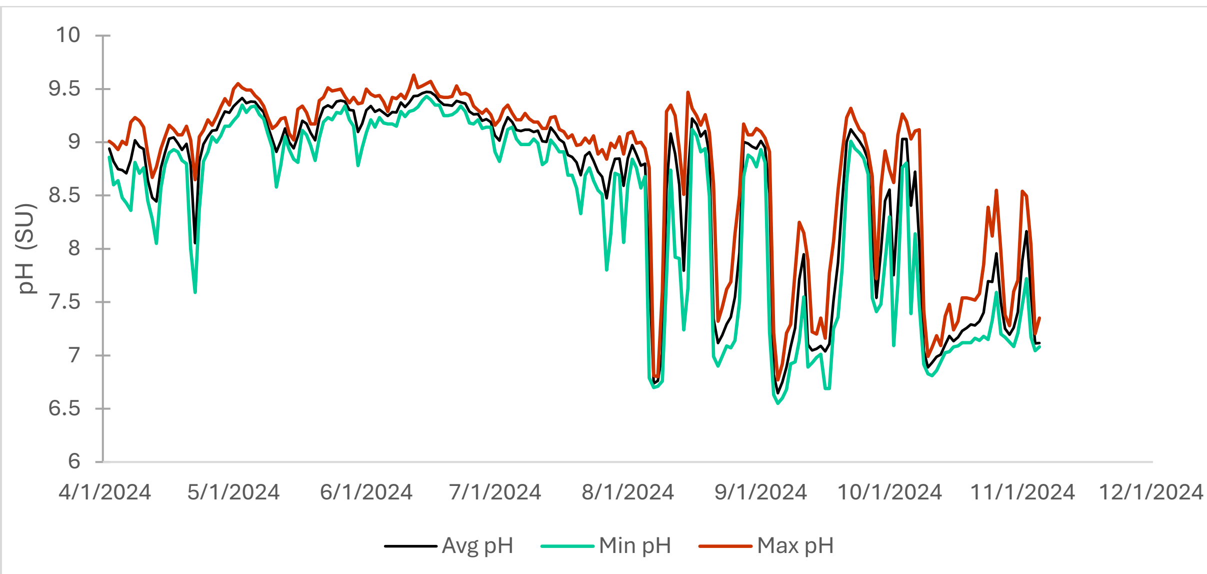
110
105
100
95
90
85
80
75
70
Specific Conductivity (uS/cm)
4/1/2024
5/1/2024
6/1/2024
7/1/2024
8/1/2024
9/1/2024
10/1/2024
11/1/2024
12/1/2024
Avg Daily Conductivity
Min Daily Conductivity
Max Daily Conductivity

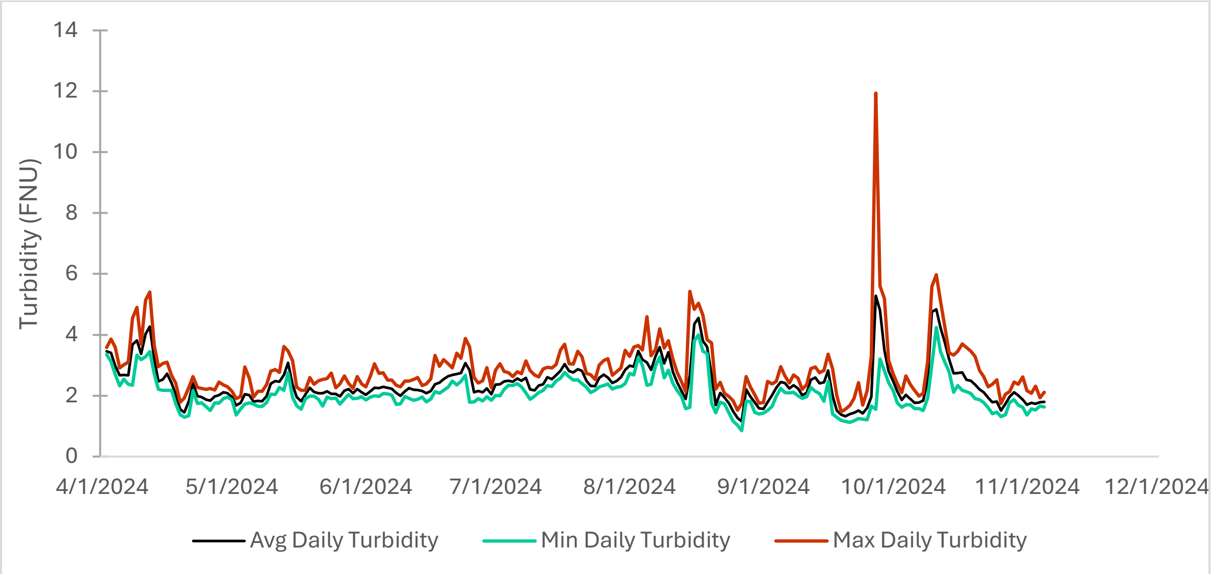


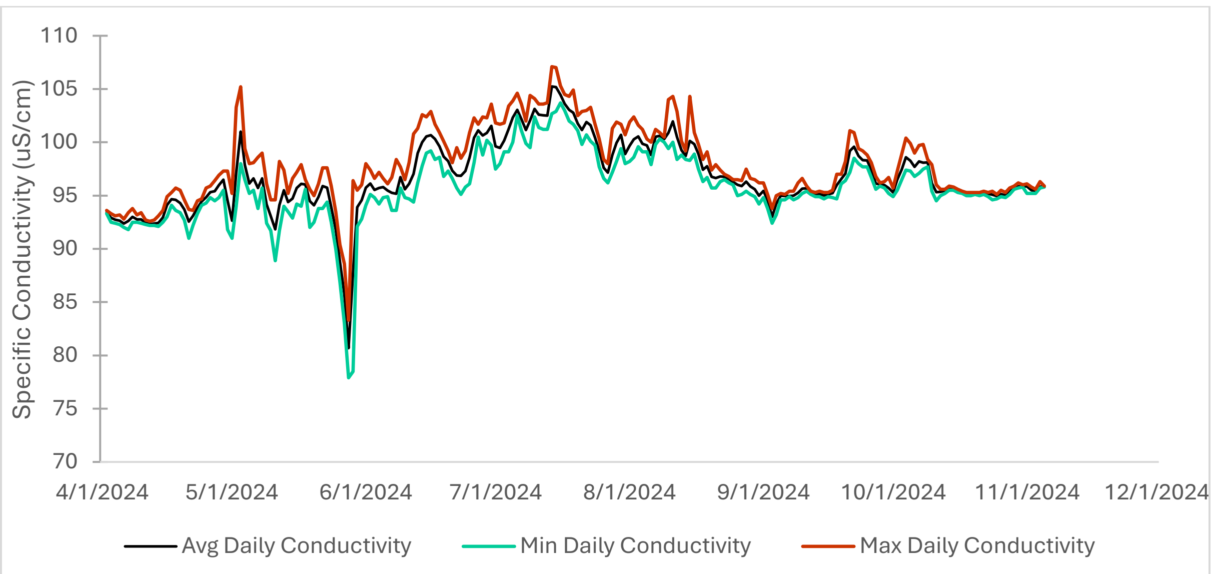
Phycocyanin (RFU)
4
3.5
3
2.5
2
1.5
1
0.5
0
4/1/2024
5/1/2024
6/1/2024
7/1/2024
8/1/2024
9/1/2024
10/1/2024
11/1/2024
12/1/2024
Avg Daily Phyco
Min Daily Phyco
Max Daily Phyco

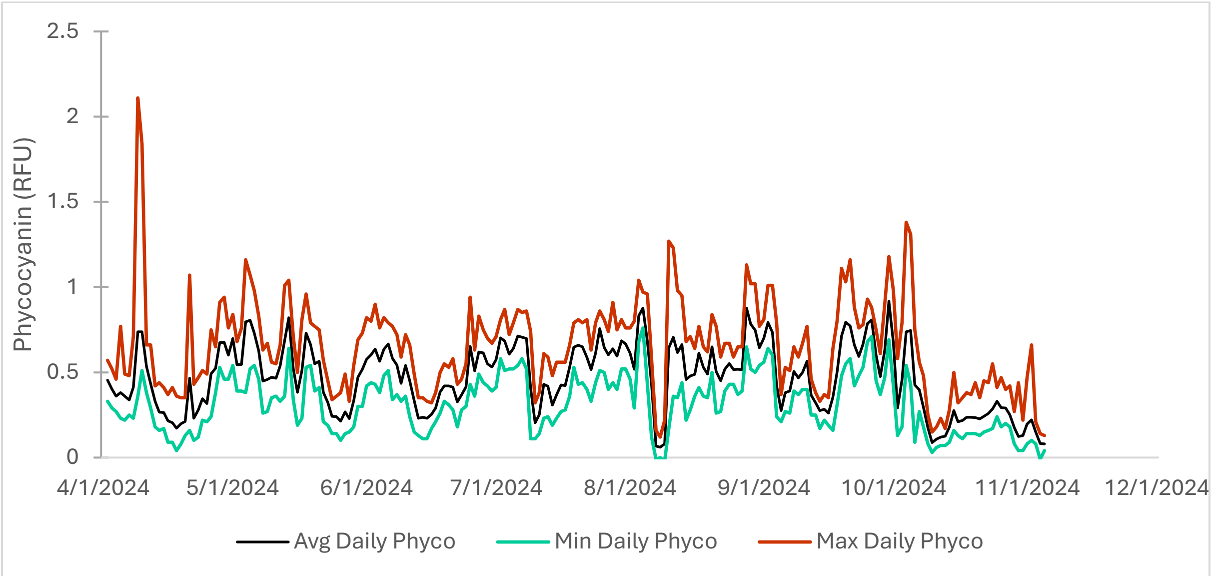
RL-04370 – additional continuous monitoring plots





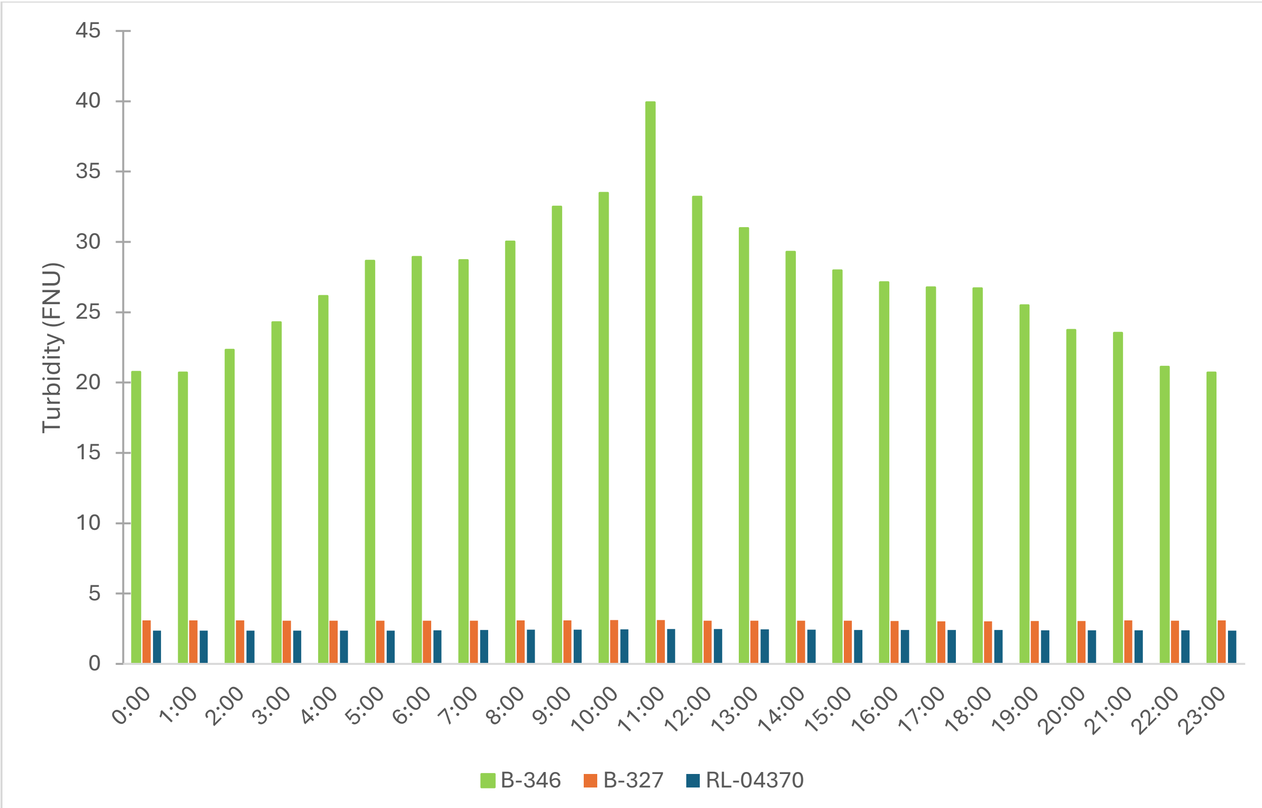

Turbidity (FNU)
14
12
10
8
6
4
2
0
4/1/2024
5/1/2024
6/1/2024
7/1/2024
8/1/2024
9/1/2024
10/1/2024
11/1/2024
12/1/2024
Avg Daily Turbidity
Min Daily Turbidity
Max Daily Turbidity

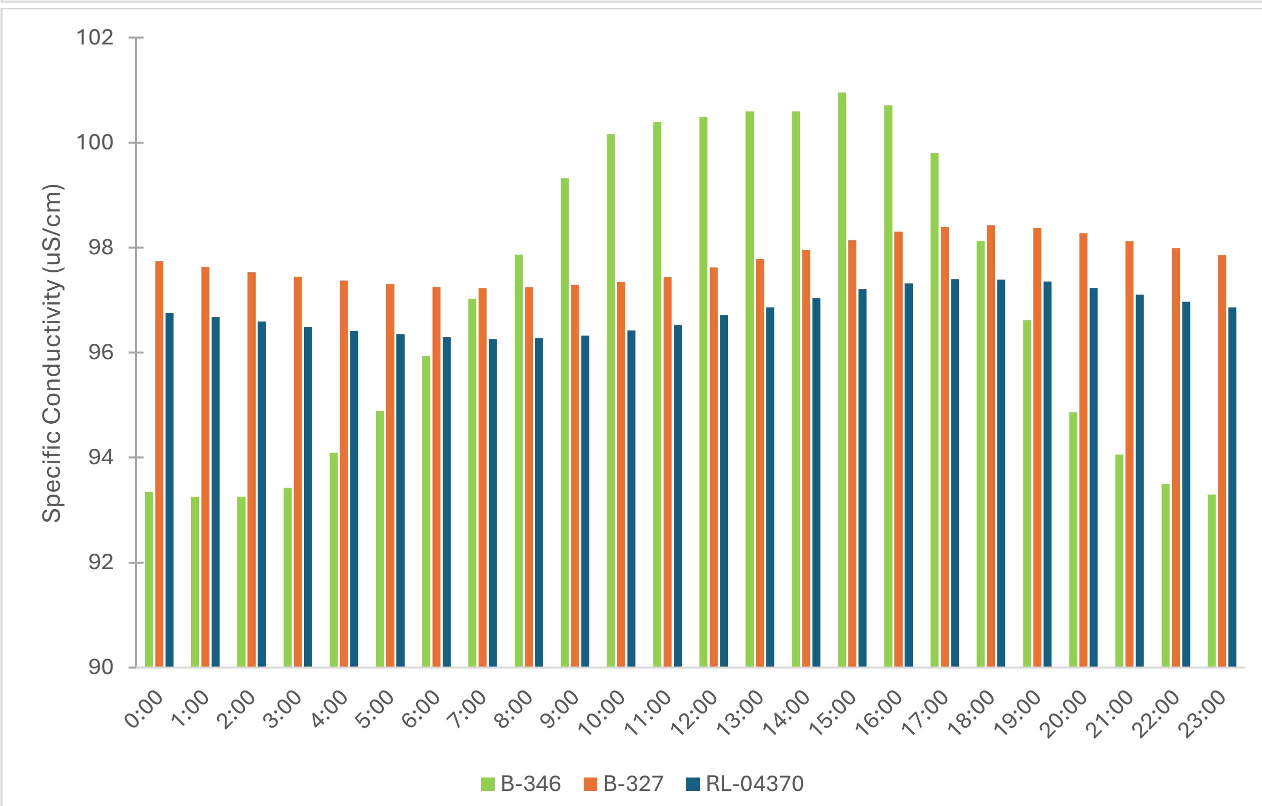

Specific Conductivity (uS/cm)
110
105
100
95
90
85
80
75
70
4/1/2024
5/1/2024
6/1/2024
7/1/2024
8/1/2024
9/1/2024
10/1/2024
11/1/2024
12/1/2024
Avg Daily Conductivity
Min Daily Conductivity
Max Daily Conductivity

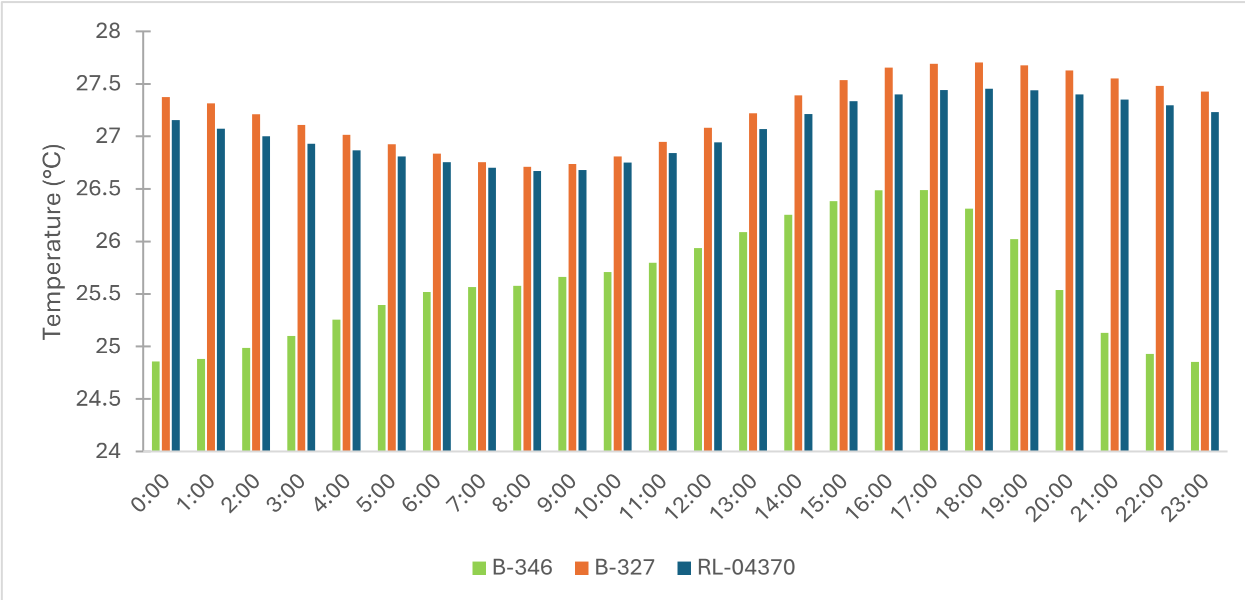


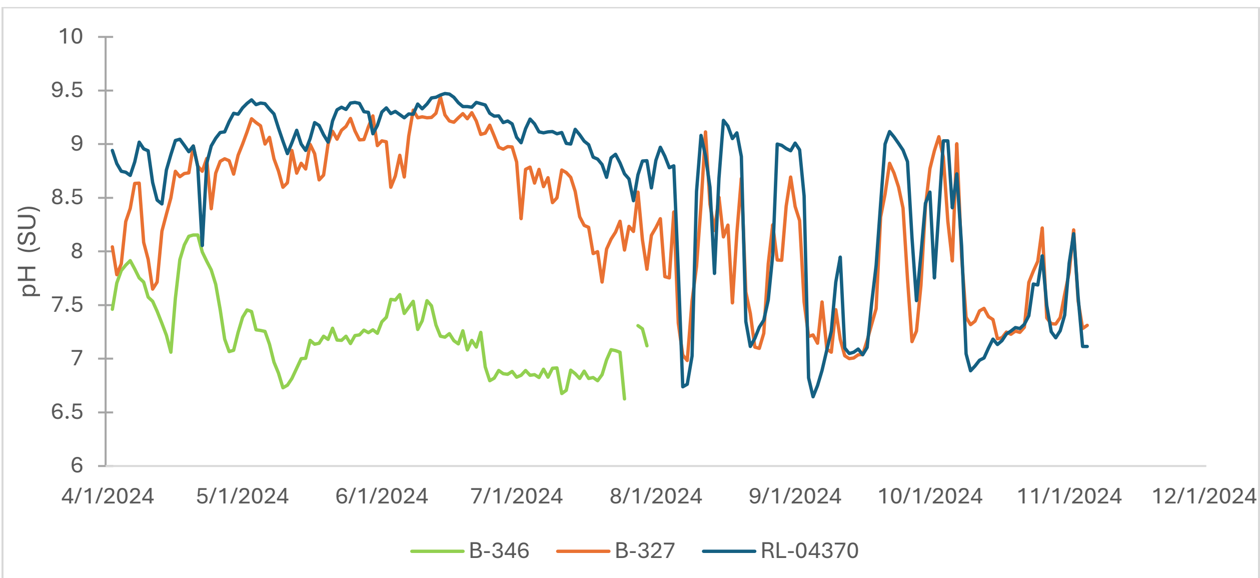
Phycocyanin (RFU)
2.5
2
1.5
1
0.5
0
4/1/2024
5/1/2024
6/1/2024
7/1/2024
8/1/2024
9/1/2024
10/1/2024
11/1/2024
12/1/2024
Avg Daily Phyco
Min Daily Phyco
Max Daily Phyco

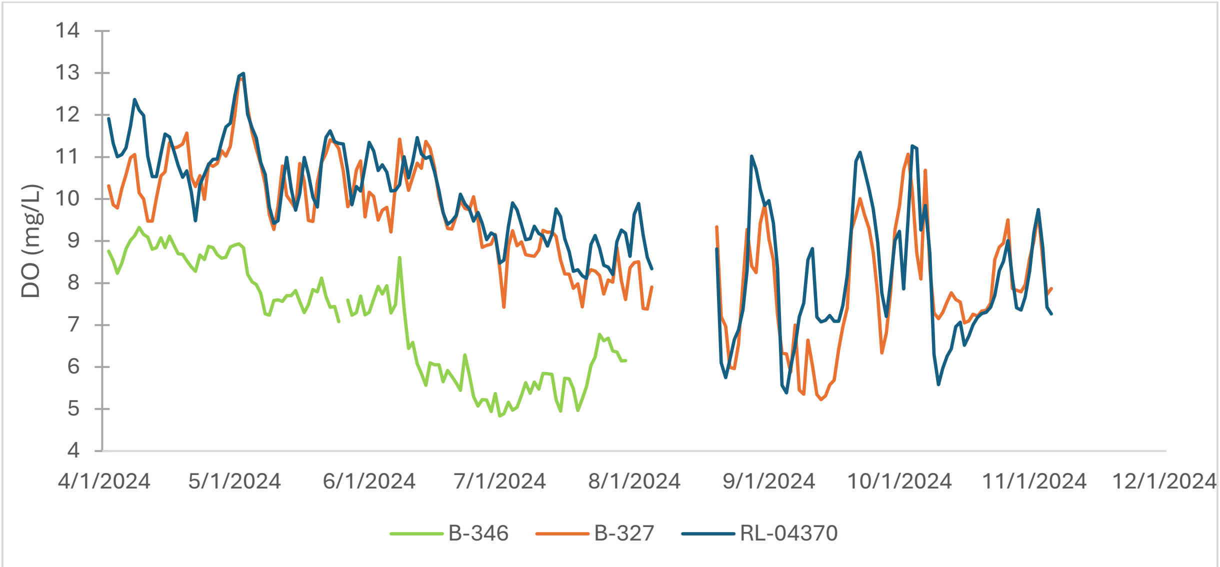
B-346, B-327, RL-04370 Combined – additional continuous monitoring plots

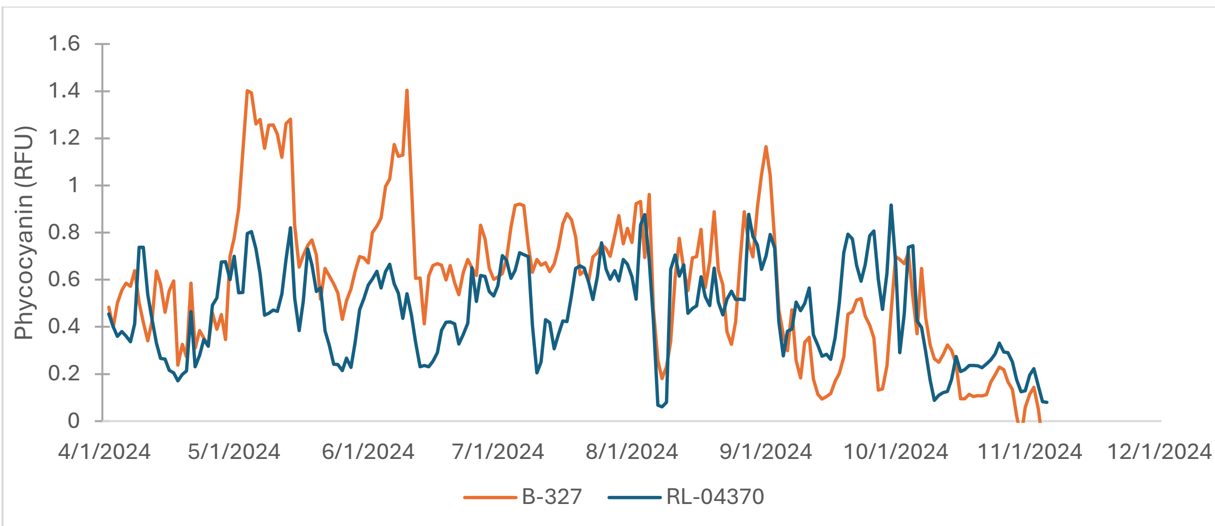





Temperature (°C)
28
27.5
27
26.5
26
25.5
25
24.5
24
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
B-346
B-327
RL-04370

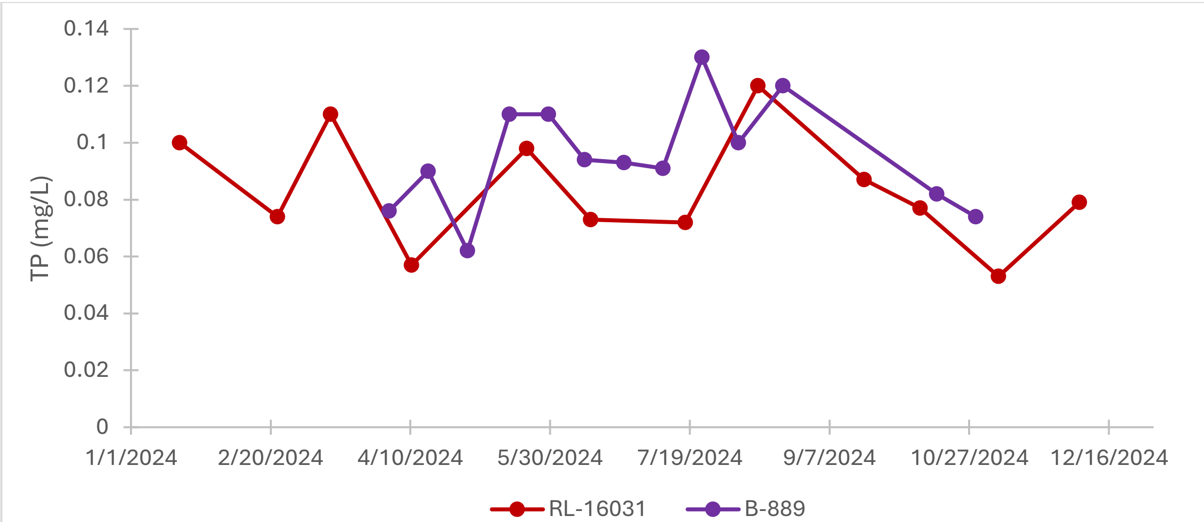

pH (SU)
10
9.5
9
8.5
8
7.5
7
6.5
6
4/1/2024
5/1/2024
6/1/2024
7/1/2024
8/1/2024
9/1/2024
10/1/2024
11/1/2024
12/1/2024
B-346
B-327
RL-04370

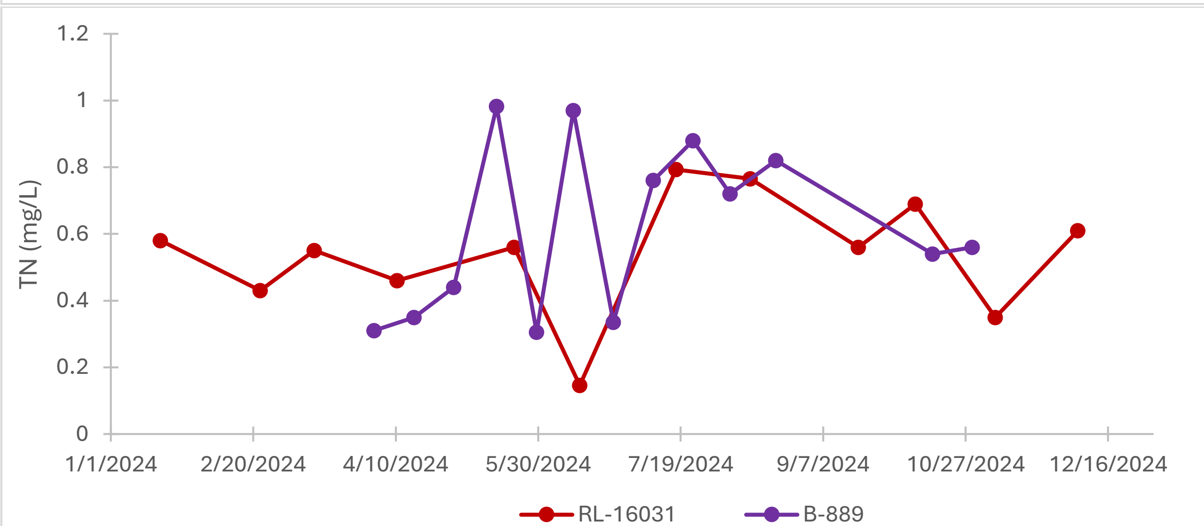

14
13
12
11
10
9
8
7
6
5
4
DO (mg/L)
4/1/2024
5/1/2024
6/1/2024
7/1/2024
8/1/2024
9/1/2024
10/1/2024
11/1/2024
12/1/2024
B-346
B-327
RL-04370

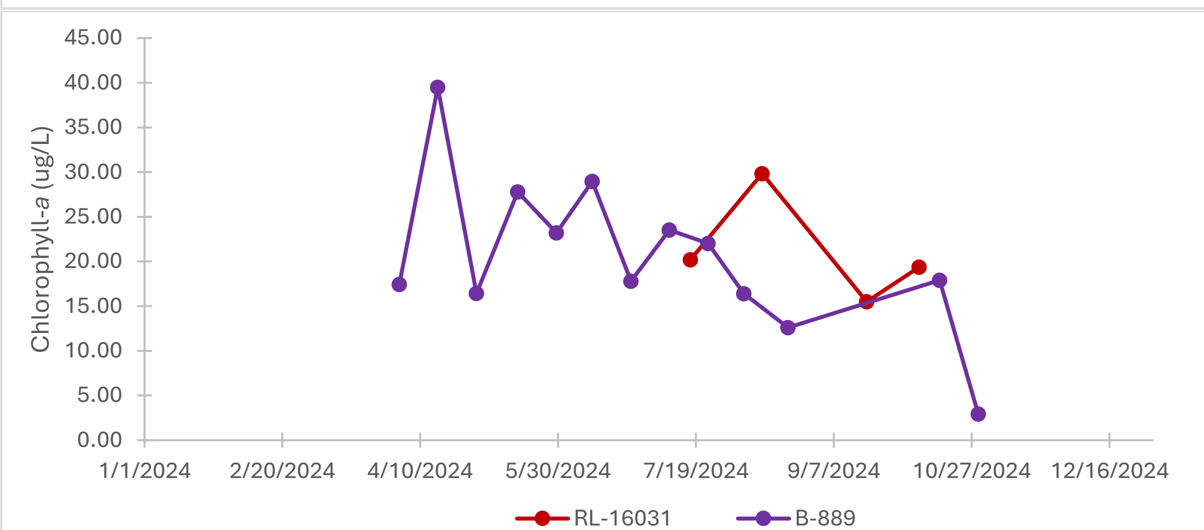

1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Phycocyanin (RFU)
4/1/2024
5/1/2024
6/1/2024
7/1/2024
8/1/2024
9/1/2024
10/1/2024
11/1/2024
12/1/2024
B-327
RL-04370

Appendix C – Additional Sampling

B-889 and RL-16031 - Lake Arm Discharge Comparison







B-327 – BOW and Regional Sampler Comparison