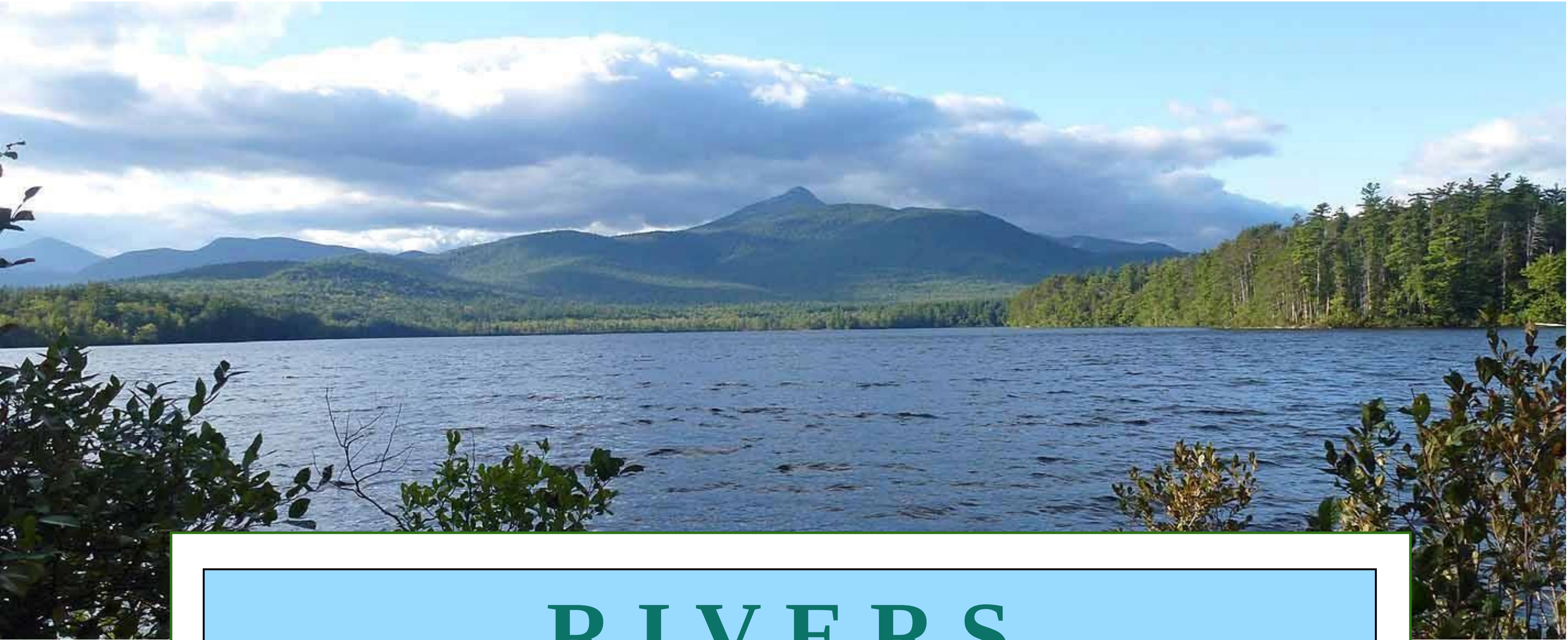
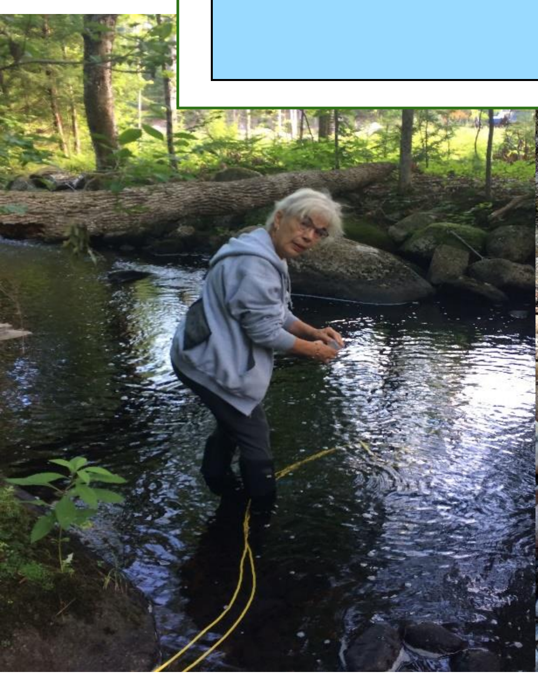


R.I.V.E.R.S.

(Regional Interstate Volunteers for the Ecosystems and Rivers of Saco)

15+ Year Water Quality Report 2002-2019



Prepared by:

GREEN MOUNTAIN CONSERVATION GROUP

Green Mountain Conservation Group

15^{+} Year Water Quality Report for the R.I.V.E.R.S. project (Regional Interstate Volunteers for the Ecosystems and Rivers of Saco)

Prepared by Trent Millum, Sarah Goldsmith, Victoria Green, and Jill Emerson of Green Mountain Conservation Group

July 2021

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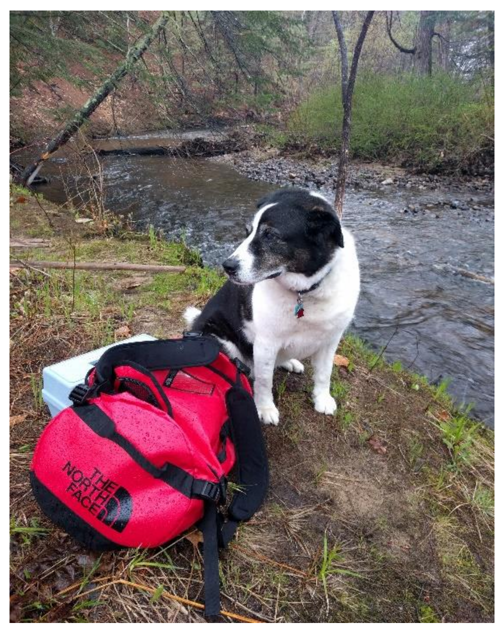

Sadie: a wonderful and dedicated RIVERS sampling partner

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- Camp Calumet: Adam Fales
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Executive Summary

Clean water is vital to New Hampshire's communities and economy, particularly in the Ossipee Watershed where pristine streams and clear lakes are abundant and feed into the state's largest stratified drift aquifer. This aquifer provides drinking water for many of New Hampshire's residents. Directly connected to the groundwater is the health of the watershed's surface water which impacts the quality of the drinking water downstream as well. Water knows no boundaries; it flows and cuts through towns, states, and even country borders, making it a resource that is shared between many different people. Streams and rivers are also home to a wide array of valuable and important aquatic organisms that depend on clean and healthy water to survive. The threat of encroaching land development and increasing population has a direct impact on how the water quality changes over time, making long-term water quality monitoring projects vital in the Ossipee Watershed.

The 15-year water quality analysis provides valuable information to help protect the water resources in the Ossipee Watershed. (Photo: GMCG)

The Regional Interstate Volunteers for the Ecosystems and River of Saco (RIVERS) program, created by Green Mountain Conservation Group (GMCG) in New Hampshire and Saco River Corridor Commission (SRCC) in Maine, is designed to be one water quality monitoring program under a single Quality Assurance Project Plan (QAPP). It encompasses one watershed, two states, and twenty-six towns. One of the goals of the program is to provide the public with volunteer-collected, baseline data that give an overall picture of water quality in the watershed. GMCG volunteers have collected water quality information regularly (up to eighteen physical and chemical parameters) from 29 Ossipee Watershed tributary sites biweekly from May to October, and 10 of those sites monthly from November to April. This report showcases an overview of the trends in each water quality parameter at each of the RIVERS sites monitored by GMCG since 2002.

This report provides surface water quality information, analyses, and recommendations for towns within the Ossipee Watershed, including Effingham, Freedom, Madison, Ossipee, Sandwich, Tamworth, and Eaton. Results are based on data collected from 2002 to 2019 through the GMCG RIVERS Watershed Monitoring Program. The data presented include four physical parameters (pH, water temperature, turbidity, and specific conductance) and fifteen chemical parameters (dissolved oxygen, total phosphorus, phosphate, total dissolved nitrogen, nitrate, ammonium, dissolved organic nitrogen, dissolved organic carbon, sodium, chloride, calcium, magnesium, potassium, silicon dioxide and sulfate). These parameters and their respective state or federal surface water standards (should they exist) are listed in Tables 2 and 3.

Analysis of water quality data for select tributary sites in the Ossipee Watershed between 2002-2019 showed that water quality in the watershed is very good overall. Many parameters across the select sites met established New Hampshire water quality standards or fell within levels indicative of natural conditions rather than direct human impact, with some exceptions. Other parameters are difficult to analyze thoroughly as the state or federal government has not defined a particular range of values that is safe for surface water. However, the general trend in the Ossipee Watershed at RIVERS sites is that most parameters show very low concentrations and appear to have negligible to minimal impact on water quality in this region.

While the water quality is generally good for the Ossipee Watershed, some tributary sites have emerging problems that need attention:

- **pH** at Phillips Brook (OL-12u) frequently showed values below 6.0 since 2012 which potentially has a moderate impact on water quality and is more acidic (below) New Hampshire's minimal background disturbance level. This site also showed higher values of turbidity and dissolved organic carbon compared to other sites. Most of this can be explained by the fact that this sampling site comes from the drainage of a wetland.
- **Water temperature** exceeded a recommended maximum of 24° C for coldwater fish species at the Ossipee River (GE-3), Danforth Pond outlet (GF-1), Huckins Pond outflow (OL-10), Banfield Brook (GM-1), Mill Brook (GM-5), and Ossipee Lake outflow (GO-7). This may be having an impact on the community of aquatic fish species at these sites, but without fish population data that cannot be confirmed. It is worth noting that all these sites demonstrated high to excellent dissolved oxygen levels despite the warmer temperatures, with the exception of OL-10 (see below).
- **Dissolved Oxygen** (DO) dipped below the standard of 5 mg/L or 75% saturation at Huckins Pond outflow (OL-10). There was an overall decreasing trend in dissolved oxygen (mg/L) at Danforth Pond outlet (GF-1), Huckins Pond outflow (OL-10), Cold Brook (OL-9u), and Pequawket Brook (GM-2). Rarely does DO at these sites drop below 5 mg/L or 75% saturation which is an indicator of good water quality. The decreasing trends are not alarming but should be monitored in future years.
- **Specific Conductance** showed increasing trends at 85% of the RIVERS sites since 2002. Values are especially high at Phillips Brook (OL-12u, max = 720 μS/cm), Frenchman Brook (GO-2, max = 390 μS/cm), Banfield Brook (GM-1, max = 378 μS/cm), and Square Brook (OL-14u, max = 203.95 μS/cm). These sites also average specific conductance values higher than 100 μS/cm which is New Hampshire's minimal background disturbance maximum value. Specific conductance is having a negative water quality impact on this watershed, and it is most likely being caused by excessive road salting (see pages 33-37, 50-51).
- S**odium and Chloride** are measured at only 10 sites monthly from January to December. Banfield Brook (GM-1), Frenchman Brook (GO-2), and Phillips Brook (OL-12u) all have values of sodium and chloride that at one point or another exceed typical values in healthy streams (Table 2). These are three of the sites above that also have high specific conductance values linking the three parameters together. It indicates that excessive road salting is impacting the water quality in this watershed and mitigation techniques need to be explored and implemented. For the in-depth data analysis on these parameters, see pages 33-37, 50-51.
- **Total Phosphorus** showed an increasing trend at seven sites, but concentrations were fairly low and within the 0.011-0.025 mg/L average values (Table 1). The only exception is Phillips Brook (OL-12u) which has higher values of total phosphorus reaching levels that are considered "more than desirable" (Table 5).

These analyses revealed four tributary sites that have multiple water quality parameters exceeding NH state water quality standards, exceeding natural background levels, and/or showing deteriorating trends: Phillips Brook (OL-12u), Huckins Pond Outflow (OL-10), Banfield Brook (GM-1), and Frenchman Brook (GO-2). These sites should be prioritized for potential restoration and/or best management practices implementation and should be monitored closely as sampling continues.

Introduction

Water is a vital resource that connects every individual on the planet. It flows through our rivers and streams, is stored in lakes and reservoirs, evaporates into the atmosphere, falls back to the earth's surface by precipitation and is stored in aquifers under the surface of the ground, in a process known as the hydrologic cycle. It is estimated that each person on earth needs 20 to 50 liters of clean, safe water each day for many uses that include drinking, cooking, and general hygiene.[1] In New Hampshire, about half of the residents receive their water from private wells either drilled deep into the underlying bedrock or dug into the overlying soil material. That percentage is even higher in the Ossipee Watershed, which overlays the largest stratified drift aquifer in New Hampshire (Figure 1). This aquifer gives many of the residents in this fourteen-town watershed their drinking water and provides drinking water for many communities in Maine downstream. The health of water resources downstream depends on clean water being present upstream,[2] and the way individuals in a watershed interact with their lakes and rivers directly impacts the health of the water that communities downstream will receive. Green Mountain Conservation Group uses the slogan "water knows no boundaries" to illustrate this point.

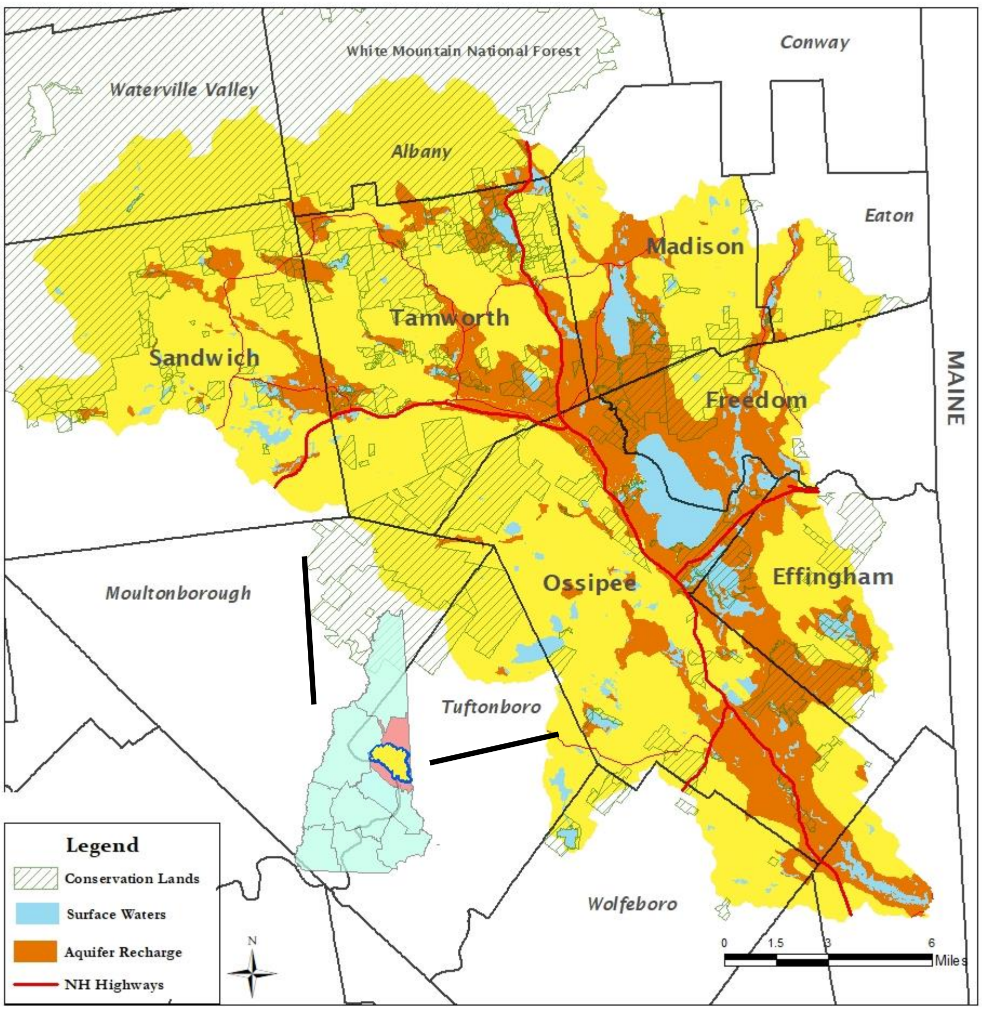


Figure 1. Map of the Ossipee Watershed and aquifer recharge area.

For this reason, it is paramount that a proper understanding of water resources and how to protect them exists in the community. The New Hampshire Department of Environmental Services (NHDES) has a Water Division that conducts a variety of programs designed to ensure the protection of these waters[3] including a Rivers Management and Protection Program which is intended to support existing water quality laws.[4] However, these state programs need the aid of local organizations and everyday citizens in order to monitor these vital resources. In Carroll County, New Hampshire, it is estimated that population has increased by about 600 people in each of the last 4 years, with the exception of 2019-2020[5] (see Appendix 4). Population either declined or remained fairly stagnant between 2010-2015, giving way to a positive population growth rate between 2015-2020[5] (see Appendix 4). According to statistics put out by the New Hampshire Housing Finance Authority, housing sales were up 17% in November, 2020 when compared to November, 2019[6] (see Appendix 5). This demonstrates an increasing population of people in the county and state, especially due to migration of citizens from elsewhere in the country, and therefore an increasing need for pristine water. As encroaching development continues to meet these increases in population, there is an even greater need for the consistent monitoring of these streams and rivers in the Ossipee Watershed and Saco River Basin to assess any changes or responses that may incur.

One of the best ways to protect surface waters that feed into underground drinking water supplies, like the Ossipee Aquifer, is to develop a long-term and consistent monitoring program for major streams, rivers, and lakes. GMCG has taken the lead in establishing a consistent water quality monitoring program for 19 parameters at 29 active tributary sites in the Ossipee Watershed since 2002. This effort is in direct collaboration with the SRCC through a shared Quality Assurance Project Plan (QAPP), updated in 2020, that spans 1 watershed, 2 states, and 26 towns. With over 15 years of consistent data collected at many stream sites, GMCG is now able to provide trend analysis, enabling towns to make educated watershed management decisions. The intended use of these analyses will be to establish a baseline from which to assess how development has impacted water quality as a result of human disturbance and/or climate change.

Program Background

In 2000, GMCG worked with UNH Cooperative Extension and the Society for the Protection of New Hampshire Forests to produce a series of Natural Resource Inventory maps of each town in the Ossipee Watershed. The RIVERS program grew out of this NRI mapping project in 2001 and was developed with project partners and stakeholders such as NHDES, SRCC, UNH, Chocorua Lake Association, and 7 watershed towns: Effingham, Freedom, Eaton, Ossipee, Madison, Sandwich and Tamworth.

Stream monitoring began in 2002 and has occurred every year since. Currently, GMCG staff and volunteers monitor 29 tributary sites seasonally (Figure 4). From May through October, dedicated volunteers from the community sample sites biweekly and collect data that are essential to track water quality changes in the watershed over time. From November to April, 10 of the 29 sites are monitored monthly by GMCG staff and year-long volunteers. Stream sites were chosen based on accessibility and surrounding land use; for example, some sites are located downstream from gravel pits, designated drinking water zones, transfer stations, landfills, or next to major roads or developments. Other sites were chosen to track the quality of water entering and leaving Ossipee Lake. Concerns over septic systems, erosion, timber-cutting, mill sites, junkyards, old tanneries, or other potential sources of contamination also contributed to site selection. For more detailed information about site selection and stream monitoring, refer to the QAPP (GMCG & SRCC, 2020; available upon request).

The goal of the RIVERS Water Quality Monitoring program was to establish a 10-year baseline of water quality data as a reference for assessing future water quality to help preserve the high-quality surface and groundwater resources of the entire Saco River basin and to provide the public with volunteer-collected data. There now exists for the Ossipee Watershed over 15 years of water quality data, and over 52,000 (and counting) data points. The duration and expanse of the data yield a solid foundation for establishing trends and drawing preliminary conclusions about the data.

Sites monitored by GMCG staff and volunteers are tested for 15 chemical parameters: dissolved oxygen (DO), total phosphorus (TP), phosphate (PO_4^{3-}), total dissolved nitrogen (TDN), nitrate (NO_3^-), ammonium (NH_4^+), chloride (Cl^-), dissolved organic carbon (DOC), sulfate (SO_4^{2-}), sodium (Na^+), potassium (K^+), magnesium (Mg^{2+}), calcium (Ca^{2+}), dissolved organic nitrogen (DON), and silicon dioxide (SiO_2), as well as four physical parameters: pH, temperature, turbidity, and specific conductance. This report only highlights results from these water quality parameters and their changes over time in the seven towns that make up the Ossipee Watershed.

Green Mountain Conservation Group

GMCG is a community-based, charitable organization dedicated to the protection of natural resources in the Ossipee Watershed towns of Effingham, Freedom, Madison, Ossipee, Sandwich, Tamworth, and Eaton. Founded in 1997, GMCG's mission is to coordinate and carry out environmental education, research, natural resource advocacy, and voluntary land protection with the goal to promote an awareness of and appreciation for clean water and the wise use of shared natural resources across the Ossipee Watershed. Its guiding principle is to present objective information in a non-confrontational manner to enable the public to make informed natural resource decisions. The foundation of the organization rests on the R.E.A.L. principle, which includes:

Research - To collect data and sponsor scientific research that informs GMCG's educational and advocacy efforts.

Education - To foster an appreciation of the natural resources of the Ossipee Watershed by involving the public in activities such as symposiums, panel discussions or community presentations. GMCG also publishes a quarterly newsletter and offers a wide variety of educational opportunities to youth and individuals.

Advocacy – To present objective information with the belief that informed citizens will make good judgments about our unique watershed resources and to encourage individual and small group activism on resource protection and conservation issues.

Land Conservation - To encourage voluntary land conservation for the protection of water resources, wildlife habitat, sustainable forestry, and agriculture and quality of life.

Saco River Corridor Commission

The Saco River Corridor Commission is committed to protecting public health and safety and the quality of life for the state of Maine. The commission regulates land and water uses, protects and conserves the region's unique and exceptional natural resources, and prevents the detrimental impacts of incompatible development. The commission was established in 1973. SRCC monitors water quality with the goal of collecting and storing data for use by towns in the corridor and the state of Maine, and for refining regulations to suitably meet the needs of the rivers and the citizens in the region. Identification of problem areas along the Saco River will lead to more informed decision making as a direct outcome of the RIVERS program.

Site Description

The Saco River Basin occupies about 1700 square miles of southwestern Maine and eastern New Hampshire, with its headwaters located at Crawford Notch in the White Mountains in New Hampshire about 75 miles from the mouth at Biddeford, Maine.[7] The river drops 1,500 feet in elevation before entering Maine and eventually draining into the Atlantic Ocean. About 876 square miles are located in New Hampshire and 823 square miles in Maine. Approximately half of the watershed in New Hampshire contributes to the main stem of the Saco River while the other half contributes to the Ossipee River, the latter which has a confluence with the Saco River in Maine.[7] Three lakes of notable size in this watershed are Ossipee Lake, Silver Lake, and Conway Lake. With the exception of the Conway area, the Saco River watershed is mostly all forested, undeveloped land which means the capacity of the watershed to support a wide diversity of life is assured due to the continuous presence of large forested riparian habitat buffer regions.[7] It is also estimated that roughly 250,000 people receive their drinking water from the Saco River.[8] It is important to maintain this pristine condition of the Saco River's headwaters and continue to monitor the water quality as the river and its tributaries flow downstream toward the Atlantic Ocean.

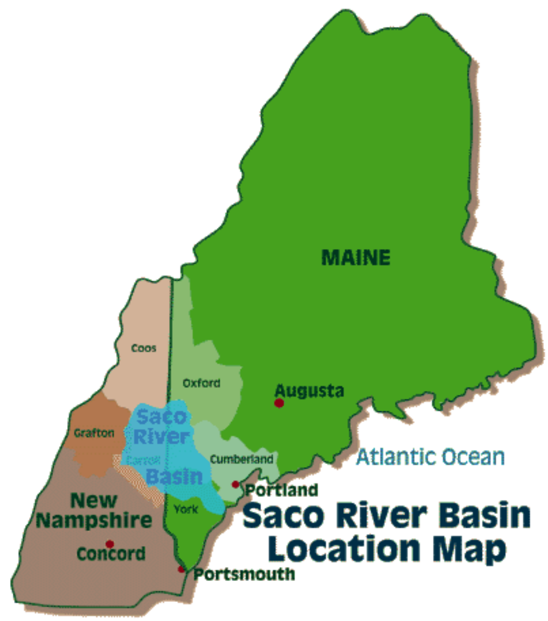


Figure 2. Location of the Saco River Basin

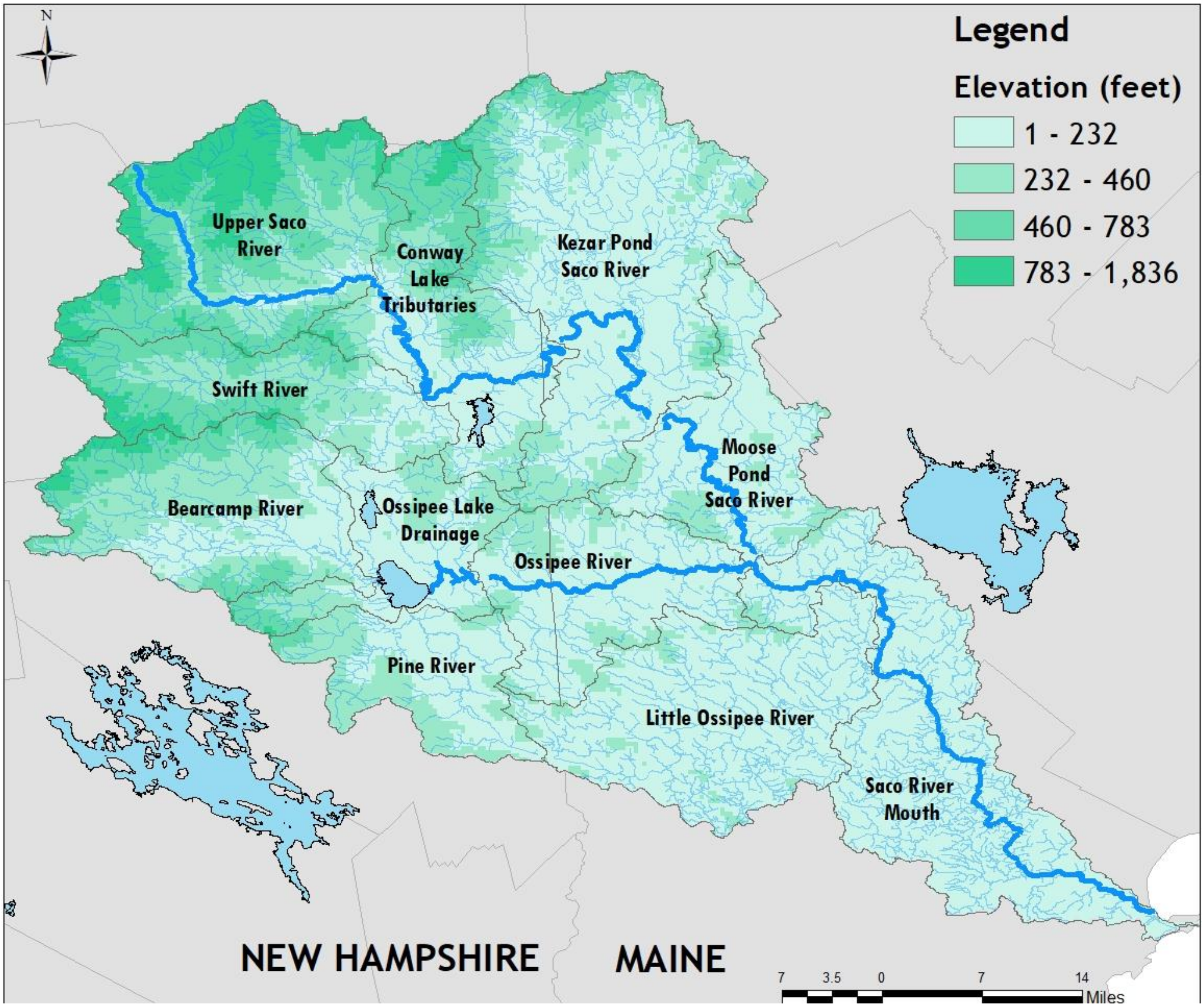


Figure 3. Map of the Saco River Basin and its HUC-10 sub-basin drainage areas.

The Ossipee Watershed is a sub-watershed of the Saco River Basin that encompasses about 380 square miles and parts or all of 14 towns in Carroll and Grafton Counties, New Hampshire. Ossipee Lake, the seventh largest lake in New Hampshire is at the center of the watershed (Figure 4). Ossipee Lake is connected to five other major waterbodies in the watershed (Broad Bay, Leavitt Bay, Berry Bay, Danforth Ponds, and Huckins Pond), all of which are fed by 14 major tributaries. A few major tributaries monitored in this program include the Swift River (90 square miles), Bearcamp River (150 square miles), and the Ossipee River (120 square miles).[7]Although this sub-watershed has enjoyed high water quality over the years due to the large area of protected land, there are sites in the watershed that generate hazardous waste, solid waste, have underground storage tanks that are leaking, and/or are contaminated with MTBE -a flammable liquid that has been used in the production of gasoline.[9]

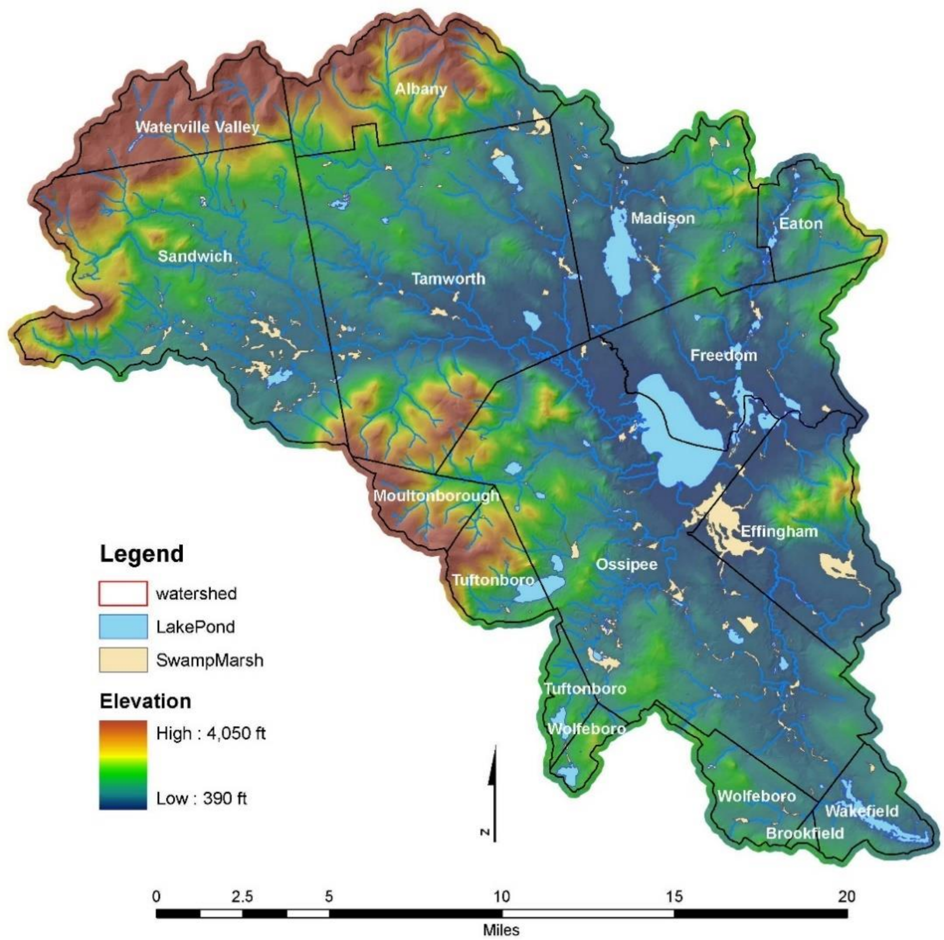


Figure 4. Map of Ossipee Watershed with town boundaries, elevation and waterbodies.

Within this Ossipee sub-watershed is New Hampshire's largest and deepest stratified drift aquifer. Stratified drift aquifers are composed of unconsolidated glacial deposits of sand and gravel making them highly permeable due to the large pore size of the material.[10] These aquifers are an important source of groundwater for commercial, industrial, domestic, and public water supplies in the state of New Hampshire. They are typically the most productive sources of groundwater and recharge easily. These types of aquifers are favored by public water supply utilities due to their high yield,[10] making this one in the Ossipee Watershed a very important storage location for groundwater. These aquifers are fairly uncommon because their associated materials were laid down 12,000 to 14,000 years ago by receding glaciers that melted from the Pleistocene ice age period.[11] In many areas of the Ossipee Aquifer, water can travel more than 2,000 ft^2 per day, depending on the permeability of soils above the aquifer. Much of the water that ends up in this watershed will eventually seep into the ground and become a part of this aquifer. Therefore, this connection between surface water and groundwater is essential to the overall water quality.

Water Quality Monitoring

Before moving directly into the discussion of water quality results from this study, it is necessary to understand the concept of water quality, what it examines, and why it is important. As mentioned before, water is an essential natural resource that connects all people together. It does not adhere to boundaries humans have set up between towns, counties, states, and even countries. Human survival necessitates clean water and therefore long-term water quality monitoring is essential.

Water quality can be defined as the chemical, physical and biological characteristics of water, usually in respect to its suitability for a designated use.[12] In New Hampshire, there are six designated uses for freshwaters: aquatic life, fish consumption, drinking water supply after adequate treatment, primary contact recreation (swimming), secondary contact recreation (boating), and wildlife.[4] Analysis of water quality is about measuring the required parameters of water following standard methods and checking whether those parameters meet a specific standard.[12] The main elements of water quality monitoring are on-site measurements, the collection and analysis of water samples, the study and evaluation of the analytical results, and the reporting of the findings.[13] The purpose of a monitoring program, such as RIVERS, is to gather sufficient data (by means of regular or intensive sampling and analysis) to assess variations over space and time in water quality. The composition of surface or underground waters is highly dependent on environmental factors such as geology, topography, meteorology, hydrology, and biology of the watershed being examined.[13] Outside of this, human intervention has the greatest impact on water quality. Obvious human impacts include pollution activities such as discharge of domestic, urban, and other wastewaters into waterbodies, the spreading of chemicals on agricultural land, or even the spreading of salt onto paved roads. The physical and chemical parameters analyzed present a strong picture of the water quality of the system as a whole.

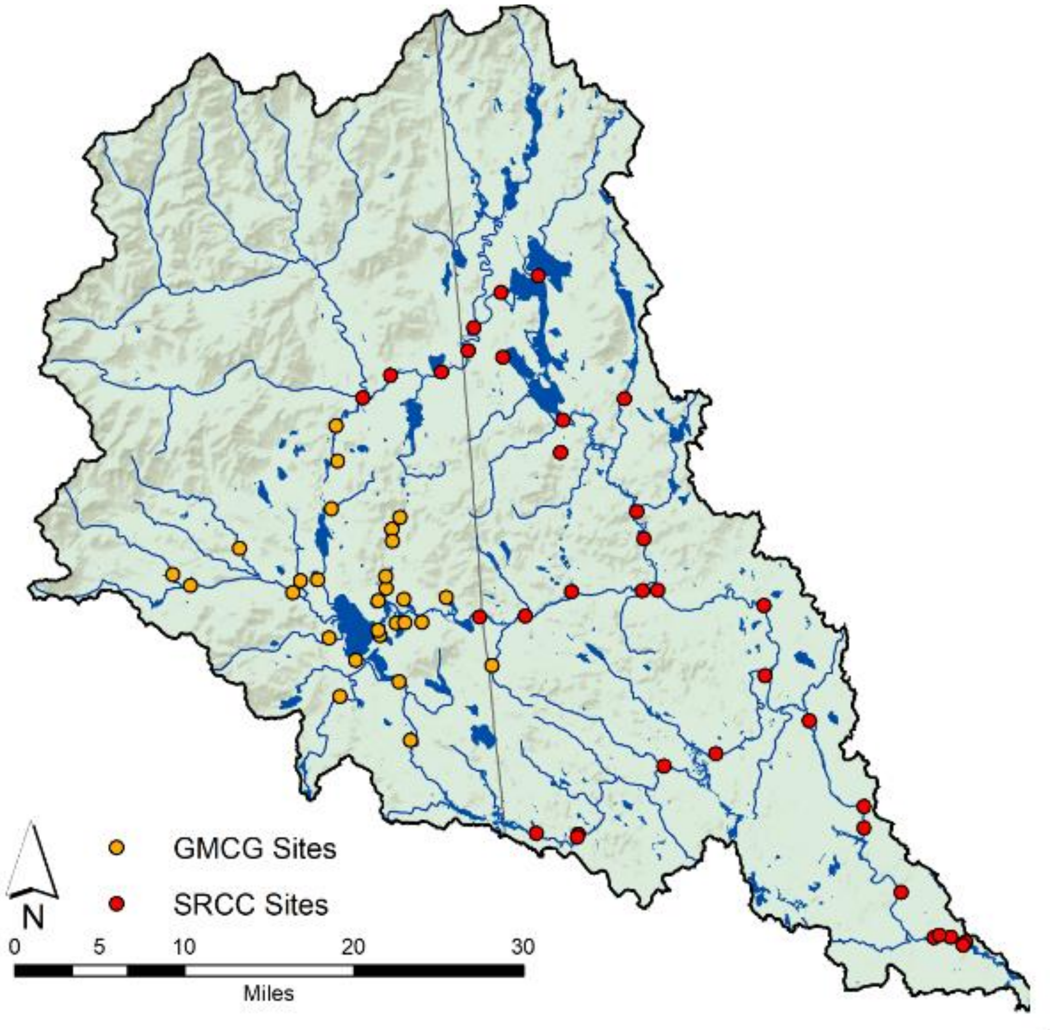


Figure 5. Map of Saco River Basin and the locations of each RIVERS site. Orange indicate sites followed by GMCG in the Ossipee Watershed.

As stated in New Hampshire's legislation, all surface waters must be classified as either class A or class B waters, and this establishes certain minimum surface water quality criteria for each classification (Table 2). Class A waters are described as being of the highest water quality and can be used for drinking water after sufficient treatment.[14] Class B is the second highest quality, considered acceptable for fishing, swimming and other recreational purposes and, after adequate treatment, for use as water supplies.[14] Out of the classified streams in the state, including those in the Ossipee Watershed, most are considered class B waters. Many water quality parameters are defined by a standard value that must be met in surface waters depending on classification. If a defined regulated standard does not exist, a minimum disturbance level may be identified by the state of New Hampshire. If no state defined or federally mandated limit exists for a water quality parameter (Tables 2 and 3) it can be challenging to determine "how much is too much?" In these circumstances, previous scientific studies of surface freshwaters can help define typical values found in a waterbody.

The state of New Hampshire can set regulations for water quality, but they rely on the help of watershed organizations and community scientists to collect data and help monitor. For many of the designated uses, a large percentage of rivers and streams in New Hampshire have not been assessed; therefore volunteer data is heavily relied on to assess the water quality.

Methods

Data Collection

Community volunteers are trained in data collection methods at the beginning of the sampling season in order to comply with a state and EPA approved QAPP. Volunteers collect data bi-weekly May-October at 29 sites in NH (Figure 5). Of these 29 sites, 10 are sampled year-round and are also analyzed for additional parameters (Table 1).

During the summer, sampling is conducted before 9 AM to minimize diurnal fluctuations in oxygen demand.

Table 1. Summary of sampling frequencies

Frequency	Parameters
Bi-Weekly	Conductivity, dissolved oxygen, temperature, pH, turbidity
Monthly	Total phosphorus
Monthly (at 10 year-round sites)	Ammonium, total dissolved nitrogen, dissolved organic carbon, orthophosphate, anions and cations

Volunteers use a Hach HQ40D multiparameter meter with probes to sample for dissolved oxygen, temperature, and specific conductance in the field. Turbidity samples are collected and analyzed in the field using a Hach 2100P portable turbidimeter.

Samples for pH, total phosphorus, and cations/anions are collected monthly in plastic bottles and returned to GMCG for immediate processing. pH samples are analyzed immediately using a Hach HQ40D meter, while total phosphorus samples are preserved by adding 1ml 36N sulfuric acid and then freezing them. Total phosphorus samples are analyzed by colorimetric analysis at the University of New Hampshire (UNH). Cation/anion samples are filtered through a 0.455 µm filter and frozen until received by UNH for analysis.

Analysis

Analysis for this report includes data between the years 2002-2019. Some sites, parameters, and years were left out of the analysis because there were not enough data points. The data analysis was broken up into two sections: field data and cation/anion data. Field data include field parameters and total phosphorus measured at all 29 stream sites bi-weekly from May-October each year (Table 2). These data are broken up by stream sites within each of the seven watershed towns. The cation/anion section includes analysis on all cations and anions that are measured at 10 of the 29 stream sites monthly each year (Table 3).

Any site that did not have at least 5 data points per parameter per year was left out of the analysis due to insufficient data. Outliers in this analysis were defined as anything 1.5 times greater than the interquartile range of the data (Appendix 1). Statistical analysis for the field data was conducted in R software and the graphs were designed in Microsoft excel. Statistical analysis for the field data includes Mann-Kendall tests to identify trends over the course of the sampling period.

Table 2. New Hampshire Class B standards or indicators for streams for interpreting the 5 field data physical and chemical parameters.

Parameter	NH Water Quality Standard for Class B Waters	Natural Background/Minimal Disturbance Levels for NH
Temperature	No quantitative standard	Coldwater fish species thrive under maximum weekly and instantaneous temperatures of 19° and 24° C
Turbidity	1-10 NTU	1.0 NTU is average
Specific Conductance	No quantitative standard	Values between 1-100 µS/cm are normal and cause minimal disturbance
pH	6.5-8.0	As low as 6.0
Dissolved Oxygen	5 mg/L or 75% minimum saturation as an average daily	No level defined in this category
Total Phosphorus	No quantitative standard	0.011-0.025 mg/L is an average value

Table 3. Description of EPA standards or indicators for streams for interpreting the 12 cations/anions analyzed by UNH laboratories. In addition, typical surface water concentrations for parameters as outlined in Deborah Chapman's "Water Quality Assessment" book are given for reference.[15]

Parameter	EPA Imperative (I/PV) Value	Source	Typical Surface Water Concentrations[15]
Chloride	250 mg/L	Surface Water Regulations (1989)	Less than 10 mg/L in pristine freshwater systems
Sulfate	200 mg/L	Surface Water Regulations (1989)	Between 2 and 80 mg/L
Sodium	200 mg/L	EPA Drinking Water Directive	Less than 50 mg/L
Potassium	No reference/ recommendation	N/A	Less than 10 mg/L
Magnesium	No reference/ recommendation	N/A	Between 1 and 100 mg/L depending on rock types
Calcium	No reference/ recommendation	N/A	Less than 15 mg/L or between 30 and 100 mg/L in waters with carbonate-rich rocks.
Silicon Dioxide	No reference/ recommendation	N/A	Between 1 and 30 mg/L
Dissolved Organic Nitrogen	No reference/ recommendation	N/A	N/A
Ammonium	No reference/ recommendation	NH minimal Background Disturbance Levels	Less than 0.2 mg/L
Nitrate	No reference/ recommendation	NH minimal Background Disturbance Levels	Less than 0.5 mg/L. 5mg/L or greater indicates significant pollution
Phosphate	0.5-0.7 mg/L	Surface Water Regulations (1989)	0.005-0.020 mg/L
Dissolved Organic Carbon	No reference/ recommendation	N/A	N/A
Total Dissolved Nitrogen	5-20 DF/25C	Surface Water Regulations (1989)	N/A

Results

Field Data

In this first results section of the report, the field data are highlighted and organized by each of the 7 towns in the watershed. These data come from 27 of the 29 stream sites and include samples from the months of May to October, the summer sampling season for RIVERS. The data range from 2002-2019, with start dates varying depending on the stream sites. Due to the fact that this project has collected a huge amount of data points thus far, median values per year are being shown in each of the line graphs for each town, so that an overview of water quality data over the last 15 years can be highlighted. Some figures will display more site specific and time-specific analysis, and these graphs will be explained where they appear in the report. It is important to note that these data are simply highlighting overarching trends throughout the entire duration of this community science program, and much of these data do not show specific conditions in particular years. Many of the figures shown in this section are known as line graphs, which are simple time plots that show the changes in a particular parameter across a particular time frame. This section includes results on pH, DO, temperature, specific conductance, and turbidity. Total Phosphorus will also be shown at the end of this section because even though it is not collected on site, it is sampled at all 29 stream sites throughout the summer.

Mann-Kendall statistical test:

A Mann-Kendall trend test is used to analyze data collected over time for consistently increasing or decreasing trends. It is a particularly useful statistical test to use for large datasets because it does not require a normal distribution of data to work. The more data points, the more likely this test will identify a true trend in the data. Mathematically speaking, the Mann-Kendall test looks at the differences in signs between the earlier and later data points. If a trend is present, the sign value will continue to increase or decrease consistently. The pie charts displayed in this section are showing results from the Mann-Kendall test. Each will show how many RIVERS sites demonstrated an increasing trend, decreasing trend, or no trend, for each field parameter. See Appendix 2 for a more complete picture of Mann-Kendall results for each site.

pH

What is pH?

pH is a dimensionless number that indicates how strongly acidic or basic a solution is. It stands for the potential of hydrogen. It is essentially a measure of the acid balance in water, and it is impacted most by the dissolved chemical substances in water and how they react with each other.[13] pH is on a scale of 0-14 with 7 being neutral. Numbers lower than 7 are considered acidic and numbers higher than 7 are considered basic. pH values in streams are affected naturally by the bedrock or streambed material and the flow of groundwater into the stream. Streams with an underlying bedrock of limestone for example have a greater ability to buffer acidity in a stream and raise pH. The waterbodies in the Ossipee Watershed are mostly underlain by granite which due to its properties does not have the ability to buffer acidity.

Why do we measure pH?

pH influences chemical and biological processes that occur in water and are essential for aquatic organisms. Human impacts on pH in streams include polluting the air with acidic gases that bind to water molecules which then fall to the earth when it rains, pollution of the soil, mining activity that leaves acidic materials open to rain runoff, and more. Waters in this area tend to be naturally around a pH of 6.5.

The Watershed View

About 40% of the sites saw a trend of pH decreasing since 2014, and another 40% saw no trend. Very few sites have a pH that falls below 6.0 which is an indicator of good water quality.

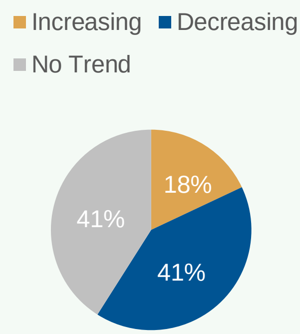
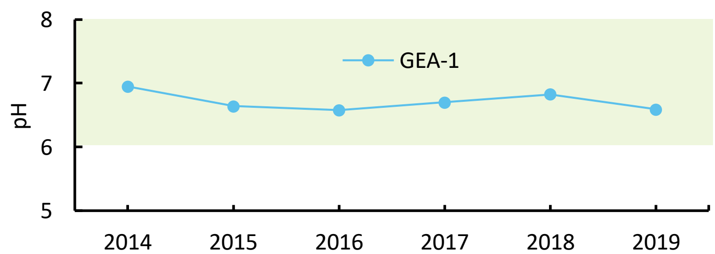


Table 4. pH scale and expected water quality impact

pH	Category
< 5	High Impact
5.0 - 5.9	Moderate - High Impact
6.0 - 6.4	Normal; Low Impact
6.5 - 8.0	Normal; Low Impact
6.1 - 8.0	Satisfactory

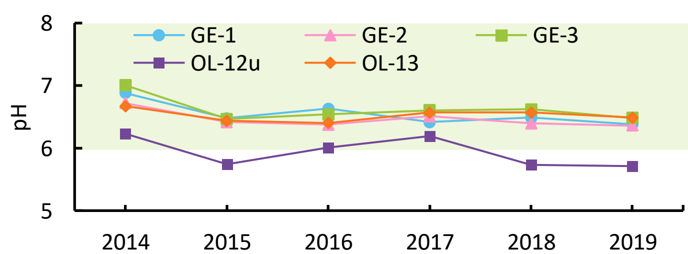
Eaton



GEA-1 in Eaton shows a slight rise and fall in pH over the last 5 years but remains at a healthy level between 6 and 7 indicating good water quality.

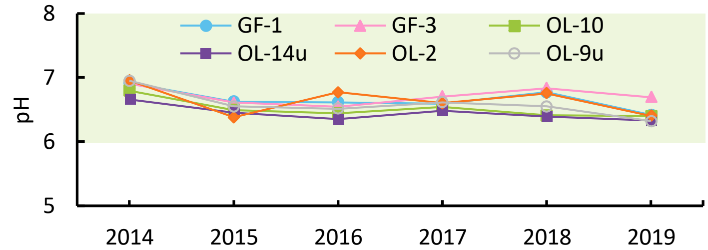
Effingham

The stream sites in Effingham demonstrate a slight decrease in pH over the course of the last 5 years, but the values remain generally between 6 and 7 indicating good water quality. OL-12u (Phillips Brook) consistently sees a lower pH generally between 5 and 6 which could have a moderate impact on water quality. (See note in executive summary, page 7).

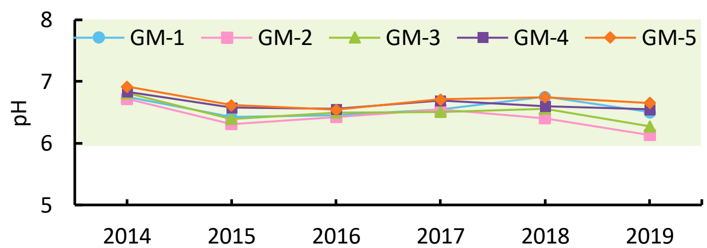


Freedom

All stream sites in Freedom demonstrate a fairly consistent and stable pH since 2014 and indicate good water quality.



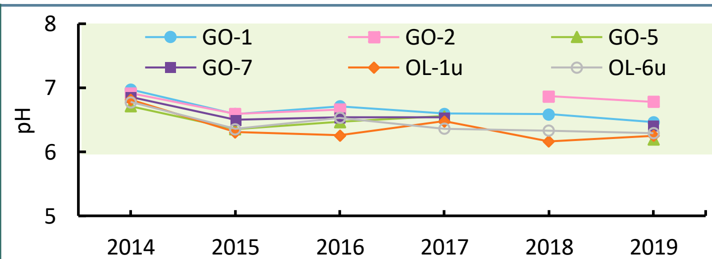
Madison



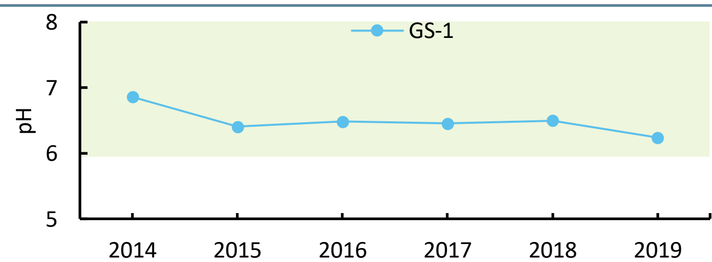
Madison's stream sites decline very slightly in pH values over the last 5 years but overall remain between 6 and 7 indicating healthy water quality. There could be a negative water quality impact If pH decreases below 6 in the coming years.

Ossipee

The trends in pH measurements at Ossipee stream sites are similar to the other towns. Nothing about this trend is concerning, and demonstrates good water quality.



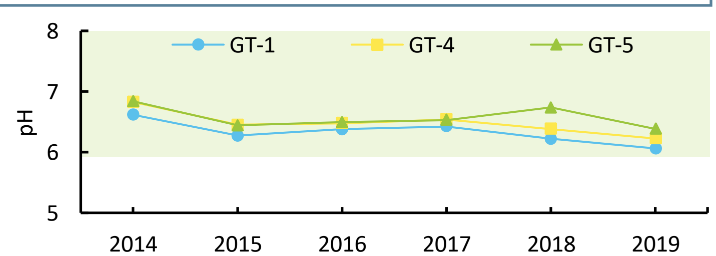
Sandwich



GS-1 (Cold River) in Sandwich shows very consistent pH values between 6 and 7 over the last five years indicating good water quality.

Tamworth

Tamworth's stream sites fluctuate a bit more in pH values between 6 and 7, however they are indicating good water quality overall. If values continue to decrease below 6 that would indicate a negative water quality impact.



Turbidity

What is turbidity?

Turbidity is a measure of the amount of light scattered by material in the water and it is impacted by the amount of suspended matter and particles. These particles include silt, clay, organic and inorganic matter, soluble compounds, and plankton and other microscopic organisms.[15] The more of these particles in the water, the higher the turbidity value. Water bodies that are well buffered by forested regions and have little land development around them will typically have very low values of turbidity which is an indicator of good water quality. In open land surfaces where runoff from rain events is high, all kinds of chemicals and substances that humans use on agricultural land, or roadways, can wash down into streams and dramatically increase turbidity.

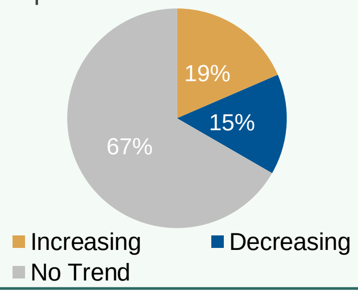
Why do we measure turbidity?

These particles have a high capability of absorbing sun heat which raises water temperatures and consequently, the concentration of dissolved oxygen can decrease.[16] High amounts of these suspended materials can clog or damage fish gills, decrease their resistance to diseases, reduce their growth rates, and affect egg and larval maturation.[16] Values of 1.0 NTU are average, and the NH standard is between 1-10 NTU (Table 2).

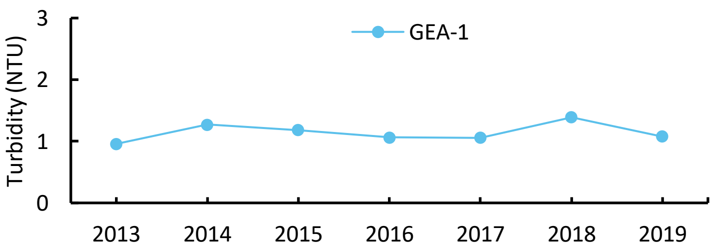
The Watershed View

Throughout the watershed, the majority of sites had no trends in turbidity, and 15% of sites had decreasing trends, indicating an improvement in water quality. Four sites (OL-13, OL-9u, GM-2, and GO-2) were increasing in turbidity, indicating a trend towards declining water quality.

Values of turbidity are consistently low with a few spikes above 2.0 NTU, indicating low amounts of suspended solids overall.



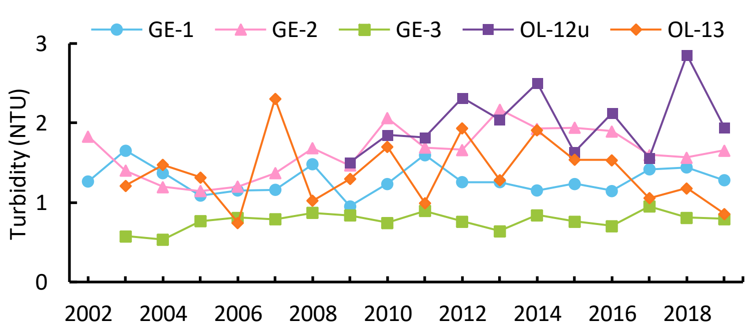
Eaton



GEA-1 (Long Pond Outlet) demonstrates a consistent turbidity trend since 2013 with no indications of declining water quality.

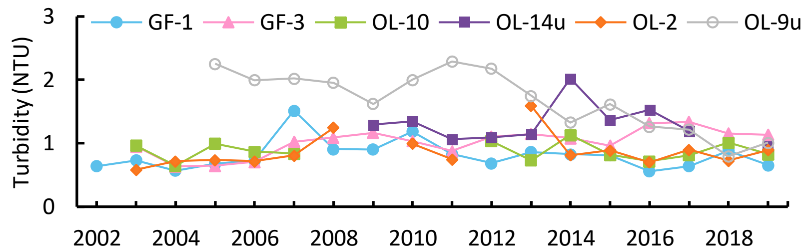
Effingham

Overall, values of turbidity are low with a few spikes at OL-12u and OL-13. These two sites in particular flow adjacent to each other (Leavitt Brook and Phillips Brook). GE-3 (Ossipee River) shows consistently low turbidity values with a slight increase over the sampling period, indicating high water quality. The "up and down" spikes in these Effingham sites are more frequent than sites in other towns indicating that turbidity values are more inconsistent. Streams in this area could be subject to more suspended material fluctuations, but values are low overall and indicate good water quality.

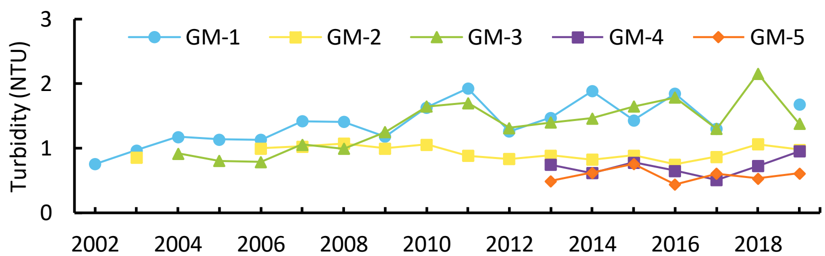


Freedom

Most sampling sites in Freedom have turbidity values between 0-1 NTU which indicates high water quality. OL-9u (Cold Brook) has showed a decrease in turbidity over the sampling period which indicates water quality improvement. OL-14u saw a spike in 2015 that decreased a year later.



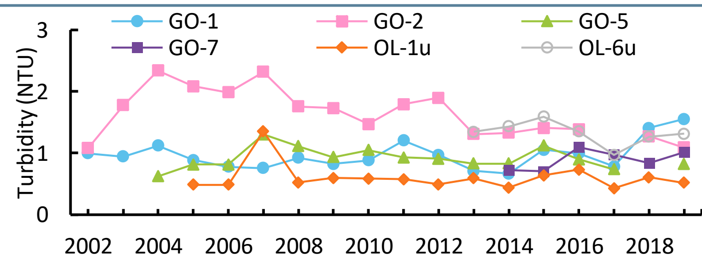
Madison



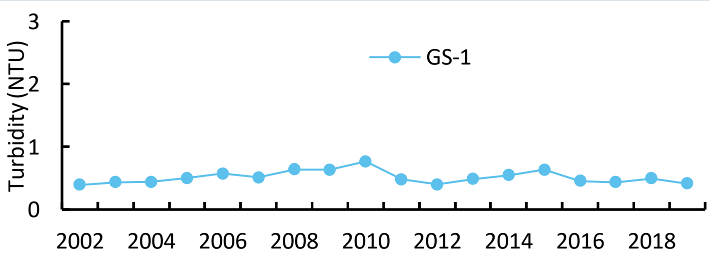
Some sites in Madison such as GM-3 (Forrest Brook) and GM-1 (Banfield Brook) show a slight increase in turbidity values from 2002-2019. However, values are not very high overall suggesting a mild impact, if any, on water quality at these sites.

Ossipee

Sites in Ossipee remain fairly consistent in turbidity measurements between 0-1 NTU. GO-2 (Frenchman Brook) is the only exception and saw a pretty steep increase in turbidity values between 2002-2008. After that, values gradually drop over the years up to 2019. No samples reached 3 NTU which indicates good water quality overall.



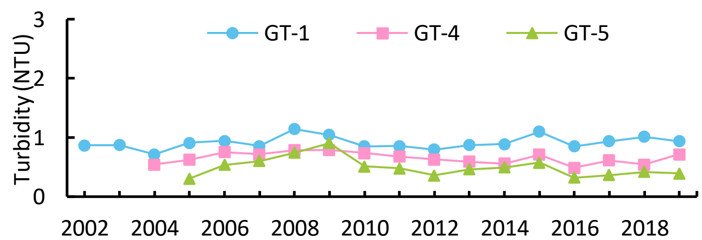
Sandwich



GS-1(Cold River) demonstrates no trend in turbidity measurements since 2002 and the values are consistently below 1 NTU indicating high water quality.

Tamworth

Sites in Tamworth show consistent turbidity measurements with very little fluctuation over the sampling period. Values are low indicating high water quality.



Dissolved Oxygen and Temperature

What is dissolved oxygen?

Dissolved oxygen (DO) is considered to be one of the most important parameters of water quality in streams, rivers, and lakes.[16] It is a key test of water pollution. Every aquatic organism needs oxygen to survive and some key species that indicate high water quality, such as brook trout, need high amounts of DO. Essentially, the higher DO concentration, the higher the water quality. Increases in water temperature decrease the solubility of gases, meaning that less DO is present in warmer waters than colder waters. As biological respiration in a stream increases, oxygen is used up more quickly and decreases in concentration.[15] DO is typically measured as a concentration (mg/L) and a percent saturation. Both values are useful for looking at the amount of DO present in the water.

What is temperature?

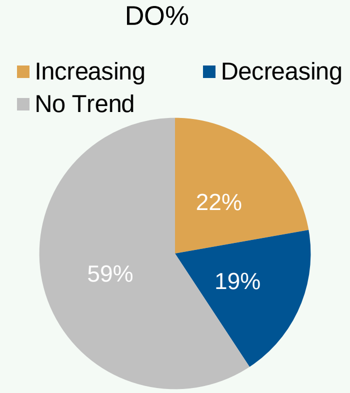
Temperature at its most basic definition is a measure of the average kinetic energy of water molecules.[16] As water temperature increases, the rate of chemical reactions generally increases, and the solubility of gases in the water decreases,[15] meaning that less dissolved oxygen can be present in warmer waters. As organisms in the water take in oxygen at greater rates with increasing water temperature, oxygen is consumed faster. Water temperature also influences the rate of photosynthesis by algae and other aquatic plants, sensitivity of organisms to toxic wastes, parasites and diseases, and timing of reproduction and migration of aquatic organisms.[16] Water temperature is often measured in units of degrees Celsius (^{o}C). Aquatic organisms are sensitive to changes in this value and some can only survive in waters within a certain temperature range, which also makes it a very important parameter in water quality measurement.

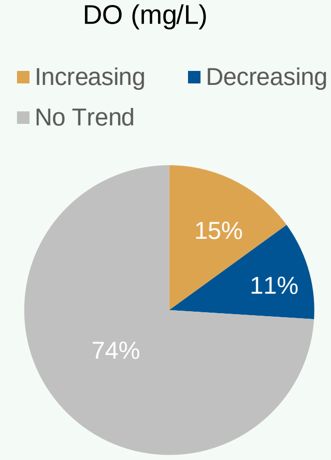
Why do we measure dissolved oxygen and temperature?

Depletions in dissolved oxygen can cause major shifts in the species of aquatic organisms found in water bodies. Species that cannot tolerate low levels of dissolved oxygen may be replaced by a few species of pollution-tolerant organisms, nuisance algae, and anaerobic organisms. Temperature has a big impact on the types of organisms that will be present in a water body as well and it has a natural inverse relationship with dissolved oxygen. NH defines a standard of 5 mg/l or 75% saturation for class B waters (Table 2).

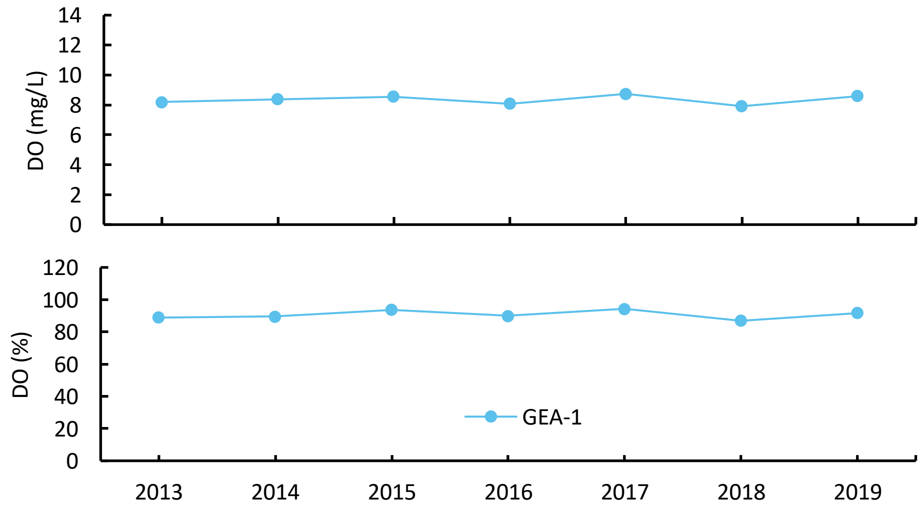
The Watershed View

Overall, DO (mg/L and %) shows little to no trend over the sampling period. A slightly higher percentage of sites have experienced an increase in DO which indicates improving water quality.





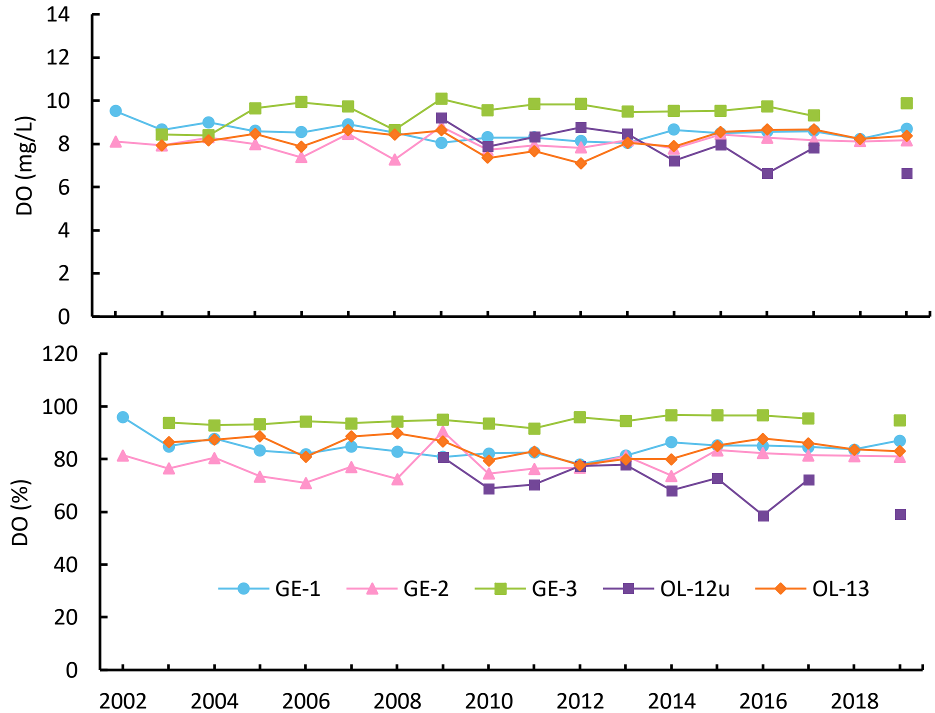
Eaton



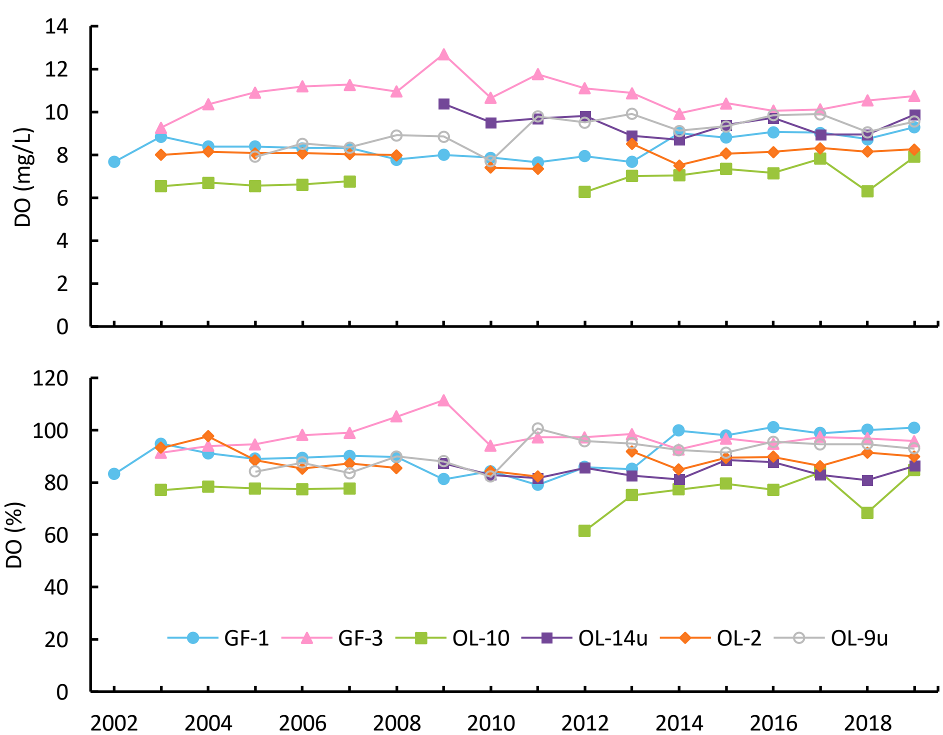
GEA-1 (Long Pond Outlet) shows a stable dissolved oxygen trend over time with high values in both concentration and % saturation indicating good water quality.

Effingham

Almost all of the sites in Effingham show a stable trend in dissolved oxygen. OL-12u (Phillips Brook) is the one exception. The dissolved oxygen concentrations and percent saturations decrease slightly over the sampling period indicating that the water quality at this site could be decreasing as well.



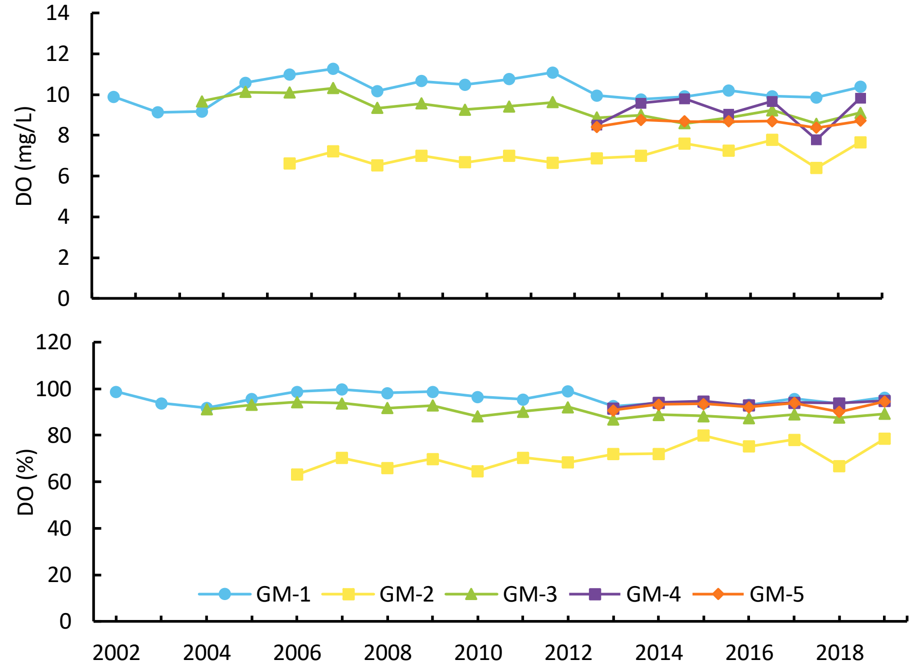
Freedom



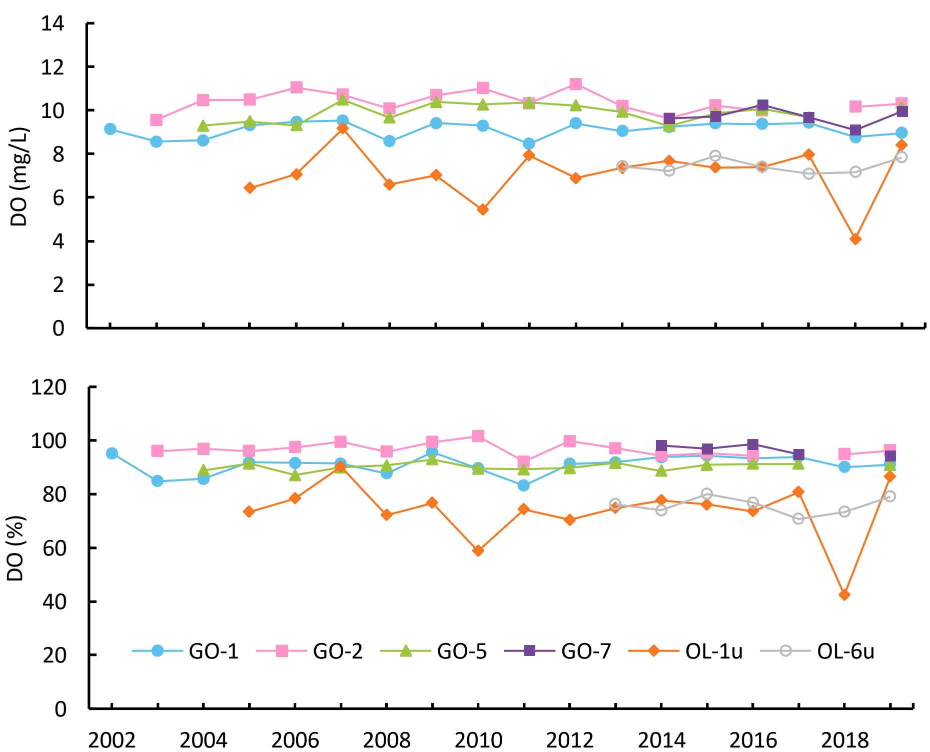
There were increases in dissolved oxygen at GF-1 (Danforth Outlet), OL-9u (Cold Brook), and OL-14u (Square Brook) indicating a positive water quality trend. OL-10 (Huckins Outlet) demonstrates the lowest DO levels (both mg/L and %) out of the sites in Freedom. This is the only site that has exhibited DO concentrations below the NH standard of 5 mg/L or 75% saturation at times throughout the sampling period. Otherwise, DO levels at RIVERS sites in Freedom indicates good water quality.

Madison

Dissolved oxygen had a decreasing trend at GM-3 (Forrest Brook) and a slight decrease in % DO at GM-1 (Banfield Brook).GM-2 (Pequawket Brook) exhibits the lowest DO levels out of the sites in Madison, with % saturation decreasing below 75% several times throughout the sampling period. Otherwise, these sites demonstrate high DO values and indicate good water quality overall.



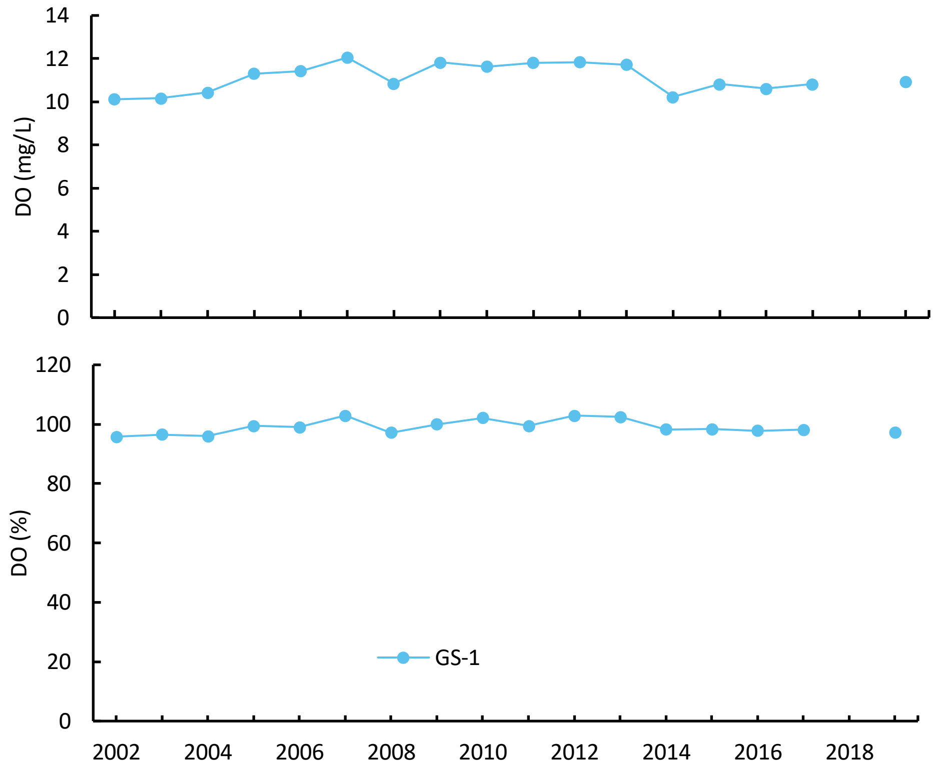
Ossipee



There was an increase in % oxygen at GO-1 (Beech River) and decreases at GO-2 (Frenchman Brook) and GO-7 (Ossipee Outflow). OL-1u (West Branch) shows DO values that consistently dip fairly low indicating a poorer water quality at that site. These values dip below 5 mg/L and 75% saturation at times which is problematic for water quality Otherwise, most of the sites in Ossipee demonstrate good water quality in relation to DO values.

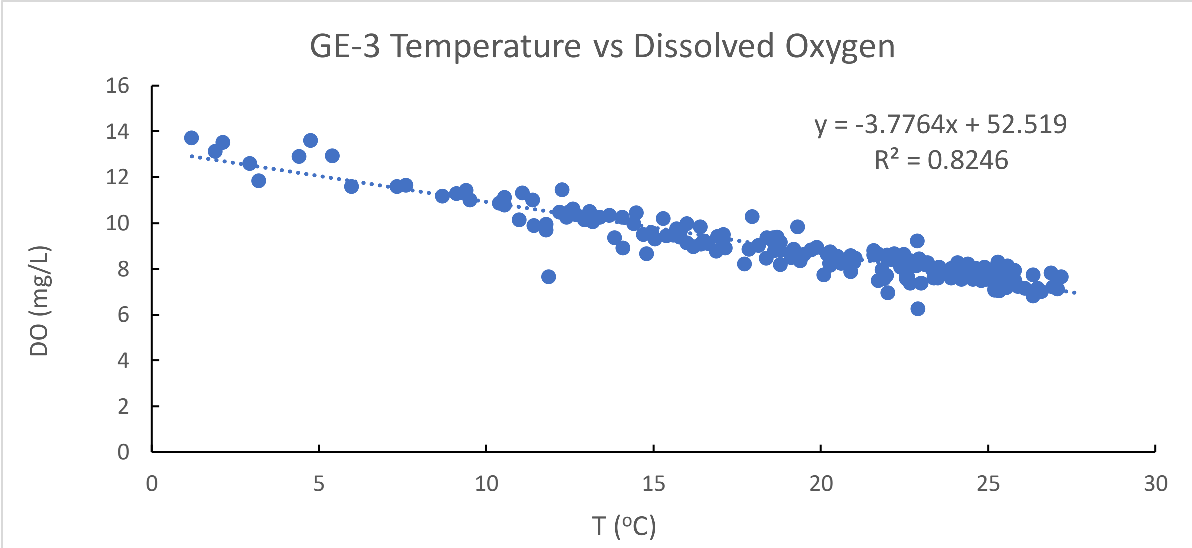
Sandwich

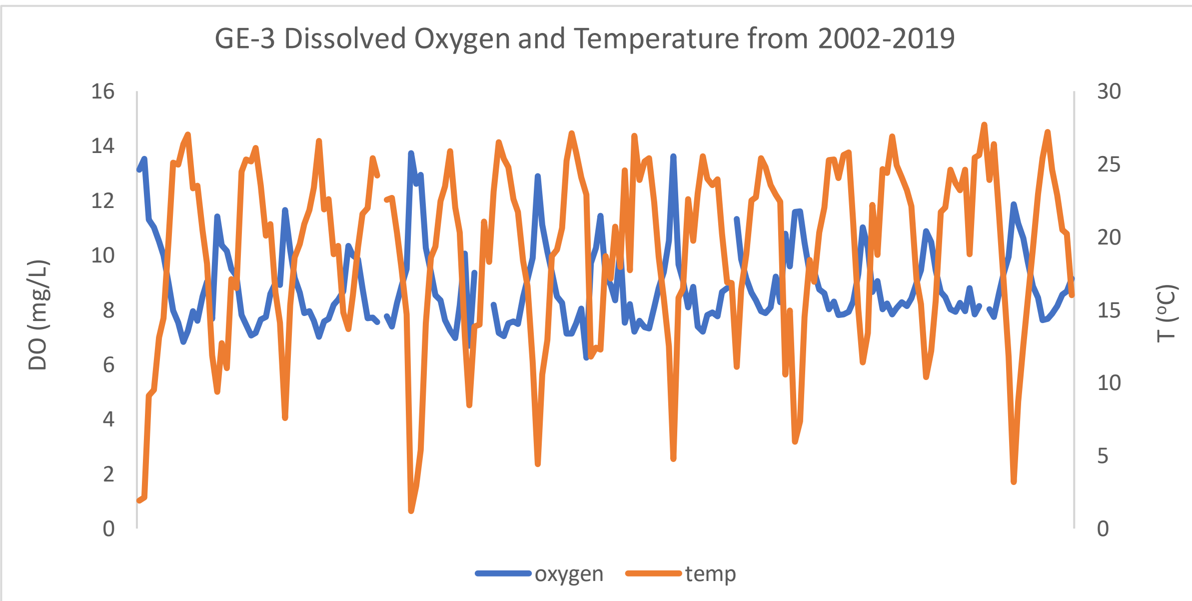
Dissolved Oxygen values at GS-1 (Cold River) are very high indicating excellent water quality.



Tamworth

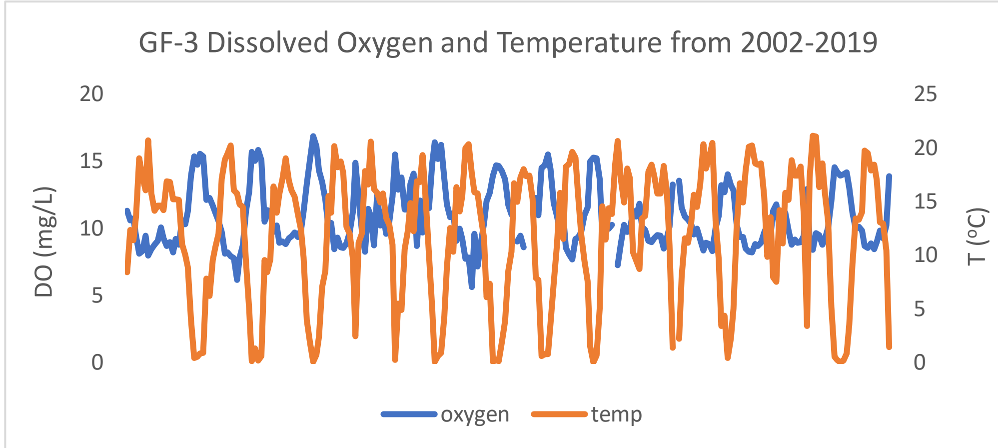
Dissolved oxygen at these three sites in Tamworth are consistently high and indicate good water quality.

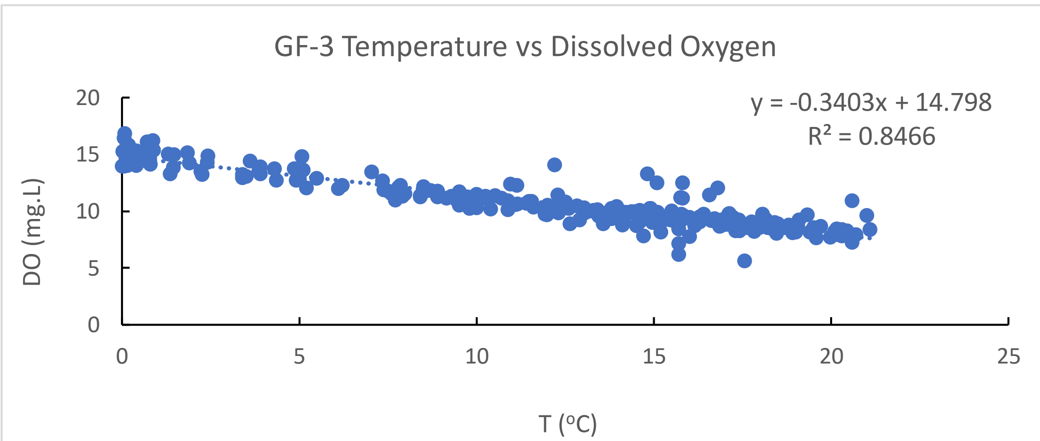




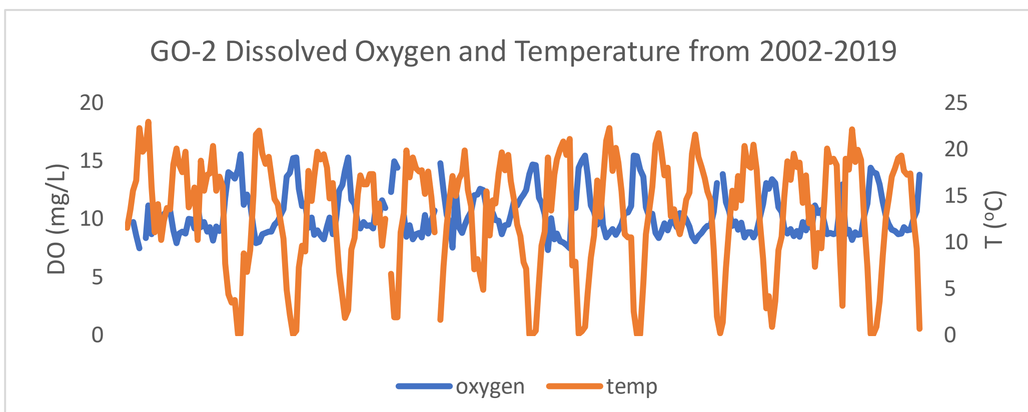
Dissolved oxygen and temperature have a natural inverse relationship in freshwater systems and when examined together can provide more information about the water quality of a stream. As seen in the two figures of GE-3 above (Ossipee River, Effingham), when temperature increases, DO decreases. At this particular site, the scatterplot (top graph) shows a negative trend with an R^2 value of 0.82, which indicates a fairly strong correlation between the two parameters. This means that 82% of the changes in one value can be attributed to the changes in the other. This inverse relationship is a natural occurrence: at increased temperatures the rate at which organisms use up chemicals in the water increases, and oxygen is used up faster. Natural changes in DO due to changes in water temperature typically do not indicate harmful changes in water quality. However, certain aquatic species such as brook trout or mayfly nymphs can only survive within particular temperature and DO ranges. The NH standard for minimum DO concentrations in surface waters is 5 mg/L. At GE-3 it is evident that DO values have never dropped below 6 mg/L since sampling began in 2002 indicating that the natural fluctuations in DO and temperature are likely not hurting the water quality at this site. Most streams in the Ossipee Watershed are well buffered by forested regions and with land development being less robust in this area, DO values are not being affected as much by nutrient overload to the stream system (which would be likely in a more developed region or area dominated by agriculture). Examples of the same graphs from a couple more RIVERS sites are shown below.

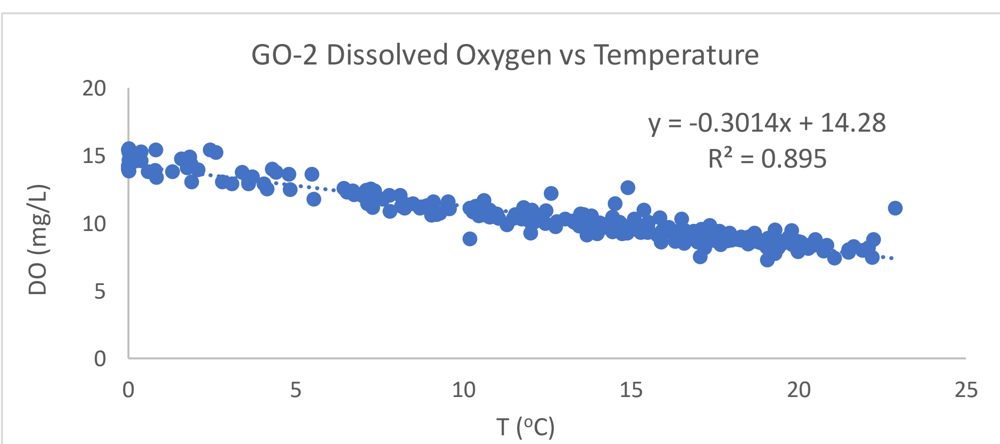
The same trends as above (GE-3) can be seen here with GF-3 (Cold Brook) and there is a strong correlation between temperature and DO (R^2 = 0.85). These are natural changes that occur throughout the course of the year with temperature and DO.





The same trend between temperature and DO is visible here at GO-2 (Frenchman Brook) but with an even stronger correlation (R^2 = 0.90). All of these sites (GE-3, GF-3, and GO-2) have DO and temperature values that indicate good water quality and a healthy stream ecosystem.





Specific Conductance

What is specific conductance?

Specific conductance is a measure of the ability of a solution to carry an electrical current through it. Basically, it looks at how well the stream or waterbody conducts electricity. Indirectly, it also examines the amount of dissolved ions and dissolved solids in the water[15] because these can carry an electrical current. As the number of ions in solution increases, so does the conductivity value. In many cases, specific conductance can be used as a proxy for salt concentrations.

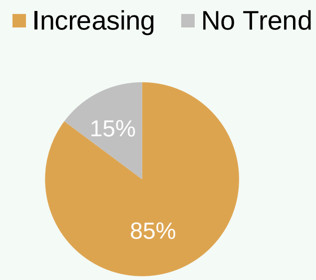
Why do we measure specific conductance?

Large amounts of runoff from land surfaces into streams can lead to high amounts of conductivity, and ultimately indicate increasing pollution. Road salt in areas that experience long winter seasons can accumulate in stream systems and lead to increased conductivity values over time, a trend that is notable in New Hampshire streams and rivers. NH has identified values between 1-100 μS/cm as normal and anything above as potentially causing disturbance to the stream system (Table 2).

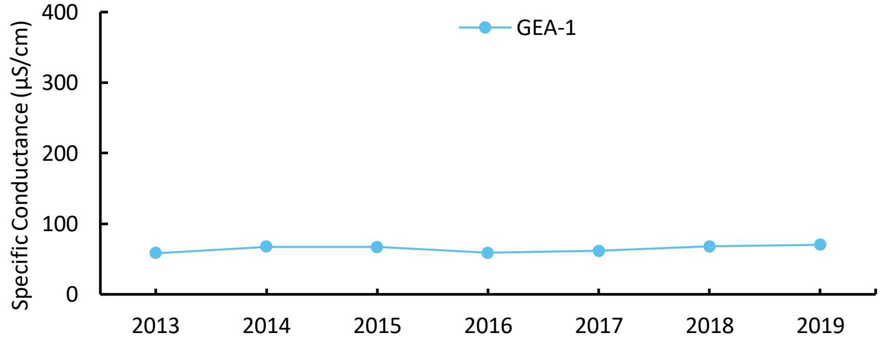
The Watershed View

Over the past 15 years, 85% of sites have been increasing in specific conductance.

This indicates that road salting is impacting our waterways.

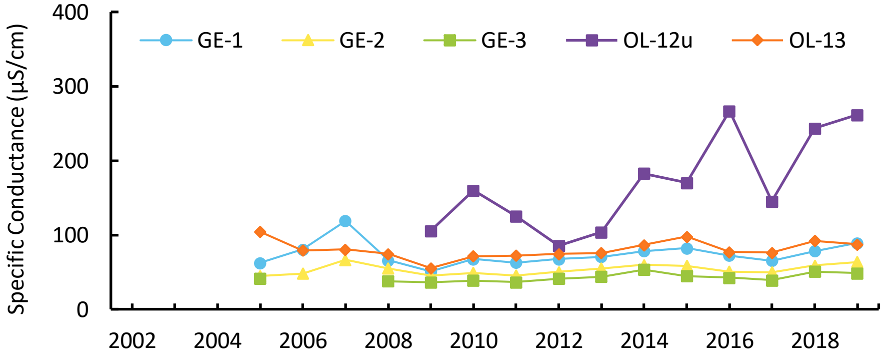


Eaton



GEA-1 (Long Pond Outlet) in Eaton shows a consistent measurement of specific conductance and it is lower than 100 μS/cm which indicates good water quality.

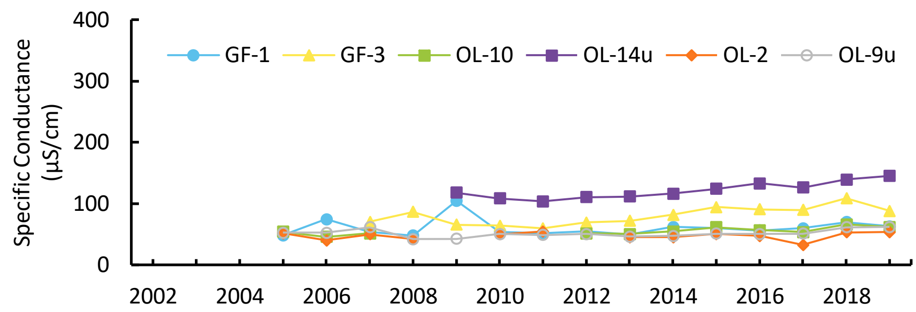
Effingham



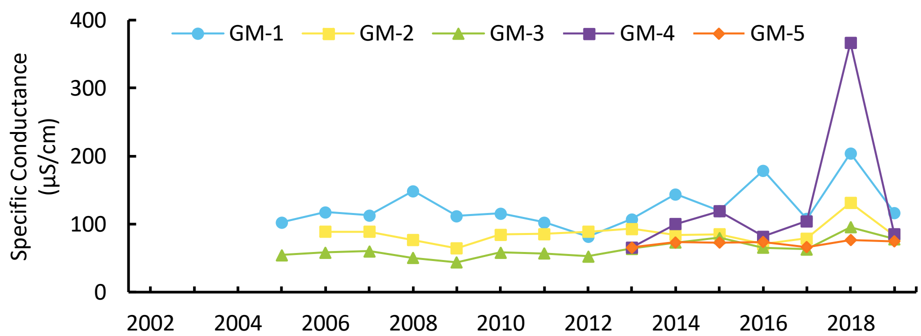
All sites in Effingham have a stable specific conductance throughout the sampling period except for OL-12u (Phillips Brook). Specific conductance here increases drastically and remains above the NH minimal disturbance level of 100 μS/cm indicating a negative water quality impact.

Freedom

Sites in Freedom show lower values of specific conductance with the exception of OL-14u (Square Brook). This site consistently demonstrates conductance values above 100 μS/cm and an increasing trend which is an indicator of worsening water quality and salt overload in the stream.

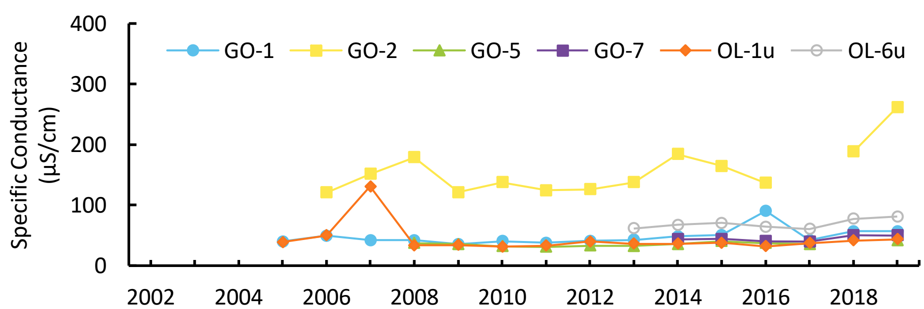


Madison



GM-1 (Banfield Brook) is the only site in Madison that has values of specific conductance consistently above 100 μS/cm. This again indicates salt overload and poorer water quality compared to other streams. GM-4 (Ferrin Brook) saw a huge spike in conductance values in the 2018 summer.

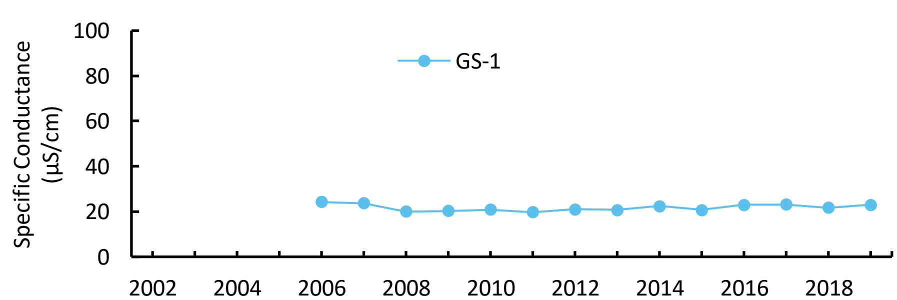
Ossipee



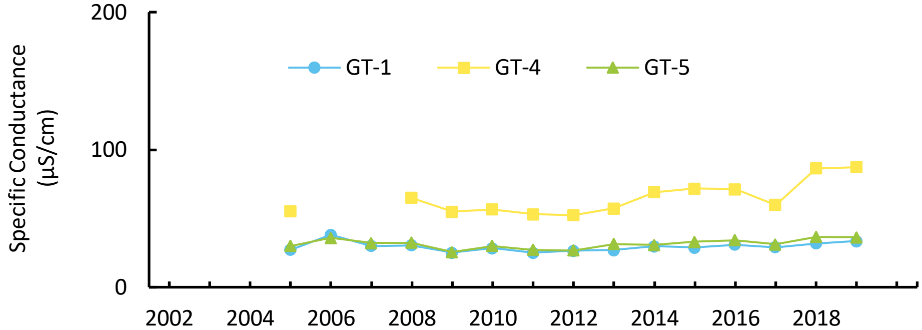
GO-2 (Frenchman Brook) has shown steadily increasing specific conductance with values above 100 μS/cm and into the 200-300 range at times. This is concerning for water quality and indicates a worsening trend with increased salt loading. The other sites in Ossipee show fairly healthy levels of specific conductance.

Sandwich

GS-1 (Cold River) demonstrates a very low and stable specific conductance trend which indicates excellent water quality.



Tamworth



Sites in Tamworth show lower values for specific conductance. GT-4 (Chocorua River) has higher values increasing each year but remains below 100 µS/cm on average since 2002.

Total Phosphorus

What is phosphorus?

Phosphorus is an essential nutrient for algae and plants and is generally considered the limiting factor for algae and plant growth. Phosphorus is not typically found naturally in high concentrations as it is actively taken up by algae and plants. RIVERS samples are analyzed for Total Phosphorus (TP) which consists of all phosphates and organically combined phosphorus in the water sample.

Why do we measure phosphorus?

Too much phosphorus can overwhelm the stream with nutrients and facilitate eutrophication which will deplete the DO supply. Common sources include septic systems, sewage, animal waste, lawn fertilizer, soil erosion, natural wetlands, and atmospheric deposition.

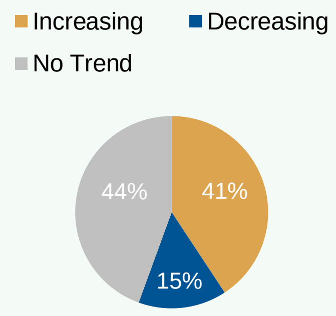
Table 5. Water quality impact of different ranges of total phosphorus values.

Total Phosphorus (ug/L)	Category
< 10.0	Ideal
11.0 – 25.0	Average
26.0 – 49.0	More than desirable

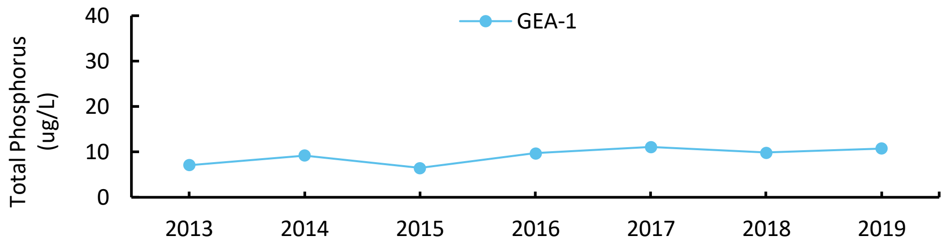
The Watershed View

Total Phosphorus

There were increasing trends in total phosphorus at 41% of sites. Overall, values were mostly within the average range, indicating good water quality.



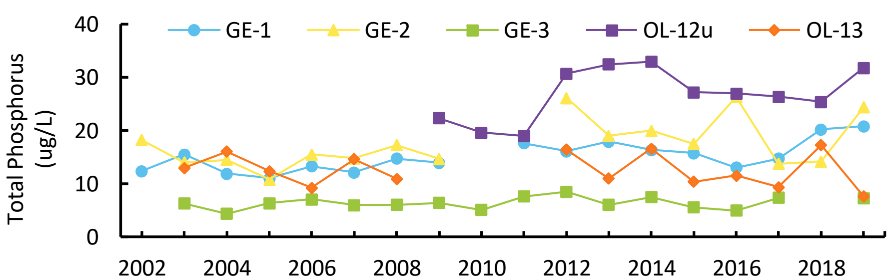
Eaton



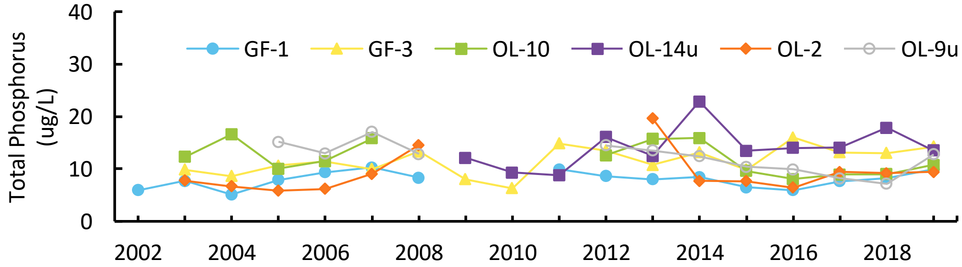
GEA-1(Long Pond Outlet) demonstrates a stable and healthy trend of TP concentrations.

Effingham

Overall, TP is much more variable at the Effingham sites when compared to others. OL-12u (Phillips Brook) has concentrations of TP that can be considered “more than desirable” at times (Table 5) meaning they are between 26 and 49 ug/L. This is an indicator of less than good water quality at this site.



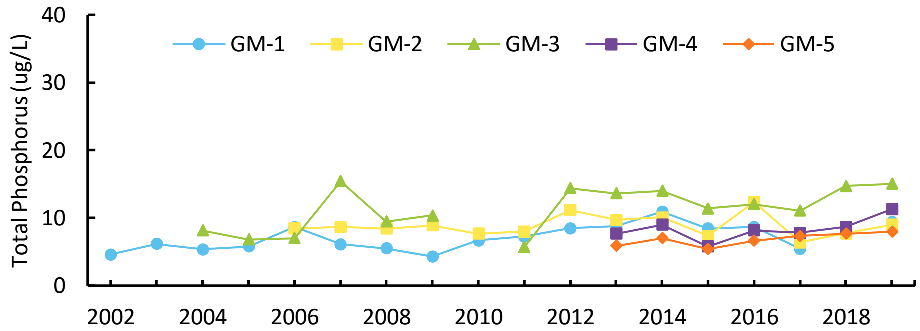
Freedom



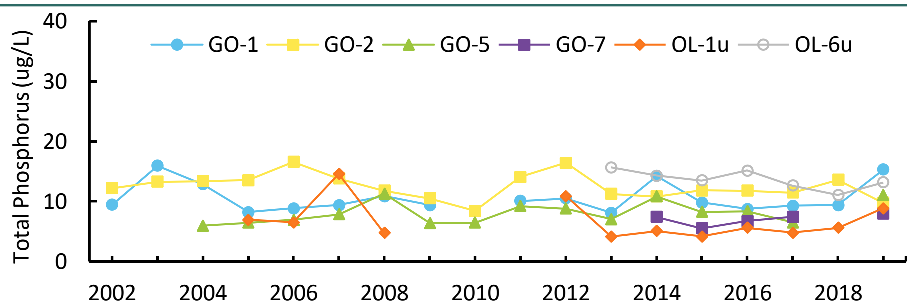
For the sites in Freedom, TP stays within desired limits and varies slightly throughout the sampling period. Overall, there is no trend here that is concerning for water quality.

Madison

All sites in Madison demonstrate a consistent and stable TP trend that indicates good water quality.



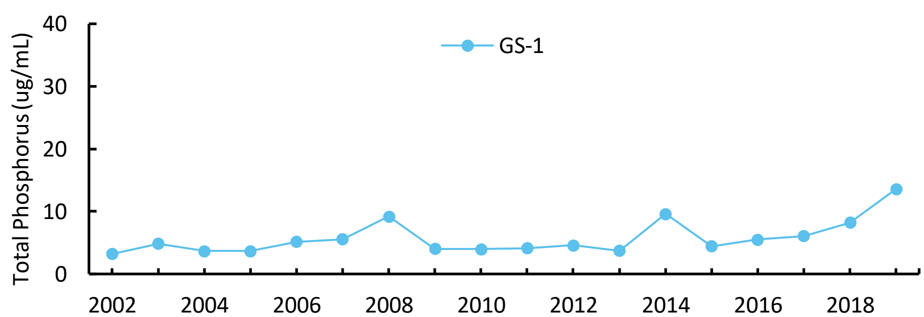
Ossipee



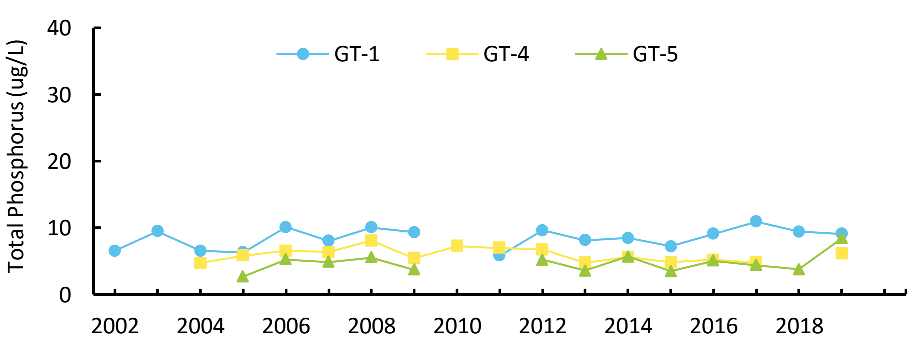
Sites in Ossipee show slight variation in TP concentrations, but overall, they remain low and indicate good water quality.

Sandwich

GS-1 (Cold River) shows a slight increase in TP over time that should be monitored. As of now, values remain low and indicative of good water quality.



Tamworth



The three sites in Tamworth demonstrate stable and consistently low concentrations of TP indicating good water quality.

Cation/Anion Data

This second results section in the report will highlight the cation/anion data which include all the chemical parameters that water grab samples are analyzed for at the NH Water Resources Research Center (WRRC) located at UNH. Much of these data are only shown up until 2018 due to a lack of received results in the last couple years. Different from the field data section of this report, these results will mostly be shown in bar charts highlighting median values for each parameter throughout the sampling period which extends from 2002-2018. These data are separated from the rest of the field data because samples are only taken at 10 of the 29 stream sites once a month. Overall, this dataset is smaller and encompasses fewer stream sites in the program. Some field data will be displayed in this section of the report as some ion concentrations correlate with field sample values. Some of the numbers will seem very small while others will seem much larger, so it is important to put the data in context and refer back to Tables 2 and 3 to see if there is a regulatory standard for a particular chemical in surface waters. For example, the standard for ammonium (NH_4^+) is going to be a lot lower than that of chloride (Cl^-) which means it is expected to see greater amounts of chloride in surface water than ammonium. Each parameter will be examined either individually, or in connection with a few others, and each town's sites are highlighted in a different color on the graphs.

A note about error bars:

Each bar chart shows error bars associated with data from each of the 10 R.I.V.E.R.S. sites. The bar charts are displaying median values for each parameter and so the error bars show the standard error from the median for each set of data. Essentially, these error bars indicate the level of uncertainty in each reported measurement. They give a general idea of how precise a measurement is.

Sodium, Chloride, and Specific Conductance

What is sodium?

Sodium is the sixth most abundant element on earth, and it is found soils, plants, water, and foods naturally. It is also a very water-soluble element meaning amounts can quickly increase in waterbodies. Groundwater typically contains higher concentrations of salts than surface waters due to leaching from soils and bedrock. Human activity can increase sodium concentrations in surface waters from sewage and industrial effluents and the use of road salts to control snow and ice.

What is chloride?

Chloride (Cl^-) is an element that is naturally present in most water bodies. Concentrations are typically low and depend on geology, atmospheric deposition, and human activities. The salting of roads during winter periods can contribute significantly to increases in Cl^- concentrations and causes salt levels to be very seasonal in areas where road salt is used in the winter.

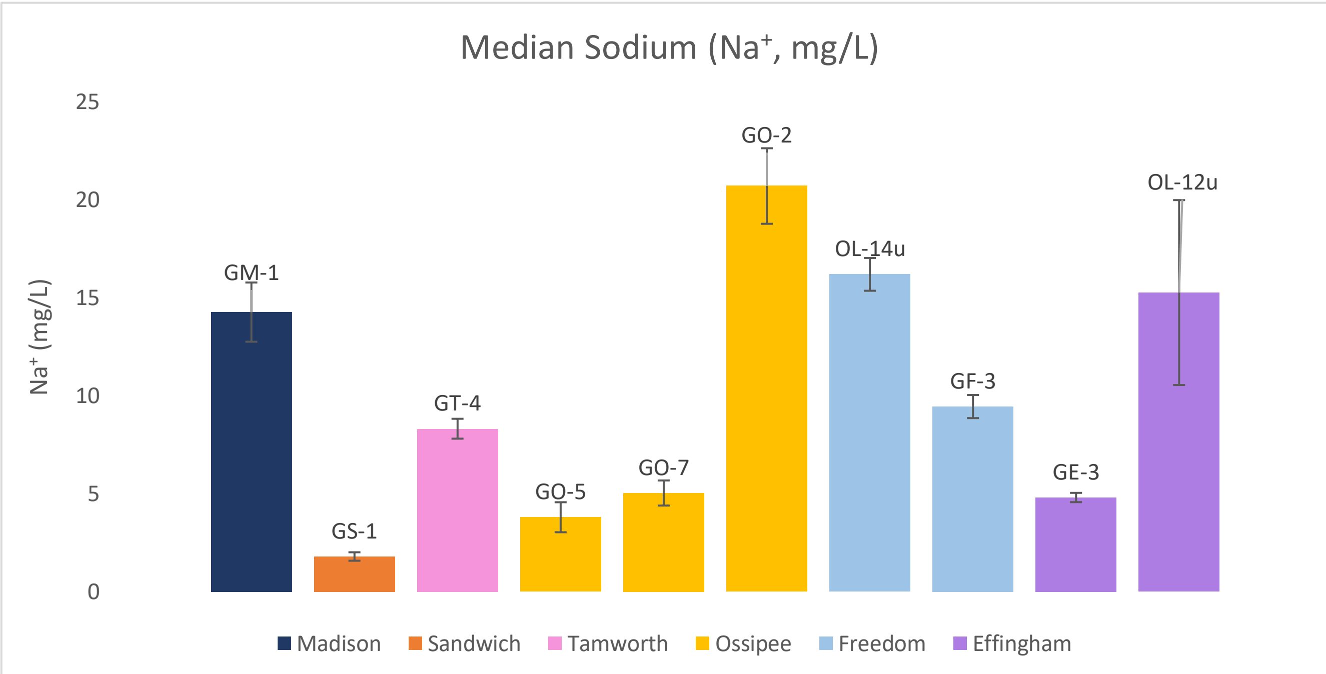
Why do we analyze these parameters together?

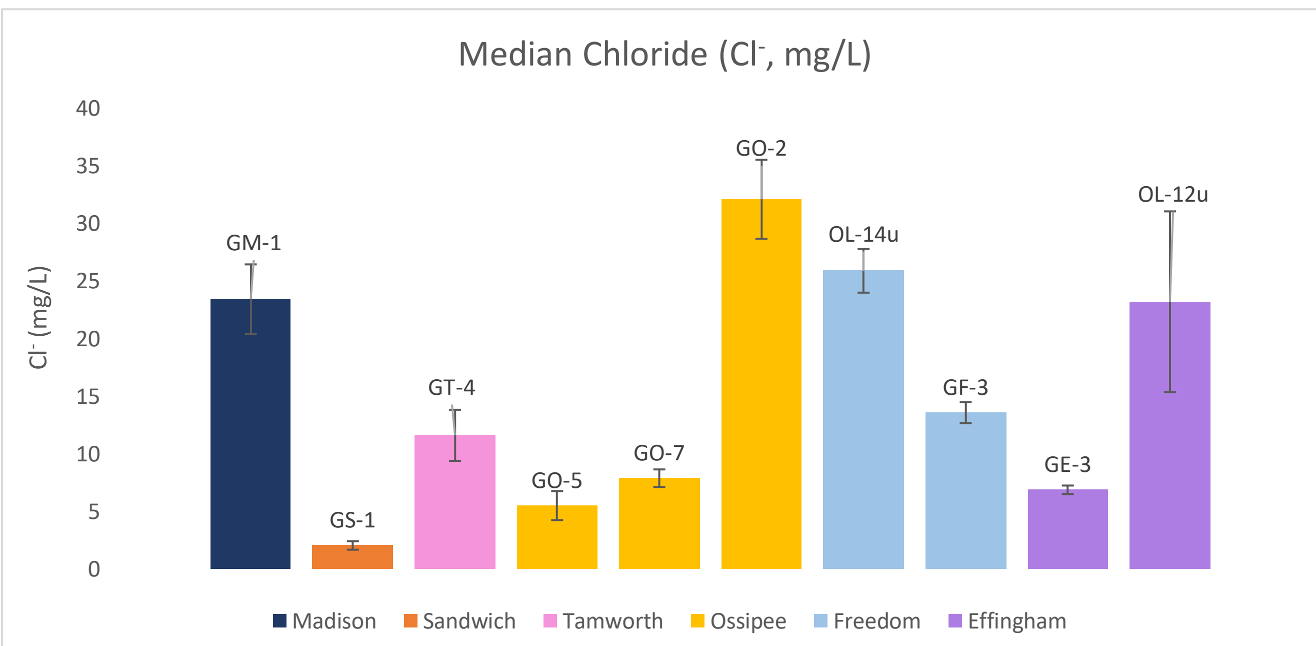
Sodium and chloride go hand in hand as two important dissolved ions in surface and ground waters. Changes in concentrations of either parameter will likely accompany changes in the other as well. They are the two main constituents of table salt, a common road maintenance substance in areas with harsher winters.

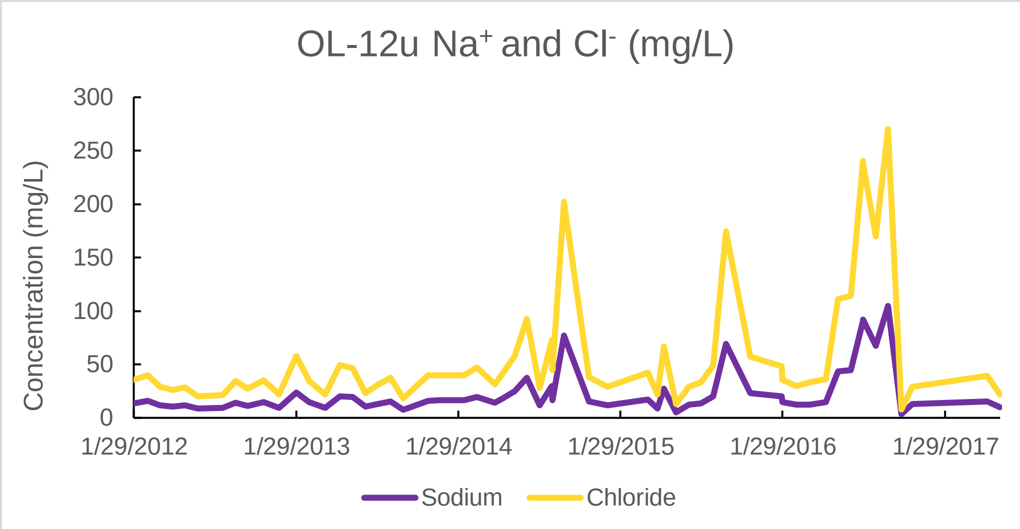
As mentioned before, specific conductance is a highly important water quality parameter that indirectly measures the amount of dissolved ions in the water column. Since Na^+ and Cl^- make up a large majority of these ions in water, specific conductance is frequently used as a proxy for salt.

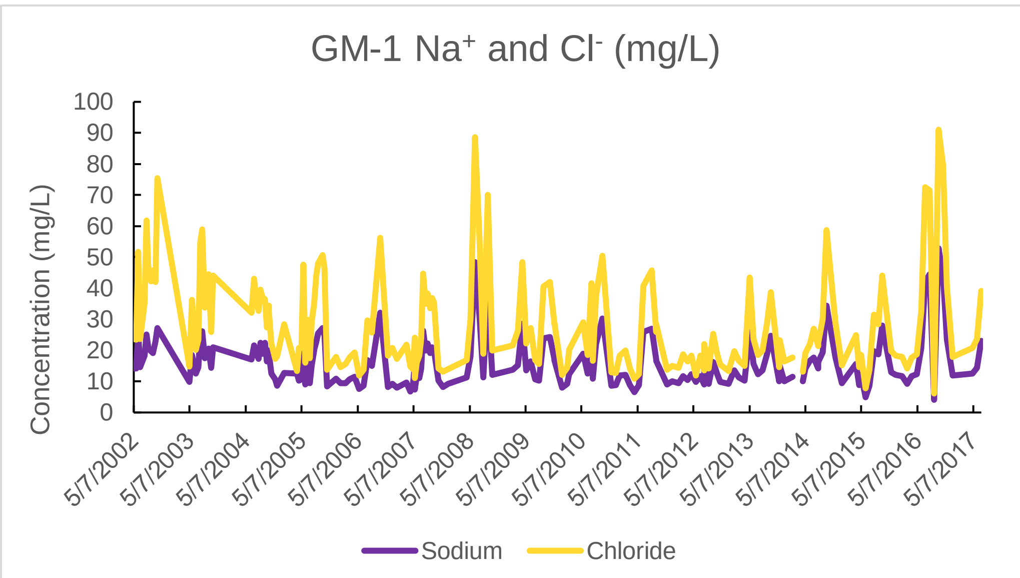
Correlative scatter plots and time series graphs will be shown in addition to the overview bar charts in order to demonstrate the seasonality of Na^+ and Cl^- due to road salting in this area of New Hampshire.

For sodium, the EPA standard maximum value is 200 mg/L and for chloride it is 250 mg/L (Table 3).

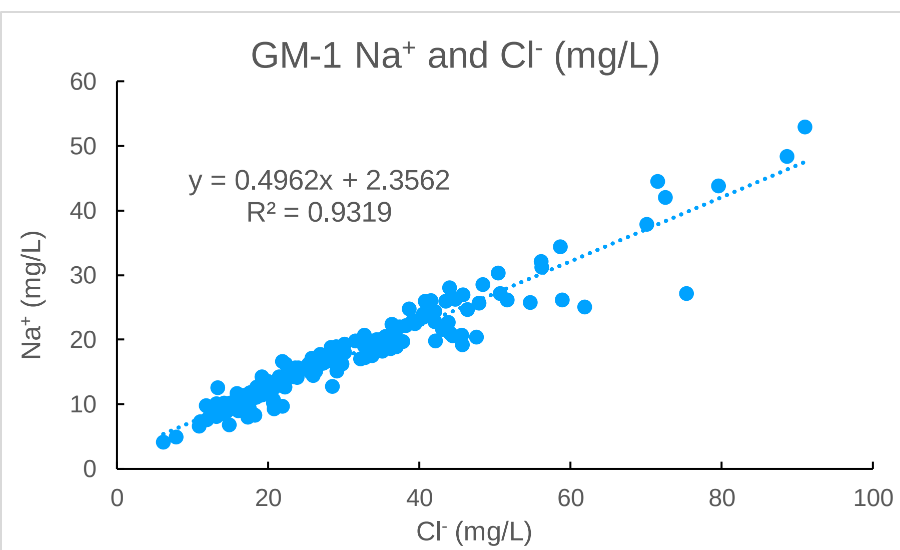

Median Sodium (Na+, mg/L)
Na+ (mg/L)
0
5
10
15
20
25
GM-1
GS-1
GT-4
GO-5
GO-7
GO-2
OL-14u
GF-3
GE-3
OL-12u
Madison
Sandwich
Tamworth
Ossipee
Freedom
Effingham


Median Chloride (Cl-, mg/L)
Cl- (mg/L)
0
5
10
15
20
25
30
35
40
GM-1
GS-1
GT-4
GO-5
GO-7
GO-2
OL-14u
GF-3
GE-3
OL-12u
Madison
Sandwich
Tamworth
Ossipee
Freedom
Effingham

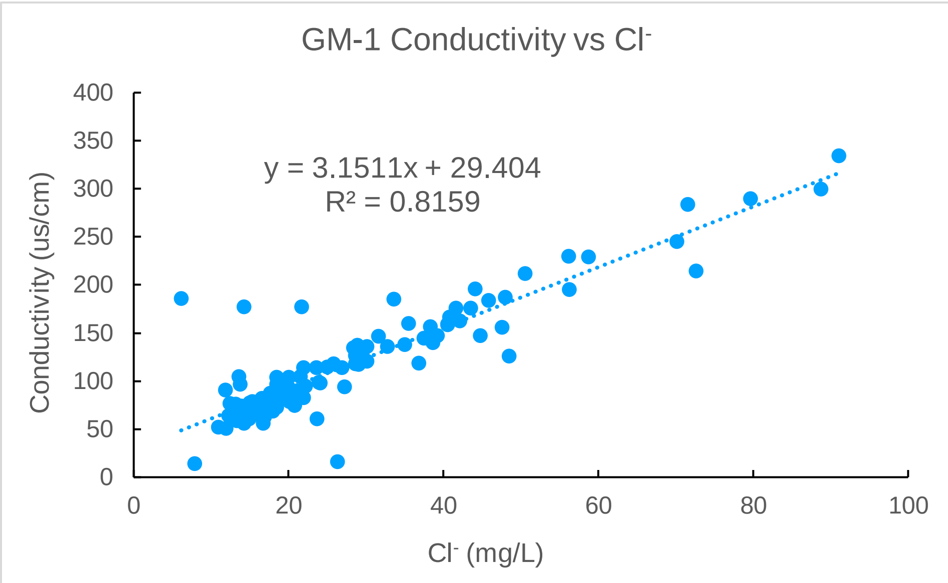




Sodium and chloride are two parameters that experience changes at the same times. To the left are examples of this from 2 out of the 10 RIVERS sites sampled. The two lines (sodium and chloride) mirror each other throughout the sampling period for both OL-12u (Phillips Brook) and GM-1 (Banfield Brook) showing that increases and decreases in sodium and chloride are occurring at the same time. Relatively, between these two sites, it is evident that OL-12u tends to reach higher maximum values of these two parameters than GM-1. OL-12u is located off a major road which is likely contributing to its high values of sodium and chloride. Typical values of sodium in streams are less than 50 mg/L and concentrations at OL-12u will exceed that frequently which is concerning for water quality. However, both of these streams have very similar median sodium and chloride values which can be seen in the bar charts above.

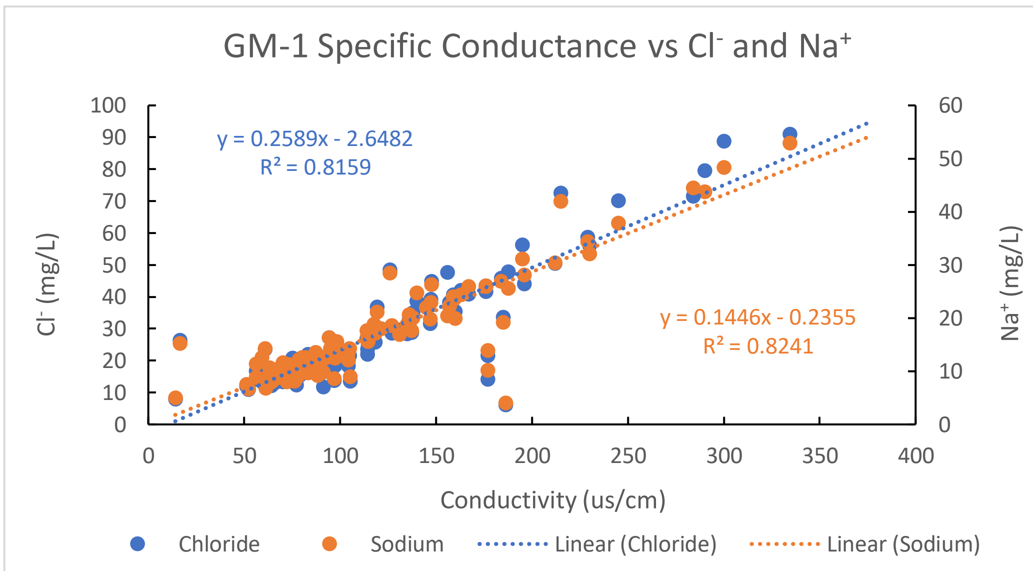


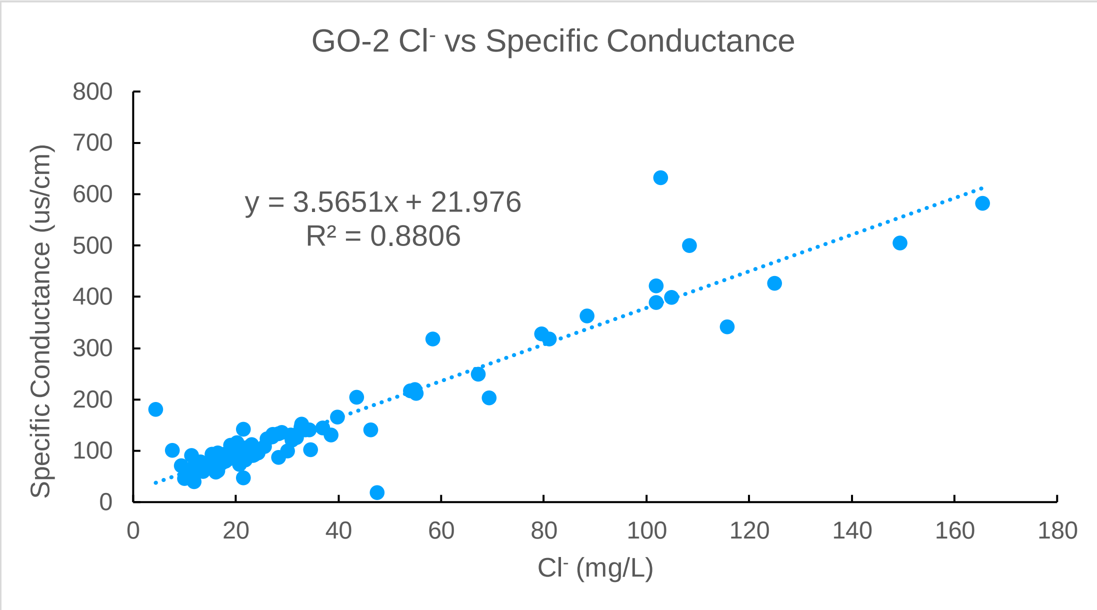
This figure shows a scatter plot which graphs Cl^- concentrations on the x-axis, and Na^+ concentrations on the y-axis. Time is not taken into consideration here. It is evident that the two parameters are strongly correlated with each other at GM-1 (Banfield Brook). There is an increasing trend meaning that when Cl^- concentrations increase, Na^+ concentrations do as well. The R^2 value displayed on the graph is a measure of how strong a linear trend is between the two variables. Values close to 1 indicate a strong trend. In this case, the R^2 value is 0.93 which indicates a strong increasing trend. Statistically speaking, these two variables are correlative at this stream site demonstrating again how they tend to change with each other. Essentially, this scatterplot is showing the same thing as the line graph above: sodium and chloride have a direct relationship.



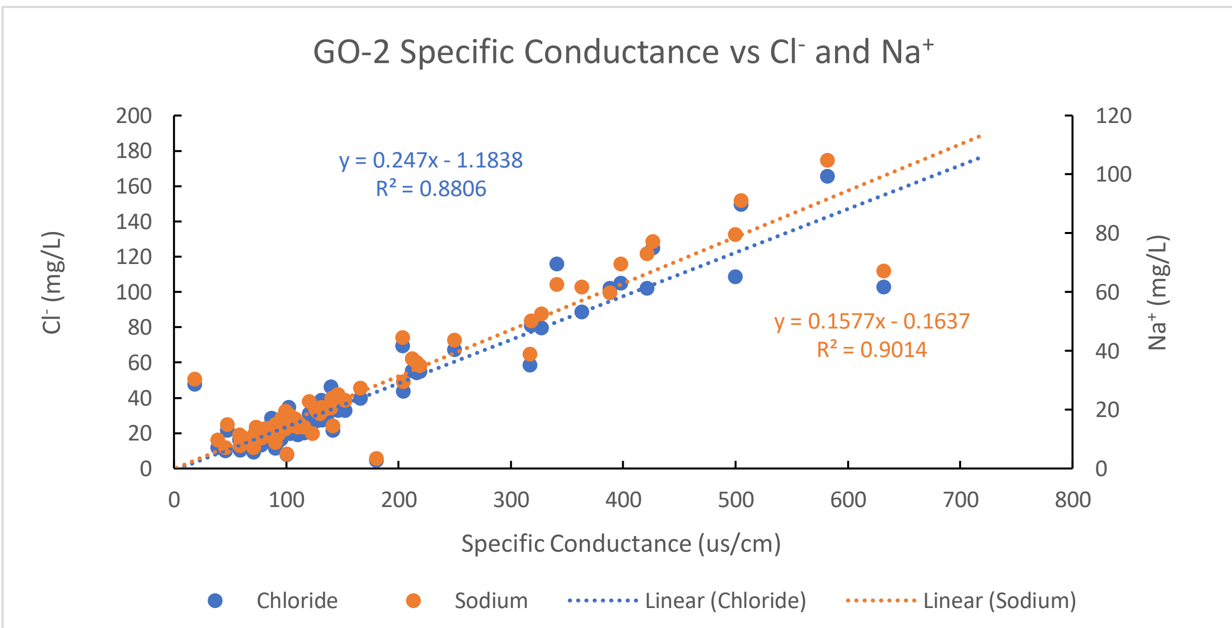
This figure on the left shows a scatterplot comparing Cl^- (x-axis) and specific conductance (y-axis). There is a strong linear trend indicating that increases in Cl^- at GM-1 (Banfield Brook) are directly correlated to increases in specific conductance. This is expected because specific conductance can be an indirect measurement of salt concentrations in surface waters, making it a valuable parameter when assessing the water quality of any waterbody. The R^2 value is fairly high (0.82) indicating a solid correlation between the two variables.

The scatterplot to the right is similar to the one above, except Na^+ is included on a secondary y-axis along with Cl^-. Both parameters are given their own trend line and R^2 value which indicate their relationship to specific conductance. R^2 values of 0.82 for each continue to indicate a strong correlation between both parameters, and specific conductance.





These scatterplots show the same as above but for the GO-2 (Frenchman Brook) site. Again, there is a strong correlation that exists between Na^+, Cl^- and specific conductance.



Values of sodium and chloride here in the Ossipee watershed are high at certain sites due to road salt being used in the winter months. No Na^+ values ever reach the 200 mg/L EPA imperative standard (Table 3), but values will frequently be above 100 mg/L at certain sites which is higher than typical values found in freshwater streams for these parameters. This is especially true of GM-1 (Banfield Brook), OL-12u (Phillips Brook), GO-2 (Frenchman Brook), and OL-14u (Square Brook). Increasing conductance levels at 85% of stream sites since the RIVERS program began indicate increasing concentrations of sodium and chloride as well. For more information on road salt impact to streams see the discussion section on pages 50-51.

Nitrogen

What is nitrogen?

Nitrogen is an essential nutrient for plant and animal growth, and it is widely distributed throughout the world in many chemical forms.

As part of the nitrogen cycle, nitrogen can be found in the natural environment in several forms such as nitrogen gas (N_2), nitrite (NO_2^-), nitrate (NO_3^-) and ammonium (NH_4^+).[14] NO_3^- is the most common form of nitrogen found in surface waters. When oxygen is present, which is the case in most fluvial systems, N_2 gas from the atmosphere is fixed by microorganisms into NO_2^- which quickly becomes oxidized to NO_3^-. NO_3^- can also enter surface water from chemical fertilizers used in agricultural areas.[16] High concentrations of NO_3^- in water essentially feeds aquatic plants such as algae which can lead to rapid algal growth and a decrease in water quality. Concentrations of 5 mg/L or more typically indicate animal waste or fertilizer runoff.[15] If quantities of NO_3^- in excess of 10 mg/L exist in drinking water it can present an immediate and severe health threat to infants.[16] NH_4^+ concentrations should be extremely low in typical undisturbed streams because in the presence of oxygen it is oxidized to NO_3^- as a part of the nitrogen cycle. Values even above 2mg/L are considered toxic to most aquatic organisms.

We measure several different forms of nitrogen. Total Dissolved Nitrogen (TDN) consists of dissolved organic (DON) and inorganic nitrogen (DIN). We also measure two primary components of inorganic nitrogen: ammonium (NH_4^+) and nitrate (NO_3^-).

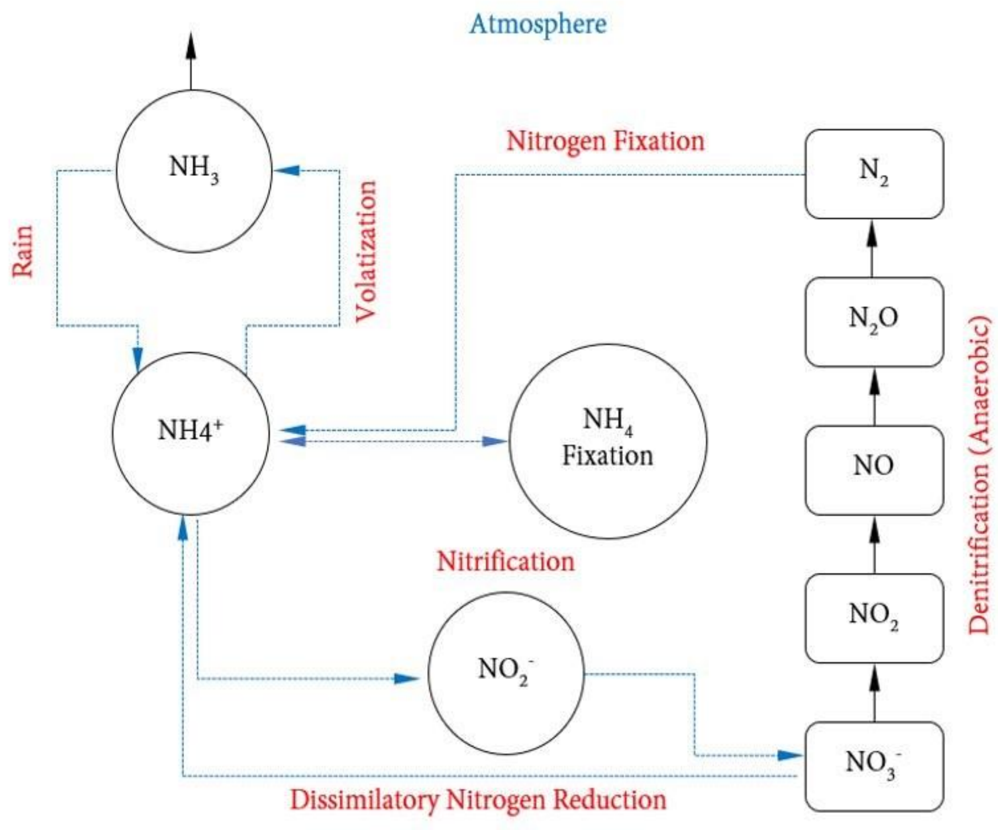
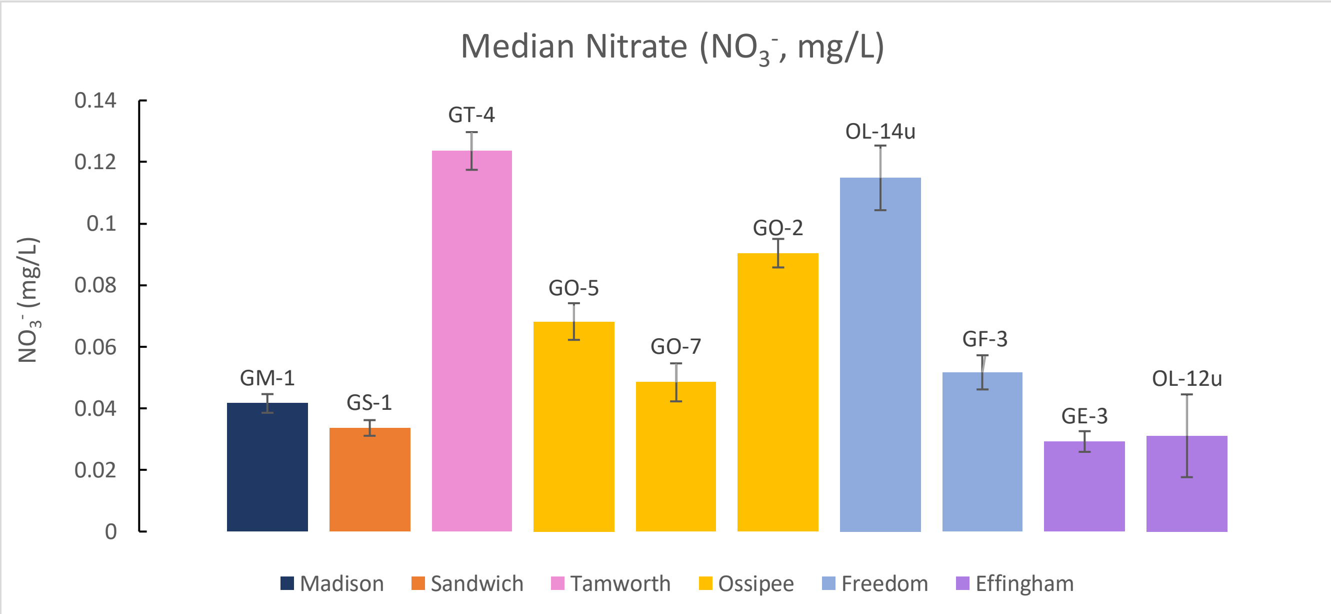


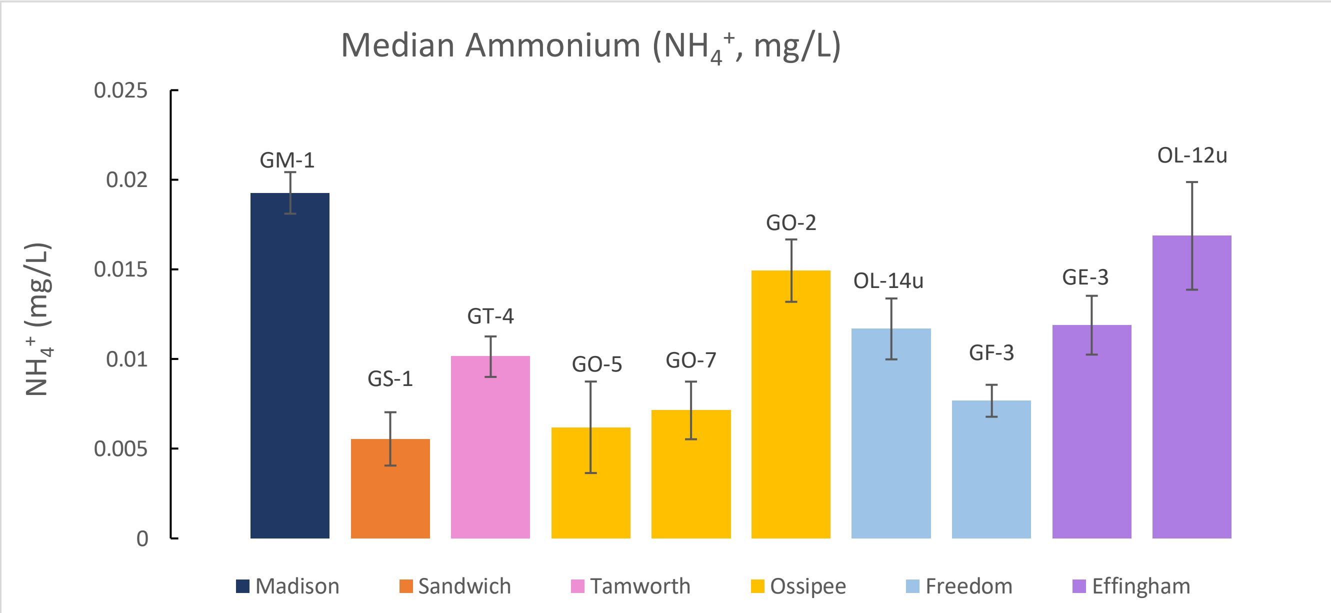
Figure 6. Diagram of the Nitrogen Cycle[19]

Nitrate



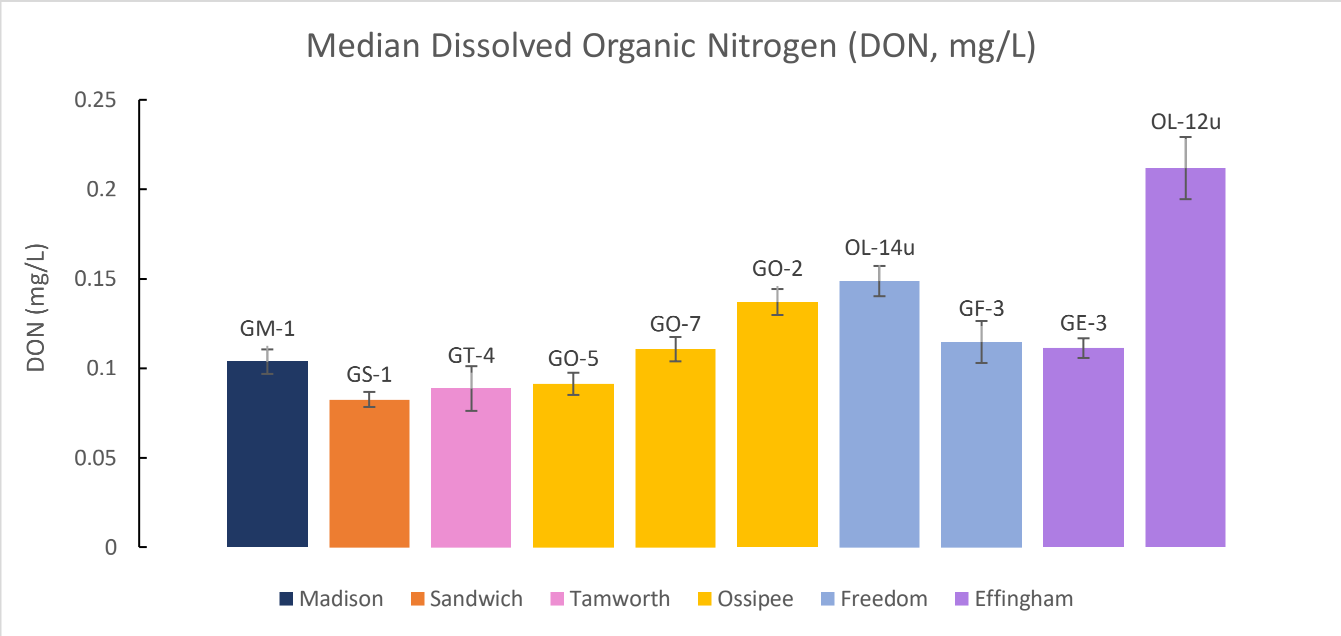
NO_3^- is the most common form of nitrogen found in waterways due to the natural processes of the nitrogen cycle. New Hampshire has listed that 0.5 mg/L of NO_3^- is the minimal background disturbance level in surface waters, with 5 mg/L or greater indicating significant pollution. Levels of NO_3^- in streams that reach higher than this usually experience significant loading from agricultural runoff in areas with poor buffers to protect streams from this type of pollution. As is evident in the figures above, NO_3^- levels never reach concentrations that would be considered harmful to the stream systems in the Ossipee Watershed. This is to be expected as much of the land cover of the Ossipee Watershed is forested region. Most of the stream sites in this program are buffered by forests and protected land which help reduce concentrations of chemicals such as NO_3^-. The relatively small amount of land development in this watershed also lends itself to healthy streams and waterways.

Ammonium



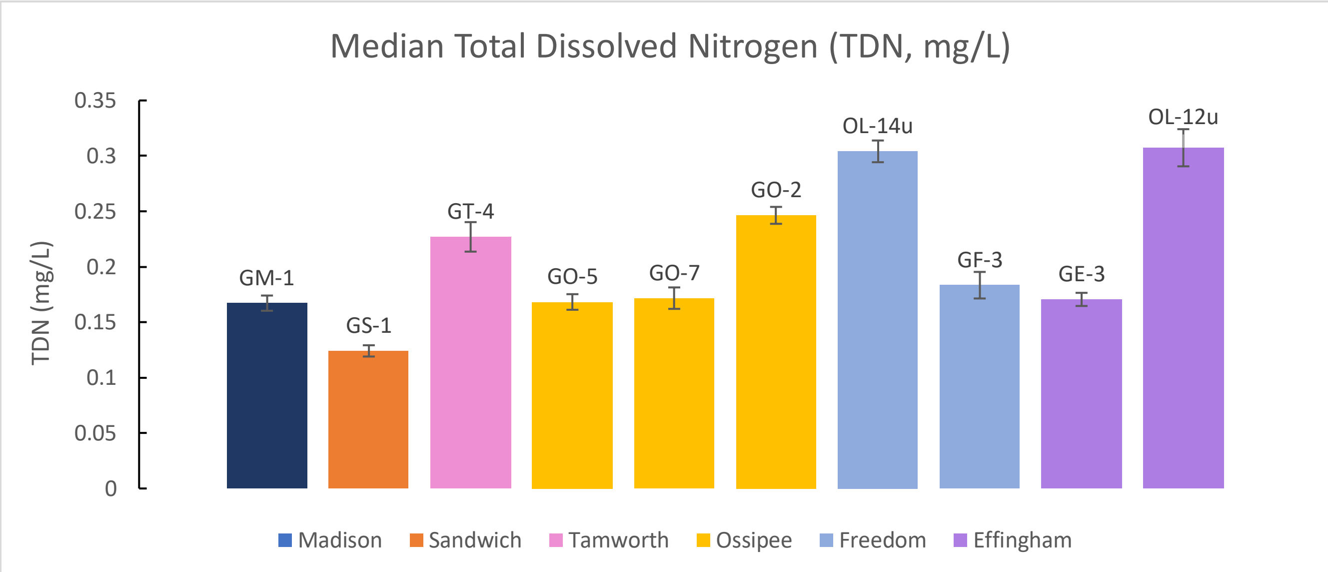
New Hampshire lists 0.2 mg/L as the minimal background disturbance level for NH_4^+ in surface waters. Similar to the NO_3^- levels above, NH_4^+ concentrations at the 10 stream sites are overall very low and show no significant levels of disturbance or pollution. Healthy streams that have adequate levels of dissolved oxygen are expected to show extremely low levels of NH_4^+ which is the case with the streams from this program. Only when oxygen is severely depleted can NH_4^+ persist at high concentrations in freshwater systems. It is often found at the bottom of deep eutrophic lakes or reservoirs where oxygen has been used up by algae and cyanobacteria producing anoxic conditions. NH_4^+ does not currently pose a threat to these stream sites in the RIVERS program.

Dissolved Organic Nitrogen (DON)



Dissolved organic nitrogen (DON) compounds in waterways typically come from photosynthetic organisms such as algae or other plants, or from animal waste leaching from the soil.[20] DON compounds substances are commonly found as proteins, free amino acids, sugars and nucleic acids (from RNA and DNA).[20] DON is a parameter that is still poorly understood in scientific literature. It plays an important role in the nitrogen cycle, but relatively little is known about the compounds that make up DON.[20] There are currently no official New Hampshire state or federal standards for how much DON should be present in surface waters. OL-12u (Phillips Brook) has the highest median and maximum values of DON measured out of the 10 sites. Overall, measured values never reach or exceed 1 mg/L. It is uncertain whether the slightly larger amounts at OL-12u are impacting the water quality of that stream site or not. OL-12u is impacted by the drainage of a wetland area and since wetlands contain a lot of organic material, that could be causing higher amounts of DON.

Total Dissolved Nitrogen (TDN)



Total dissolved nitrogen (TDN) is a measure of the total amount of dissolved organic nitrogen (DON) and dissolved inorganic nitrogen (DIN). Essentially, TDN adds up NO_3^-, NO_2^-, NH_4^+ and DON to get a total value. NO_3^-, NO_2^- and NH_4^+ are the major constituents of DIN. It is expected that a particular stream site would have higher amounts of TDN than the other 3 parameters mentioned above because TDN is looking at the sum of those nitrogenous materials. It is not surprising therefore, that OL-12u has the highest median and maximum values of TDN because that was the case for the DON. Overall, it is desirable to have lower levels of total nitrogen in stream systems and none of these 10 sites have levels of nitrogen that would be considered concerning or harmful to water quality.

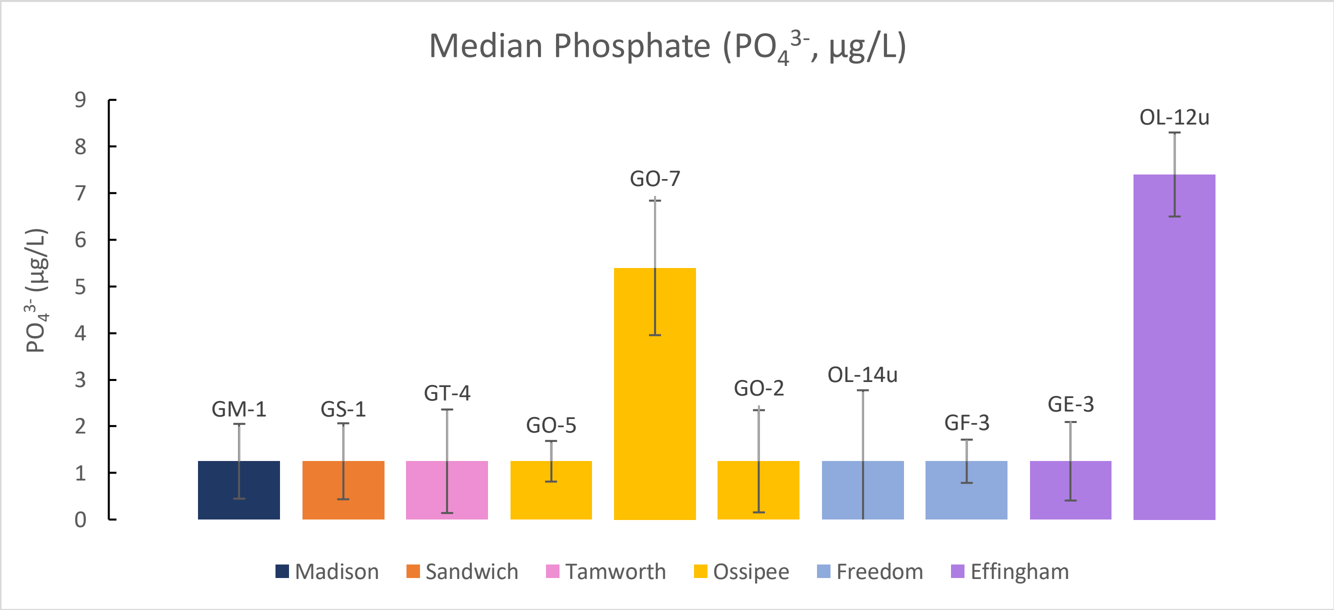
Phosphate (PO_4^{3-})

What is Phosphate?

Phosphate (PO_4^{3-}) is the most common form of phosphorus found in waterways under typical conditions. Phosphorus is important because it is often a limiting nutrient for plant and algal growth in waterways. High amounts of phosphorus in the water suggests a high level of agricultural or residential runoff into the stream. Phosphorus is actively taken up by aquatic plants, so it is rarely found in high quantities in freshwater. The EPA has set a standard of between 0.5-0.7 mg/L of PO_4^{3-} in class A surface waters (Table 3). Typical concentrations are between 5.0 and 20.0 µg/L.[15]

Phosphate in the Ossipee Watershed

The graphs for PO_4^{3-} look a bit different because they are so low across the board. The instrumentation that analyzes the water samples has a detection limit, meaning that if PO_4^{3-} concentrations are lower than that limit, it will give an output result of the limit. Only GO-7 (Ossipee Outflow) and OL-12u (Phillips Brook) do not have their median value equal to the detection limit. However, the values at these two sites never reach concentrations that would be concerning for water quality.



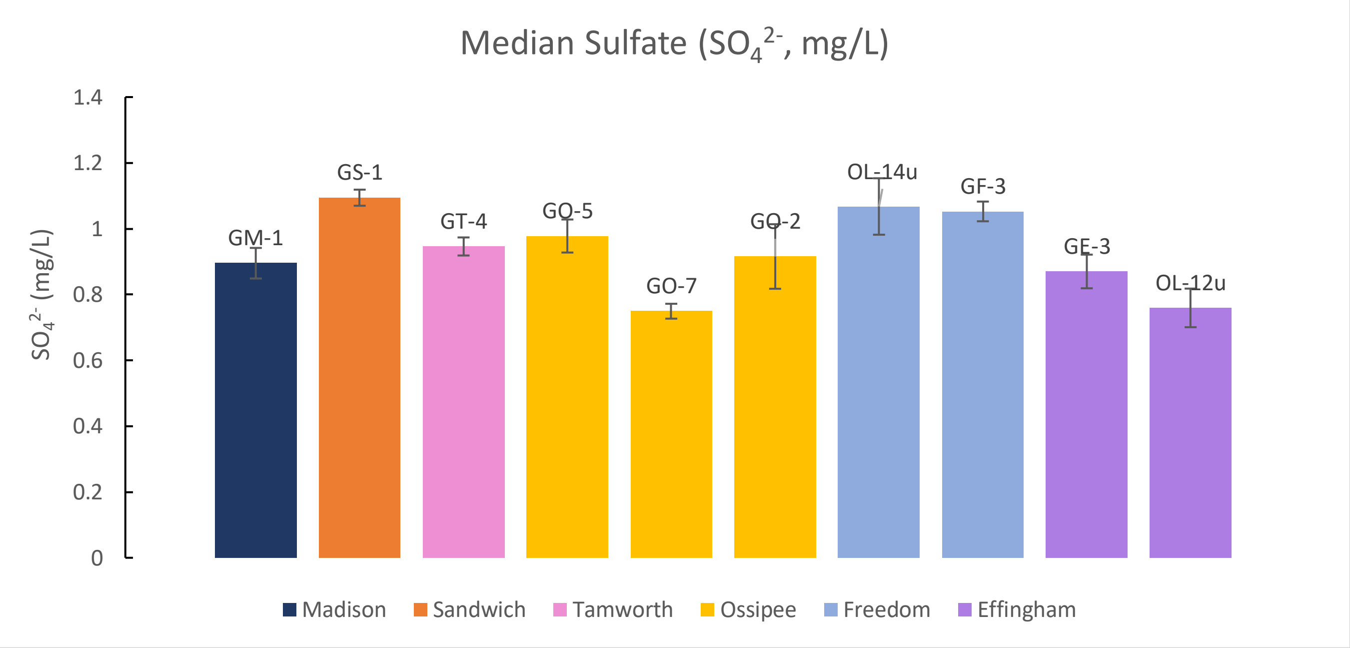
Sulfate (SO_4^{2-})

What is Sulfate?

Sulfate is a stable, oxidized form of sulfur that is readily soluble in water. Similar to nitrate in the nitrogen cycle, sulfate is the most common oxidized form of sulfur in the sulfur cycle. Many sulfates attach to salt ions to form compound salts of sulfuric acid (for example $MgSO_4$).[21] They are typically discharged into waterways from mines, smelters, paper mills, textile mills, and tanneries.[21] The combustion of fossil fuels at power plants releases sulfur dioxide (SO_2) into the atmosphere which can also contribute to sulfate content in surface waters. If oxygen is not present in a stream environment, sulfate can be used as an oxygen source by bacteria and other microorganisms which convert it to hydrogen sulfide (H_2S), a chemical with a familiar rotten egg odor.[15] Sulfate concentrations in surface waters are usually between 2 and 80 mg/L. The EPA has a standard that sulfate concentrations should not exceed 200 mg/L in surface waters (Table 3).

Sulfate in the Ossipee Watershed

Sulfate levels are fairly uniform throughout the 10 stream sites showing no major trends. Concentrations remain below 2 mg/L indicating no levels of sulfate pollution, and good water quality overall.



Dissolved Organic Carbon (DOC)

What is Dissolved Organic Carbon?

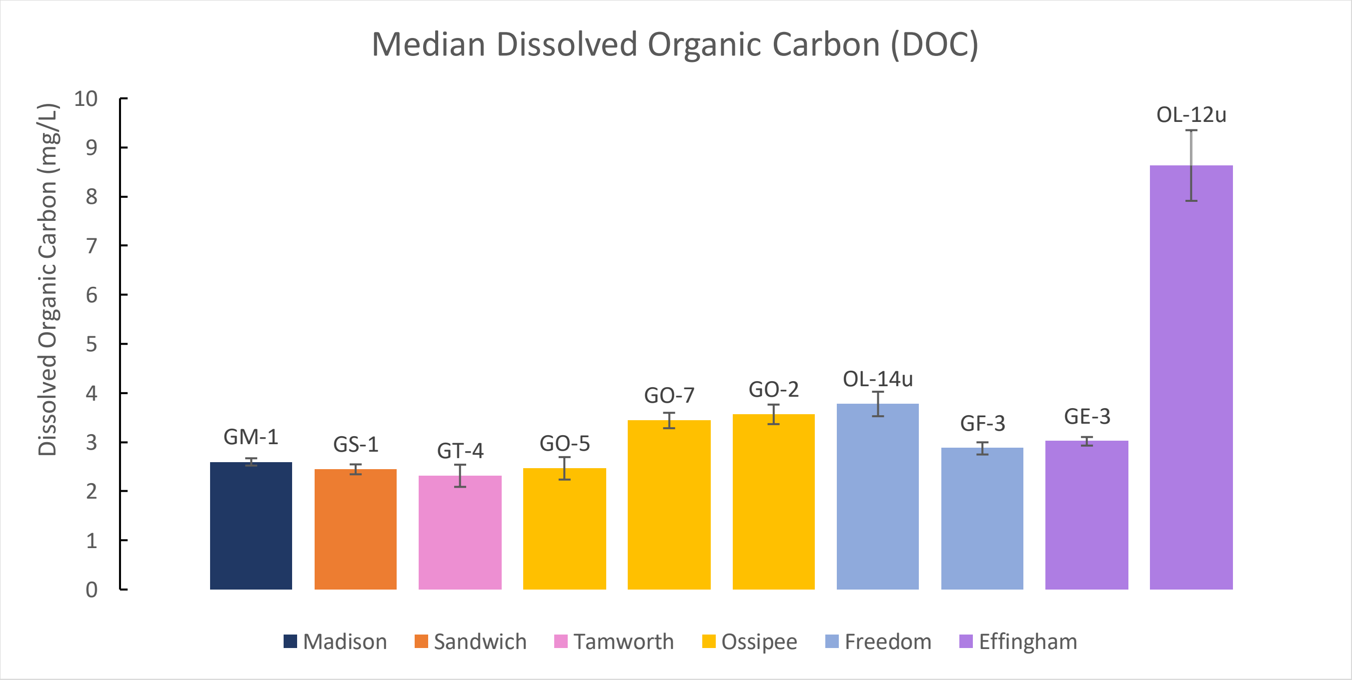
Dissolved Organic Carbon (DOC) is a measurement of an array of organic carbon compounds and molecules that are dissolved in the stream water. These compounds typically come from plant matter and debris that has been broken down by microorganisms in the soil or water column. Although there is no surface water standard for minimum DOC levels, most streams and rivers would typically have low quantities of DOC (0-10 mg/L). Streams and rivers fed by wetlands or bogs would likely contain between 5-50 mg/L of DOC. DOC is important because it can alter nutrient levels, pH, light absorbance and photochemistry of the river system.[22]

Table 6. Typical DOC values found in surface water and sewage effluent.[22]

Water type	Expected DOC
Lowland rivers	0 – 10 mg L^{-1}
Upland / peat rivers	5 – 50 mg L^{-1}
Primary/secondary effluent	5 – 70 mg L^{-1}
Raw municipal sewage	50 – 200 mg L^{-1}
Contaminated Industrial effluent	100 – 500 mg L^{-1}

Dissolved Organic Carbon in the Ossipee Watershed

One site in particular, OL-12u (Phillips Brook), stands out as having a higher median DOC value, and a higher range of DOC concentrations. This can likely be attributed to the fact that the sampling site along Phillips Brook is right near a wetland drainage. DOC tends to affect pH and turbidity as well DOC being higher could very well be affecting the pH values at OL-12u which tend to be between 5-6 suggesting moderate water quality impact. Although not by much, these pH values do drop below the NH minimum standard at times as well. It is likely that a relationship between the DOC, pH, and turbidity exists at OL-12u creating a minimal water quality impact that is important to note. Otherwise, the sites show no sign of elevated levels of DOC that would be harmful for water quality.



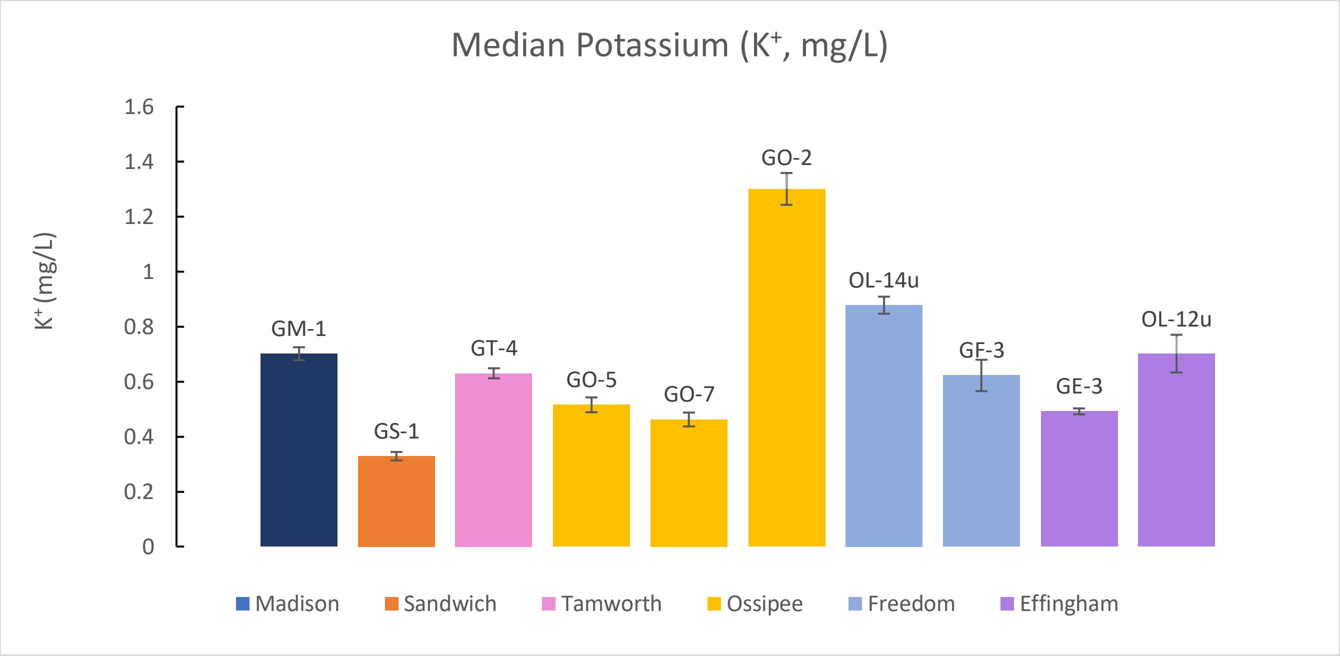
Potassium (K^+)

What is Potassium?

Potassium (K^+) is a dissolved mineral that is found naturally in surface waters. However, it is typically found in smaller concentrations as rocks which are made up of K^+ are usually very resistant to weathering.[15] Potassium can enter waterways via potassium salts which are widely used in industry and in fertilizers for agriculture.[15] Therefore, areas with more agricultural activity might see loading of K^+ into stream systems. There is no state or federal standard for the amount of K^+ that should be in the waterway, but concentrations are typically less than 10 mg/L.[15]

Potassium in the Ossipee Watershed

K^+ measurements for the 10 RIVERS sites differ slightly with GO-2 (Frenchman Brook) having the highest median value and greatest range of concentrations. Overall, values are very low (less than 2 mg/L throughout the sampling period), and it is safe to say that K^+ concentrations are not causing a negative impact on water quality in the Ossipee Watershed.



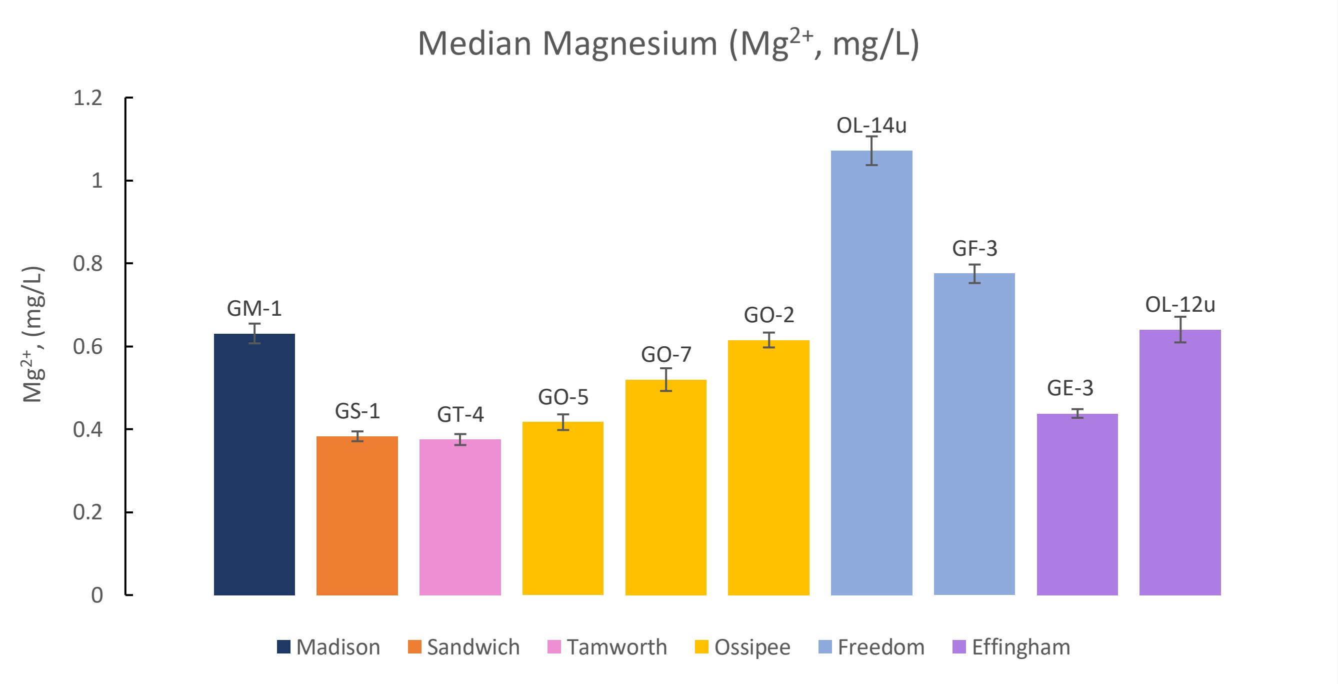
Magnesium (Mg^{2+})

What is Magnesium?

Magnesium is common in natural waters as Mg^{2+}, and along with calcium, is a main contributor to water hardness. Magnesium additions to streams are almost entirely from the natural environment, typically the weathering of magnesium-rich rocks or organic-rich soils.[15] As a component of water hardness, it is typically more important when it comes to drinking water. It is typically found in low concentrations in surface waters but is an essential ion for many organisms. Once again, no state or federal standard exists for how to evaluate minimum and maximum levels of Mg^{2+} in surface waters.

Magnesium in the Ossipee Watershed

Similar to potassium and calcium, magnesium concentrations differ slightly between the 10 sites with OL-14u (Square Brook) having the highest median value and greatest range of concentrations. Overall, measurements seldom surpass 1 mg/L suggesting a very minimal to negligible impact of Mg^{2+} on water quality at these sites.



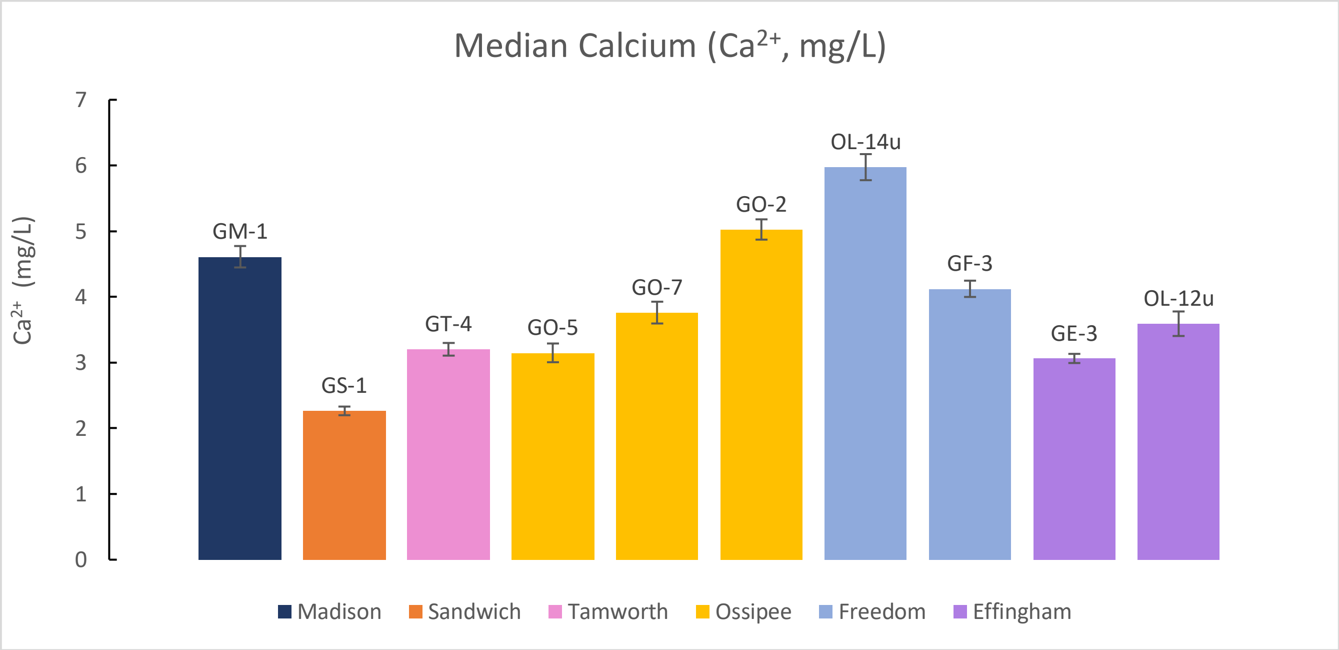
Calcium (Ca^{2+})

What is Calcium?

Calcium is present in all waters as Ca^{2+} and is readily dissolved from rocks rich in calcium minerals such as limestone and gypsum.[15] It is especially abundant in groundwater and when combined with magnesium accounts for water hardness, which is more applicable to drinking water. Calcium is an essential element for all organisms and is incorporated into the shells of many aquatic invertebrates.[15] Acidic rainwaters can contribute more Ca^{2+} to streams, as can wastewater treatment processes and industrial water treatment. No active standard for Ca^{2+} concentrations in surface water exists, but concentrations in streams will typically be less than 15 mg/L for streams without carbonate-rich rocks. Streams with carbonate-rich rocks will likely have between 30-100 mg/L

Calcium in the Ossipee Watershed

Calcium concentrations are low across all 10 stream sites (less than 10 mg/L). There is no significant difference between the sites and minimal concentrations are observed. The most common bedrock of the Ossipee watershed is granite which underlies most of the streams. This is not a carbonate-rich rock that would leach Ca^{2+} into the waterway which contributes to the lack of Ca^{2+} present.



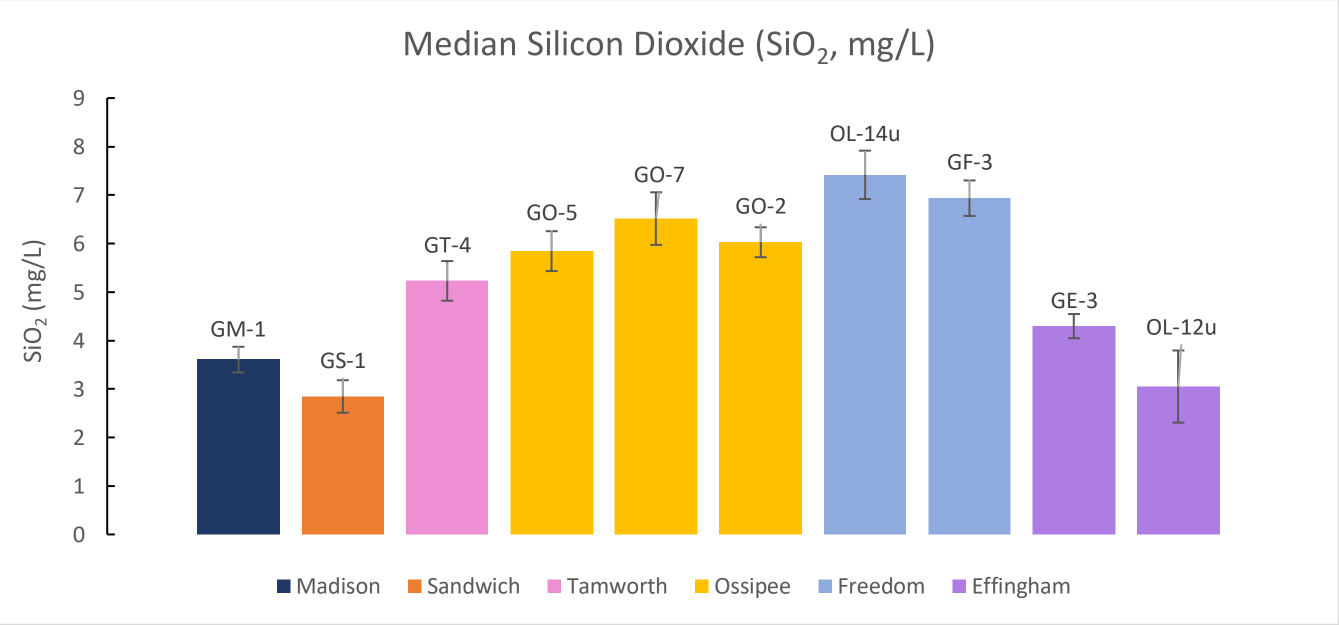
Silicon Dioxide (SiO_2)

What is Silicon Dioxide?

Silica is widespread and always present in surface and groundwater. It exists in water in dissolved, suspended, and microscopic states.[15] Silicon dioxide (SiO_2) is a particular compound of silica that is dissolved in surface water. SiO_2 is a major constituent of sand and is essential for certain aquatic plants such as diatoms. Silica can be added to surface waters from industries using siliceous compounds in their processes such as potteries, glass works and abrasive manufacturing.[15] There is no state or federal standard for SiO_2 concentrations in surface waters, but it typically exists in concentrations between 1-30 mg/L (Table 3).

Silicon Dioxide in the Ossipee Watershed

SiO_2 concentrations at each of the 10 sites are very similar. Maximum values do not get to be higher than 22 mg/L and median values do not surpass 8 mg/L. These are low concentrations and do not cause concern for water quality based on SiO_2.



Discussion

Based on the data collected and analyzed since 2002 in the RIVERS program, it is safe to say water quality in the Ossipee Watershed is excellent overall. Very few parameters exceeded typical values or state/federal standards at each of the stream sites, and most trends throughout the sampling period remained stable. With that being said, there are a few parameters and trends that are concerning here in the watershed, and in the New England region as a whole. It is worth taking some more time to discuss trends in salt concentrations (sodium, chloride, and specific conductance) and their collective water quality impact.

Salt levels may be one of the biggest water quality threats the otherwise pristine surface waters in this watershed face as time progresses. Sodium and chloride are the most important parameters of the anion/cation data to monitor as development and population increase in this area (see Appendix 5). Increasing regional salinity is having a negative impact on water quality. Studies in the past have shown that organisms cannot process organic matter and other detritus as effectively with increased salinity in the water.[17] Ecosystem functionality is negatively affected, and high amounts of these ions can be toxic to fish and insects. More salt on the roads for controlling ice and snow leads to more salt running off and entering surface and groundwater resources when washed away by the rain or snowmelt. As the numbers increase each year, it is important to note the bigger picture trends going on with road salt and increasing salinity in freshwater systems.

Across America as a whole, streams and rivers are becoming saltier with a big reason being the deicing of roads.[23] A study conducted by the National Science Foundation (NSF) looked at changing salt levels in over 232 data monitoring sites across the country over the past 50 years. The data showed that there have been significant increases in salinization in waterways. About 37% of all the drainage area in the United States experienced a significant increase in salt concentrations.[23] Below is a figure that shows these changes regionally in the United States.

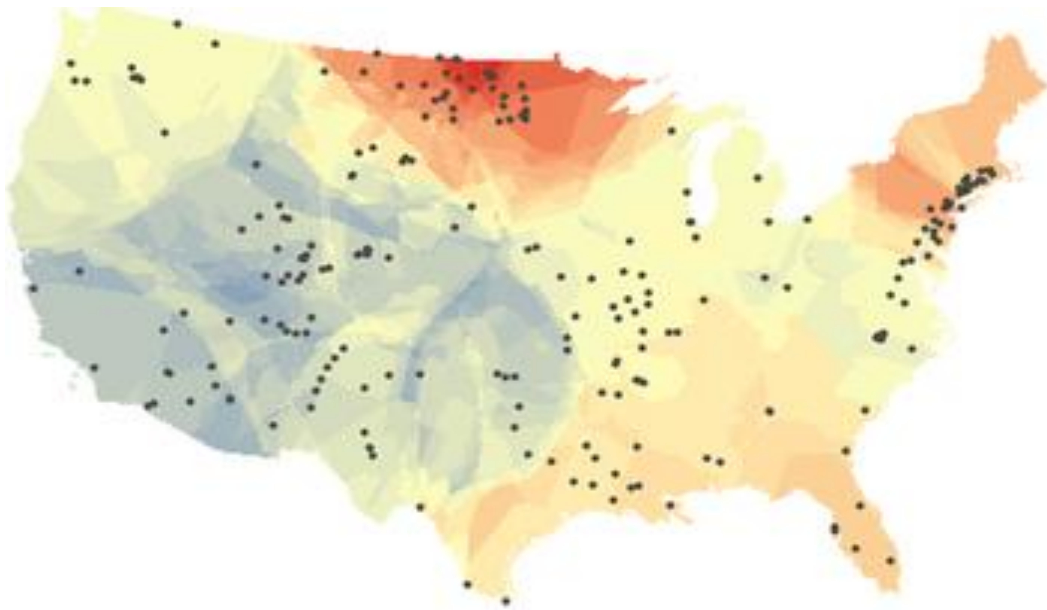


Figure 7. Map from the NSF salinization study. Warm colors show increasing salinity; cool colors show decreasing salinity. [23]

With the exception of a few states in the north-central part of the country, New England is the region where salinity increases are seen the most dramatically (Figure 7). It is evident that road salt applied to maintain roadways in the winter is the main cause of these increased concentrations in streams.[23] According to the NSF report, many northeastern cities and states have outdated salt spreading equipment that needs to be upgraded. Roadways are not the only issue either. Even the small amounts of salt used to melt ice in parking lots, driveways, and on sidewalks can contribute to a much larger contamination problem.[25]

In addition, this issue becomes amplified when surface water is used for drinking water. The Flint, Michigan problem began because the Flint River became a drinking water source, and the high salt content in that stream combined with the chemical treatment, caused the water to become corrosive and leach lead from the water pipes.[23] Studies show that the amount of salt going into NH's streams has been increasing since the 1960's and the high amount of salt being used on roads has created an expectation among drivers to see wet, black pavement during snow storms.[24] Putting this into context, it is not surprising that the Ossipee Watershed is facing similar issues with its streams and rivers. In recent years New Hampshire has been working to identify ways to reduce road salt use while maintaining proper safety at the same time.

In general, state and municipal plowing in New Hampshire has made strides in reducing salt use. For example, the town of Derry has added more than 35 miles of paved roadways since 2014 but has reduced its salt use by 25% during that time.[24] Creative alternatives to road salt are being used in several locations, and there are data out there to suggest more effective methods than traditional salting. With increasing salinity in streams being the greatest water quality issue that the Ossipee Watershed faces, it is important to focus in on how to combat this problem.

What can be done to assist with the issue of salt runoff?

- Brining is an effective alternative to putting pure salt on the roads. Spreaders can mix salt and water to form brine, which makes the deicing solution work better. Pre-treating the roads with this is like greasing a pan and makes it easier to plow the snow off.[24] Studies have shown that brine solutions can reduce salt usage by up to 70% and cut costs of salt for towns drastically.
- Ensure that best management practices (BMPs) are in place between roadways and waterways. Forest buffers and wetlands for example can help reduce the salt runoff that directly enters the stream.
- Simply reducing salt usage on roads can greatly help reduce salt runoff. It is important to understand that salt will not remove ice from roads if temperatures are below 15°F. There is no need to put more salt down in these conditions.
- Update salt-spreading equipment that has been outdated and is less efficient.
- Participate in Green SnowPro classes offered by the New Hampshire Department of Environmental Services (NHDES). They promote state-of-the-art salt reduction practices that prioritize public safety while mitigating salt usage.
- Get involved with local legislation in bringing these issues to the local government.

Recommendations

Making recommendations is an important part of the watershed management planning process. The following recommendations should be viewed as a starting point for local discussion, planning, and implementation that may be modified based on new information and/or stakeholder priorities. A more specific plan is outlined in the watershed management plans for the Ossipee Watershed (available at http://www.gmcg.org/watershed_management_plan/), and those recommendations are based on local review that will target appropriate actions for the watershed.

Continue Long-Term Monitoring Program

The most important step for future protection of the surface and groundwater resources in the Ossipee Watershed is to continue a monitoring program. Only through consistent, long-term data can we understand our ecosystems and recognize how and why they change. This is essential for making informed decisions about their future use and protection, and for maintaining good water quality in the future.

Some of the RIVERS sites have shown concerning trends that have not yet reached a level that is considered detrimental to water quality. With increased development and population increase (see Appendices 4 and 5) in the watershed, maintaining a well-established water quality monitoring program is essential. This program is close to reaching 20 years of consistent data collection at several sites. This program should be maintained by GMCG and SRCC and trends should continue to be monitored every year.

Emphasize Coordinated Local Planning

- Follow the Ossipee Lake Watershed Management Plan action steps and guidelines in order to control sources of pollution and improve water quality.
- Engage in collaboration of local organizations (town government, watershed associations, etc.) to continue monitoring water quality, promoting BMPs, and creating watershed initiatives.
- Encourage town officials to promote sustainable development and to develop watershed or aquifer overlay districts.
- Encourage town officials to coordinate planning and policy making with the other watershed towns.

Promote Best Management Practices

Best Management Practices (BMPs) describe ways to manage land and mitigate pollution to surface water quality, groundwater quality, and soils. They typically include low tech construction or action steps that help improve and restore the environment, while benefitting the landowner as well. Common BMPs include: rain gardens and barrels, grass swales, vegetative riparian forest buffers, alternatives to road salting, etc. The most important BMP to focus on in the Ossipee Watershed is reducing road salt usage, and using alternatives to road salting (see page 51).

Visit the following pages for more information:

- BMPs from the EPA: https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater
- GMCG's work with BMPs: http://www.gmcg.org/project-bmp/
- BMPs related to road salting: http://ccetompkins.org/resources/best-practices-for-road-salt-and-deicers

Educate the Public

Continue to educate and engage watershed residents about the quality and value of the watershed's resources, the sources of pollutants in the watershed, and the positive and negative ecological, recreational, and economic impacts their utilization can have on the lakes, ponds, rivers, and streams of the Ossipee Watershed. This is essential in order for communities to be able to engage with their shared resources in a healthy way. GMCG believes in presenting objective information in neutral formats with the belief that well informed citizens will make good judgement about the unique resources in the Ossipee Watershed.

Summary

It would be beneficial to consider taking action to begin restoration or BMP installation at certain RIVERS sites that have shown negative water quality trends. Overall, the data show that most of the streams and rivers in the Ossipee Watershed have high water quality and support healthy aquatic ecosystems. Much of this is because these sites are surrounded by forested land, some of which is protected and cannot be developed on. It is essential that smart decisions are made by local governments, watershed associations, development companies, and citizens regarding the health of the watershed. The treatment of water upstream impacts communities and people downstream.

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Appendices

Appendix 1: Boxplots showing range of data collected for all cations/anions since the beginning of the R.I.V.E.R.S. program. These parameters are sampled for at 10 of the 29 sites, monthly, year-round. The color of the box in each graph corresponds to one of the watershed towns.

Quick guide on how to read boxplots:

A boxplot highlights the range of a dataset, meaning how different the highest numbers in the dataset are from the lowest. It also points out some important markers in the data. It consists of a rectangular box, two whiskers, and a line somewhere in the box. A boxplot is meant to split the data up into quartiles:

Quartile 1: from the lower extreme to the bottom of the box. (The first 25% of the data)

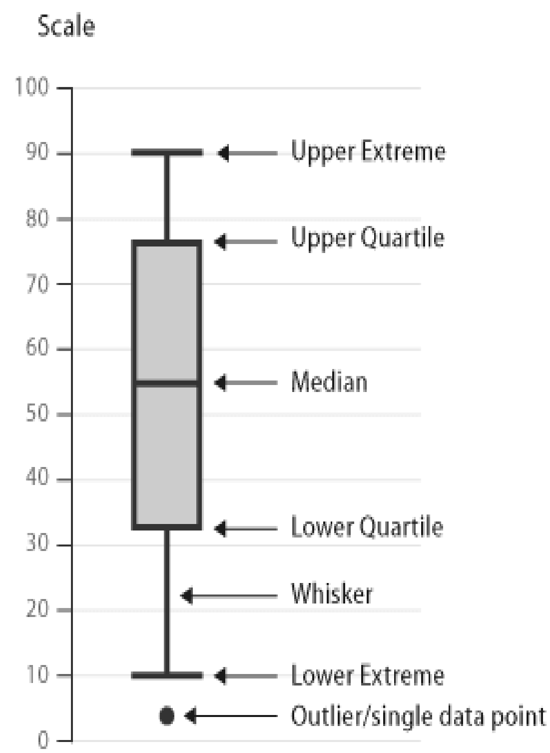
Quartile 2: From the bottom of the box to the line across the box. The line across the box is the **median** which is a point that separates the data into halves. 50% of the data lies below the median and 50% lies above.

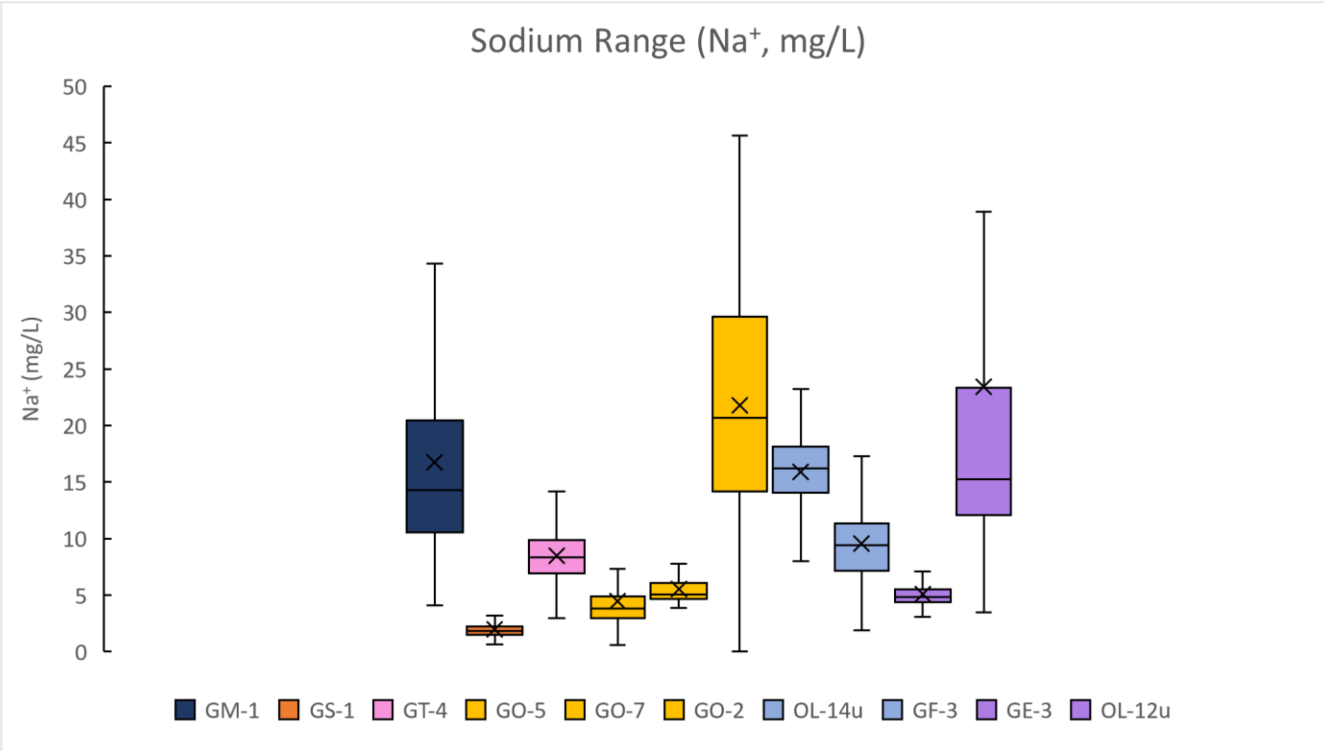
Quartile 3: from the median to the top of the box. (From 50-75% of the data)

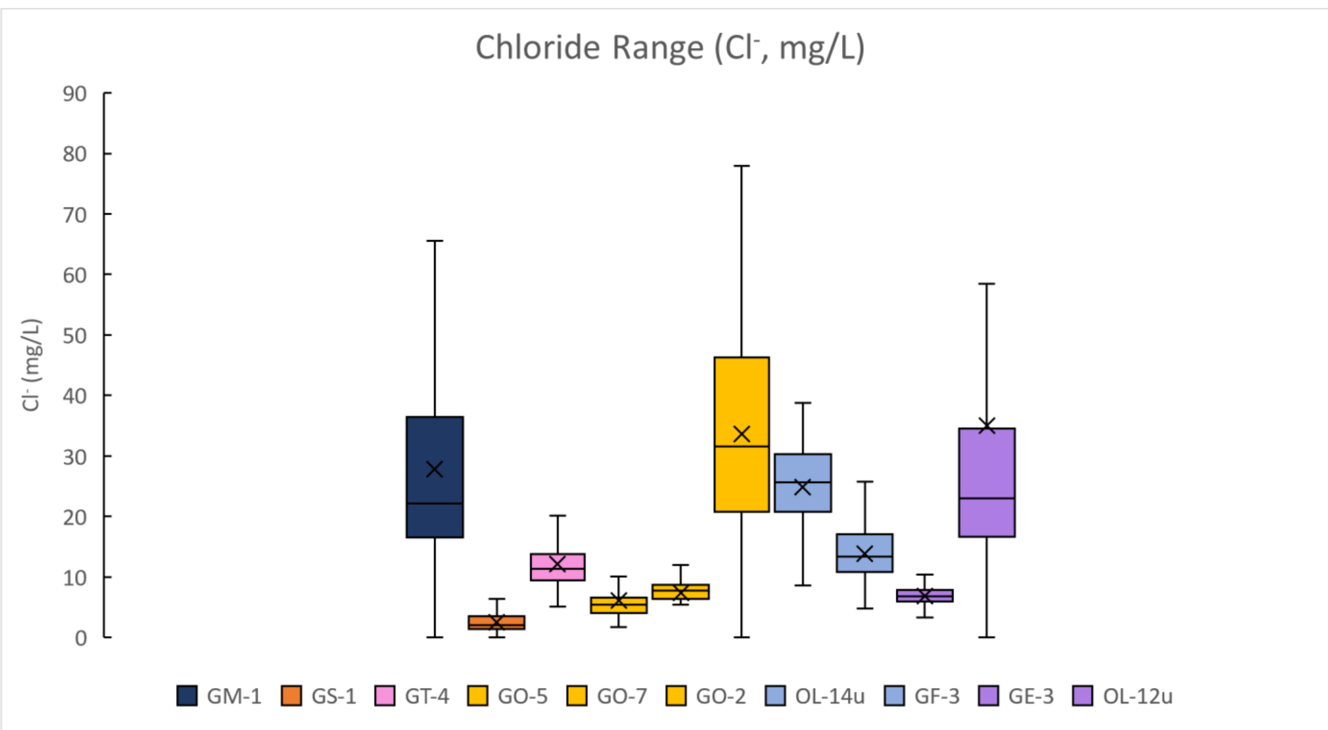
Quartile 4: from the top of the box to the upper extreme. (The last 25% of the data)

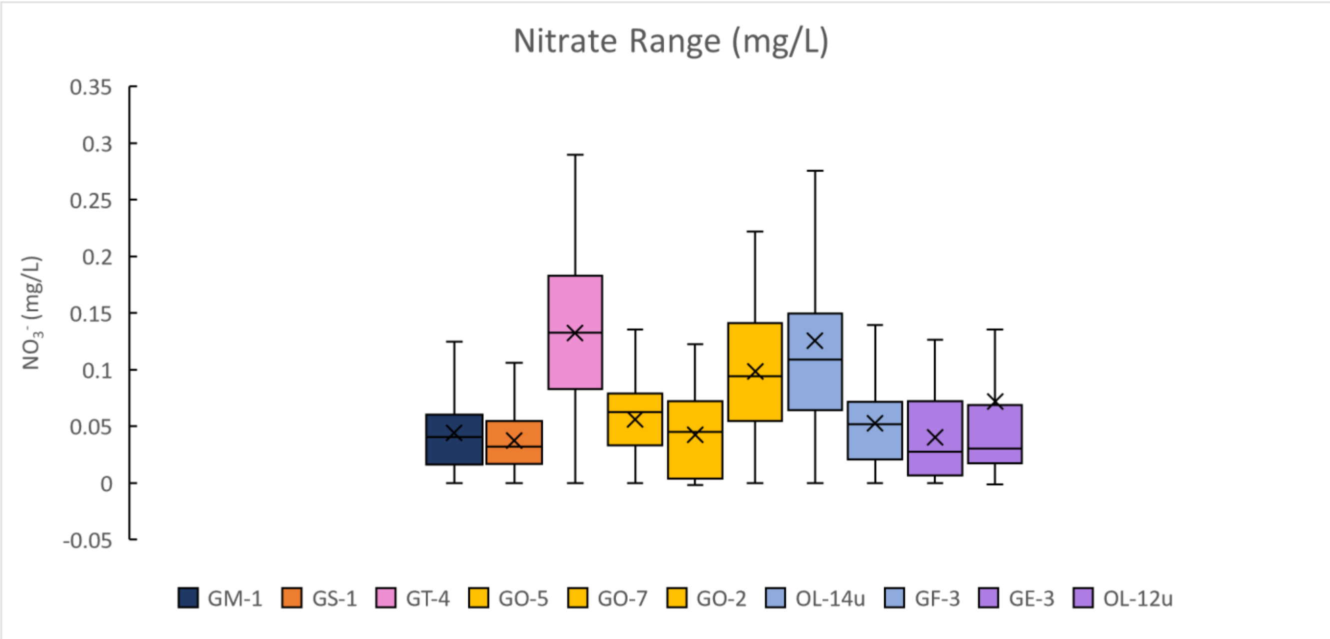
IQR: Interquartile range which is represented by the box itself. The box encompasses the middle 50% of a dataset.

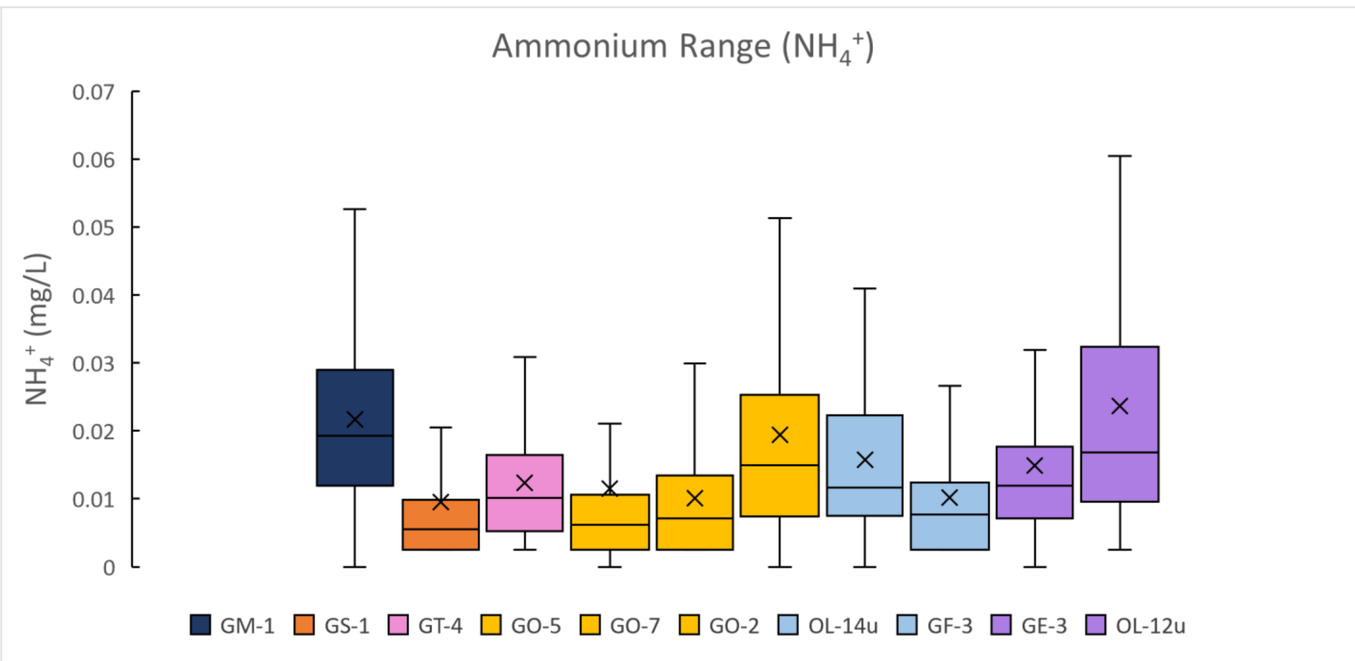
Mean: The average of the dataset, indicated by an “x” in the boxplot.

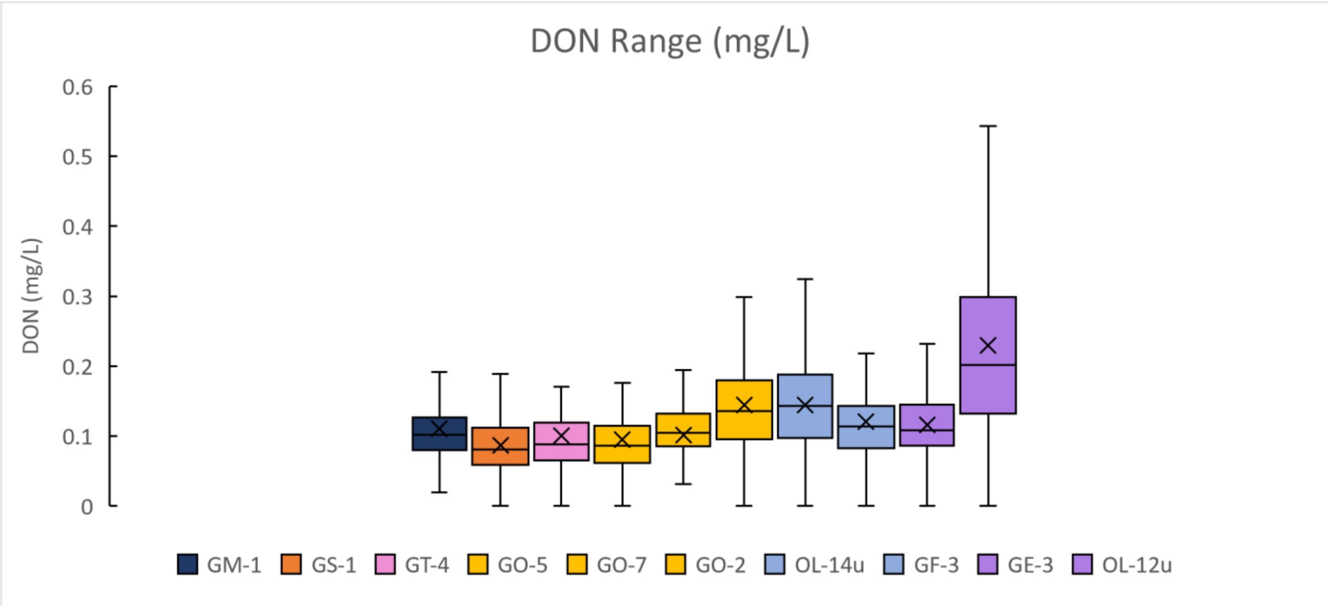


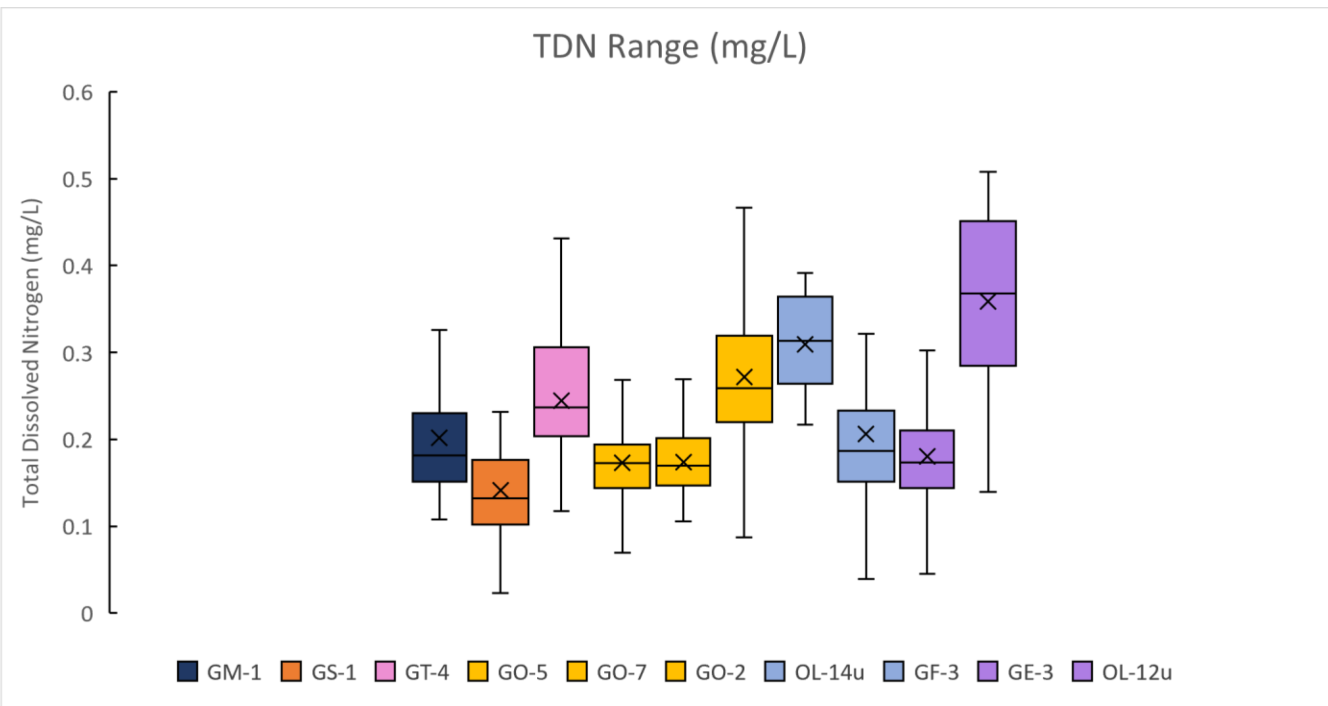

Sodium Range (Na⁺, mg/L)
Na⁺ (mg/L)
50
45
40
35
30
25
20
15
10
5
0
GM-1
GS-1
GT-4
GO-5
GO-7
GO-2
OL-14u
GF-3
GE-3
OL-12u

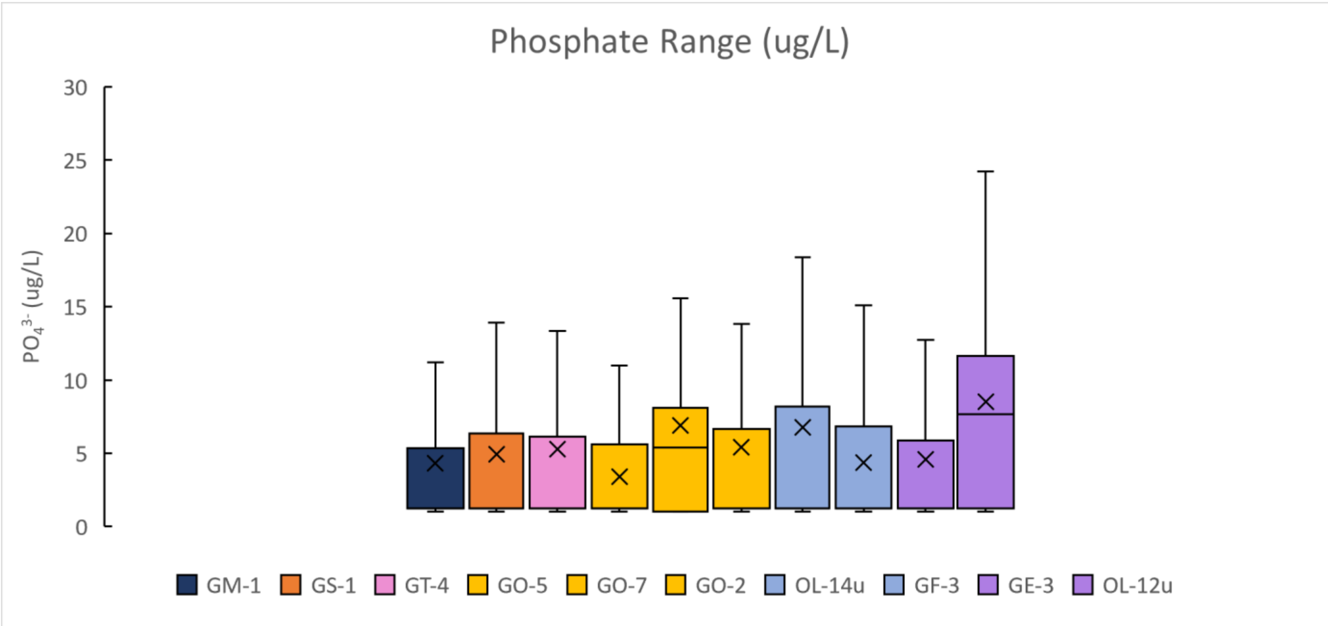

Chloride Range (Cl⁻, mg/L)
Cl⁻ (mg/L)
90
80
70
60
50
40
30
20
10
0
GM-1
GS-1
GT-4
GO-5
GO-7
GO-2
OL-14u
GF-3
GE-3
OL-12u

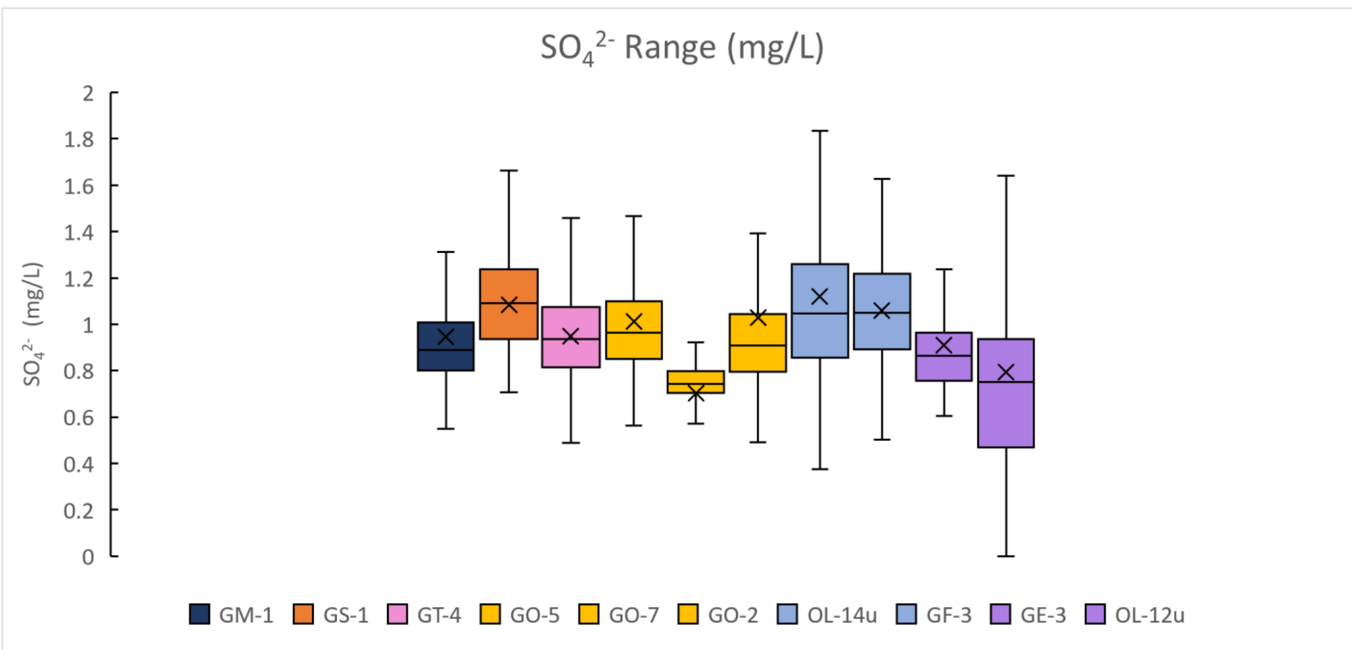

Nitrate Range (mg/L)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
NO3- (mg/L)
GM-1
GS-1
GT-4
GO-5
GO-7
GO-2
OL-14u
GF-3
GE-3
OL-12u

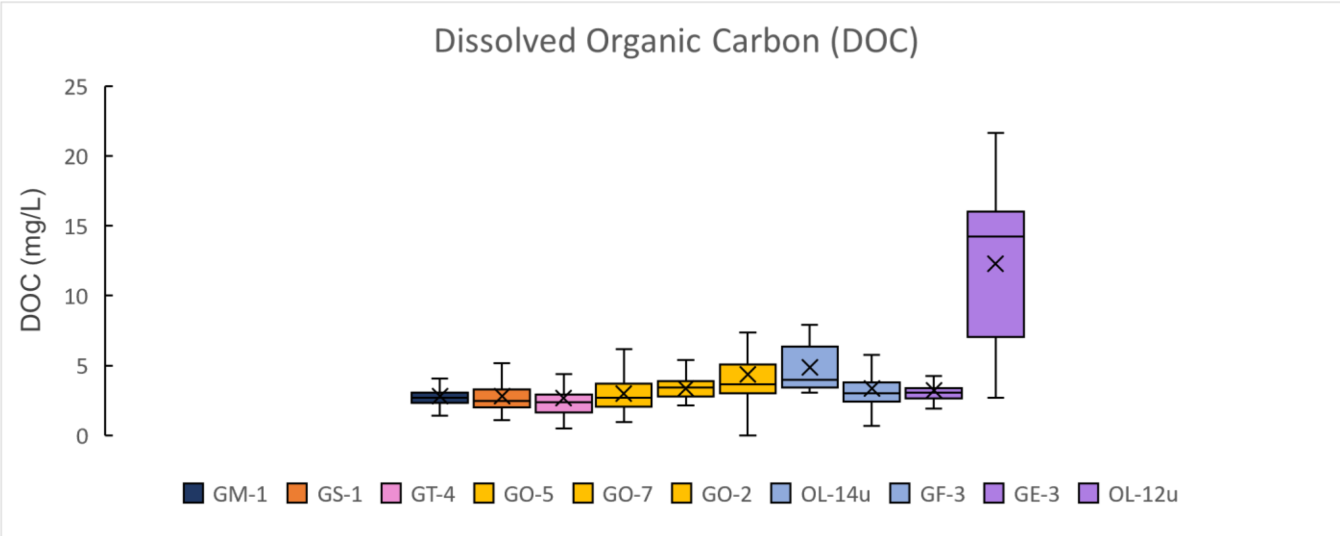

Ammonium Range (NH4+)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
NH4+ (mg/L)
GM-1
GS-1
GT-4
GO-5
GO-7
GO-2
OL-14u
GF-3
GE-3
OL-12u

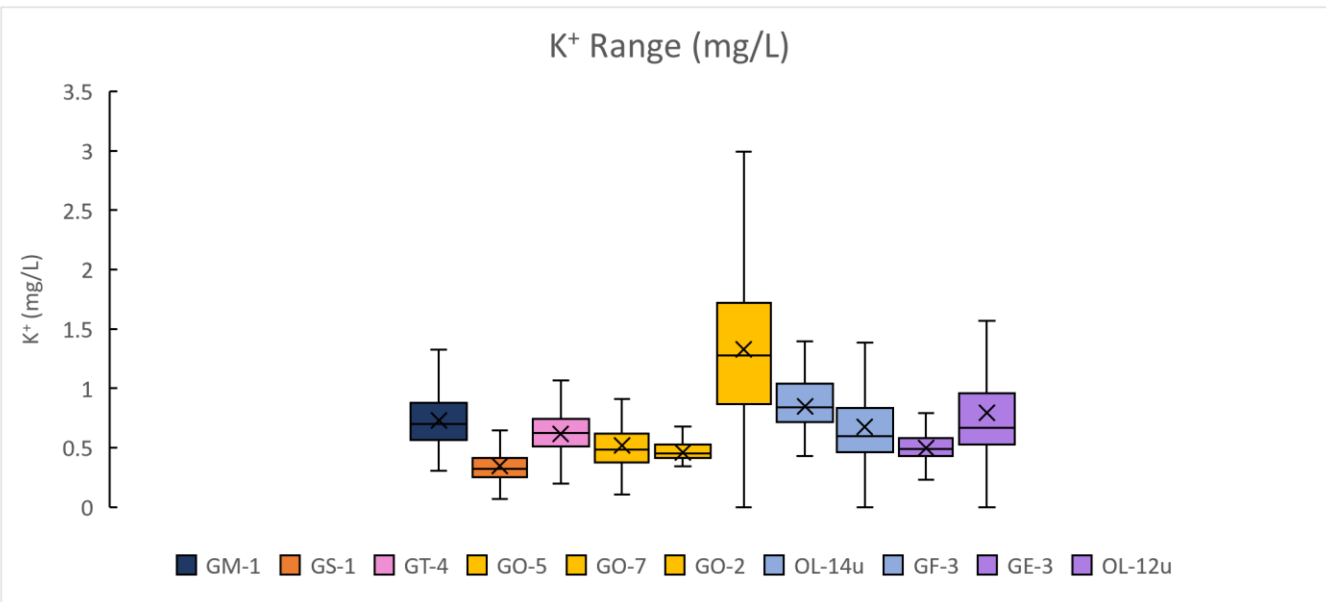

DON Range (mg/L)
DON (mg/L)
0.6
0.5
0.4
0.3
0.2
0.1
0
GM-1
GS-1
GT-4
GO-5
GO-7
GO-2
OL-14u
GF-3
GE-3
OL-12u

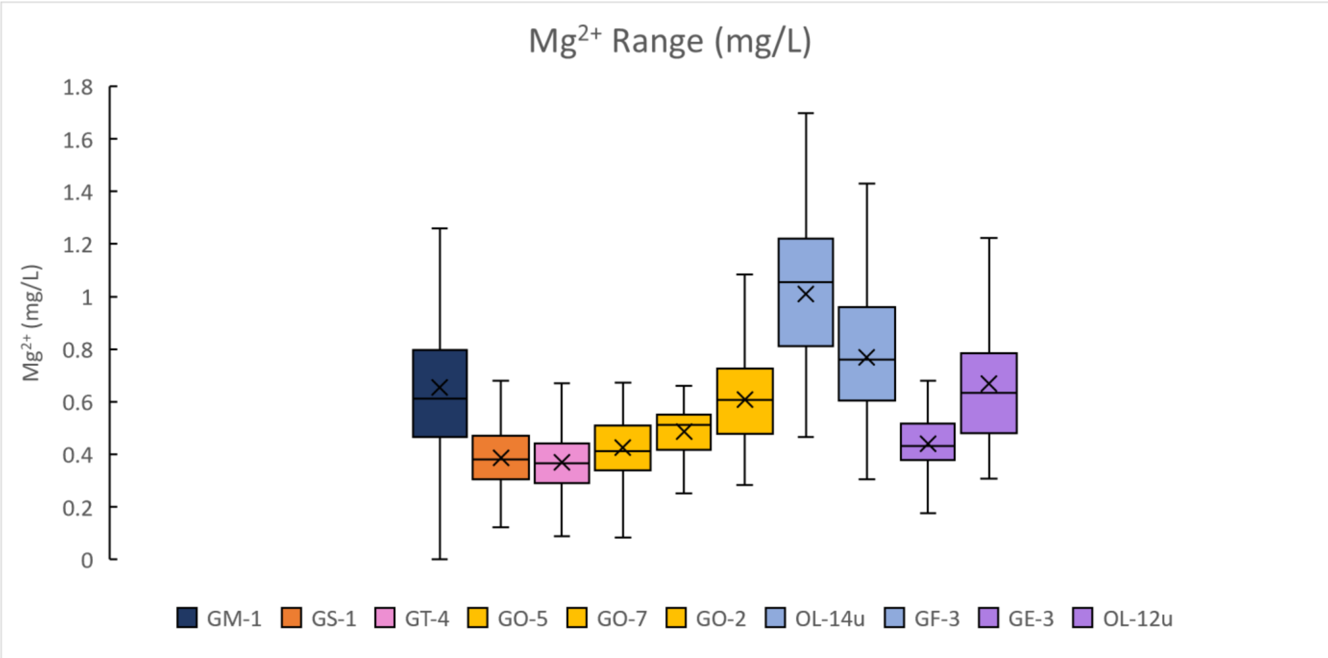

TDN Range (mg/L)
Total Dissolved Nitrogen (mg/L)
0.6
0.5
0.4
0.3
0.2
0.1
0
GM-1
GS-1
GT-4
GO-5
GO-7
GO-2
OL-14u
GF-3
GE-3
OL-12u

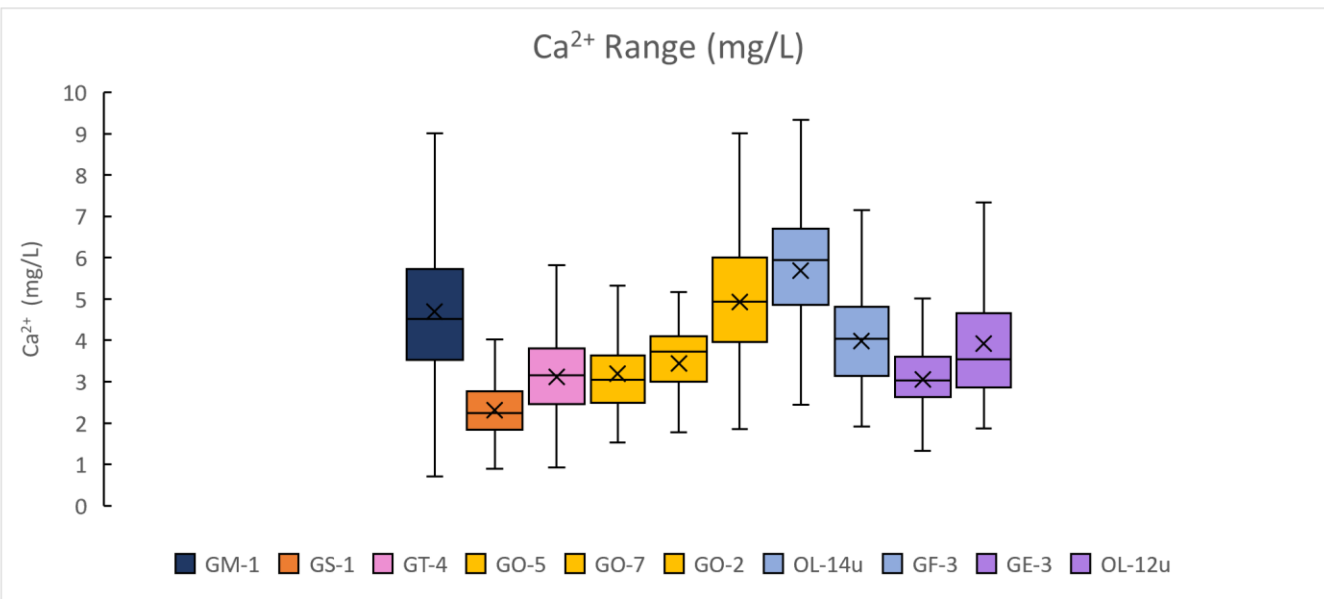

Phosphate Range (ug/L)
30
25
20
15
10
5
0
PO4 3- (ug/L)
GM-1
GS-1
GT-4
GO-5
GO-7
GO-2
OL-14u
GF-3
GE-3
OL-12u

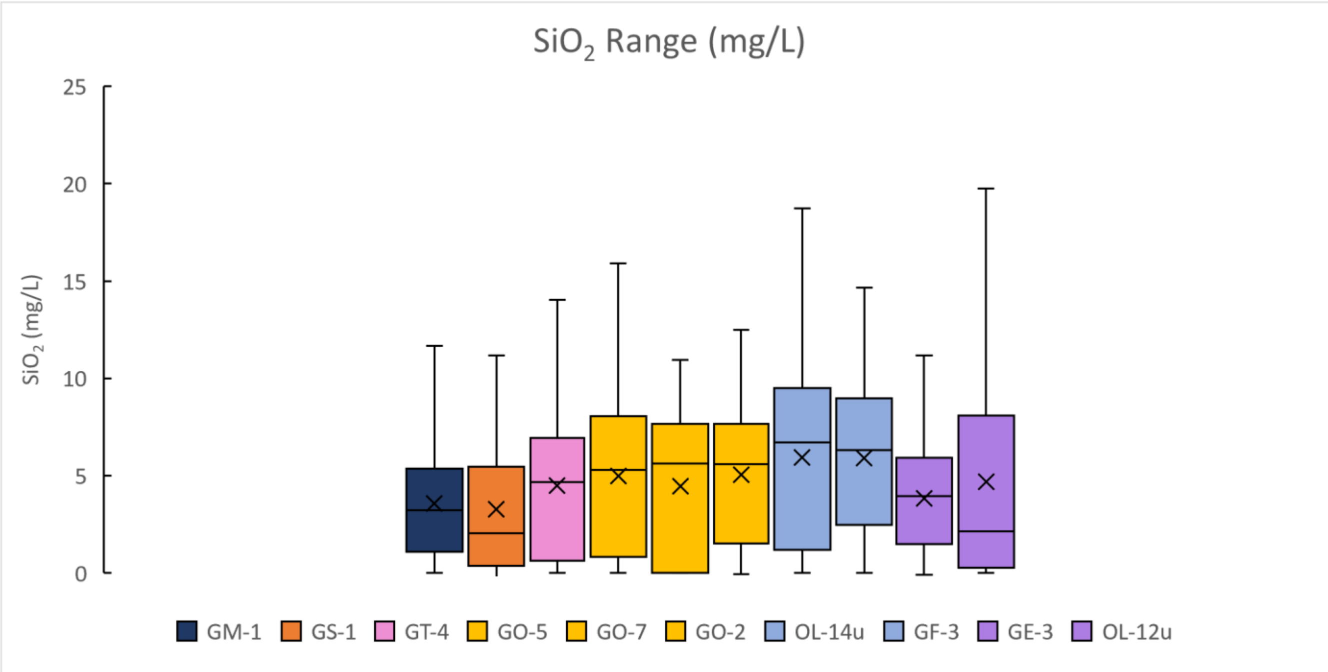

SO4 2- Range (mg/L)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
SO4 2- (mg/L)
GM-1
GS-1
GT-4
GO-5
GO-7
GO-2
OL-14u
GF-3
GE-3
OL-12u


Dissolved Organic Carbon (DOC)
DOC (mg/L)
25
20
15
10
5
0
GM-1
GS-1
GT-4
GO-5
GO-7
GO-2
OL-14u
GF-3
GE-3
OL-12u


K+ Range (mg/L)
K+ (mg/L)
3.5
3
2.5
2
1.5
1
0.5
0
GM-1
GS-1
GT-4
GO-5
GO-7
GO-2
OL-14u
GF-3
GE-3
OL-12u


Mg2+ Range (mg/L)
Mg2+ (mg/L)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
GM-1
GS-1
GT-4
GO-5
GO-7
GO-2
OL-14u
GF-3
GE-3
OL-12u


Ca2+ Range (mg/L)
Ca2+ (mg/L)
10
9
8
7
6
5
4
3
2
1
0
GM-1
GS-1
GT-4
GO-5
GO-7
GO-2
OL-14u
GF-3
GE-3
OL-12u



SiO2 Range (mg/L)
SiO2 (mg/L)
25
20
15
10
5
0
GM-1
GS-1
GT-4
GO-5
GO-7
GO-2
OL-14u
GF-3
GE-3
OL-12u

Appendix 2: Summary of Mann-Kendall statistical results by stream site. Red indicates an increasing trend over the course of the sampling period, and blue indicates decreasing. No color indicates no significant trend.

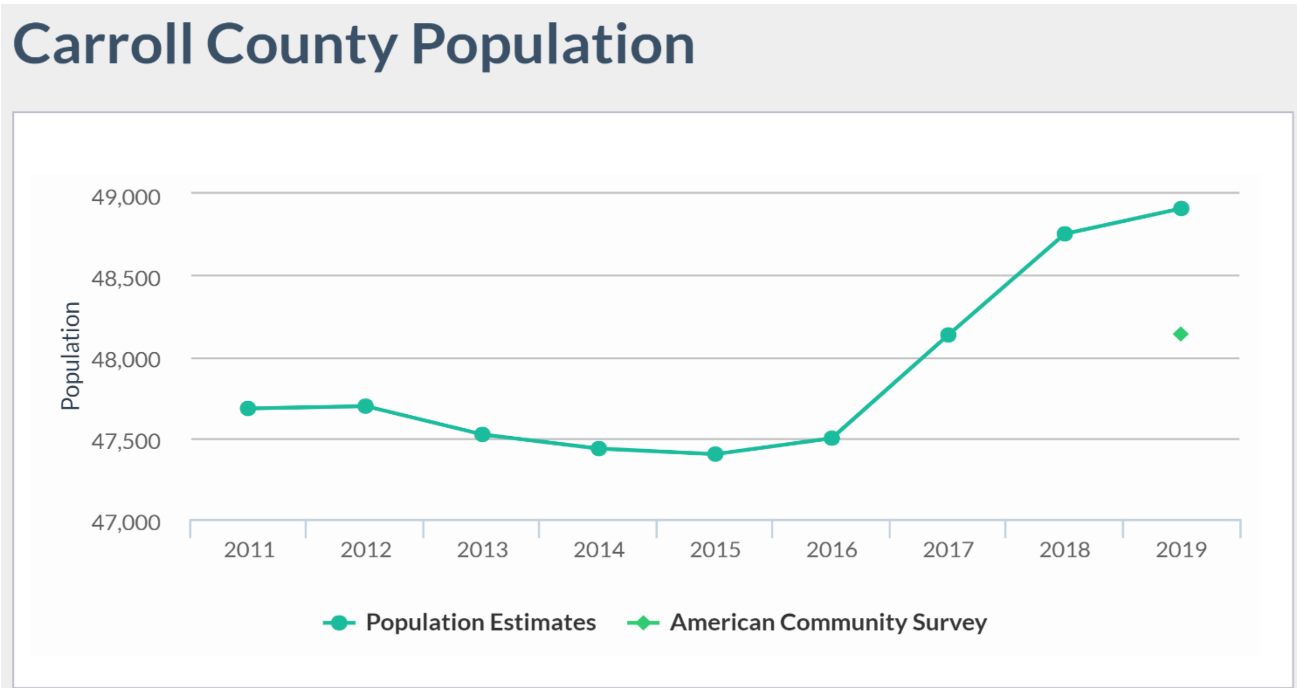
Site	Town	DO (mg/L)	DO (%)	Temp.	Specific Conductance	Turbidity	pH	TP
GEA-1	Eaton	0	0	0	3	0	0	3
GE-1	Effingham	0	0	0	4	0	0	1
GE-2	Effingham	0	2	0	4	4	1	0
GE-3	Effingham	0	1	0	4	0	0	1
OL-12u	Effingham	-2	-3	0	4	0	0	-1
OL-13	Effingham	0	0	-2	2	-1	0	1
GF-1	Freedom	3	4	0	4	0	-3	0
GF-3	Freedom	0	-1	0	4	3	0	0
OL-10	Freedom	1	0	-2	4	0	0	0
OL-14u	Freedom	0	3	0	4	0	2	0
OL-2	Freedom	0	0	-1	0	0	0	0
OL-9u	Freedom	3	4	-2	2	-4	0	0
GM-1	Madison	0	-1	0	0	1	4	-1
GM-2	Madison	1	4	0	0	-1	4	1
GM-3	Madison	-4	-4	2	4	4	2	0
GM-4	Madison	0	0	0	1	0	-1	0
GM-5	Madison	0	0	0	1	0	-1	2
GO-1	Ossipee	0	3	0	4	0	0	0
GO-2	Ossipee	0	-1	0	0	-3	0	1
GO-5	Ossipee	0	0	0	4	0	4	-1
GO-7	Ossipee	0	-1	0	3	0	-3	1
OL-4u	Ossipee	0	0	-1	3	0	1	-1
OL-6u	Ossipee	0	0	0	3	0	-2	0
GS-1	Sandwich	0	0	0	0	0	4	0
GT-1	Tamworth	0	0	0	0	0	4	0
GT-4	Tamworth	0	0	0	4	0	4	0
GT-5	Tamworth	-1	-4	0	1	0	4	-2

Appendix 3: Water quality trends in RIVERS sites based on town.

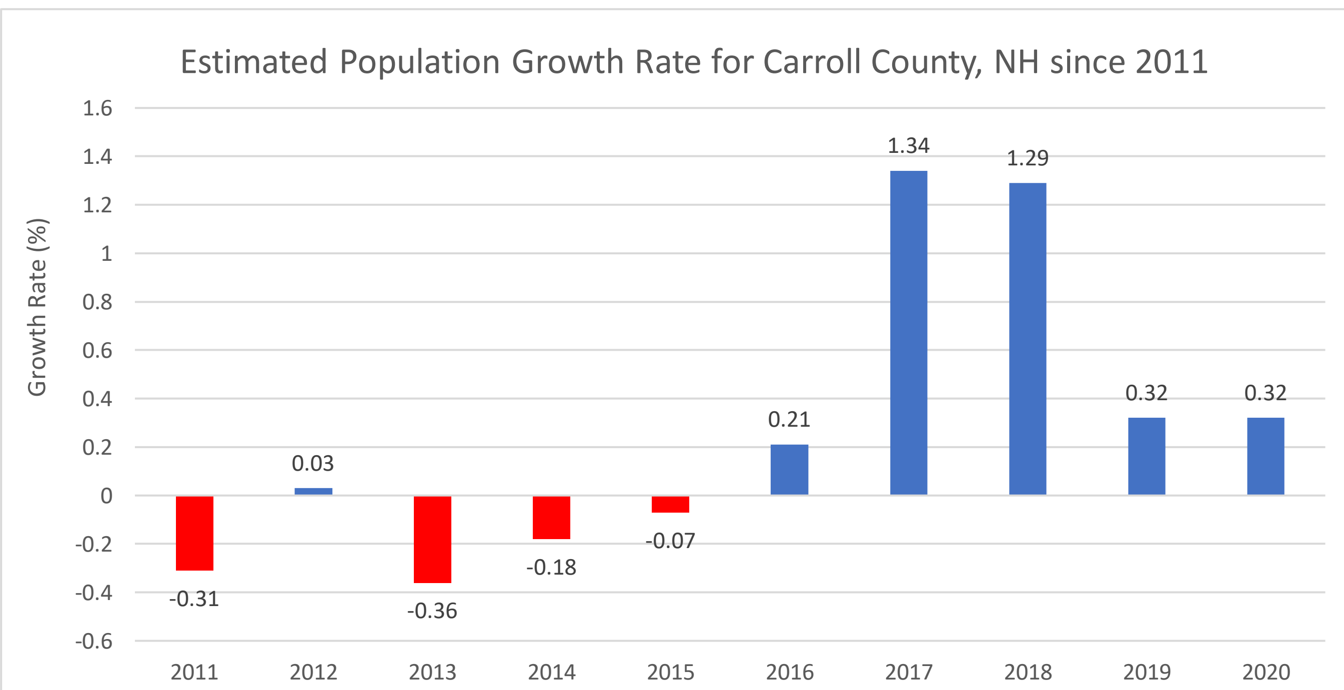
Town	Number of RIVERS Sites	RIVERS site exceeding state/federal WQ standards OR minimal disturbance levels	RIVERS sites that meet state/federal WQ standards OR minimal disturbance levels
Eaton	1	None	1: GS-1
Effingham	6	GE-3: Temp. OL-12u: pH, Specific Conductance, Sodium, Chloride, TP	3: GE-1, GE-2, OL-13
Freedom	6	GF-1: Temp. OL-10: Temp., DO (mg/L) OL-14u: Specific Conductance	3: GF-3, OL-2, OL-9u
Madison	5	GM-1: Temp., Specific Conductance, Sodium, Chloride GM-5: Temp.	3: GM-2, GM-3, GM-4
Ossipee	7	GO-2: Specific Conductance, Sodium, Chloride GO-7: Temp.	4: GO-1, GO-5, OL-1u, OL-6u
Sandwich	1	None	1: GS-1
Tamworth	3	None	3: GT-1, GT-4, GT-5

Appendix 4: Population trends in Carroll County, NH over the last decade showing an estimated increase in population over the last 5 years.[5] (4A) population. (4B) population growth rate. (4C) population by town.

A



B



C

Town	Size (mi^2)	Population (2010 Census)	RIVERS Sites
Effingham	39.6	1,465	**6** - GE-1, GE-2, GE-3, OL-12u, OL-13, and OL-7
Freedom	38.1	1,489	**6** - GF-1, GF-3, OL-10, OL-14u, OL-2, and OL-9u
Ossipee	75.6	4,345	**7** - GO-1, GO-2, GO-5, GO-7, OL-1u, OL-6u, and OL-4u
Tamworth	60.7	2,856	**3** - GT-1, GT-4, GT-5
Sandwich	93.5	1,326	**1** - GS-1
Madison	40.9	2,502	**5** - GM-1, GM-2, GM-3, GM-4, and GM-5
Eaton	25.6	393	**1** - GEA-1

Appendix 5: Trends in housing sale increases over the state of New Hampshire. These figures were put out by the New Hampshire Housing Finance Authority in 2020.[6] (5A) total closed sales since 2006 and (5B) closed sales in the last 3 years.

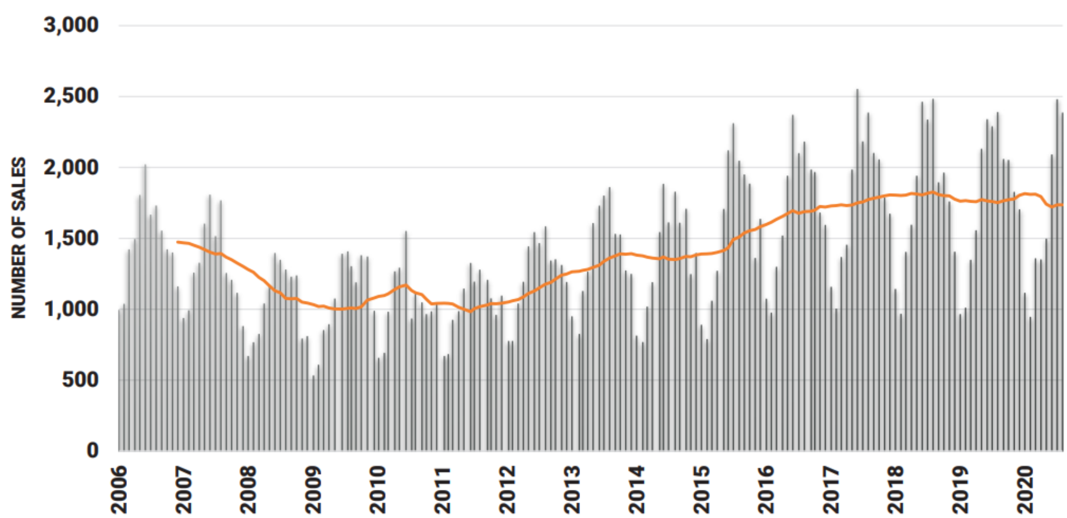
A

MLS CLOSED SALES

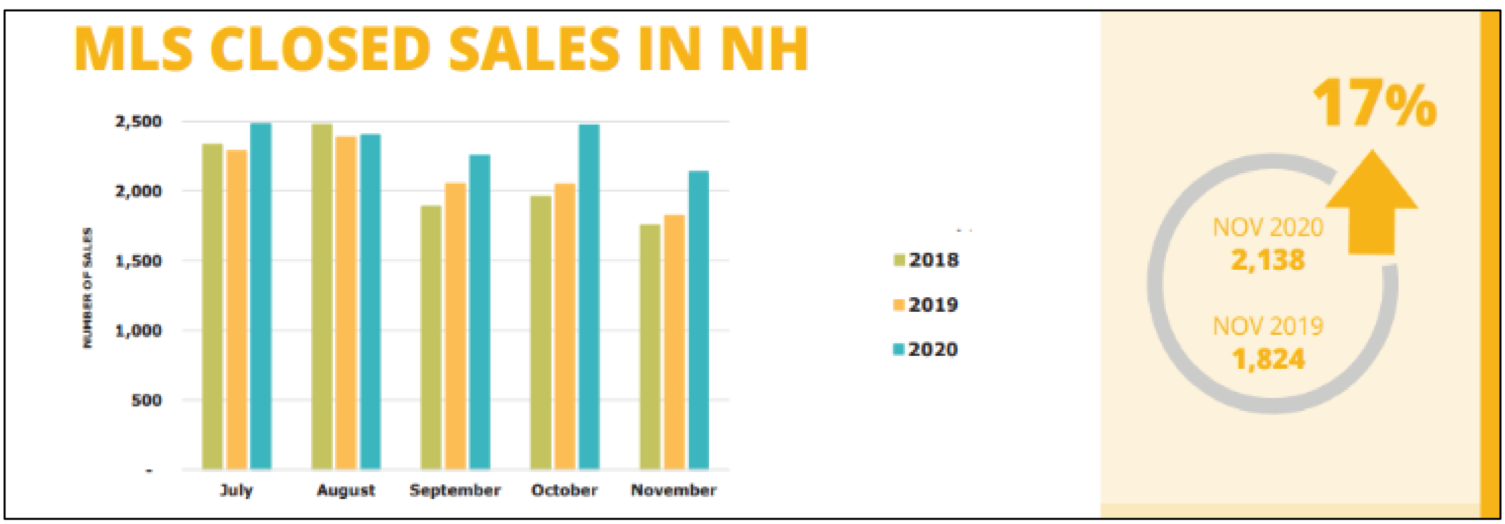
Orange line reflects a six-month moving average

Source: Based on information from the Northern New England Real Estate Network and compiled by NHHFA. Excludes land, interval ownership, seasonal camps/ cottages, multi-family property, mobile/ manufactured homes and commercial/ industrial property

August 2020 sales decreased less than 1% from the number of sales in August of last year. Sales are down 6% from January - August compared to the same period last year. These figures reflect extremely low inventory levels, not a lack of demand.



B



Appendix 6: Chloride concentration trends in three of the most prominent rivers in the New England region, paired with salt sales in the United States from 1895-2000.[23]