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Assessment of 2024 Water Quality in Rogers Lake

With An Historical Analysis from 2005 to 2024

Prepared for
Rogers Lake Authority
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Lyme, CT 06371

Sincerely,

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1. EXECUTIVE SUMMARY

1.1 Introduction

David Post's research lab at Yale University conducted a water quality analysis of Rogers Lake for the year 2024 as agreed upon with the Rogers Lake Authority (RLA). This report shares the results of 2024 water quality data and makes comparisons to historical data collected from 2005-2023 to identify trends in Rogers Lake water quality.

1.2 Methods

Rogers Lake was sampled 13 times in 2024 on the dates of Apr 1, Apr 15, Apr 30, May 17, May 29, Jun 10, Jul 2, Jul 19, Aug 1, Aug 21, Sep 17, Oct 21, and Nov 13. This follows the yearly sampling protocol the Post Lab has historically used to sample the lake, beginning in April and continuing biweekly until mid-September, and then monthly in October and November. Historical samples from 2005-2023 were collected on 10-14 dates per year. No sampling was conducted in 2012. Water samples were collected from a single sampling site located south of Blood St. and northeast of Shore Dr. where the lake is deepest (20 m).

<u>Water Quality Parameters Measured</u>

- Temperature
- Dissolved Oxygen
- Secchi Depth Transparency
- Chlorophyll-a
- Total Phosphorus
- Total Nitrogen
- Nitrate-Nitrogen
- Nitrite-Nitrogen
- Phosphate-Phosphorus
- pH
- Conductivity
- Chloride
- Bromide
- Fluoride
- Sulfate

1.3 Key Results

Rogers Lake remains in good ecological health and remains classified as a mesotrophic lake. 2024 annual concentrations of total phosphorus and total nitrogen were slightly lower than 2023, though they were the second highest for the 2005-2024 sampling period and continue a long-term gradual increasing trend. Water clarity in 2024 slightly improved and was clearer than 2021-2023, though trends continue to show a long-term decrease. Nitrate-Nitrogen values are also increasing in summer. Low dissolved oxygen levels in the month of July in recent years were not observed in 2024.

A summary of the mean annual values for all parameters and their long-term trends can be found in Table 1. Descriptions of each water quality parameter and more detailed results with figures can be found in Section 5 Results. A basic primer on the statistics used in this report can be found in Appendix I, with statistical results tables for the analyses in Appendices II and III.

Table 1. Mean annual values for Rogers Lake water quality parameters for 2024, 2023, and long-term status.

Parameter	Mean Annual Value for 2024	Mean Annual Value for 2023	Long-term Trends
Temperature	19.34 ± 6.24 °C	20.0 ± 5.94 °C	Stable
Dissolved Oxygen	8.9 ± 1.37 mg/L	8.49 ± 1.20 mg/L	Stable
Secchi Disk Transparency	2.25 ± 0.74 m	2.11 ± 0.23 m	Decreasing
Chlorophyll-a	6.18 ± 2.92 µg/L	7.83 ± 4.92 µg/L	Stable
Total Phosphorus	15.82 ± 3.15 µg/L	17.21 ± 4.66 µg/L	Increasing
Total Nitrogen	0.373 ± 0.08 mg/L	0.39 ± 0.11 mg/L	Increasing
Nitrate-Nitrogen	0.177 ± 0.02 mg/L	0.118 ± 0.030 mg/L	Increasing in summer
pH	6.9 ± 0.18	6.71 ± 0.26	Stable
Conductivity	47.9 ± 2.14 µS/cm	63.4 ± 4.99 µS/cm	Stable
Bromide	0.117 ± 0.002 mg/L	0.035 ± 0.002 mg/L	Stable
Chloride	6.60 ± 0.60 mg/L	7.99 ± 0.88 mg/L	Stable
Fluoride	0.089 ± 0.02 mg/L	0.076 ± 0.004 mg/L	Stable
Sulfate	4.27 ± 0.66 mg/L	4.74 ± 0.59 mg/L	Stable

1.4 Summary Recommendations

Continued water quality sampling is recommended for 2025 to track potential changes and determine whether total phosphorus and total nitrogen levels continue to gradually rise, and water clarity continues to gradually decline. In 2024, the Post Lab analyzed preliminary samples collected by the RLA from tributaries entering Rogers and found significantly higher concentrations of total phosphorus and total nitrogen in some tributaries compared to lake samples. To better identify potential nutrient sources, a tributary sampling plan should be developed for the 2025 sampling season. A suggested tributary sampling plan for 2025 is outlined in the Recommendations section on Page 34. The following are again suggested as general good environmental practices to reduce nutrient inputs into Rogers Lake:

- Reduction and proper timing of lawn fertilization
- Maintaining septic systems and using phosphate-free detergents
- Planting vegetation buffers along the shoreline
- Invasive species monitoring and spread prevention

2. INTRODUCTION

Since 2005, David Post's lab in the Department of Ecology and Evolutionary Biology at Yale University (Post Lab) has collected water samples from Rogers Lake as part of a decadal research program. Water samples are collected and analyzed to track changes in water quality and lake ecology through time.

The Rogers Lake Authority (RLA) has commissioned analyses of water quality in Rogers Lake since at least 2014. Rogers Lake is a 260-acre lake in Connecticut which borders the towns of Lyme and Old Lyme. The lake sees moderate watercraft activity in summer months and is surrounded by wooded areas and private residences. In 2022, an agreement was reached between the Post Lab and the RLA for the Post Lab to collect and analyze water samples and to share results of samples collected since 2005.

This report will summarize findings of water samples collected in 2024 and make comparisons to samples collected from 2005-2023. The Post Lab dataset on Rogers Lake water quality spans nearly 20 years and ~230 sampling dates. This data will enable the RLA to better understand long-term trends in water quality and ecological health of the lake. Recommendations will also be provided for future water quality monitoring and management.

Reporting changes for 2024 report:

- 2024 data points on summary charts are represented in red.
- Nitrite-Nitrogen and Phosphate-Phosphorus continued to be below detection limits in most 2024 samples and were therefore excluded from this report.
- Fluoride, Chloride, Bromide, and Sulfate have been analyzed using a linear calibration curve. This has slightly changed some of the historical samples but has not affected results.
- Two historical dissolved oxygen data points were omitted from last year's report but are included here.

3. BACKGROUND

Spring turnover, summer lake stratification, and fall turnover are three lake processes that play critical roles in nutrient cycling, oxygen distribution, and overall ecological health within temperate lakes. Understanding when these events occur during the year will help in interpreting the water quality results, as they can have large impacts on some of the parameters measured.

Spring turnover occurs in Rogers Lake in March-April, when ice melts and the top layer of water is warmed to a temperature that equals the water below. At this temperature equilibrium, denser water sinks and mixes with water below resulting in turnover. During turnover, the physical and chemical properties of the lake, including temperature, dissolved oxygen, and nutrient concentrations, are generally uniform from top to bottom.

Lake stratification occurs in Rogers Lake primarily in spring and summer. As solar radiation and air temperatures increase in spring, the top layer of the lake is warmed more than during turnover. The lake begins to stratify forming distinct temperature layers:

a. The epilimnion, the warm and less dense top layer of the water column, has temperature and dissolved oxygen levels that are generally uniform. This layer is mixed by wind and the less dense warm water does not easily mix with cooler water below. The summer epilimnion in Rogers Lake is typically found from the surface down to 3-4 meters deep.

b. The metalimnion is middle layer and is characterized by sharp declines in temperature and dissolved oxygen with depth. The summer metalimnion in Rogers Lake is typically located at depths from 3-8 meters.

c. The hypolimnion, the cold and dense bottom layer, is not readily mixed with the warmer waters above. As organic matter decays and sinks to the bottom, it is decomposed in the hypolimnion by bacteria. This process consumes oxygen and because the water in this layer does not mix with warmer water from above, the hypolimnion remains oxygen-depleted until fall turnover. The summer hypolimnion in Rogers Lake is typically found at depths from 8-20 meters.

Fall turnover occurs in Rogers Lake sometime between October-December when solar radiation and air temperatures decrease causing surface waters to cool and become denser. The dense water sinks and begins to mix with the layers below, eventually resulting in an equilibrium where the whole lake has uniform temperature, dissolved oxygen, and nutrients concentrations (similar to spring turnover).

4. METHODS

4.1 Sample Collection

The Post Lab begins collecting water samples at Rogers Lake near spring turnover (~April 1), continuing biweekly until mid-September to capture summer lake stratification, and then monthly in October and November to capture fall turnover. There were 10-14 sampling dates per year from 2005-2024, including 13 for 2024. No sampling was conducted in 2012. Water samples have been collected at the same location since 2005 (as shown in Figure 1). This sampling site is located south of Blood St. and northeast of Shore Dr. where the lake is deepest, with depths of just over 20 m.

Data for temperature, dissolved oxygen, and secchi disk transparency were collected on-site from 2005 to 2024. Depth profiles of temperature and dissolved oxygen were generated from 0 to 14 m depth. Samples were collected every 0.5 m from 0-6 m and every 1 m from 6-14 m. Measurements were taken using YSI Digital Water Quality Meters. The secchi disk transparency was measured using a secchi disk that was lowered into the water until the disk was no longer visible.

The epilimnion, which supports most of the productivity and aquatic life in summer, was the focus for sampling chlorophyll-a, total nitrogen, total phosphorus, phosphate-phosphorus, nitrate-nitrogen, nitrite-nitrogen, fluoride, chloride, bromide, sulfate, pH, and conductivity measurements. Water samples were collected with a Van Dorn water sampler and transported to Yale for analysis in the Post Lab laboratory or at the Yale Analytical and Stable Isotope Center (YASIC). Chlorophyll-a, total phosphorus, and total nitrogen were measured from 2005-2024. Nitrate-nitrogen, nitrite-nitrogen, fluoride, chloride, bromide, sulfate, and phosphate-phosphorus were measured from 2014-2024. pH and Conductivity were measured from 2022-2024 only. Equipment used to conduct the analyses and units of measure can be found in Table 2.

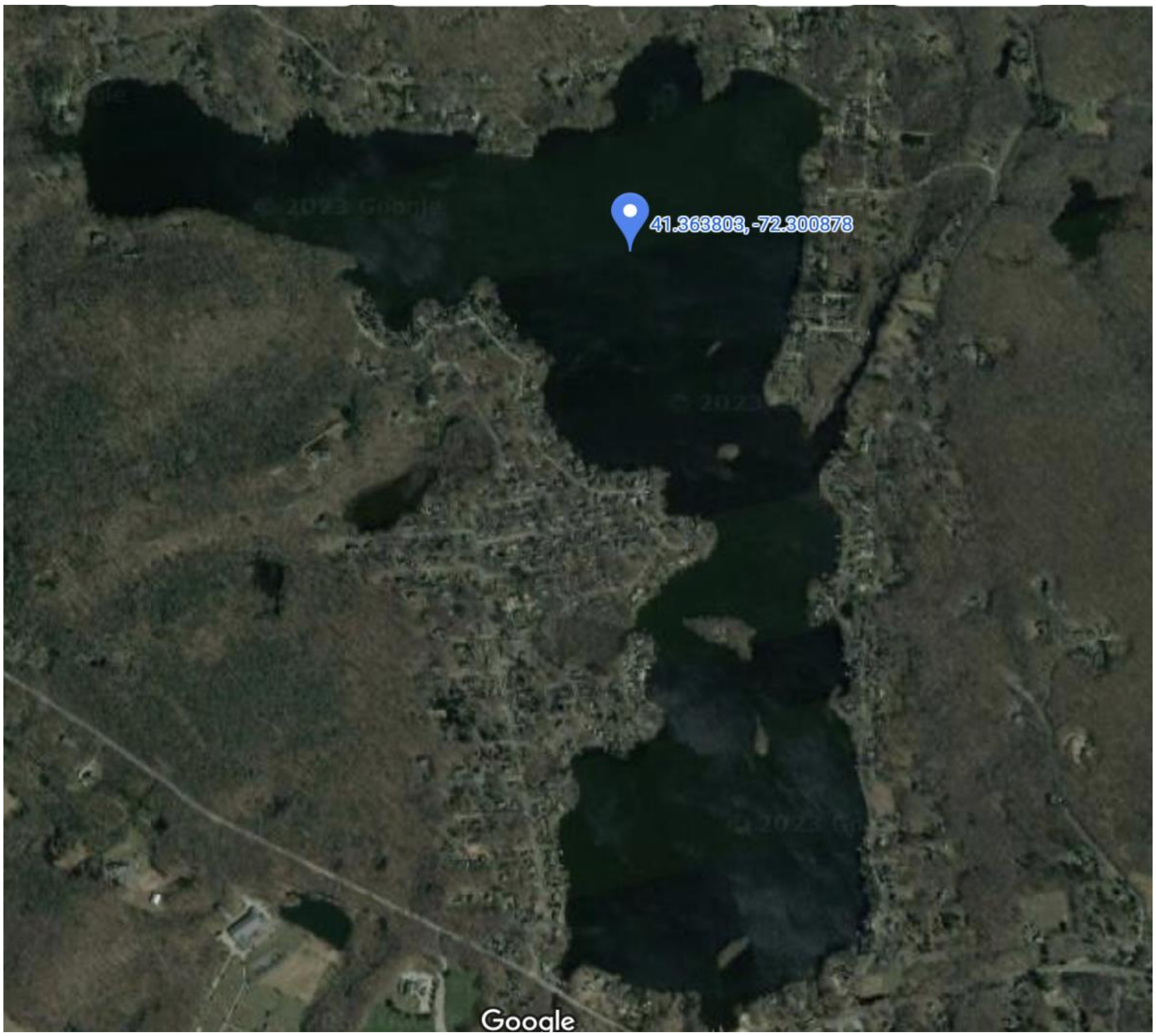

Figure 1. Photo of Rogers Lake from Google Maps showing the Sampling Site location and coordinates.

4.2 Sample Processing

Water samples collected using the Van Dorn water sampler were stored in a cooler and transported back to the laboratory. For chlorophyll-a, a 250 ml sample from each of the top, middle, and bottom of the epilimnion were run separately through Whatman GF/C glass microfiber filters to capture all algae. The filters were frozen for 7-14 days and then analyzed on a Turner Designs Trilogy Laboratory Fluorometer. Values for these three samples were then averaged to get the final chlorophyll-a value. A 250 ml aliquot of combined water samples from the top, middle, and bottom of the epilimnion was used for pH and conductivity measurements. Another 250 ml aliquot of the combined sample was frozen for analysis of total phosphorus, total nitrogen, nitrate-nitrogen, nitrite-nitrogen, phosphate-phosphorus, fluoride, chloride, bromide, and sulfate. This sample was thawed and total phosphorus and total nitrogen analysis was conducted using an Astoria 2 Flow Analyzer. Nitrate-nitrogen, nitrite-nitrogen, phosphate-phosphorus, fluoride, chloride, bromide, and sulfate were analyzed on a Metrohm Ion Chromatograph.

Table 2. List of parameters analyzed, their unit of measure, and the equipment used to analyze samples.

Analyses	Units	Equipment
Temperature	Degrees Celsius (°C)	YSI Digital Water Quality Meter
Dissolved Oxygen	Milligrams per Liter (mg/L)	YSI Digital Water Quality Meter
Chlorophyll-a	Micrograms per Liter (µg/L)	Trilogy Laboratory Fluorometer
Total Phosphorus	Micrograms per Liter (µg/L)	Astoria 2 Flow Analyzer
Total Nitrogen	Milligrams per Liter (mg/L)	Astoria 2 Flow Analyzer
Phosphate-Phosphorus	Milligrams per Liter (mg/L)	Metrohm Ion Chromatograph
Nitrate-Nitrogen	Milligrams per Liter (mg/L)	Metrohm Ion Chromatograph
Nitrite-Nitrogen	Milligrams per Liter (mg/L)	Metrohm Ion Chromatograph
Fluoride	Milligrams per Liter (mg/L)	Metrohm Ion Chromatograph
Chloride	Milligrams per Liter (mg/L)	Metrohm Ion Chromatograph
Bromide	Milligrams per Liter (mg/L)	Metrohm Ion Chromatograph
Sulfate	Milligrams per Liter (mg/L)	Metrohm Ion Chromatograph
Turbidity	Meters (m)	Secchi Disk
Conductivity	Micro siemens per centimeter (µS/cm)	Orapxi Salinity and Conductivity Meter
pH	pH	Orion Star A121 Portable pH Meter

***mg/L** is equivalent to parts per million (ppm). **µg/L** is equivalent to parts per billion (ppb).

4.3 Statistical Analysis

R Studio version 2023.12.0+369 was utilized for all data analyses and figures. To analyze changes in parameters across years, we calculated a **mean annual** value that was the average of all samples taken within the year and **mean monthly** values that averaged all the samples taken within a month. For most water quality parameters, we created plots showing the change in mean monthly values throughout the 2024 sampling season, the change in mean monthly values across years within each month (providing a higher resolution look at changes in water quality), and the change in mean annual values across years.

Data from 2-3 m depth were used for temperature and dissolved oxygen to maintain consistency and avoid weather variance by sampling date. Data from samples combined from the top, middle, and bottom of the epilimnion were used for other parameters. Long-term trends were examined via linear regression for both mean annual and mean monthly values for each parameter (see Appendix I for a description of linear regression and statistical measurements used in the analysis). Additionally, depth profile plots were generated for temperature and dissolved oxygen.

5. RESULTS

5.1 Temperature

During the 2024 sampling period, mean annual temperature at 2-3 m depth in the epilimnion was 19.34 ± 6.24 °C (Table 1). Mean monthly temperature was coolest in November at 11.8°C and warmest in July at 26.5°C. Spring turnover occurred in April. Fall turnover was not picked up during the November sampling as is typical, likely due to a warm and calm fall (Figure 2).

There remains no significant relationship between mean monthly temperature (Figure 3) or mean annual temperature with year from 2005-2024 (Figure 4). Statistical results are provided in Appendix II, Table 2.1 and Appendix III, Table 3.1.

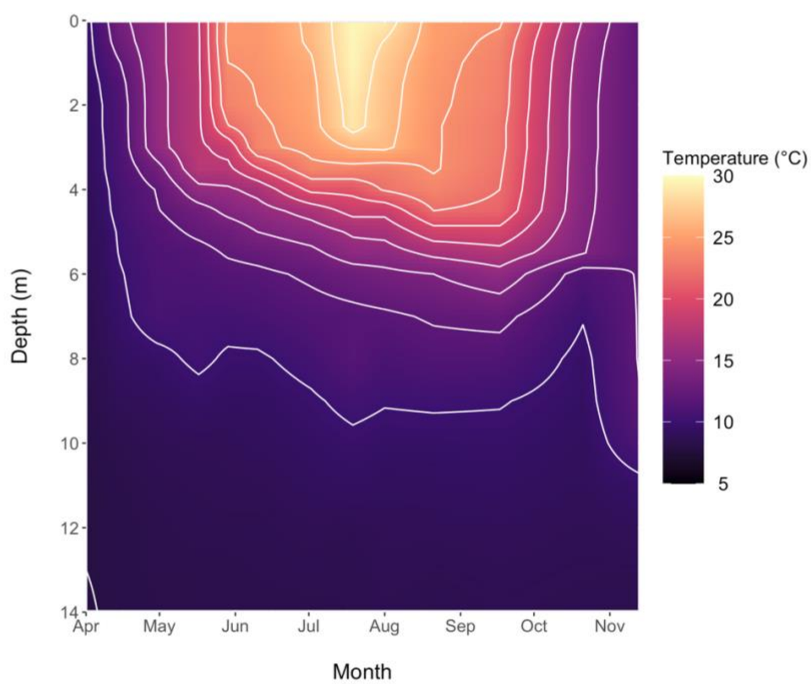

Figure 2. Temperature stratification with depth in Rogers Lake from April to November 2024.

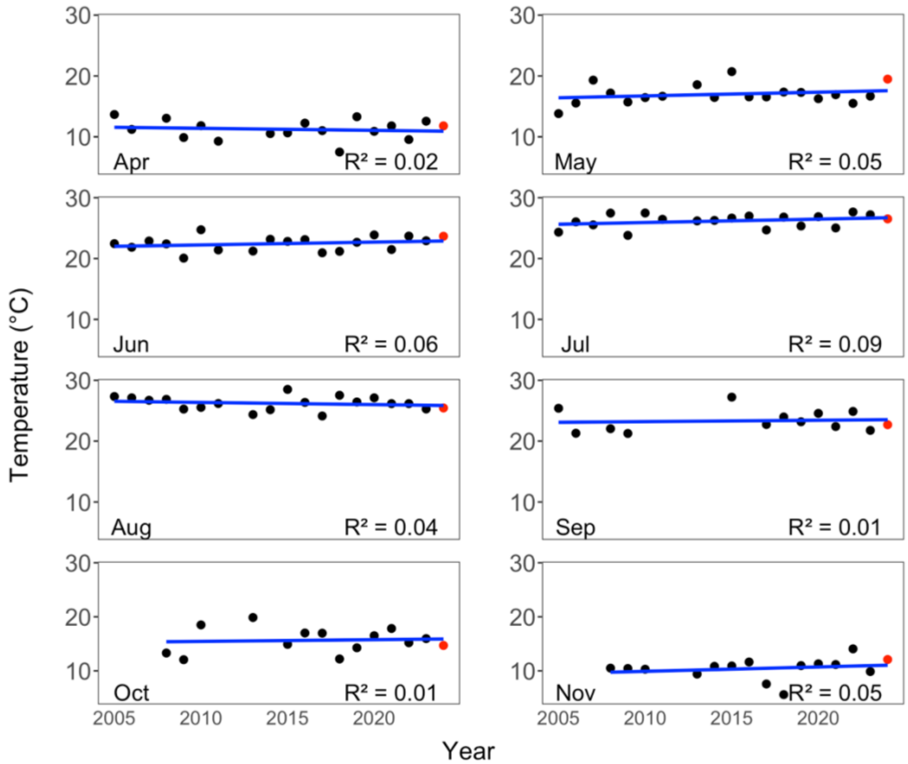

Figure 3. Mean monthly epilimnetic temperature at 2-3 m depth from 2005-2024.

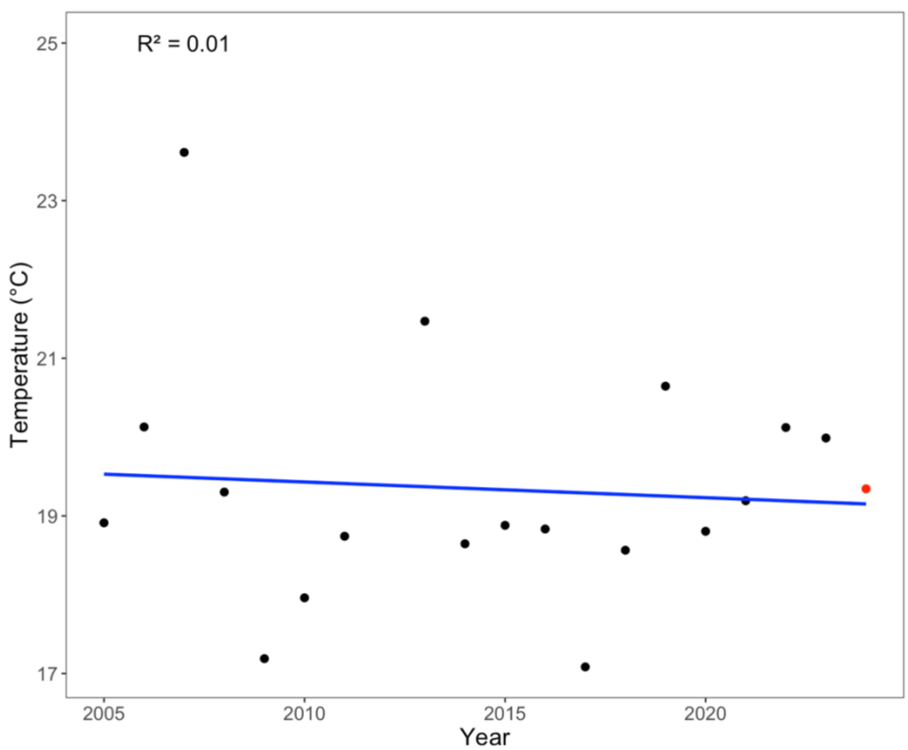

Figure 4. Mean annual epilimnetic temperature at 2-3 m depth from 2005-2024.

5.2 Dissolved Oxygen

Adequate dissolved oxygen (DO) in freshwater is critical for life and maintaining the health and well-being of the ecosystem. Low DO conditions can stress or cause death to most plants and organisms. DO values are typically lower in the summer as warmer water holds less oxygen and higher aquatic plant and algae densities use more DO during photosynthesis. Oxygen-depletion is common in deeper waters of freshwater lakes that have moderate to high productivity in summer as bacteria consumes oxygen during decomposition of organic matter that has sunk to the bottom.

During the 2024 sampling period, mean annual DO at 2-3 m depth in the epilimnion was 8.9 ± 1.37 mg/L (Table 1). Mean monthly DO was highest in April at 10.9 ± 0.16 mg/L and was lowest in July at 7.24 ± 0.83 mg/L (Figure 5).

The 2024 mean annual DO was higher than in 2023 and aligned with previous yearly averages. While past reports showed decreasing mean monthly DO values in July, the inclusion of two previously omitted years, along with higher July DO in 2024, does not support a declining trend for that month.

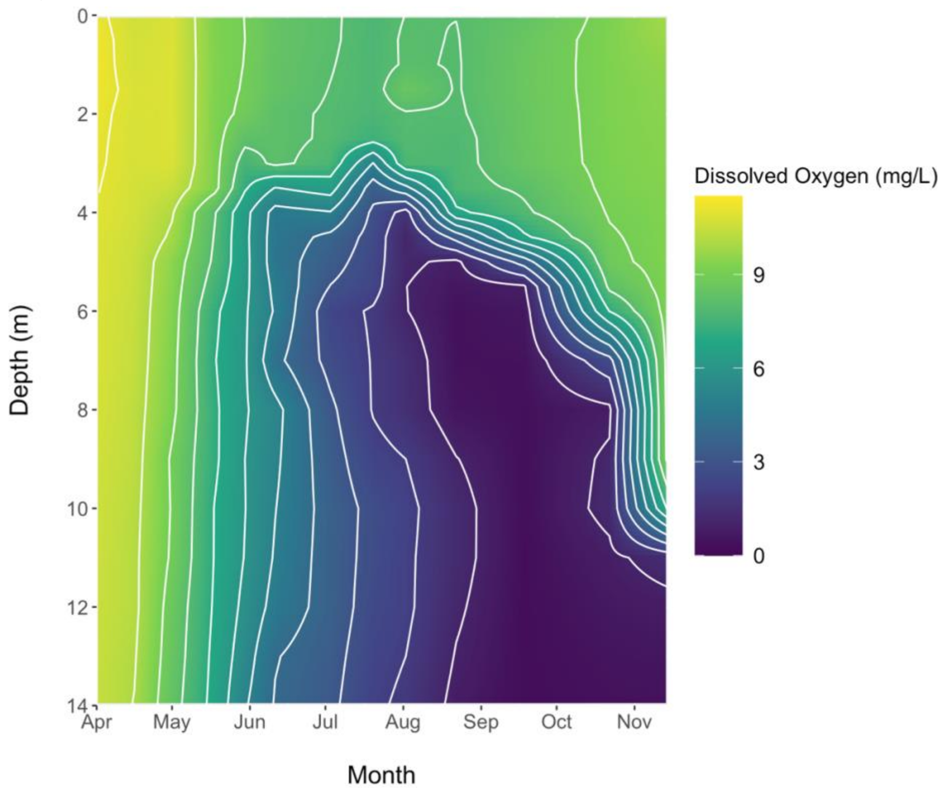

Figure 5. Depth profile of dissolved oxygen in Rogers Lake from April to November 2024.

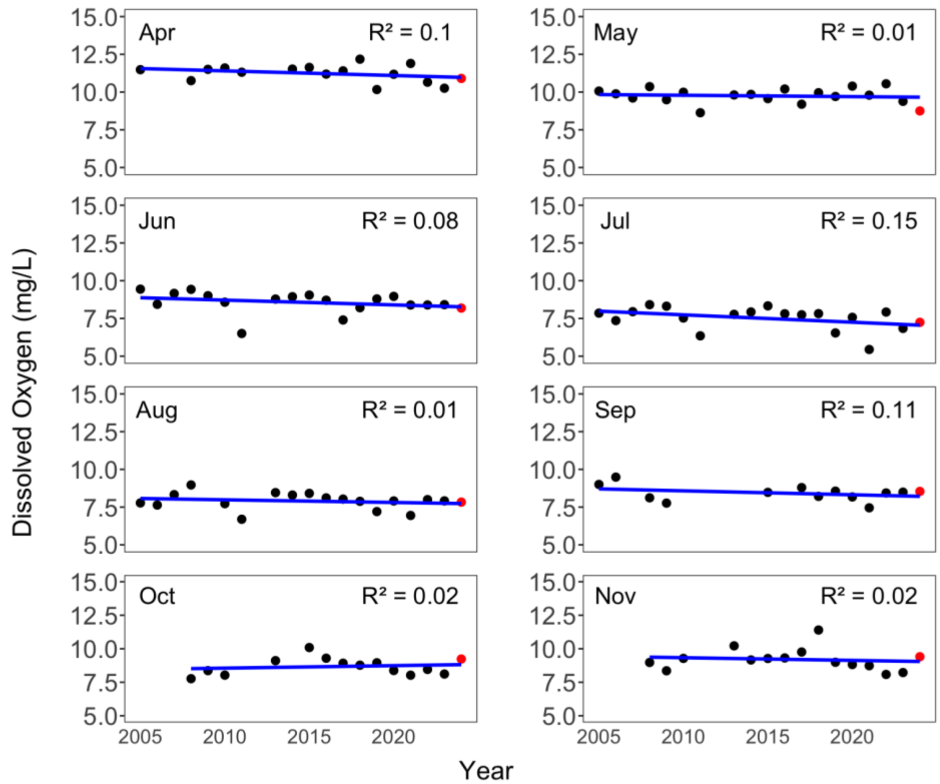

Figure 6. Mean monthly epilimnetic dissolved oxygen at 2-3 m depth from 2005-2024.

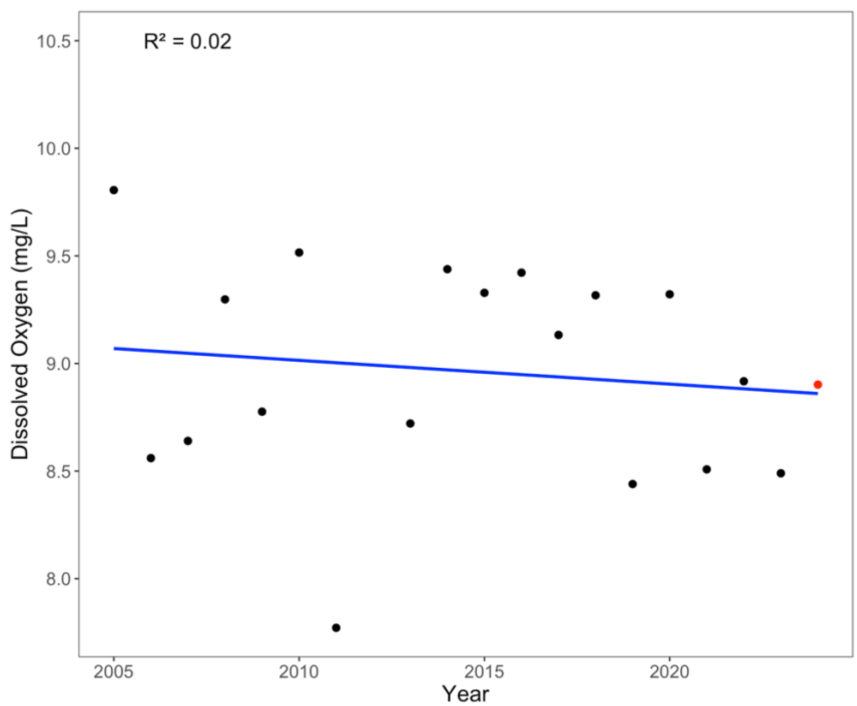

Figure 7. Mean annual epilimnetic dissolved oxygen at 2-3m depth from 2005-2024.

5.3 pH

pH influences a wide array of biological, chemical, and ecological processes within a lake. These include the solubility and cycling of nutrients, the buffering capacity of the water, and the overall health of the ecosystem. Generally, the pH range observed in most freshwater ecosystems falls between 6 and 8 during summer months but can fluctuate during spring and fall turnover.[4]

During the 2024 sampling period, pH in the epilimnion ranged between 6.5-7.1 (Figure 8). These values are typical for freshwater and are similar to 2022 and 2023. The Post Lab did not measure pH prior to 2022. Slightly lower pH observed in early spring and fall compared to summer is likely due to turnover. Turnover can lead to a decrease in pH due to the release of carbon dioxide and redistribution of nutrients from the deeper layers.

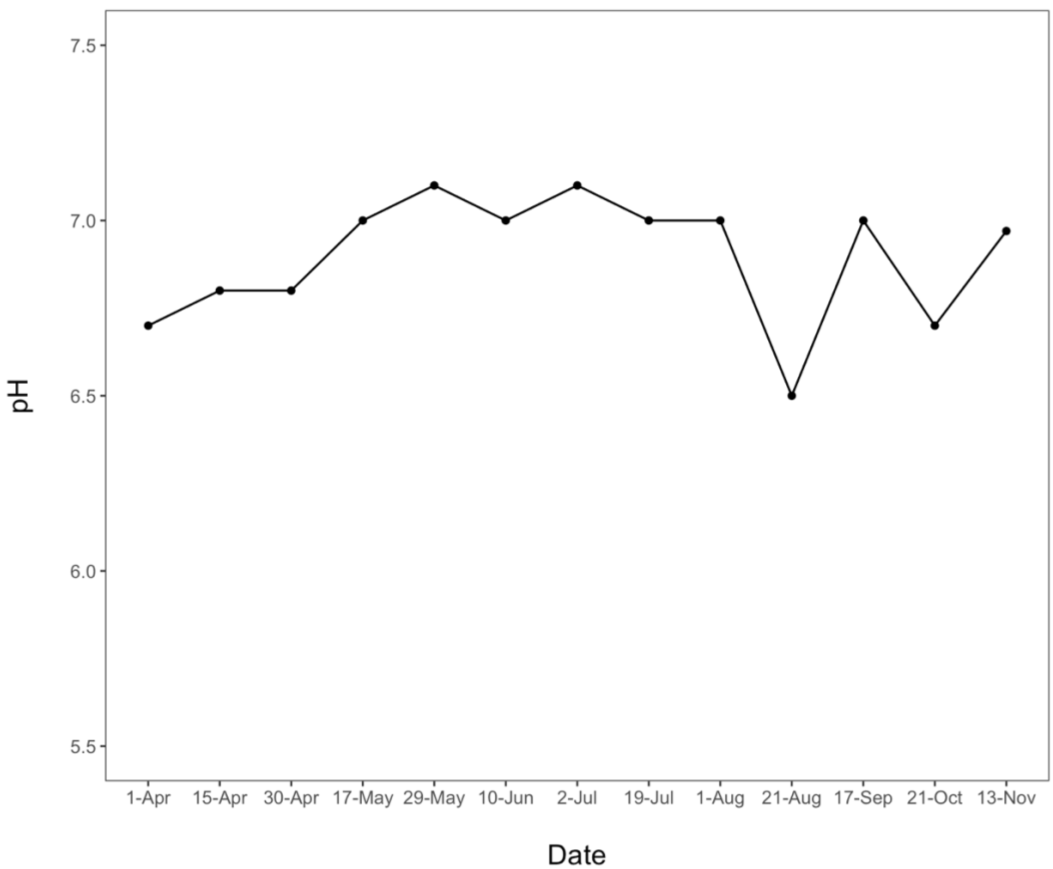

Figure 8. Change in Rogers Lake epilimnetic pH from April to November 2024.

5.4 Conductivity

Lake conductivity is the measurement of the electrical conductivity of the water. Conductivity measurements provide insights into the presence of dissolved ions, salts, pollutants, nutrients, and other substances.

Conductivity during 2024 was between 44-51 μS/cm during for the duration of the sampling period (Figure 9). These values were on average ~10 μS/cm lower than 2023. The observed fluctuations throughout the year are typical, likely the result of rainfall, temperature changes, and lake mixing. The Post lab did not measure conductivity prior to 2022.

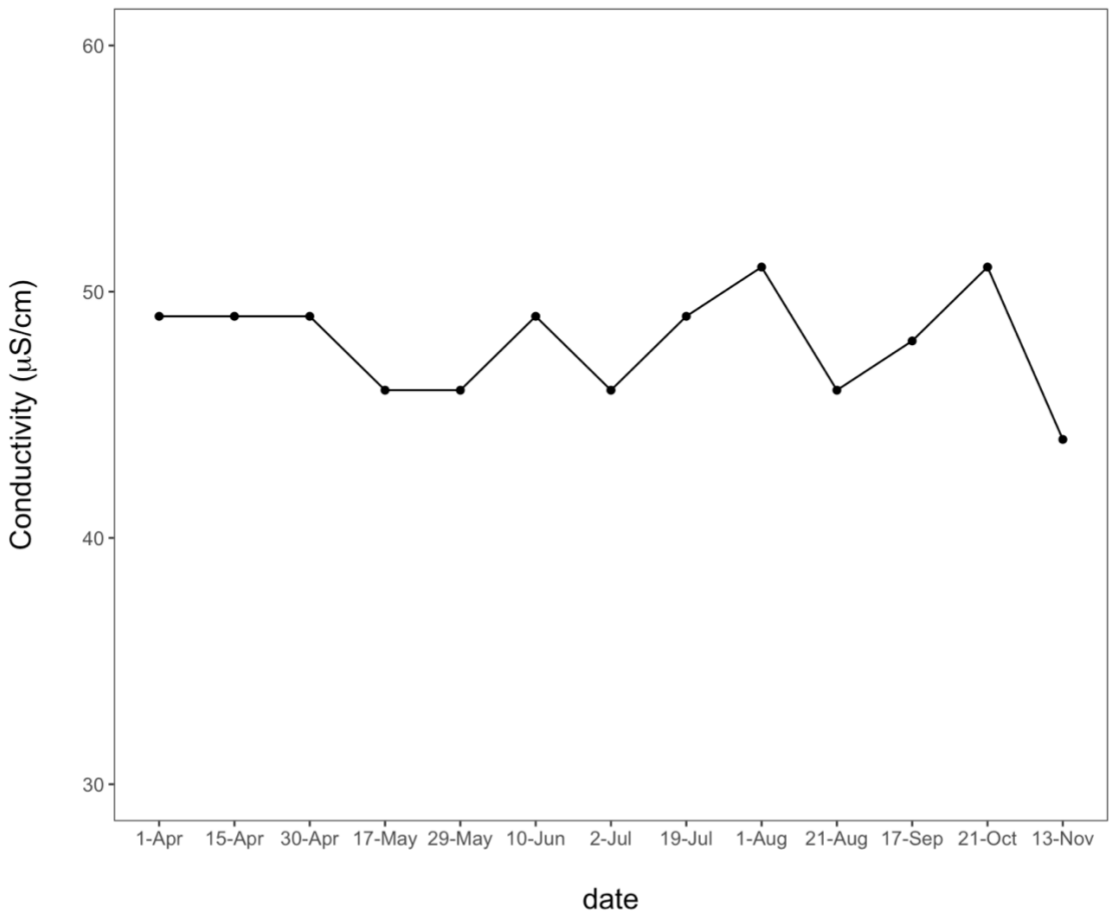

Figure 9. Change in Rogers Lake epilimnetic conductivity from April to November 2024.

5.5 Secchi Disk Transparency

The Secchi disk is a tool to measure turbidity (clarity) in bodies of water. It is used to assess overall water quality and the presence of suspended particles or algae. The secchi disk is lowered into the lake to a depth when it is no longer visible. This point is called the secchi depth, which will describe secchi disk transparency in the rest of this section. Secchi depth is measured in meters. Higher secchi depths indicate clearer water.

During the 2024 sampling period, mean annual secchi depth was 2.25 ± 0.74 m (Table 1). Mean monthly secchi depth ranged from 1.88 ± 0.18 m in May to 4.5 ± 0 m in September (Figure 10).

The 2024 mean annual secchi depth was slightly higher than recent years (2021-2023) although the long-term trend of gradual decrease in water clarity continues. (Figure 12, Appendix III, Table 3.1). Mean monthly secchi depth has decreased significantly with year in all months from April-August. (Figure 11, Appendix II, Table 2.1). Frink and Norvell (1984) found secchi depths in Rogers Lake in 1979 and 1980 were 4.0 m.[6] These findings indicate a long-term decline in water clarity over several decades.

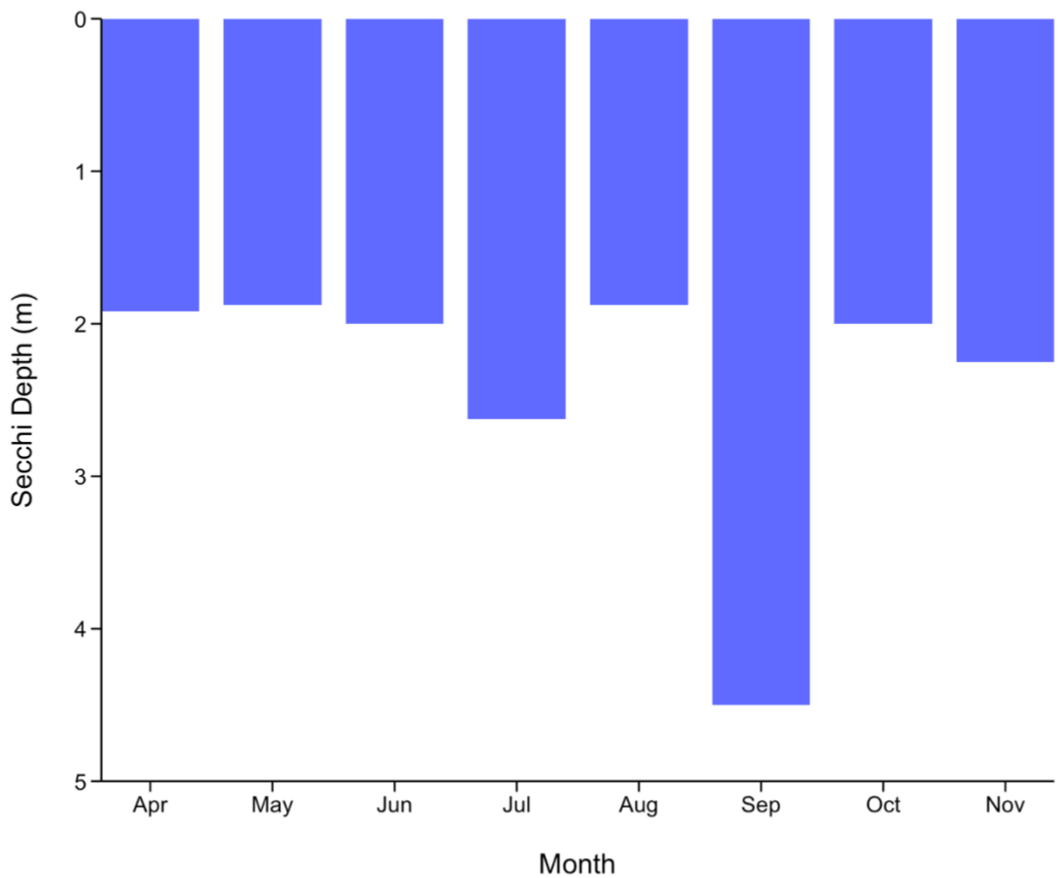

Figure 10. Mean monthly secchi depth in Rogers Lake from April to November 2024.

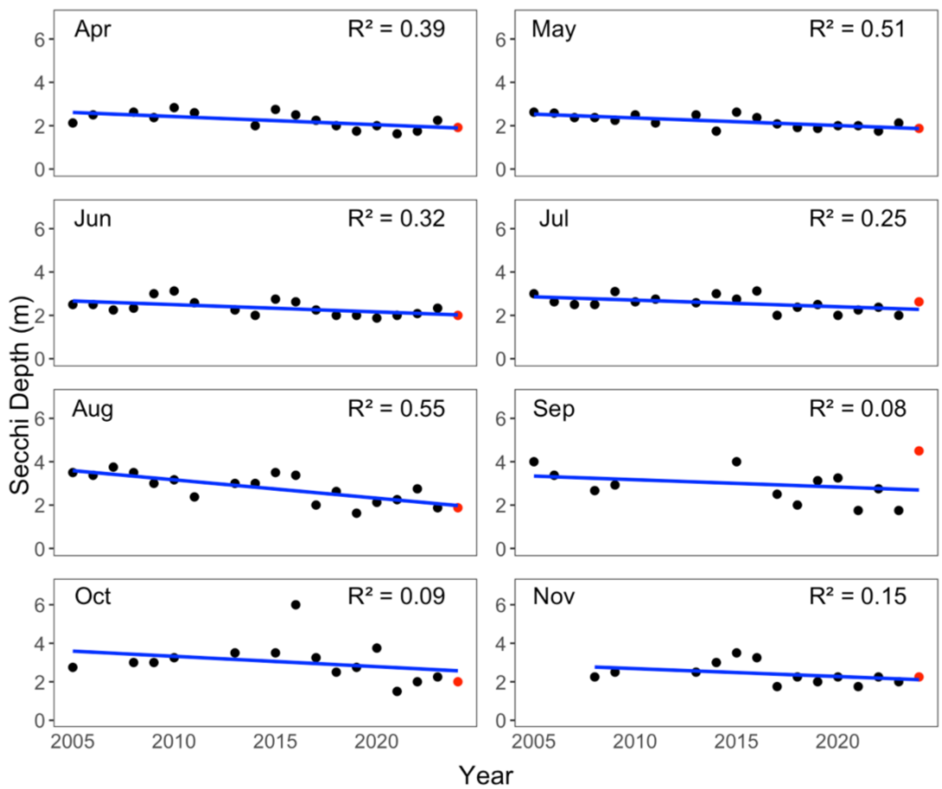

Figure 11. Mean monthly secchi depth from 2005-2024.

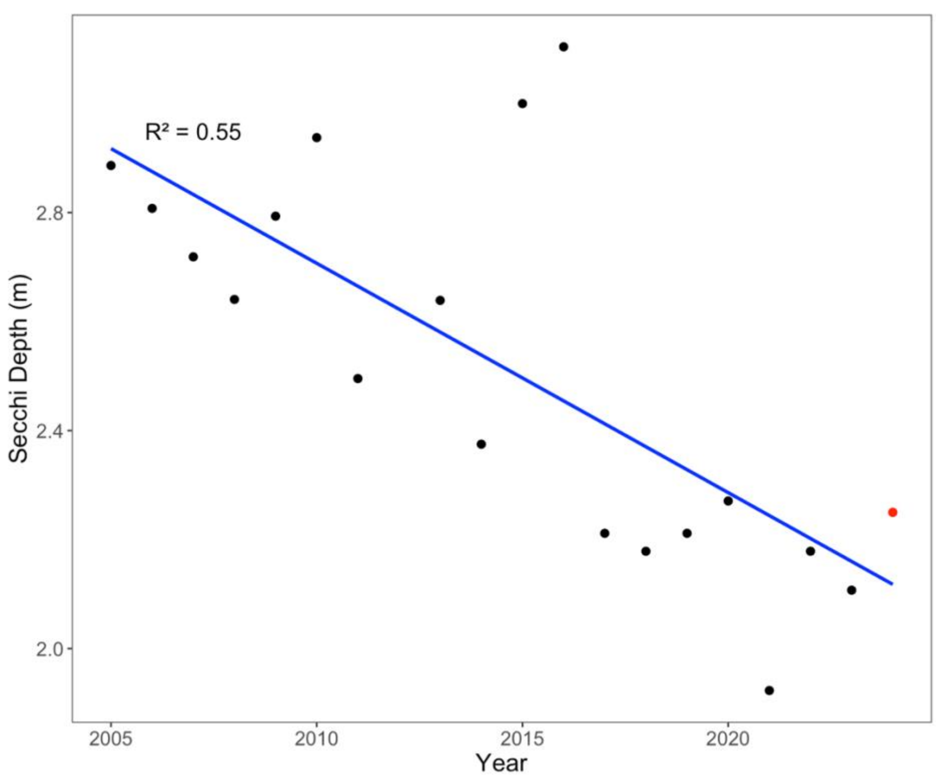

Figure 12. Mean annual secchi depth from 2005-2024.

5.6 Chlorophyll-a

Chlorophyll-a is a pigment found in aquatic plants and algae that has long been used as a standard water quality indicator in freshwater systems. Chlorophyll-a measures the amount of algal biomass present.

During the 2024 sampling period, mean annual chlorophyll-a in the epilimnion was 6.17 ± 2.92 μg/L (Table 1). Mean monthly chlorophyll-a was lowest in October at 3.29 ± 0.07 μg/L and highest in May at 9.94 ± 5.4 μg/L (Figure 13).

Mean annual chlorophyll-a for 2024 was lower than 2023 and in line with historical averages. This value is within the range of mesotrophic lakes. Chlorophyll levels in September 2024 were lower than in previous years, resulting in the loss of the previously observed statistically significant increase in mean chlorophyll for this month over time. As a result, no significant changes in mean chlorophyll levels are detected across any months (Figure 14, Appendix II, Table 2.1). Mean annual chlorophyll-a has not significantly changes with year (Figure 15, Appendix III, Table 3.1).

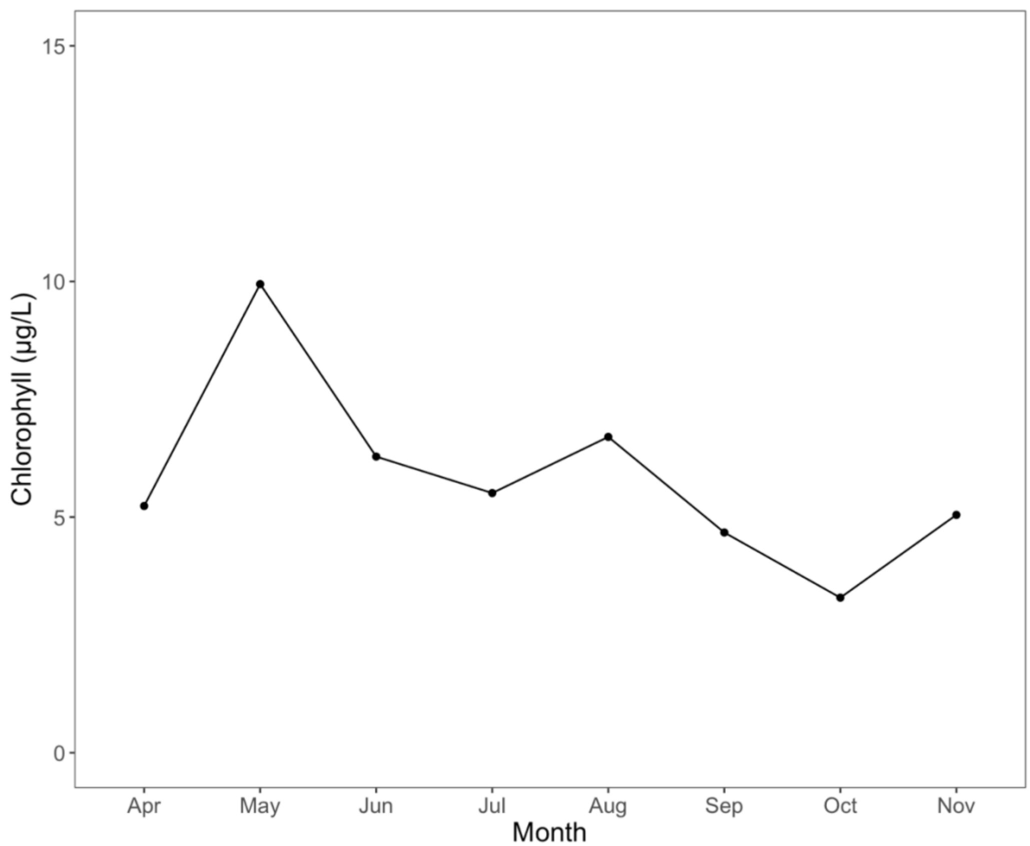

Figure 13. Mean epilimnetic chlorophyll-a (Chl) by month in Rogers Lake in 2024.

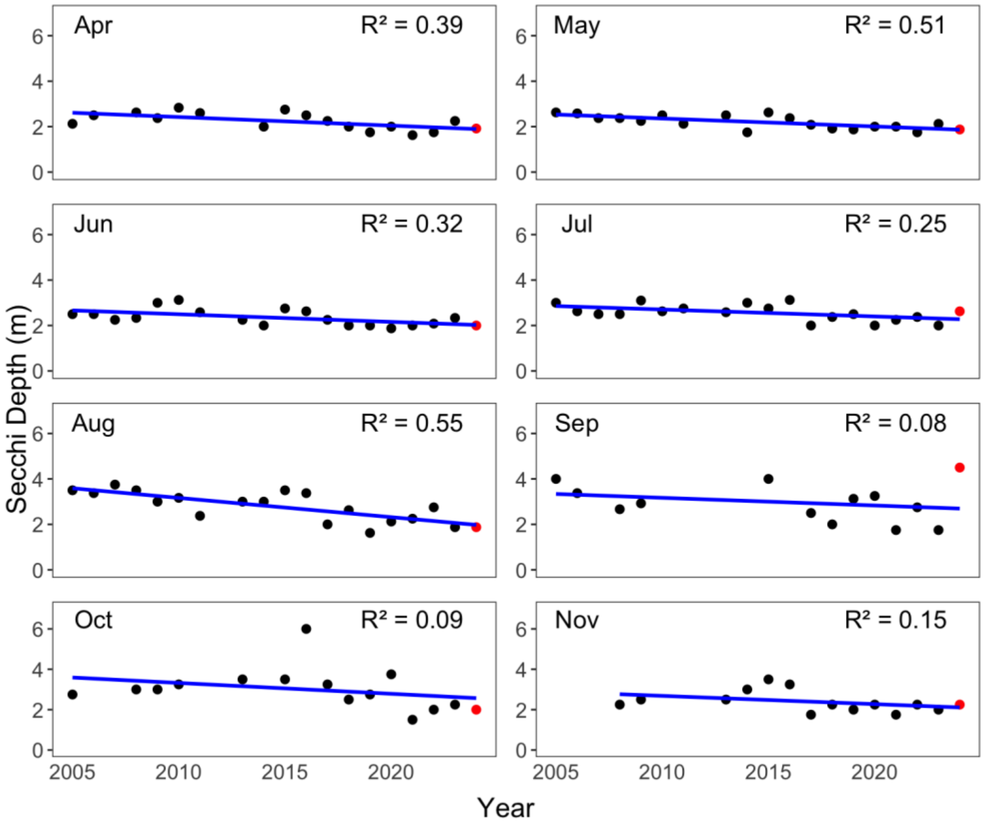

Figure 14. Mean monthly epilimnetic chlorophyll-a (Chl) from 2005-2024.

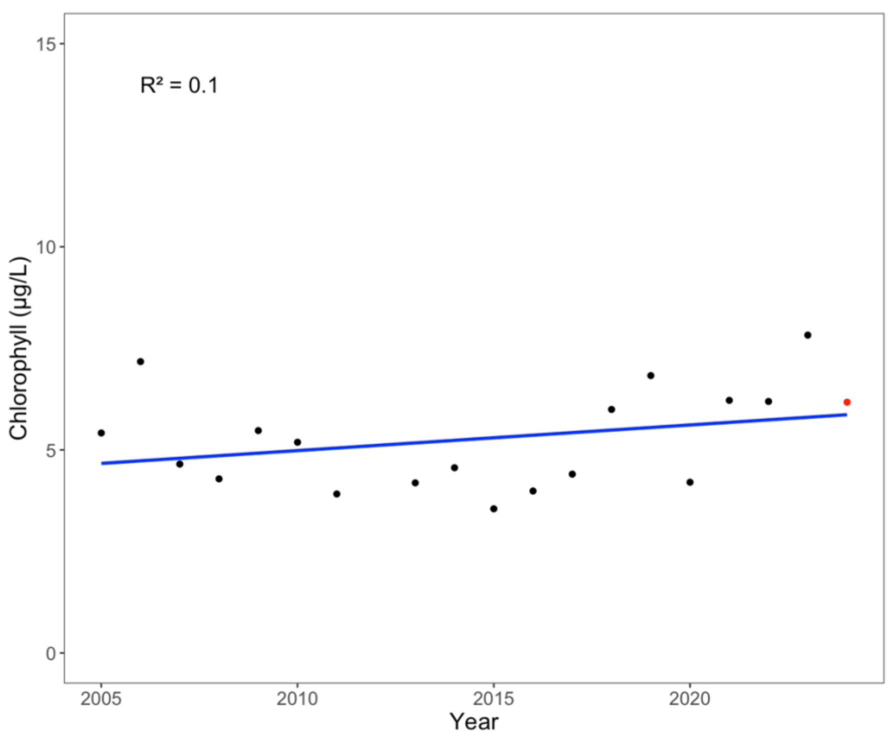

Figure 15. Mean annual epilimnetic chlorophyll-a (Chl) from 2005-2024.

5.7 Total Phosphorus and Total Nitrogen

Phosphorus and nitrogen are the primary nutrients that drive the growth of plants and algae within aquatic ecosystems, serving as essential markers for assessing the trophic status of lakes. Phosphorus acts as the predominant limiting nutrient that influences the growth of aquatic plants and algae. Total phosphorus measures all forms of phosphorus present in the water. Nitrogen is the second most important nutrient affecting aquatic plant and algal growth. Total nitrogen measures all forms of nitrogen found present in the water. Increased phosphorus and nitrogen concentrations can lead to eutrophication, algal blooms, oxygen depletion, fish kills, and can have severe effects on the ecological health of the lake.

During the 2024 sampling period, mean annual total phosphorus in the epilimnion was 15.82 ± 3.15 µg/L (Table 1). Mean monthly total phosphorus was lowest in September at 10.4 ± 0.00 µg/L and highest in May at 19.7 ± 0.58 µg/L (Figure 16).

Mean annual total phosphorus in 2024 was lower than in 2023 but was still the second highest concentration recorded since 2005. Mean monthly total phosphorus with year is increasing at a statistically significant rate for the months of July and August (Figure 17, Appendix II, Table 2.2). Mean annual total phosphorus is continuing to increase at a statistically significant rate with time (Figure 18, Appendix III, Table 3.1).

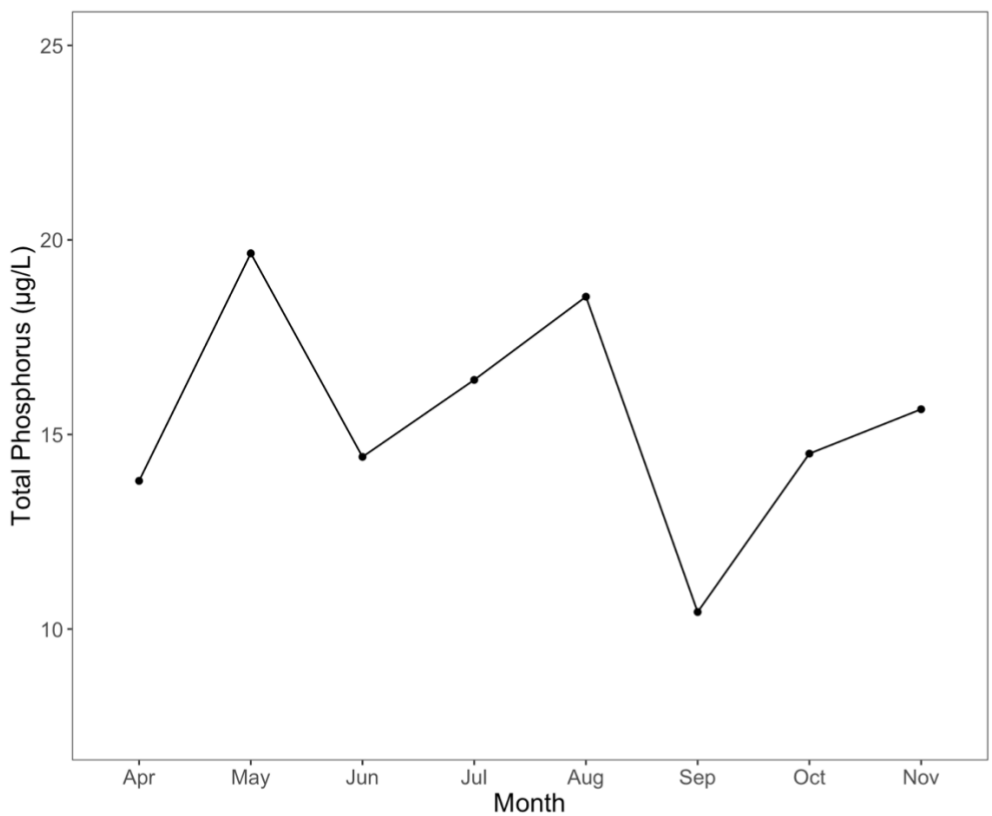

Figure 16. Mean monthly epilimnetic total phosphorus in Rogers Lake in 2024.

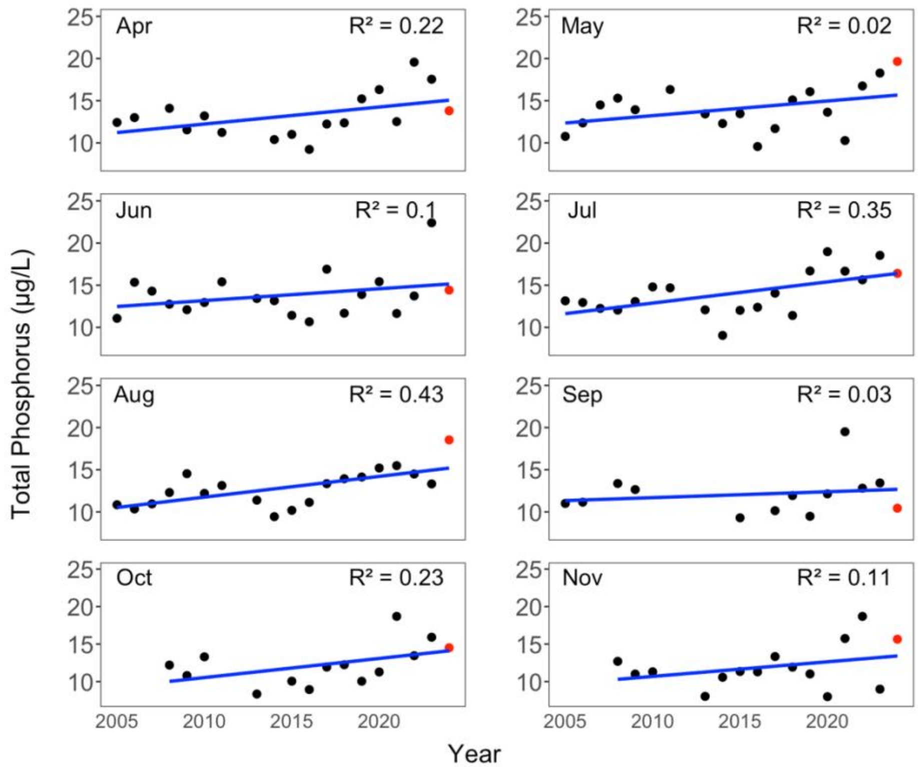

Figure 17. Mean monthly epilimnetic total phosphorus from 2005-2024.

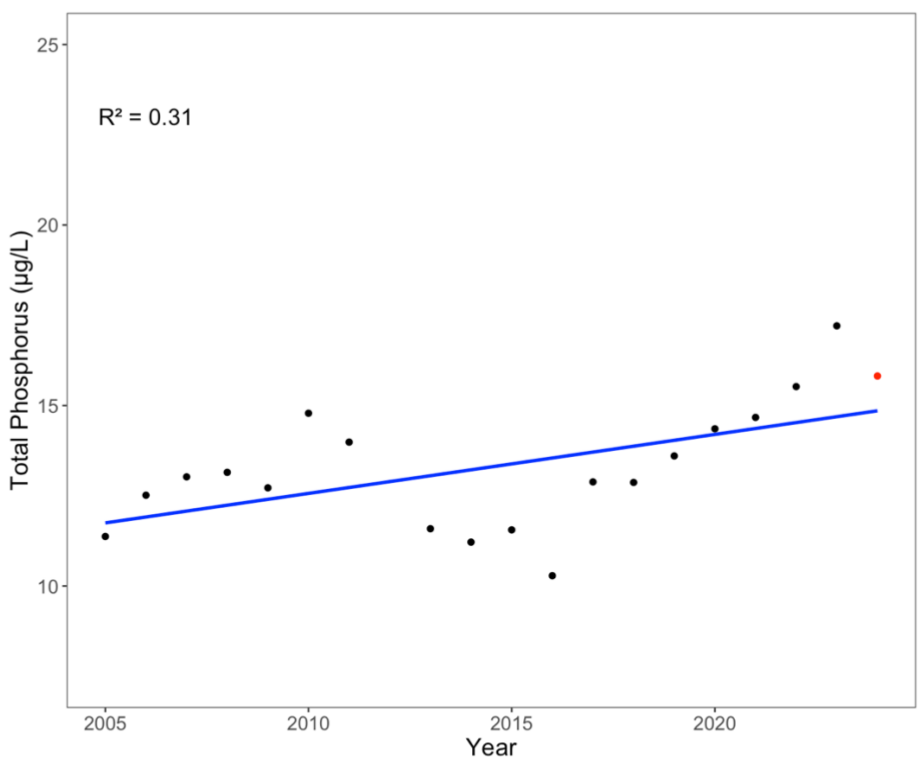

Figure 18. Mean annual epilimnetic total phosphorus from 2005-2024.

During the 2024 sampling period, mean annual total nitrogen in the epilimnion was 0.373 ± 0.08 mg/L (Table 1). Mean monthly total nitrogen was lowest in September at 0.30 ± 0.00 µg/L and highest in August at 0.45 ± 0.12 µg/L (Figure 19).

Mean annual total nitrogen in 2024 was lower than in 2023 but remained the second highest concentration recorded since 2005. Mean monthly total nitrogen has increased at a statistically significant rate with year for the months of April, May, July, August, September, and October (Figure 20, Appendix II, Table 2.2). Mean annual total nitrogen is continuing to increase at a statistically significant rate with time (Figure 21, Appendix III, Table 3.1).

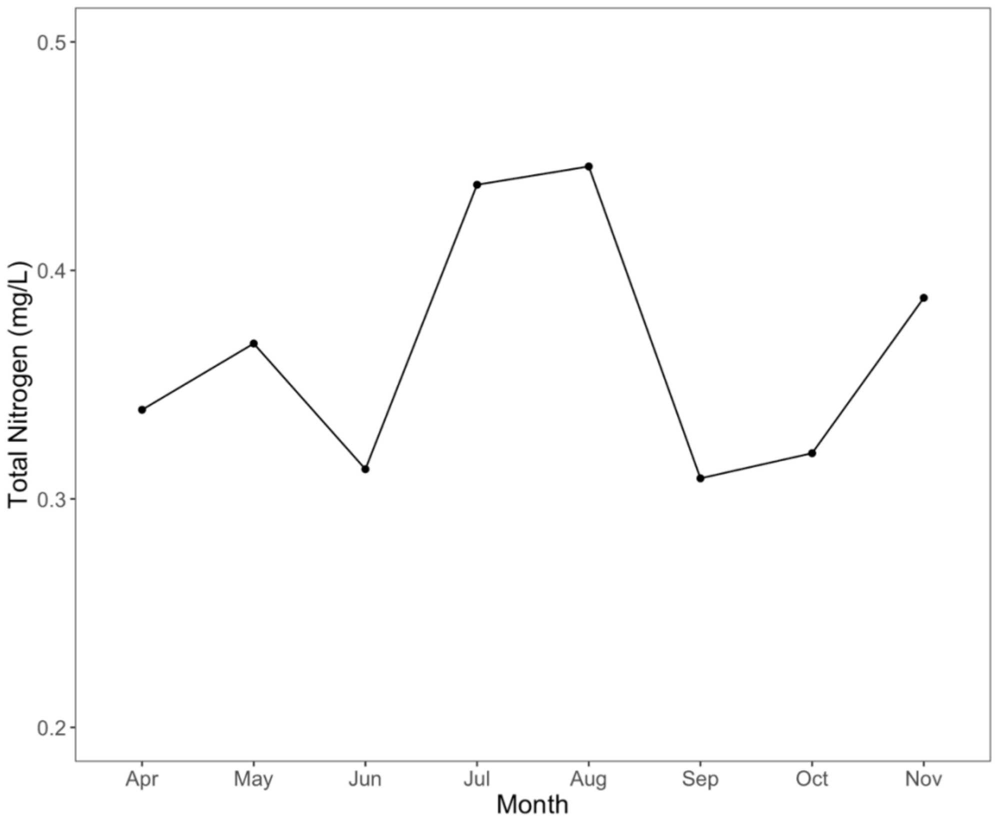

Figure 19. Mean monthly epilimnetic total nitrogen in Rogers Lake in 2024.

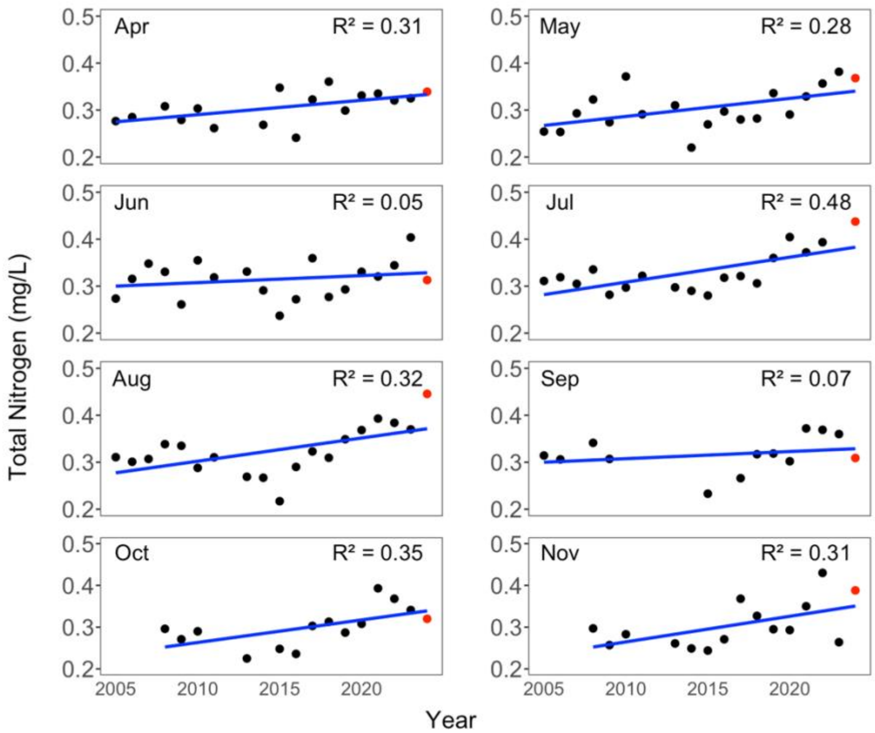

Figure 20. Mean monthly epilimnetic total nitrogen from 2005-2024.

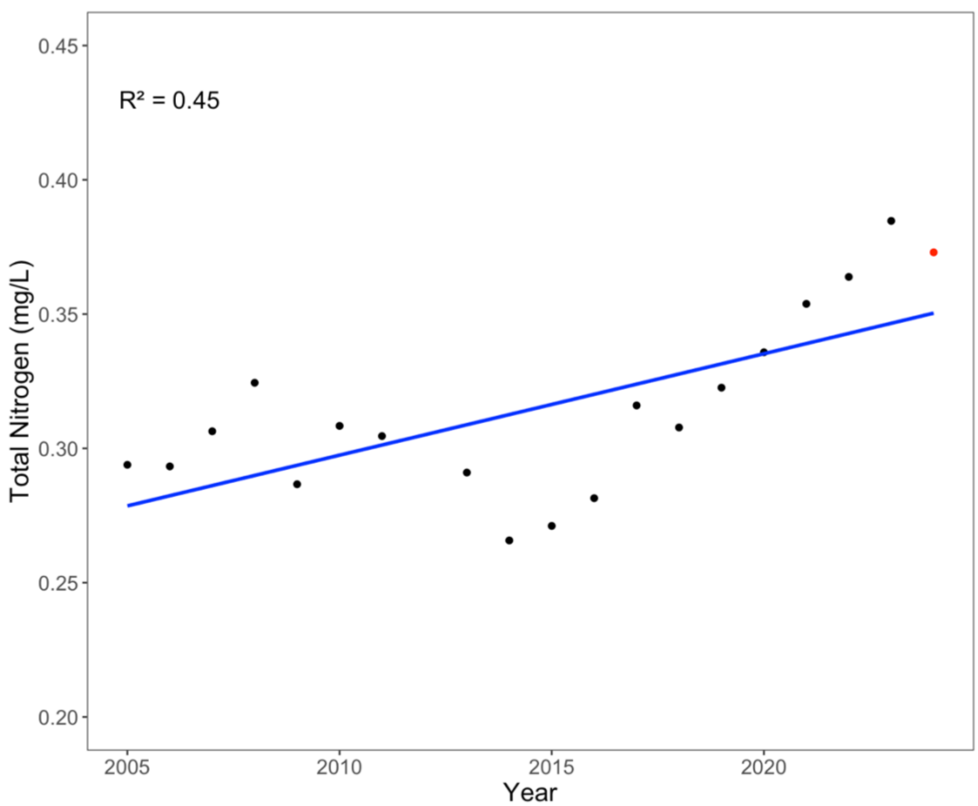

Figure 21. Mean annual epilimnetic total nitrogen from 2005-2024.

5.8 Nitrate-Nitrogen

Nitrate-Nitrogen is the nitrogen component of the nitrate anion. In water, it represents the amount of nitrogen available that is in the nitrate form. Nitrates are sources of nitrogen used by aquatic plants in freshwater ecosystems. High levels can lead to algal blooms. When these algal blooms die and the algae is decomposed by bacteria, it can cause a rapid depletion in dissolved oxygen. Nitrate-nitrogen values are typically highest in lakes during spring and fall turnover.

During the 2024 sampling period, mean annual nitrate-nitrogen in the epilimnion was 0.177 ± 0.02 mg/L (Table 1). Mean monthly nitrate-nitrogen was between 0.166 mg/L and 0.171 mg/L for all months except April when it was highest at 0.206 mg/L (Figure 22).

Mean monthly total nitrate-nitrogen and year show an increase in the month of August. There are no significant relationships with other months. (Figure 23, Appendix II, Table 2.2). There is no significant relationship between mean annual nitrate-nitrogen and year. (Figure 24, Appendix III, Table 3.1).

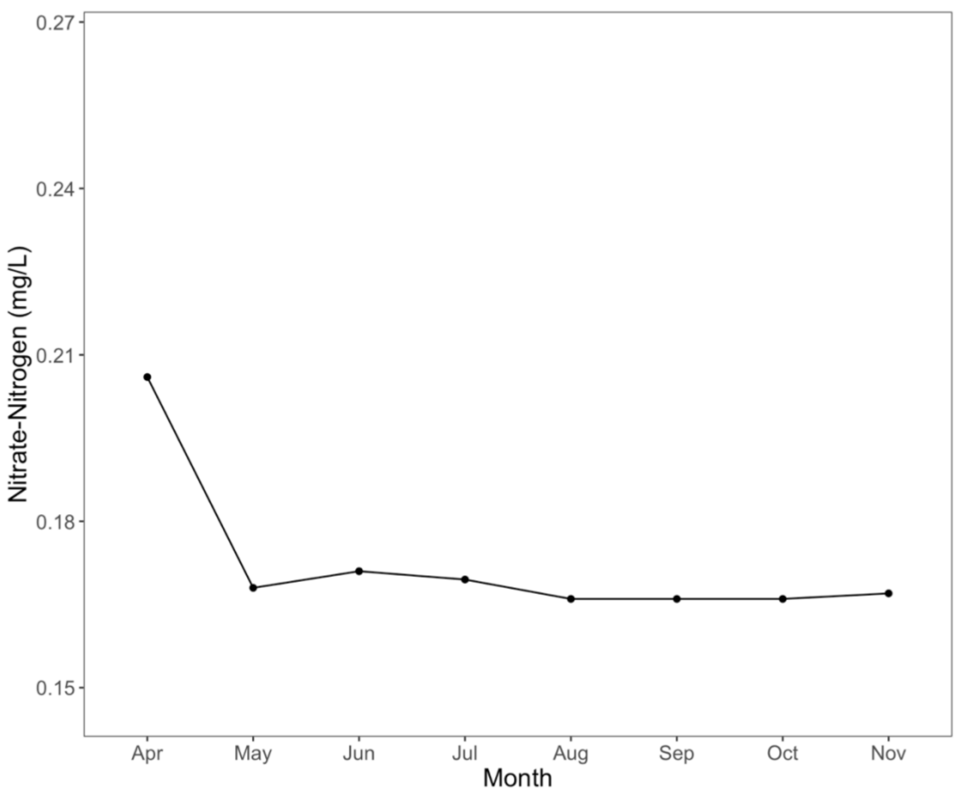

Figure 22. Mean monthly nitrate-nitrogen in 2024 in Rogers Lake.

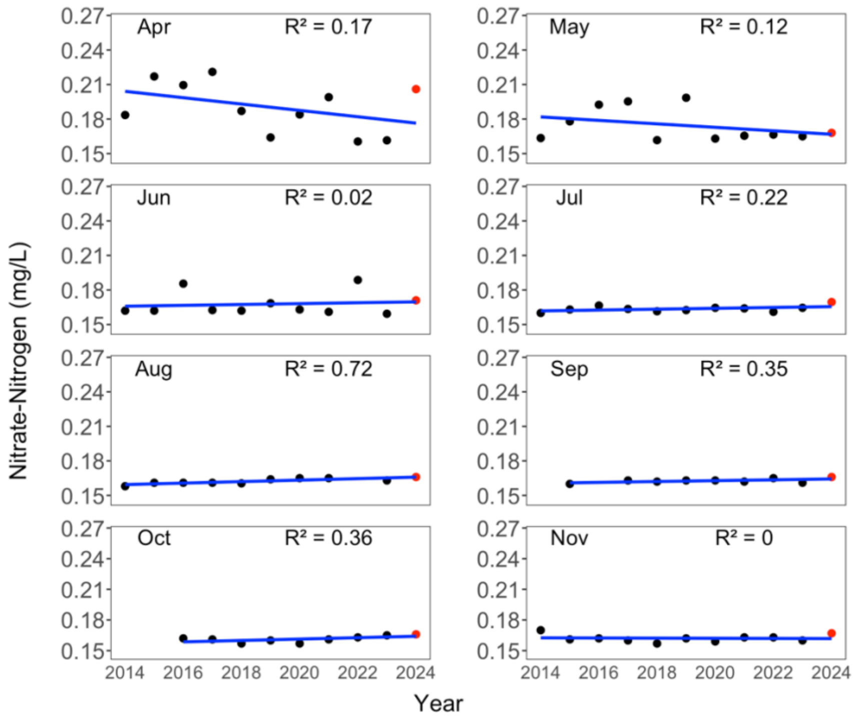

Figure 23. Mean monthly nitrate-nitrogen from 2014-2024.

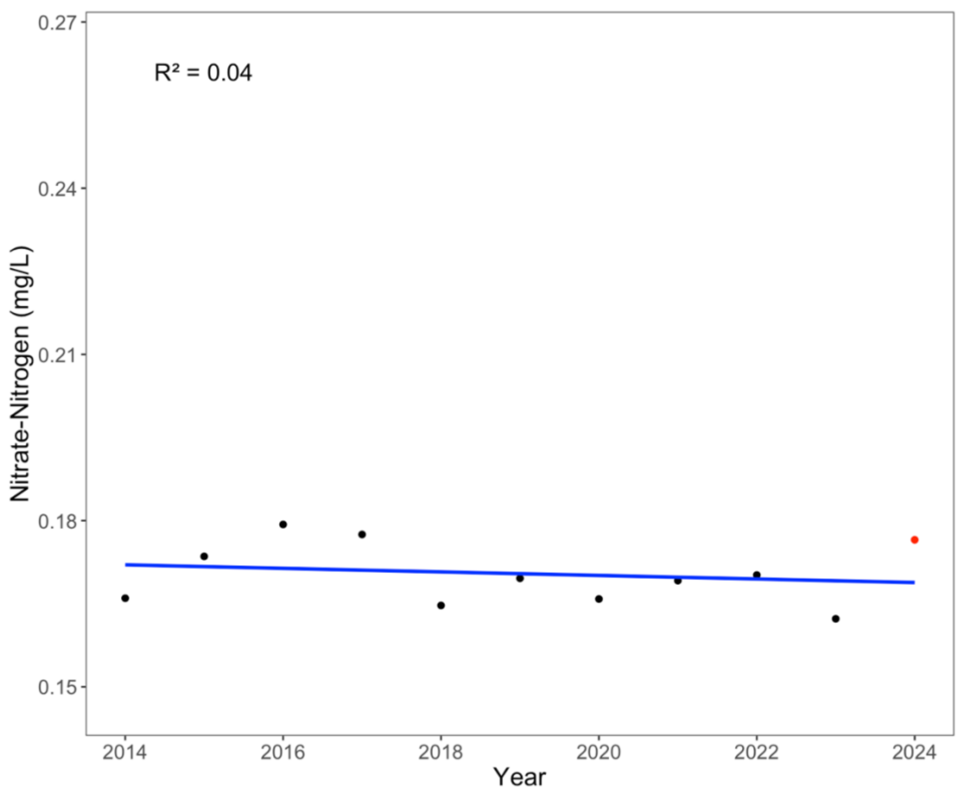

Figure 24. Mean annual nitrate-nitrogen from 2014-2024.

5.9 Fluoride

Fluoride is an anion of fluorine. It occurs naturally in rocks, soil, minerals, and is found in low concentrations in freshwater, where it can be used as a micronutrient by plants and microorganisms. High fluoride concentrations can have toxic effects on vertebrates including fish and amphibians. In freshwater lakes fluoride toxicity can begin at 0.5 mg/L.[3]

During the 2024 sampling period, mean annual fluoride in the epilimnion was 0.09 ± 0.02 mg/L (Table 5). Mean monthly fluoride ranged from 0.079 to 0.083 mg/L through the year but was highest in August at 0.135 mg/L (Figure 25).

There is no significant relationship between mean monthly fluoride with year except for the fall months of October and November showing decreases (Figure 26). Mean annual fluoride with year from 2014-2024 shows no relationship (Figure 27). Fluoride was not sampled prior to 2014. Statistical results are provided in Appendix II, Table 2.1 and Appendix III, Table 3.1.

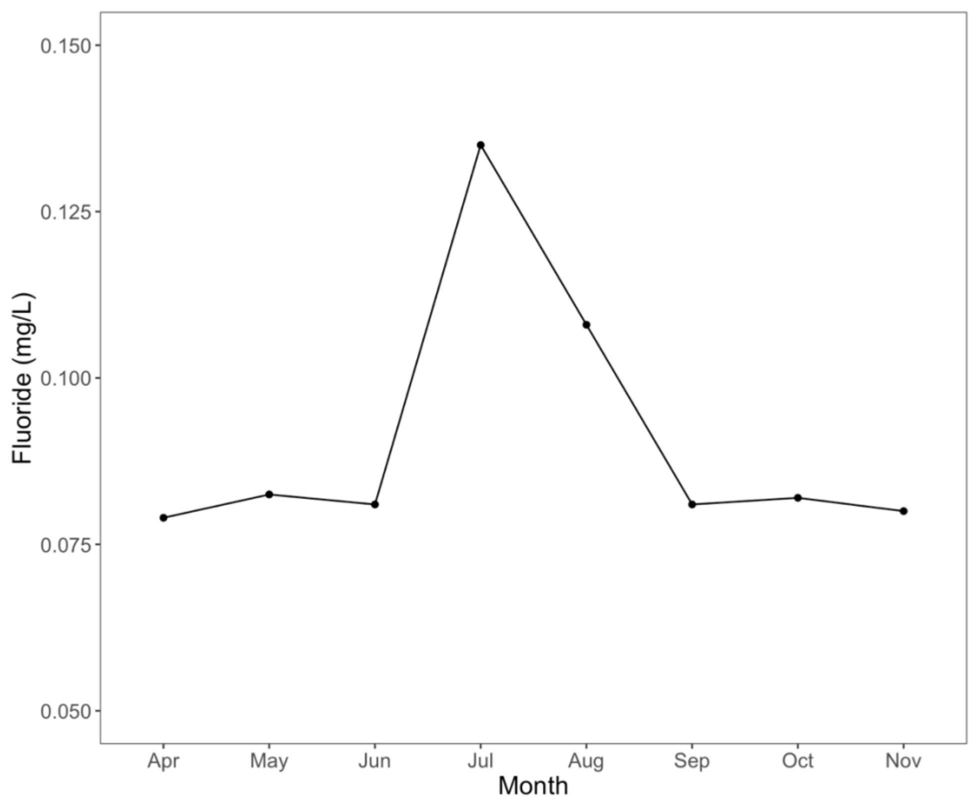

Figure 25. Mean monthly fluoride in Rogers Lake in 2024.

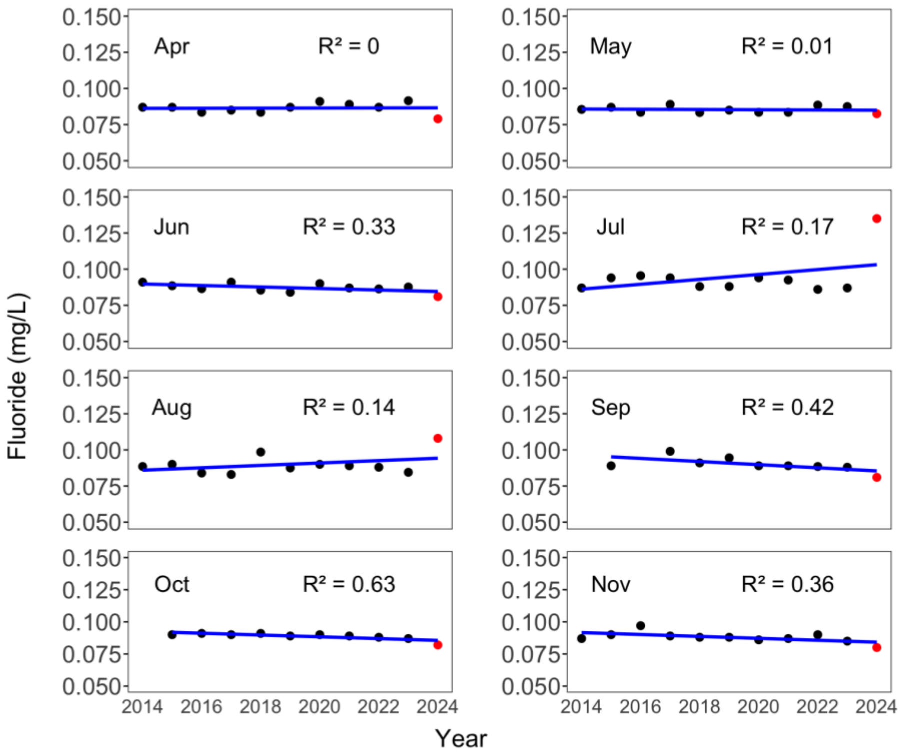

Figure 26. Mean monthly fluoride from 2014-2024.

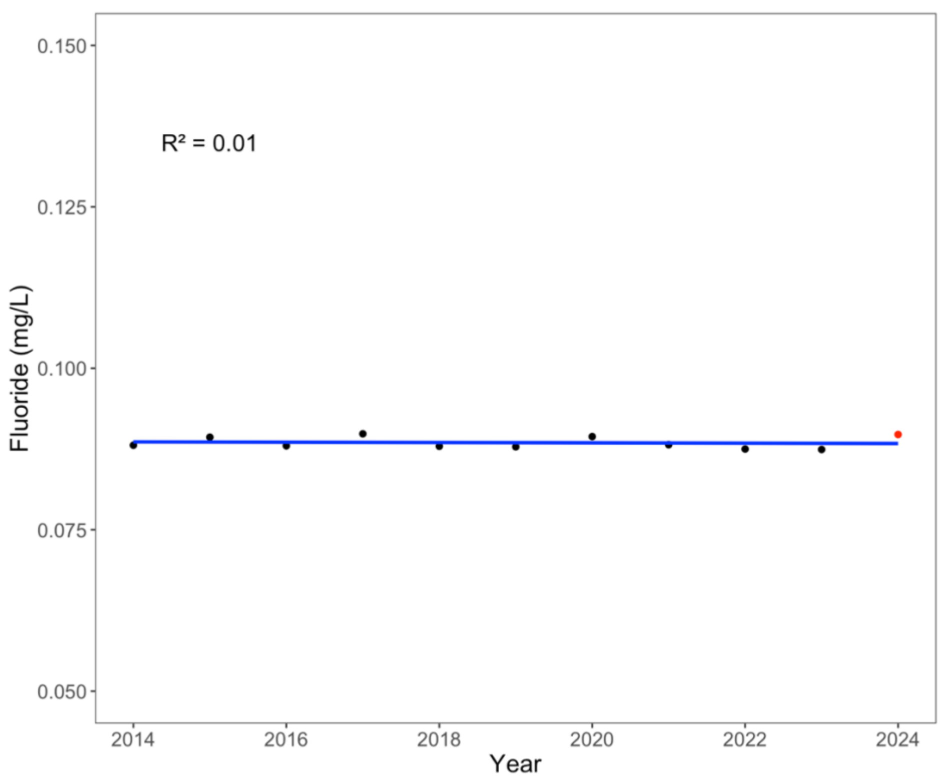

Figure 27. Mean annual fluoride from 2014-2024.

5.10 Chloride

Chloride is a chemical ion of chlorine. It is found naturally in low concentrations in freshwater. Runoff from dissolved winter road salts can cause increased chloride concentrations in lakes. Chloride above 230 mg/L for prolonged periods can be toxic to freshwater organisms.[5]

During the 2024 sampling period, mean annual chloride in the epilimnion was 6.60 ± 0.60 mg/L (Table 1). Mean monthly chloride ranged from 5.22mg/L to 7.11 mg/L through the year (Figure 28).

There is no significant relationship of mean monthly chloride with year, except for the month of May which shows a decrease (Figure 29). There is no significant relationship between mean annual chloride and year from 2014-2024. (Figure 30). Chloride was not sampled prior to 2014. Statistical results are provided in Appendix II, Table 2.1 and Appendix III, Table 3.1.

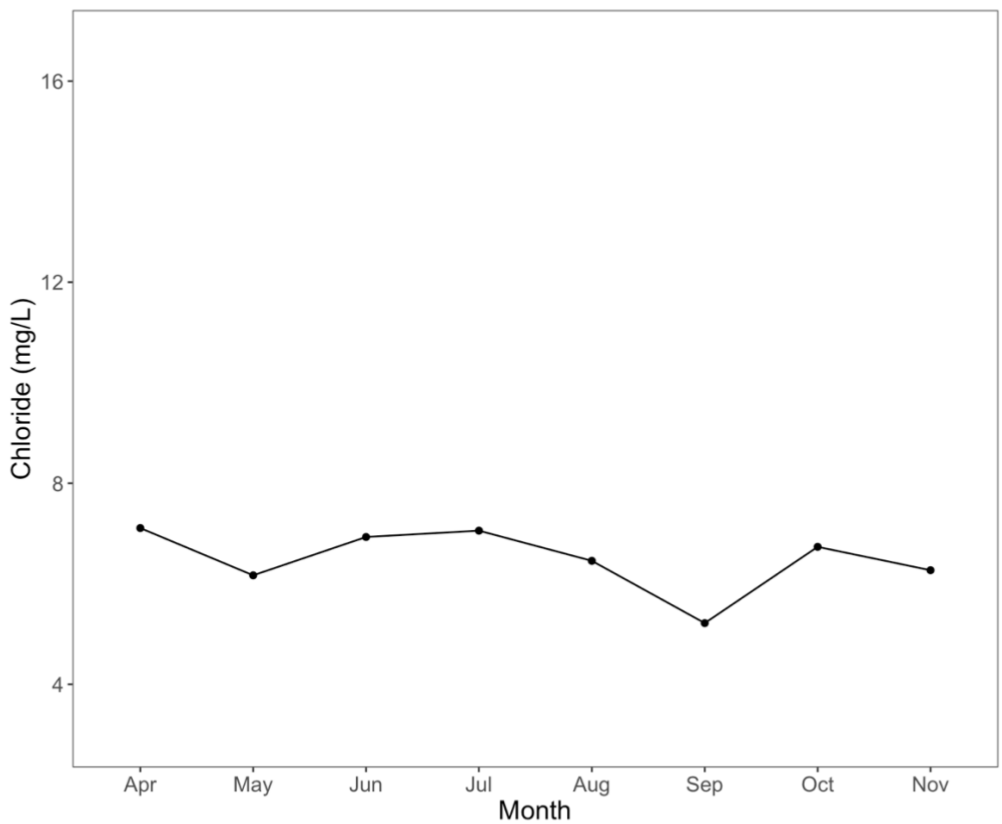

Figure 28. Mean monthly chloride in Rogers Lake in 2024.

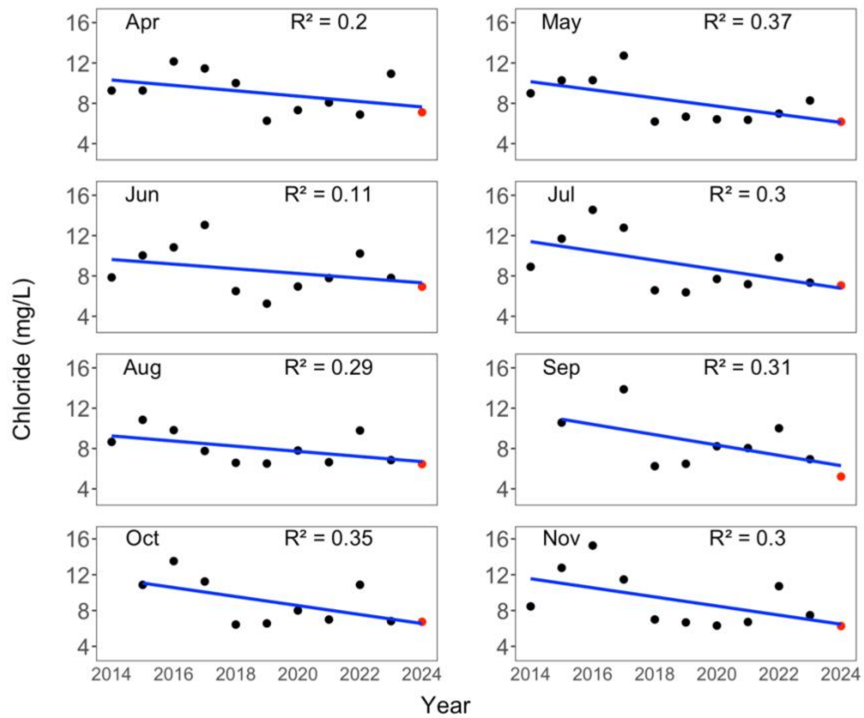

Figure 29. Mean monthly chloride from 2014-2024.

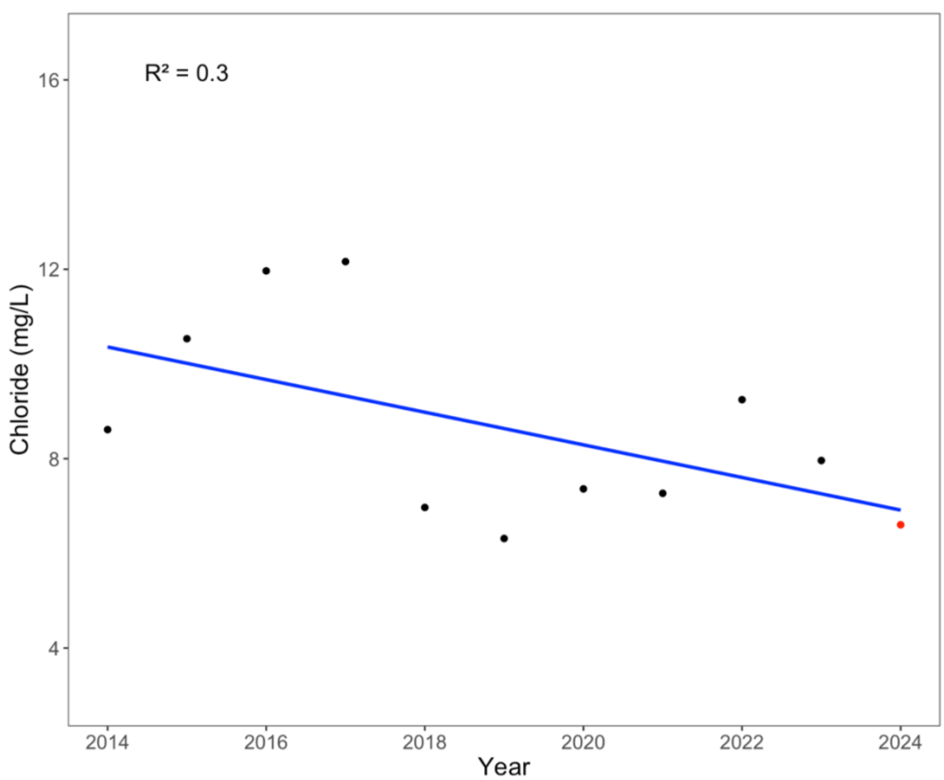

Figure 30. Mean annual chloride from 2014-2024.

5.11 Bromide

Bromide is a naturally occurring ion of bromine that is found in freshwater ecosystems, usually in very low concentrations. Its primary source in lakes is erosion of rock, but runoff from urban areas where some types of pesticides are used can cause elevated levels. Normal levels of bromide in freshwater systems are less than 0.2 mg/L.[7]

During the 2024 sampling period, mean annual bromide in the epilimnion was 0.117 ± 0.002 mg/L (Table 5). Mean monthly bromide ranged from 0.115 mg/L to 0.120 mg/L through the year (Figure 31).

There is no significant relationship between mean monthly bromide (Figure 32) or mean annual bromide with year from 2014-2024. (Figure 33). Bromide was not sampled prior to 2014. Statistical results are provided in Appendix II, Table 2.1 and Appendix III, Table 3.1.

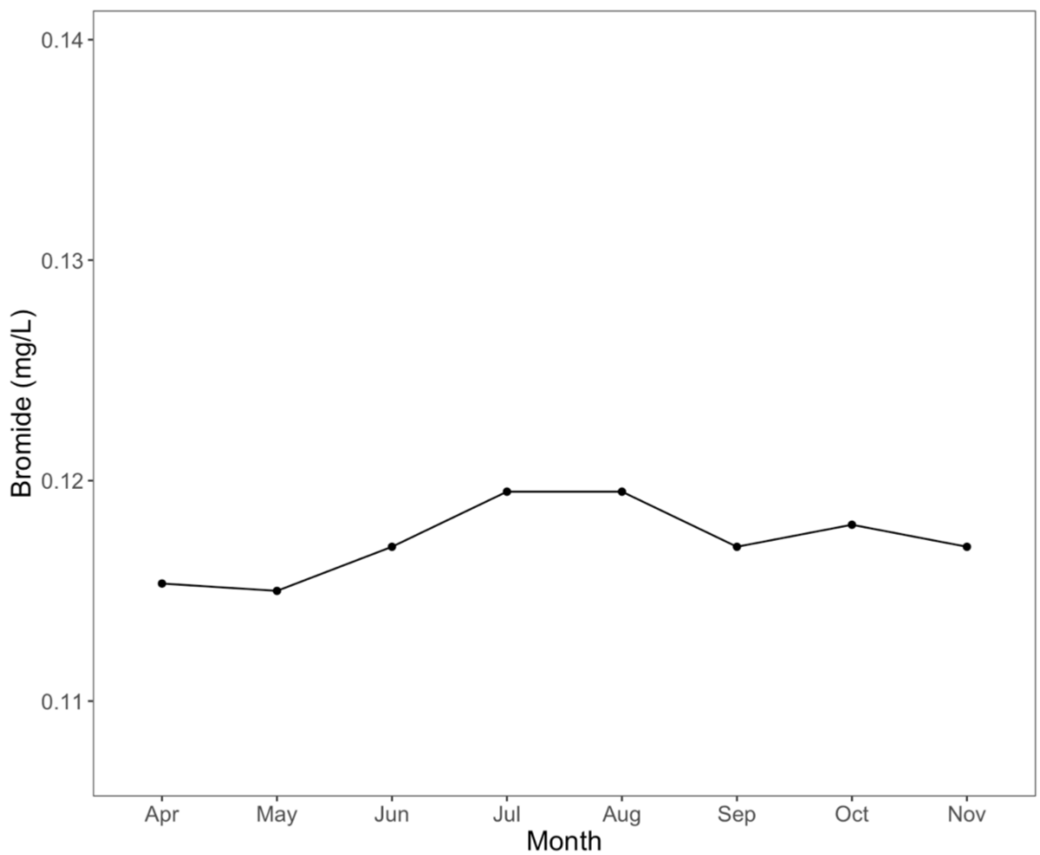

Figure 31. Mean monthly bromide in Rogers Lake in 2024.

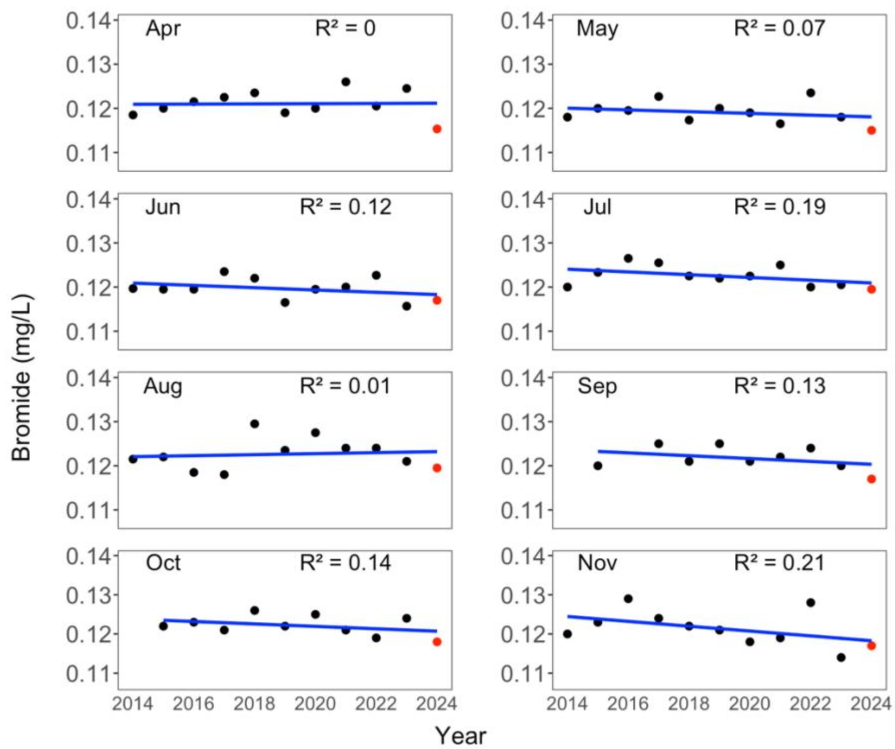

Figure 32. Mean monthly bromide from 2014-2024.

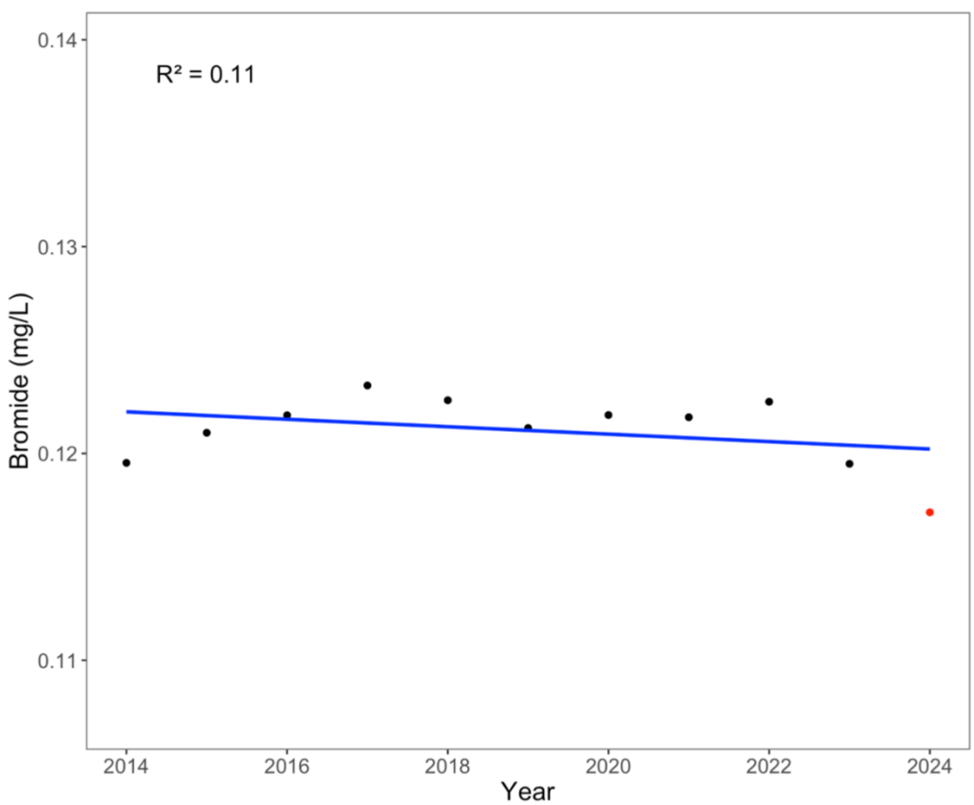

Figure 33. Mean annual bromide from 2014-2024.

5.12 Sulfate

Sulfate is a chemical ion composed of sulfur and oxygen. It occurs naturally in freshwater. High levels of sulfate are generally not toxic but can contribute to the formation of hydrogen sulfide, which can be toxic to some aquatic organisms at high levels. Typical sulfate concentrations in lakes range from 0-250 mg/L[8].

During the 2024 sampling period, mean annual sulfate in the epilimnion was 4.27 ± 0.66 mg/L (Table 5). Mean monthly sulfate ranged from 3.08 mg/L to 5.07 mg/L through the year (Figure 34).

There is no significant relationship of mean monthly sulfate and year or mean annual sulfate and year from 2014-2024. (Figures 35 and 36). Sulfate was not sampled prior to 2014. Statistical results are provided in Appendix II, Table 2.1 and Appendix III, Table 3.1.

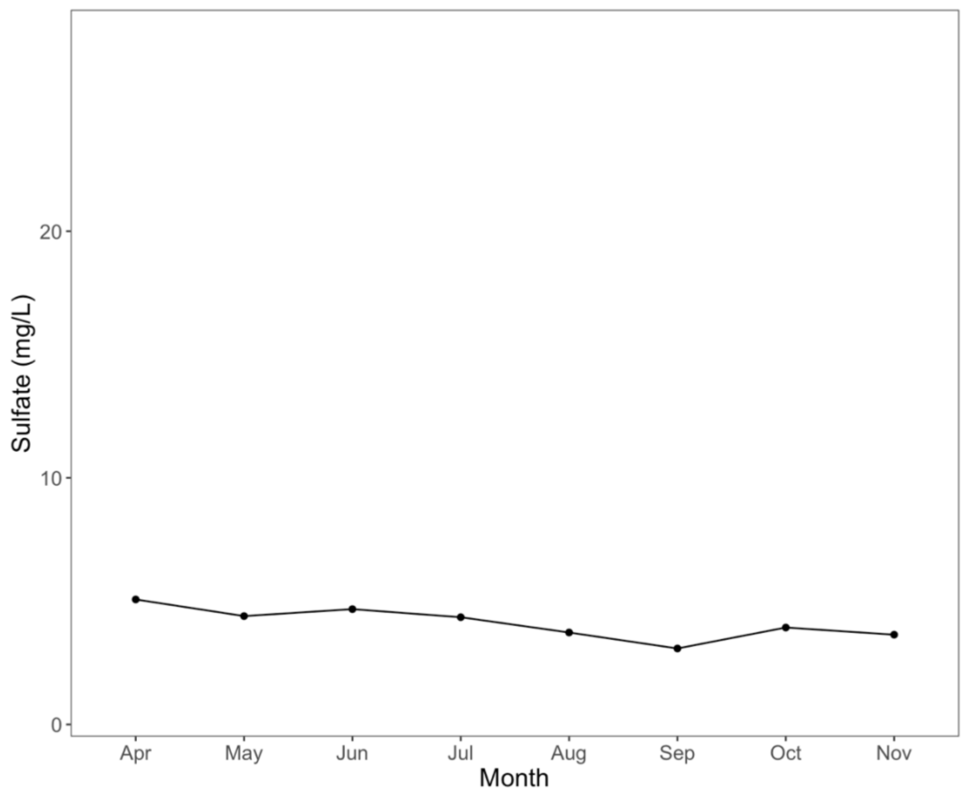

Figure 34. Mean monthly sulfate in Rogers Lake in 2024.

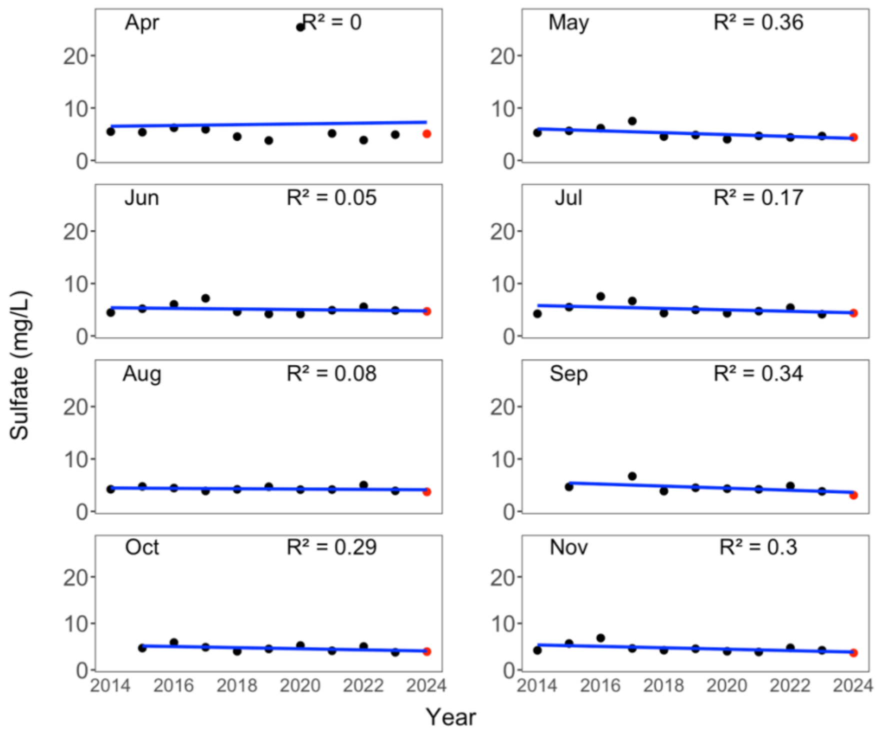

Figure 35. Mean monthly sulfate from 2014-2024.

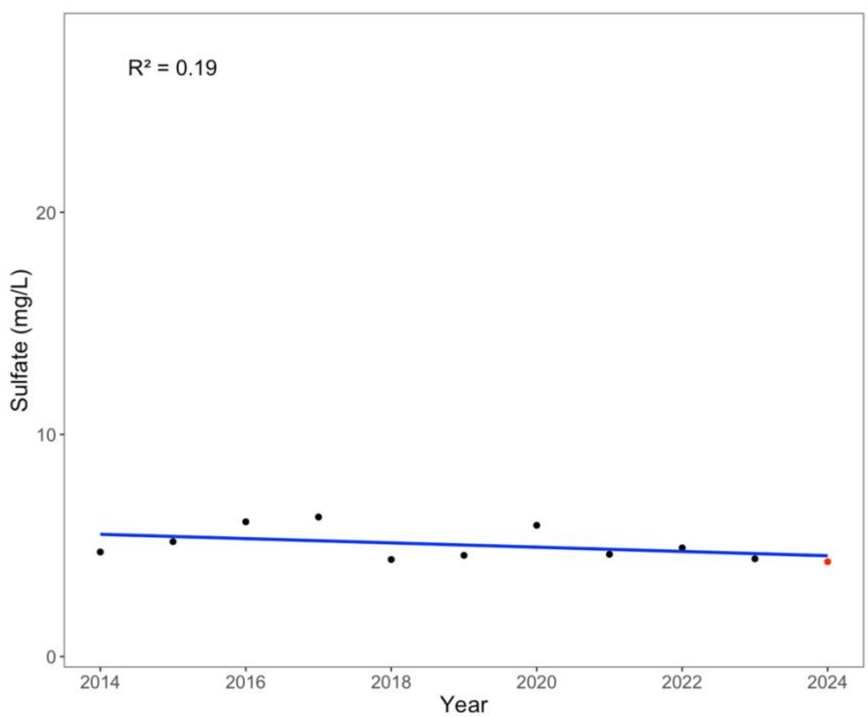

Figure 36. Mean annual sulfate from 2014-2024.

6. RESULTS SUMMARY

Rogers Lake continues to be in good ecological health and most water quality parameters measured were stable through time. Total Phosphorus and Total Nitrogen concentrations were lower than 2023 but long-term trends still show a gradual increase with year. Water clarity was clearer in 2024 than previous years but trends still show a long-term decrease with year.

The Connecticut Department of Energy and Environmental Protection (CT DEEP) has established Water Quality Standards for lake nutrients.[2] Lakes are categorized by trophic state as Oligotrophic, Mesotrophic, Eutrophic, or Highly Eutrophic based on their defining ranges of total phosphorus, total nitrogen, chlorophyll-a, and secchi depth transparency. Ranges and definitions for these lake states can be found in Tables 3 and 4. The measured values for these four parameters for Rogers Lake since 2005 all fall within the ranges of a Mesotrophic lake.

Table 5 contains the mean annual values for all water quality parameters and their trends through time. For this report, parameters that did not change *statistically* significantly with year were referred to as "stable".

Table 3. Parameters and defining ranges for the trophic state of lakes in Connecticut.[2]

Category	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)	Chlorophyll-a (µg/L)	Secchi Disk Transparency (Meters)
Oligotrophic	0-10	0-0.2	0-2	6+
Mesotrophic	10-30	0.2-0.6	2-15	2-6
Eutrophic	30-50	0.6-1.0	15-30	1-2
Highly Eutrophic	50+	1.0+	30+	0-1

Note: Defining ranges for total phosphorus and total nitrogen are for spring and summer. Chlorophyll-a and secchi disk transparency are for mid-summer.

Table 4. Definitions of each trophic lake state.[2]

Category	Definition
Oligotrophic	Water is low in plant nutrients and with low biological productivity characterized by the absence of macrophyte beds.
Mesotrophic	Water is moderately enriched with plant nutrients and with moderate biological productivity characterized by intermittent blooms of algae or small areas of macrophyte beds.

Eutrophic	Water is highly enriched with plant nutrients and with high biological productivity characterized by occasional blooms of algae or extensive areas of dense macrophyte beds.
Highly Eutrophic	Water is excessively enriched with plant nutrients and with high biological productivity, characterized by severe blooms of algae or extensive areas of dense macrophyte beds.

Table 5. Mean annual values for Rogers Lake water quality parameters for 2024, 2023, and long-term trends.

Parameter	**Mean Annual Value for 2024**	**Mean Annual Value for 2023**	**Long-term Trends**
Temperature	19.34 ± 6.24 °C	20.0 ± 5.94 °C	Stable
Dissolved Oxygen	8.9 ± 1.37 mg/L	8.49 ± 1.20 mg/L	Stable
Secchi Disk Transparency	2.25 ± 0.74 m	2.11 ± 0.23 m	Decreasing
Chlorophyll-a	6.18 ± 2.92 µg/L	7.83 ± 4.92 µg/L	Stable
Total Phosphorus	15.82 ± 3.15 µg/L	17.21 ± 4.66 µg/L	Increasing
Total Nitrogen	0.373 ± 0.08 mg/L	0.39 ± 0.11 mg/L	Increasing
Nitrate-Nitrogen	0.177 ± 0.02 mg/L	0.118 ± 0.030 mg/L	Increasing in summer
pH	6.9 ± 0.18	6.71 ± 0.26	Stable
Conductivity	47.9 ± 2.14 µS/cm	63.4 ± 4.99 µS/cm	Stable
Bromide	0.117 ± 0.002 mg/L	0.035 ± 0.002 mg/L	Stable
Chloride	6.60 ± 0.60 mg/L	7.99 ± 0.88 mg/L	Stable
Fluoride	0.089 ± 0.02 mg/L	0.076 ± 0.004 mg/L	Stable
Sulfate	4.27 ± 0.66 mg/L	4.74 ± 0.59 mg/L	Stable

7. RECOMMENDATIONS

Long-term trends indicate increasing concentrations of total phosphorus and total nitrogen in the lake, raising concerns about nutrient inputs from tributaries. In 2024, preliminary testing of tributary samples was conducted to identify potential sources of rising nutrient levels. A more comprehensive and targeted approach is recommended to better understand the extent and variability of nutrient contributions from Rogers tributary streams.

For 2025, we recommend an expanded sampling effort focused on tributaries suspected to be sources of nutrients. Samples should be collected from each tributary of interest during the following four timeframes to capture pre-, early-, late-, and post-growing season conditions:

1. **Mid-March to Early April**
2. **May to June**
3. **July to August**
4. **Late September to October**

Within each timeframe, we recommend collecting:

- **1–2 samples within 24 hours after a rainfall event of 1 inch or more** to assess storm-driven nutrient runoff.
- **1–2 samples after at least 5 consecutive days of little to no rainfall** to capture baseline nutrient levels under normal flow conditions.

Additionally, as a reminder, there are several invasive species inhabiting Rogers Lake, including: freshwater jellyfish (*Craspedacusta sowerbi*) (personal observation), Asian clam (*Corbicula fluminea*) (personal observation), curly-leaf pondweed (*Potamogeton crispus*), variable-leaf watermilfoil (*Myriophyllum heterophyllum Michx.*), and fanwort (*Cabomba caroliniana*).[1] Invasive species pose a significant threat to ecosystem health and recreational opportunities in Rogers Lake. Efforts should continue to educate the public about invasive species spread and prevention. Boat inspections should be continued and expanded to help prevent additional invasive species from entering the lake.

Continued water quality sampling of Rogers Lake is recommended to track changes and to see if trends continue.

8. REFERENCES

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Appendix I. Basic Statistics Guide

This report uses basic statistical analyses to examine how water quality parameters are changing with time. We have included a brief explanation of key statistical terms to facilitate interpretation of the results.

Linear regression

Linear regression is a way to understand and predict how one variable changes as another variable changes. It provides a simple way to understand and quantify relationships between two variables using a straight line. Linear regression is a foundational concept in statistics and data analysis, often used for making predictions and understanding patterns.

R^2

R-squared, often called the "coefficient of determination," gives an idea of how well a statistical model (like a linear regression model) fits the data points. It is a number between 0 and 1. Higher values mean the model explains more of the variation in the data, while lower values mean it explains less. Values from 0 to 0.3 represent a poor fit, 0.4 to 0.60 a moderate fit, and 0.70 to 1 a strong fit of the model to the data.

β (beta)

In linear regression, β (beta) represents the slope or the change in the dependent variable (y) for a one-unit change in the independent variable (x). It explains how much the dependent variable is expected to change when the independent variable changes by one unit, while keeping other variables constant. In simpler terms, β shows the relationship and direction of change between the variables in a straight-line equation.

p-value

A p-value helps us figure out if research results are meaningful or due to chance. A low p-value suggests real significance, while a high one implies randomness. In this report, a threshold of $p < 0.05$ was used to decide if results of the linear regression were statistically significant. It is important to remember that p-values are only one tool to explore the data. A statistically significant/insignificant result **may not always be biologically meaningful,** especially when the model fits poorly and the observed change in the variable of interest is miniscule**.**

Appendix II. Linear regression results for mean monthly values for all water quality parameters.

Table 2.1 Linear regression results of mean monthly temperature, dissolved oxygen, secchi depth, and chlorophyll-a with year.

Variable	Month	DF	F	R^2	β	p-value
Temperature	Apr	(1,15)	0.25	0.02	-0.03	0.62
	May	(1,17)	0.97	0.05	0.06	0.34
	Jun	(1,17)	1.01	0.06	0.05	0.33
	Jul	(1,17)	1.76	0.09	0.06	0.20
	Aug	(1,17)	0.68	0.04	-0.04	0.42
	Sep	(1,11)	0.08	0.01	0.02	0.78
	Oct	(1,12)	0.06	0.01	0.03	0.81
	Nov	(1,13)	0.62	0.05	0.08	0.44
Dissolved Oxygen	Apr	(1,14)	1.58	0.01	-0.03	0.23
	May	(1,17)	0.2	0.01	-0.01	0.66
	Jun	(1,17)	1.40	0.08	-0.03	0.23
	Jul	(1,17)	3.10	0.15	-0.05	0.10
	Aug	(1,17)	0.13	0.01	0.01	0.73
	Sep	(1,11)	1.4	0.11	-0.03	0.25
	Oct	(1,12)	0.29	0.02	0.02	0.60
	Nov	(1,13)	0.20	0.02	-0.02	0.66
Secchi Depth	Apr	(1,15)	9.42	0.35	-0.04	0.01*
	May	(1,17)	17.8	0.48	-0.04	<0.01*
	Jun	(1,18)	8.4	0.28	-0.03	0.01*
	Jul	(1,18)	6.14	0.21	-0.03	0.02*
	Aug	(1,18)	21.9	0.52	-0.08	< 0.01*

Variable	Month	DF	F	R^2	β	p-value
Temperature	Apr	(1,15)	0.25	0.02	-0.03	0.62
	May	(1,17)	0.97	0.05	0.06	0.34
	Jun	(1,17)	1.01	0.06	0.05	0.33
	Jul	(1,17)	1.76	0.09	0.06	0.20
	Aug	(1,17)	0.68	0.04	-0.04	0.42
	Sep	(1,11)	0.08	0.01	0.02	0.78
	Oct	(1,12)	0.06	0.01	0.03	0.81
	Nov	(1,13)	0.62	0.05	0.08	0.44
	Sep	(1,12)	1.01	0.32	-0.03	0.32
	Oct	(1,13)	1.3	0.02	-0.06	0.28
	Nov	(1,12)	2.07	0.08	-0.04	0.18
Chlorophyll-a	Apr	(1,15)	0.18	<0.01	-0.03	0.68
	May	(1,17)	1.45	<0.01	0.09	0.24
	Jun	(1,18)	<0.01	<0.01	<0.01	0.97
	Jul	(1,18)	0.77	<0.01	0.07	0.39
	Aug	(1,18)	2.13	<0.01	0.12	0.16
	Sep	(1,12)	3.14	<0.01	0.19	0.10
	Oct	(1,11)	1.09	<0.01	0.14	0.32
	Nov	(1,13)	1.00	<0.01	0.06	0.34

* designates statistically significant results.

Table 2.2 Linear regression results of mean monthly nitrate-nitrogen, total nitrogen, and total phosphorus with year.

Variable	Month	DF	F	R^2	β	p-value
Nitrate-Nitrogen	Apr	(1,9)	1.88	0.17	<0.01	0.20
	May	(1,9)	1.26	0.12	<0.01	0.29
	Jun	(1,9)	0.19	0.02	<0.01	0.72
	Jul	(1,9)	2.49	0.22	<0.01	0.15
	Aug	(1,9)	20.73	0.72	<0.01	<0.01*
	Sep	(1,7)	3.77	0.35	<0.01	0.09
	Oct	(1,8)	3.93	0.36	<0.01	0.09
	Nov	(1,8)	0.04	0.00	<0.01	0.85
Total Nitrogen	Apr	(1,15)	6.8	0.31	<0.01	0.02*
	May	(1,17)	6.5	0.28	<0.01	0.02*
	Jun	(1,17)	1.03	0.05	<0.01	0.36
	Jul	(1,16)	15.8	0.48	0.01	<0.01*
	Aug	(1,17)	8.14	0.32	<0.01	0.01*
	Sep	(1,11)	0.80	0.07	<0.01	0.39
	Oct	(1,12)	6.60	0.36	<0.01	0.03*
	Nov	(1,13)	5.86	0.31	<0.01	0.03*
Total Phosphorus	Apr	(1,15)	4.12	0.22	0.20	0.06
	May	(1,17)	0.33	0.02	0.09	0.58
	Jun	(1,17)	1.90	0.10	0.14	0.19
	Jul	(1,17)	8.97	0.25	0.34	<0.01*
	Aug	(1,17)	12.92	0.43	0.25	<0.01*
	Sep	(1,11)	0.36	0.03	0.07	0.55

	Oct	(1,12)	3.14	0.22	0.25	0.09
	Nov	(1,13)	1.67	0.11	0.19	0.22

* designates statistically significant results

Table 2.3 Linear regression results of mean monthly chloride, bromide, fluoride, and sulfate with year..

Variable	Month	DF	F	R^2	β	p-value
Chloride	Apr	(1,9)	2.19	0.20	<0.01	0.17
	May	(1,9)	5.36	0.37	<0.01	0.05*
	Jun	(1,9)	1.14	0.11	<0.01	0.31
	Jul	(1,9)	3.95	0.31	<0.01	0.08
	Aug	(1,9)	3.65	0.29	<0.01	0.09
	Sep	(1,7)	3.17	0.31	<0.01	0.12
	Oct	(1,8)	4.29	0.35	<0.01	0.07
	Nov	(1,8)	3.88	0.30	<0.01	0.08
Bromide	Apr	(1,9)	0.01	0.01	<0.01	0.94
	May	(1,9)	0.65	0.07	<0.01	0.44
	Jun	(1,9)	1.22	0.12	<0.01	0.30
	Jul	(1,9)	2.05	0.19	<0.01	0.19
	Aug	(1,9)	0.1	0.01	<0.01	0.76
	Sep	(1,7)	1.04	0.13	<0.01	0.34
	Oct	(1,8)	1.29	0.14	<0.01	0.29
	Nov	(1,8)	2.33	0.21	<0.01	0.16
	Apr	(1,9)	0.01	0.00	<0.01	0.92
	May	(1,9)	0.12	0.01	<0.01	0.74
	Jun	(1,9)	4.37	0.33	<0.01	0.07

Fluoride	Jul	(1,9)	1.78	0.17	<0.01	0.22
	Aug	(1,9)	1.51	0.14	<0.01	0.25
	Sep	(1,7)	5.07	0.42	<0.01	0.06
	Oct	(1,8)	13.4	0.63	<0.01	0.01*
	Nov	(1,9)	5.1	0.36	<0.01	0.05*
Sulfate	Apr	(1,9)	0.01	0.00	0.08	0.91
	May	(1,9)	4.97	0.36	<0.01	0.06
	Jun	(1,9)	0.47	0.05	<0.01	0.51
	Jul	(1,9)	1.84	0.17	<0.01	0.21
	Aug	(1,9)	0.73	0.08	<0.01	0.41
	Sep	(1,7)	3.55	0.34	<0.01	0.10
	Oct	(1,8)	3.26	0.29	<0.01	0.11
	Nov	(1,9)	3.82	0.30	<0.01	0.08

* designates statistically significant results

Appendix III. Linear regressions of mean annual values for all water quality parameters.

Table 3.1 Linear regression results of all mean annual values for water quality parameters with year.

Variable	**DF**	**F**	**R^2**	**β**	**p-value**
Temperature	(1,17)	0.11	0.01	<0.01	0.74
Dissolved Oxygen	(1,17)	0.31	0.02	<0.01	0.59
Secchi Depth	(1,18)	22.0	0.53	<0.01	<0.01*
Chlorophyll-a	(1,18)	1.9	0.06	0.10	0.18
Nitrate-Nitrogen	(1,9)	0.33	0.04	<0.01	0.58
Total Nitrogen	(1,17)	14.1	0.45	<0.01	<0.01*
Total Phosphorus	(1,17)	7.62	0.24	0.31	0.01*
Bromide	(1,9)	1.17	0.11	<0.01	0.31
Chloride	(1,9)	3.83	0.30	<0.01	0.08
Fluoride	(1,9)	0.07	0.01	<0.01	0.80
Sulfate	(1,9)	2.12	0.19	<0.01	0.18

* designates statistically significant results.