Lake Rescue 2008 Water Quality Monitoring Summary Report
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Introduction

Lake Rescue is situated along Route 100 in southern Vermont just 3 miles north of the town of Ludlow. Lake Rescue is a 180-acre natural lake with artificial control and is situated in a watershed of 22,859 acres. The maximum lake depth is 90 feet with a mean (average) depth of 40 feet. Lake Rescue is the southernmost waterbody of a chain of lakes following Amherst Lake and Echo Lake, all of which are connected by the Black River. Lake Rescue is highly valued by local residents for its natural beauty and recreational potential.

Lake Rescue is fortunate to have motivated and interested citizens from the Lake Rescue Association (LRA) supporting community camaraderie, watershed protection, water safety, and environmental education and water quality. The primary ecological concerns that the LRA has regarding their lake are sedimentation, water quality and aquatic invasive species. The LRA has been proactive in generating special projects that address these concerns. These current projects include: (1) The Better Backroads Project that promotes the use of erosion control and maintenance that will protect Vermont's lakes and streams; (2) Sedimentation and Citizen Surveys are being conducted through the collaboration of the LRA, lakeshore owners, and the State of Vermont to systematically record observations regarding the water quality of the lake as well as the shoreline and watershed; (3) the Lay Monitoring Program (LMP) sponsored by the Vermont Department of Environmental Conservation (VT DEC) was re-instated for Lake Rescue in 2005; and (4) the Eurasian milfoil spread prevention and control program has proven successful through monitoring, removal by hand pulling, and education and outreach for lake users.

Data collected by the various VT DEC programs indicate that Lake Rescue has an average spring phosphorus concentration of 8 µg/l, based on 12 years of data, and the average summer phosphorus concentration is 9 µg/l, based on 3 years of data. The average Secchi disk measurement is 4.4 meters, based on 6 years of data and the average chlorophyll-*a* concentration is 3.8 µg/l, based on 3 years of data. Lake Rescue is considered a mesotrophic lake, characterized by moderate nutrient enrichment; moderate algae growth, moderate aquatic plant growth; moderate sediment accumulation over the lake bottom; and typically supporting warmwater fish species.

Lake Rescue was sampled intensively in 2008 from late May through October. These monitoring visits were carried out by a collaboration of the LRA and VT DEC. Additionally, members from the LRA collected samples from the Black River, Lake Rescue's largest tributary, on three occasions (spring, summer and fall) to monitor turbidity, total suspended solids, and total phosphorus within the tributary. A volunteer monitor collected Secchi measurements weekly throughout the summer to monitor water clarity. The intent of this project is to address a number of the aforementioned concerns, specifically nutrient and sediment loading to the waterbody.

What is Sediment Loading?

Sediment is bottom material in a lake that has been deposited after the formation of a lake basin. Sediment results from the accumulation of decomposing remains of aquatic organisms, chemical precipitation of dissolved minerals, and erosion of surrounding lands. Sediment loading to a lake will increase with physical disturbances to the surrounding watershed and immediate shoreline. Sedimentation is an important process in the life of a lake, transferring nutrients throughout the lake's layers and providing a critical link between surface algae and bottom-dwelling organisms. There is a growing concern regarding sedimentation as a result of surface run-off from nearby roads and inputs from the inlet entering the northwest area of the lake. There is also concern regarding excessive aquatic plant growth from nutrient loading.

What is Nutrient Loading?

Plant and animal growth in lakes is limited by the factors present in the lowest relative supply that is required for cellular synthesis. The primary factors that limit growth are nutrients - in particular, nitrogen and phosphorus, which are naturally occurring in the environment. Phosphorus most commonly limits primary production in lakes and is referred to as the "limiting nutrient". In other words, phosphorus restricts plant growth because of its naturally low levels in the environment. Therefore, small increases in phosphorus loads to lakes and streams can promote large algal blooms and excessive plant growth.

What is Eutrophication?

Eutrophication is the term used to describe the aging of a lake. Lakes are typically classified into four "trophic" levels – oligo-, meso-, eu-, and dystrophic. See the table below for a description of each. Eutrophication occurs as the lake ecosystem transitions from a clean, clear, low-productivity water body toward waterbody with low visibility and high nutrient production. In order to understand the effects of pollution on lakes in Vermont it is important to understand the natural status and evolution of these lakes. Most lakes naturally contain aquatic plants and algae. The amount of plant and algae life a lake can support is referred to as a lake's "productivity". Productivity is determined by the amount of nutrients that are available in the water for plant and algae growth. In a natural situation productivity will gradually increase over thousands of years through a natural aging process known as eutrophication.

Typical trophic states of lakes and ponds in Vermont can be characterized into the following four classes:

Oligotrophic - Referred to as “young” lakes, characterized by deep, clear water; low nutrient enrichment; little algae growth (low productivity); few aquatic plants; bare sand or rock along most of the shoreline (little mud); and often supporting coldwater fish species.

Mesotrophic - Referred to as “Intermediate” lakes, characterized by moderate nutrient enrichment; moderate algae growth; moderate aquatic plant growth; moderate sediment accumulation over the lake bottom; and usually supporting warm water fish species.

Eutrophic - Referred to as “old” lakes, characterized by high nutrient enrichment; abundant algae growth (high productivity); extensive aquatic plant beds; extensive sediment accumulation on the lake bottom; and supporting exclusively warmwater fish species.

Dystrophic – Lakes that are “stained” brown by dissolved organic material from the surrounding watershed, these lakes frequently exhibit water quality characteristics similar to oligotrophic lakes, although occasionally a dystrophic lake may have characteristics more closely aligned with mesotrophic or eutrophic conditions.

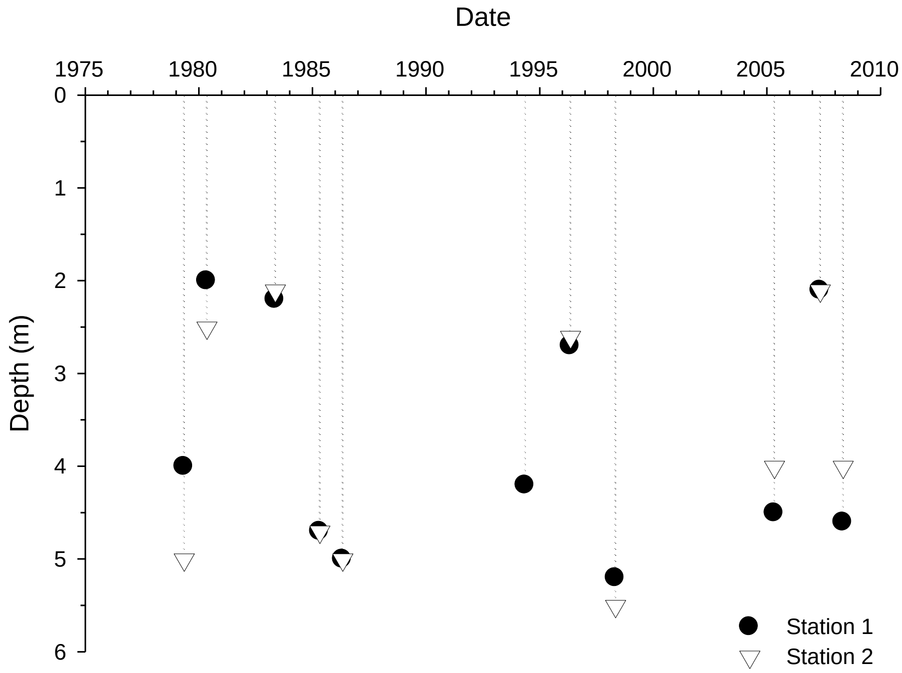
Historical records

VT DEC has visited Lake Rescue on ten occasions since 1978 for the Spring Phosphorus monitoring program. The primary purpose of the spring phosphorus program is to monitor phosphorus levels in Vermont lakes within two weeks after ice-out; phosphorus is often the primary nutrient that leads to diminished water quality lakes (eutrophication). To best gauge the level of phosphorus in lakes, we try to measure phosphorus concentrations before the lakes begin to warm and become biologically productive. Over time, other parameters have been added to the monitoring program, such as measurement of water clarity, nitrogen (another important nutrient) and chloride (indicator of road salt) concentrations, and metals analyses. Depth profiles are also recorded for temperature, dissolved oxygen, chlorophyll (estimator of algal growth), specific conductance (measurement of salts in the water), and pH (level of acidity). These parameters are measured at two unique monitoring stations on Lake Rescue, as illustrated in the figure below. Station 1 is in the main basin of the lake, at the deepest location (28 meters or 92 feet), and Station 2 is located in the north central portion of the small northern basin (also referred to as “Round Pond”). Station 2 is approximately 11 meters (36 feet) deep.

Lake Rescue Monitoring Stations 2008

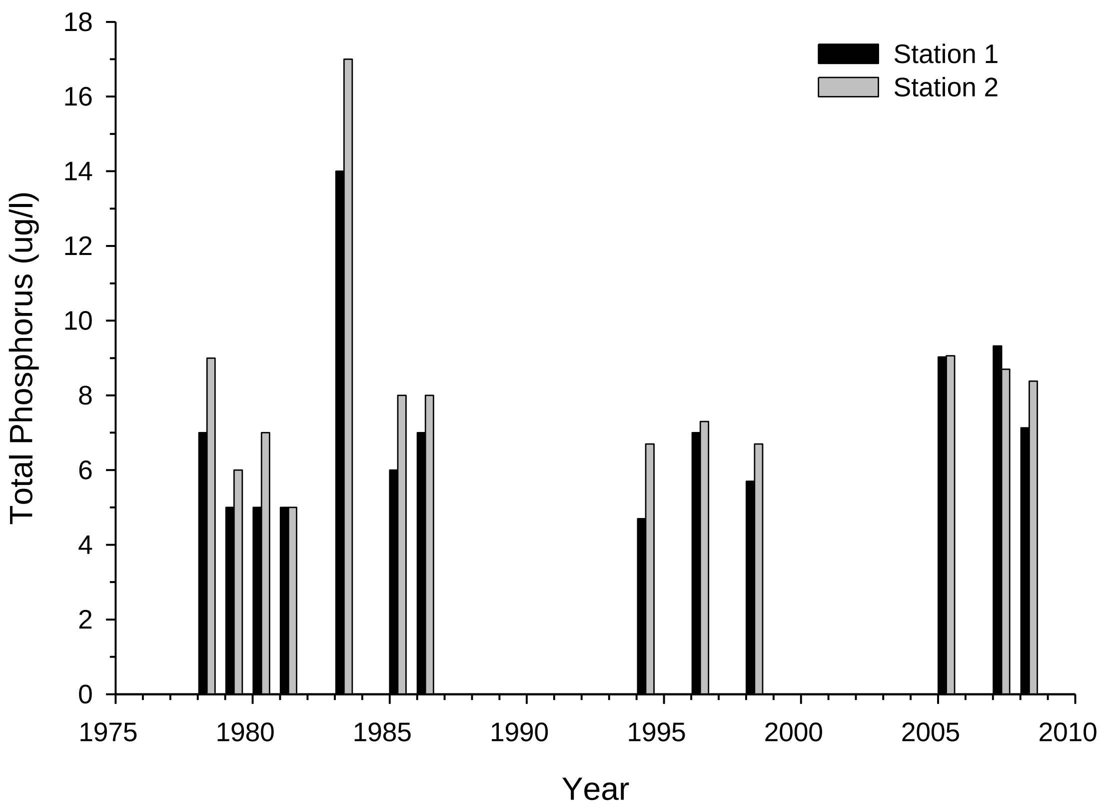
Historical trends of water clarity at both stations in Lake Rescue indicate that post-ice out water clarity has been somewhat variable and does not indicate a trend (either positive or negative change), since the first monitoring visit in 1978. The average Secchi measurement for spring phosphorus, for both stations is 3.75 +/- 1.3 meters.

Historical Water Clarity in Lake Rescue, 1979-2008
Spring Phosphorus Program



Similarly, historical records of spring total phosphorus concentrations at both stations in Lake Rescue do not indicate an obvious trend (neither improving nor declining) or change in total phosphorus over time. One sampling event in 1983 indicated a substantial increase in TP concentrations over previous years, however, this event appears to have been an unusual occasion as all other subsequent spring sampling events fell within the normal range for Lake Rescue. It should be noted that historically, spring phosphorus samples have been collected to present an average value of the total phosphorus concentration across the entire water column (surface to bottom). This is a different collection technique than the one used in the 2008 assessment results described below, in which unique, discreet samples are collected at pre-determined depths. Overall, Station 2 has a somewhat higher average spring TP concentration (7.1 +/-2.6 ug/l at Station 1, 8.2 +/- 2.9 at Station 2), although these averages are not significantly different from each other.

Historical Spring Total Phosphorus records



Methods

In the summer of 2008, VT DEC visited Lake Rescue 10 times and collected samples from two sampling locations. Profiles of temperature, dissolved oxygen, pH, conductivity, and chlorophyll were collected, and chemistry samples to test for total phosphorus, total nitrogen, and a suite of dissolved metals (calcium, magnesium, manganese, iron). Secchi disk measurements for water clarity were also conducted at each site at the beginning of the visit. These parameters are described in more detail below.

Temperature

Temperature, pH, and dissolved oxygen are three of the most important factors in terms of regulation of the lake ecosystem. Water temperature determines the rate of ecological activity (i.e. biotic organisms grow faster in warmer water) as well as gas solubility, such as dissolved oxygen (see below). The structure of water molecules changes with temperature; as the water temperature approaches 4^{o}C, the density of the water molecule increases, which is why colder water is always nearer the bottom. Lakes typically thermally stratify in the summer months, meaning that distinct thermal layers of water are formed. Warmer, wind-mixed water forms the upper layer (epilimnion), followed by a thermocline, which is a zone where the water temperature changes rapidly over a short distance (metalimnion). The bottom layer is the coldest water (hypolimnion). Each of these layers has important functions within the lake, regulating both biotic and abiotic lake functions. Temperature profiles are collected from the surface down to one meter off the bottom of the water to identify where these thermal stratifications occur.

pH

pH is a measure of the concentration of hydrogen ions in the water, or the strength of acids within the water. Thus, the more hydrogen ions that are present in the water, the lower the pH. Along with temperature and dissolved oxygen, this is one of the most important factors in the aquatic ecosystem. Acidity restricts biological functions within most aquatic organisms at some level; thus species that cannot tolerate acidic waters perish or move elsewhere (although in the lake system, this often is not possible).

Dissolved Oxygen

Dissolved oxygen (DO) is the measurement of oxygen as a dissolved gas in water. Adequate amounts of dissolved oxygen are critical for the survival of fish and aquatic organisms. Dissolved oxygen is considered one of the more important measurements of water quality and an indicator of a lake's ability to support aquatic life. Aquatic organisms have different ranges of DO for optimal functioning. Levels of DO above 6 milligrams per liter (mg/l) are considered optimal and most fish cannot survive below 3 mg/l. Conditions below 1 mg/l are referred to as *hypoxic* and when oxygen is completely absent it is called an *anoxic* environment. Vermont Water Quality Standards set a minimum DO concentration of 5 mg/l to protect warmwater fish habitat, expect where low dissolved oxygen is expected due natural lake attributes (naturally eutrophic lakes, or small but deep lakes). Limnologists (lake scientists) commonly plot DO profiles – graphs of the amount of oxygen per unit depth – to understand how lakes stratify with respect to dissolved oxygen and temperature, to understand how well aquatic life is supported. In some lakes, nutrient cycling between sediments and lake water is a function of DO. Levels of DO in a waterbody are affected also by the rate of decomposition. This is because in lakes, bacteria use oxygen to break down organic matter. In deep oligotrophic lakes the entire water column may stay completely oxygenated with high DO levels, owing to a larger pool of DO, and because there is less algae and bacteria present to consume the DO. In contrast, eutrophic lakes tend to have decreasing amounts of DO available in the water column because: 1) reduced light availability with depth limits oxygen production by limiting photosynthesis; 2) there is a smaller pool of oxygen available; and 3) organisms continue to consume the available oxygen, eventually depleting the lower portions of the lake of oxygen.

Chlorophyll-a

Chlorophyll-*a* is a green pigment found in plants and algae and is the essential component for fixing carbon dioxide in photosynthesis. Measuring the chlorophyll-*a* concentration is a way to estimate the amount of algal (phytoplankton) biomass in a lake. Algae and other plants are the base of the aquatic food web and produce oxygen needed by other aquatic organisms. Most algae obtain their nutritional needs directly from the primary nutrients (nitrogen, phosphorus, and carbon) in the lake water. Algae serve as a vital food source for microscopic animals (zooplankton), which in turn provide food for fish and other aquatic life. Because algae are the primary link between nutrient reserves and the aquatic food web, excess nutrient influx from the surrounding watershed often results in excessive growth of algae (and cyanobacteria) turning lake water green and murky. Excessive algal blooms may impart noxious odors and tastes, and some algae called cyanobacteria can produce toxins. When excessive algal growth decays, this can result in depletion of dissolved oxygen in the water column, leading to fish kills. The toxins produced by common cyanobacteria species have been linked to severe illnesses in livestock, pets and wildlife; in Vermont, this phenomenon has been observed in only two instances. There is no evidence of excessive cyanobacteria growth in Lake Rescue.

Nutrients - Total Phosphorus

Essential plant and animal nutrients include the biologically available forms of phosphorus and nitrogen (dissolved phosphate, nitrate and ammonium). In north temperate lakes, phosphorus is the greatest concern in eutrophication (nutrient enrichment) because phosphorus is the limiting nutrient. Phosphorus can take many forms in the environment, but the single most important and easiest to analyze in a laboratory is total phosphorus, which represents phosphorus attached to particles in the water, and that phosphorus which is dissolved, or ready to be used by algae to fuel growth.

Nutrients - Total Nitrogen

Various forms of nitrogen are measured (nitrate, ammonia, total nitrogen) in lake water. High concentrations of any form of nitrogen in a waterbody may indicate that pollutants from agriculture (e.g. animal manure and fertilizers) or development (sewage and stormwater) are making their way into the water via runoff and/or leaching through soil. The two most important forms of nitrogen in natural waters are nitrate and ammonium as both are readily used by plants and animals. Nitrate (NO_3) is the form of nitrogen that originates in the aforementioned sources as well as through atmospheric deposition (the same deposition that, along with sulfur, drives acidification of lakes). High levels of nitrate may indicate the presence of an algal bloom or cause changes in aquatic plant and animal communities. Ammonia (NH_3) is also an important nitrogen component to measure because in elevated levels, it can be toxic to aquatic life. In this study, total nitrogen (TN) samples were collected to measure all forms of nitrogen; this test is an indicator for the available nitrogen for plant and animal growth.

Specific conductance & chloride

Specific conductance (electrical conductivity) determines the quantity of all dissolved ions in the water column. Chloride is typically the most abundant dissolved ion in the water column, and as such, testing for conductivity and/or chloride can be used to determine if pollutants are entering the water column. In freshwater lakes, sources of chloride can be from dissolution of the underlying bedrock, from atmospheric deposition, or pollutants related to shoreline development (domestic sewage and road salt runoff). This is an important nutrient to monitor because increasing chloride levels in lake waters often indicate that pollutants are entering the system. For brevity, only the results of the chloride testing are provided below.

Metals

Calcium and magnesium are the two main components of the metals analyses conducted on Lake Rescue. Calcium is very important in both biotic and abiotic functions of the lake ecosystem, playing an important role in nutrient uptake for many species of plants and algae, and it can increase the rate at which organic material is precipitated out of the water column. Calcium and magnesium naturally occur in freshwater lakes by dissolution from the sediments, but their natural concentrations can also be increased by additions from shoreline runoff. Calcium and magnesium concentrations are used to determine the “hardness” of the lake water and the ability of the lake water to “buffer” itself from acidic inputs (i.e. acid rain) and maintain a pH level necessary for the lake ecosystem.

Iron and manganese are two metals that are commonly found in the sediments of most lakes, and are typically observed in very low concentrations within the water column under aerobic (oxygen-rich) conditions in lakes such as Rescue. When oxygen levels are depleted, these metals are transferred from the sediments into the water column, simultaneously releasing phosphorus as well.

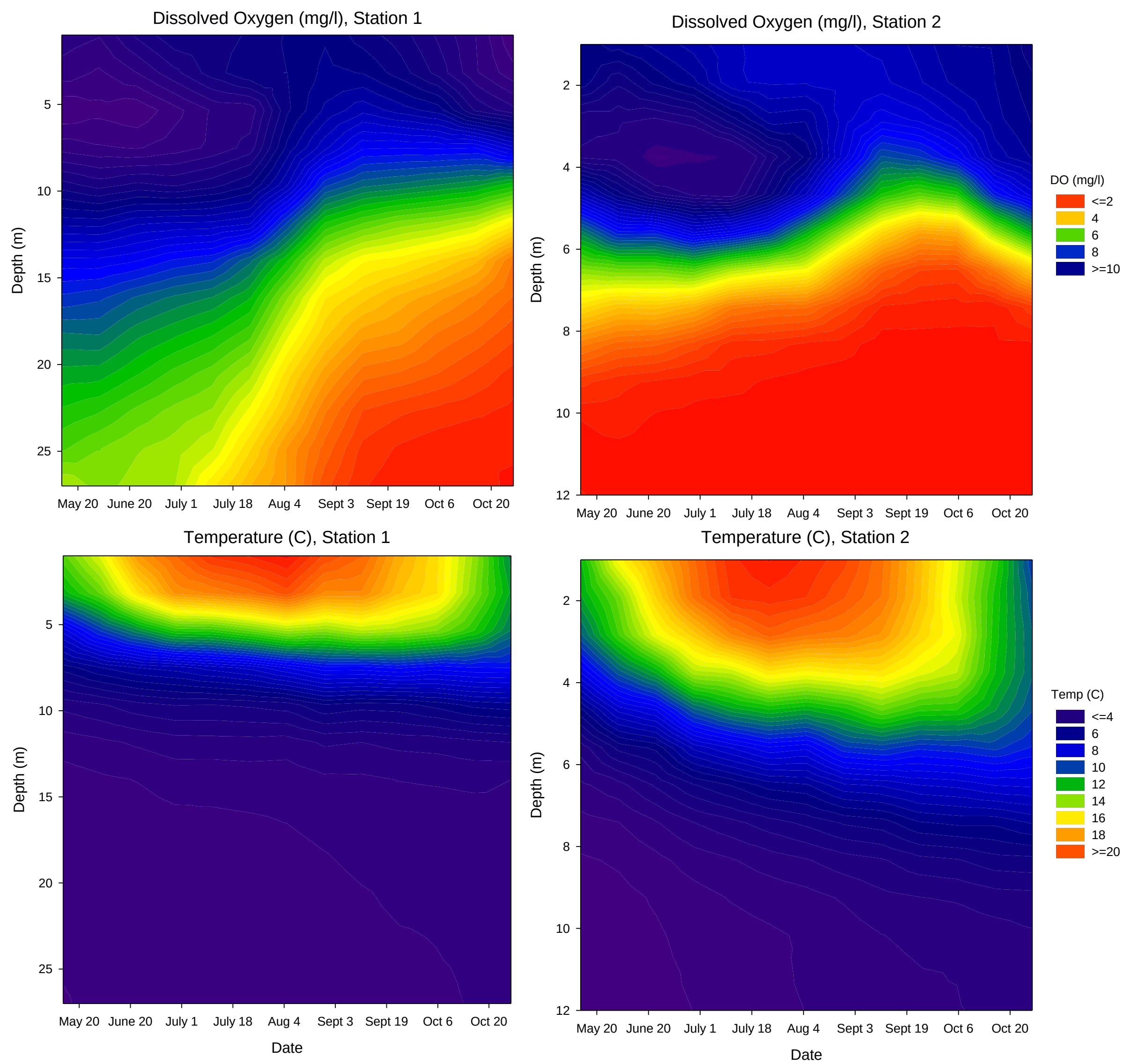
Secchi Disk Transparency

The maximum depth at which algae and macrophytes can grow in a lake is determined by the availability of light. Secchi transparency is a simple measure of the depth to which light penetrates the water column. A Secchi disk estimates lake transparency and provides an important measurement of water clarity. Secchi depth can be used to estimate the euphotic zone in a waterbody, or the depth to which algae can grow. Lake scientists have determined that light typically penetrates waters to a depth of twice that measured using a Secchi depth, and this is known as the "photic zone" of a lake.

Results

Interpreting isopleth figures. Many of the results below are displayed as isopleth figures. The techniques used to create isopleth figures are similar to those for creating elevation contour maps, and can be interpreted similarly. In elevation contour maps, the horizontal and vertical axes represent the location on the earth (latitude and longitude), and elevation is represented by the value of the contour lines drawn within the figure. For the figures below, the horizontal and vertical axes of each figure represent the date of sample collection and the sample depth, respectively, and the shape of the contour lines within the figure represents the concentration of the parameter of interest. Colors shaded closer toward red indicate that the parameter is approaching a concentration of concern. For example, red in the dissolved oxygen figure below indicates that oxygen concentrations have been depleted.

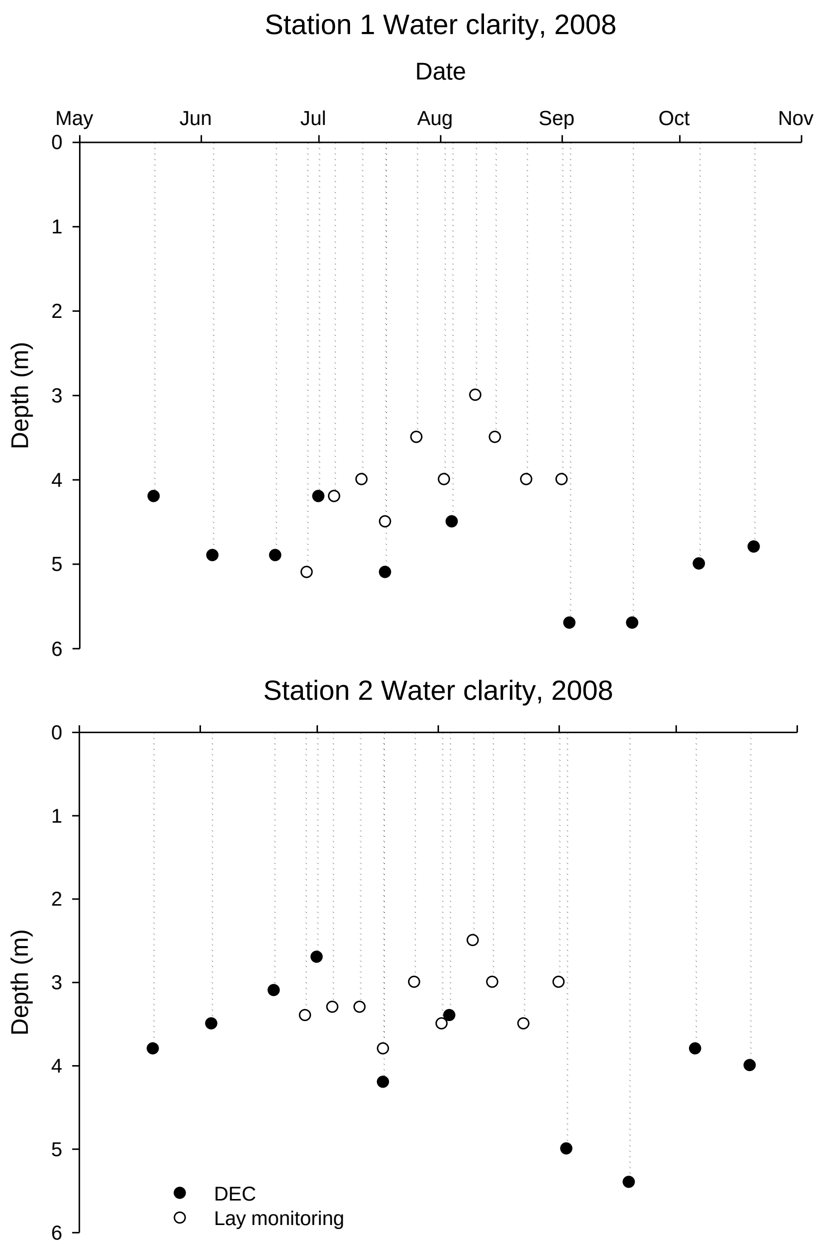
Dissolved oxygen and temperature profiles. There was thermal stratification at Station 1 for a majority of the sampling season. The upper surface waters warmed to temperatures greater than 20 ^{o}C by early July, and this warming influenced the water column down to approximately 10 m. Water temperatures at Station 1 remained colder than 6 ^{o}C below 10 m depth for the entire sampling season. The profiles measured at Station 1 indicate oxygen depletion in the lower depths (deeper than 20 m) after early July, and these concentrations had not recovered by the time of the final sampling event on October 20.



As with Station 1, surface water temperatures at Station 2 reached seasonal highs greater than 20 ^{o}C by early July. The lower layer of thermal stratification was between six and eight meters for the entire monitoring season. This stratification layer prevented the oxygen, phosphorus, and other nutrients from mixing with the surface waters. Dissolved oxygen concentrations at Station 2 were depleted below 8 m for the entire monitoring season. Extended periods of anaerobic (low-oxygen) conditions will allow anaerobic bacteria (bacteria that thrive in low-oxygenated environments) to become dominant and will alter the nutrient cycling of the lake's sediments.

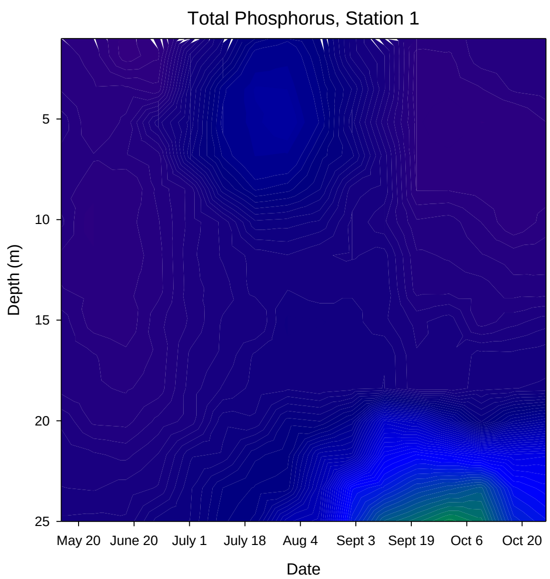
When this occurs, many nutrients that are typically locked in place within the sediments under oxygen-rich conditions are solubilized and released into the water column. These conditions are reflected in many chemistry samples collected from Station 2 in 2008 (see figures for phosphorus, nitrogen, iron, and manganese below).

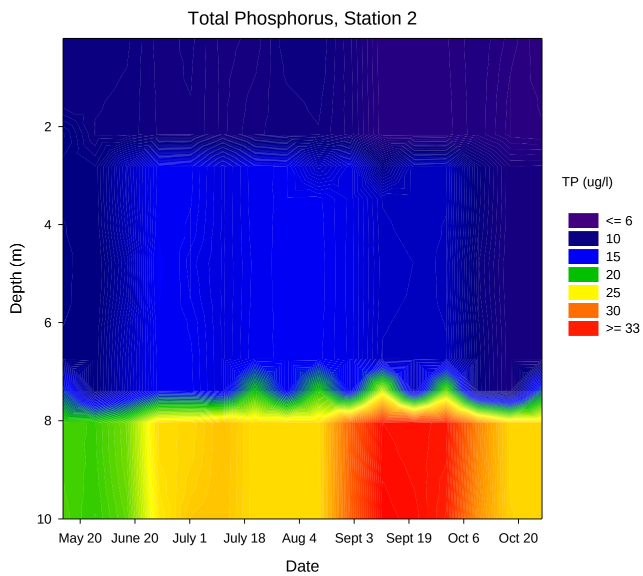
Water clarity. VT DEC crews and volunteer lay monitors recorded Secchi depth measurements throughout the 2008 field season. Minimum (poorest) depth measurements of 3.0 and 2.5 m at Stations 1 and 2, respectively, were recorded on August 10 by volunteer monitors, who recorded Secchi measurements weekly from late June through August. Maximum clarity measurements

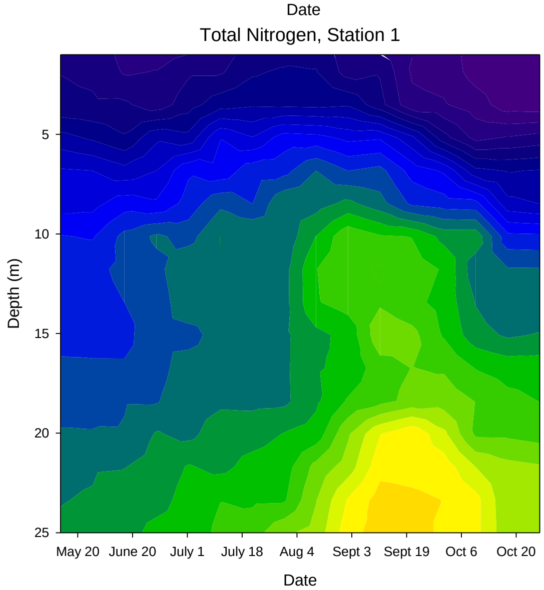


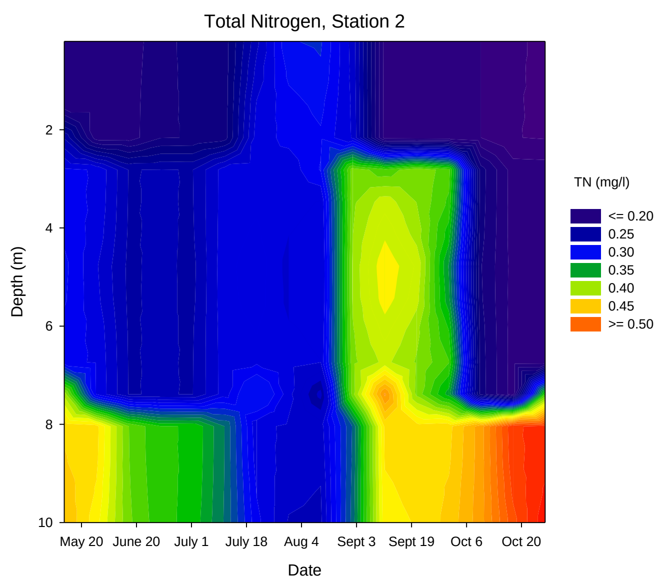
of 5.7 and 5.4 at stations 1 and 2, respectively, were recorded by VT DEC crews in mid-September. The figures below indicate Secchi depth measurements by both VT DEC and lay monitors at Stations 1 and 2 on Lake Rescue in 2008. Depth is increasing downward on the vertical axis, and date is on the horizontal axis.

<u>Nutrients.</u> Total phosphorus (TP) and total nitrogen (TN) concentrations at Station 1 were fairly typical of a mesotrophic lake such as Lake Rescue. At Station 1, TP concentrations averaged near 15 micrograms per liter (µg/l), and TN values were about 0.35 mg/l for most of the sampling season. As the deep waters started to become anaerobic in later summer/early fall, phosphorus was released from the sediments and began to accumulate in the lower portion of the water column. This is a common occurrence for mesotrophic lakes. TP and TN concentrations were significantly greater below 8 meters, which is likely due to the strong thermal stratification and subsequent oxygen depletion at Station 2.

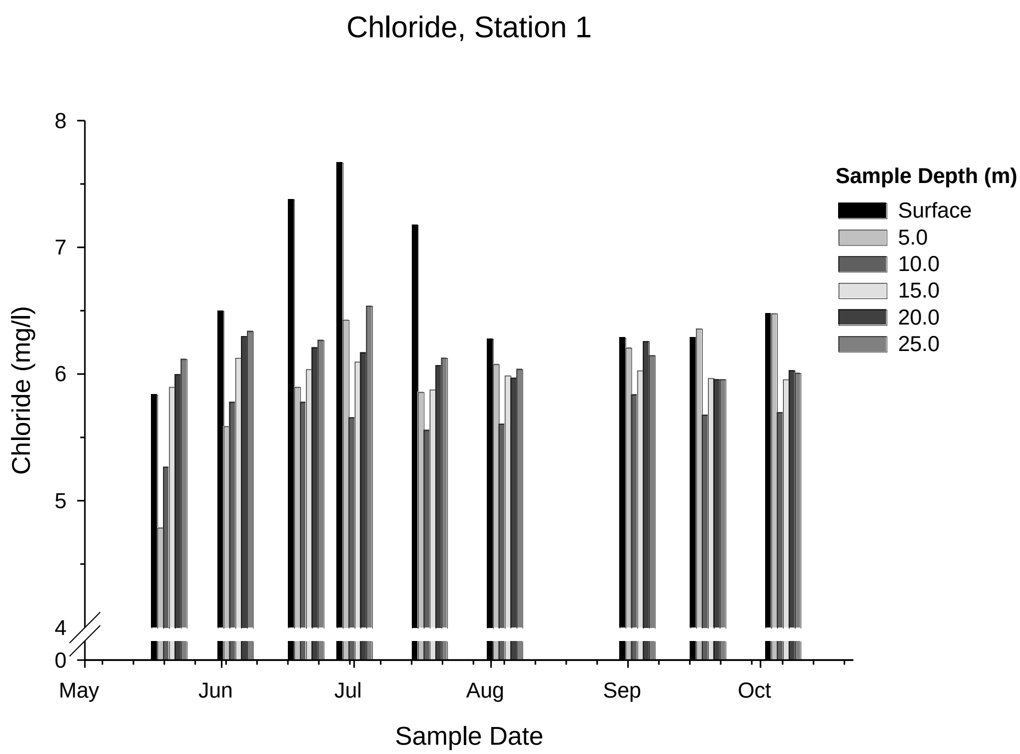


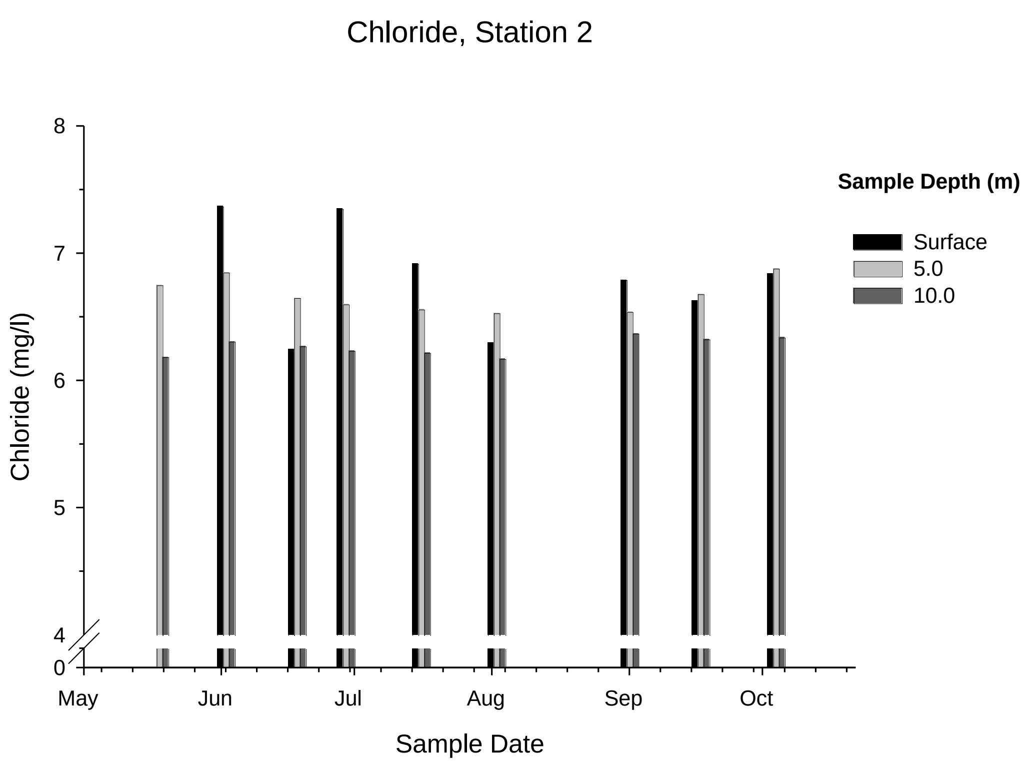




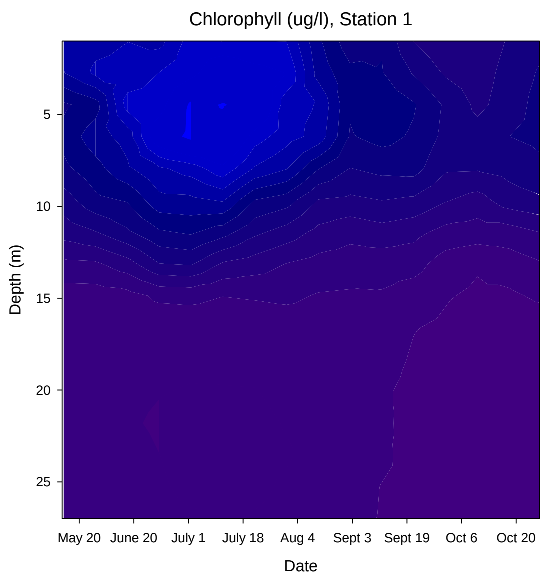


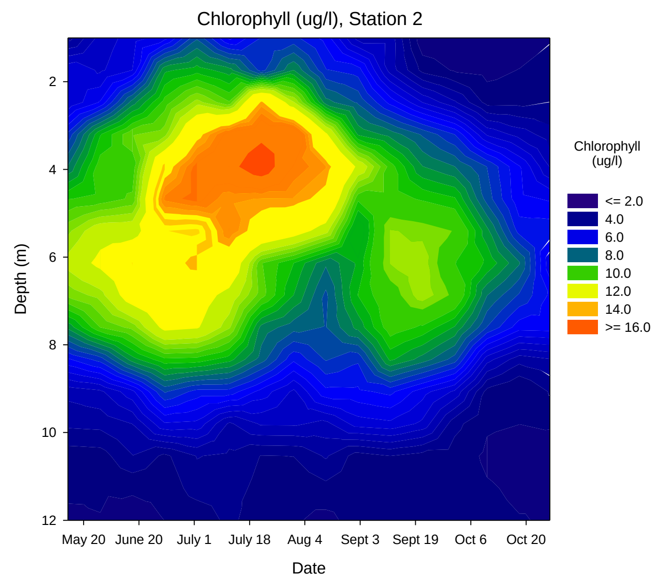
Chloride. Chloride concentrations in Lake Rescue were quite low, given the road network encompassing the lake (Route 100 in particular). Average chloride concentrations were higher at Station 2 than Station 1, although not significantly so (6.1 +/- 0.5 mg/l Cl at Station 1, 7.4 +/- 0.8 mg/l Cl at Station 2).





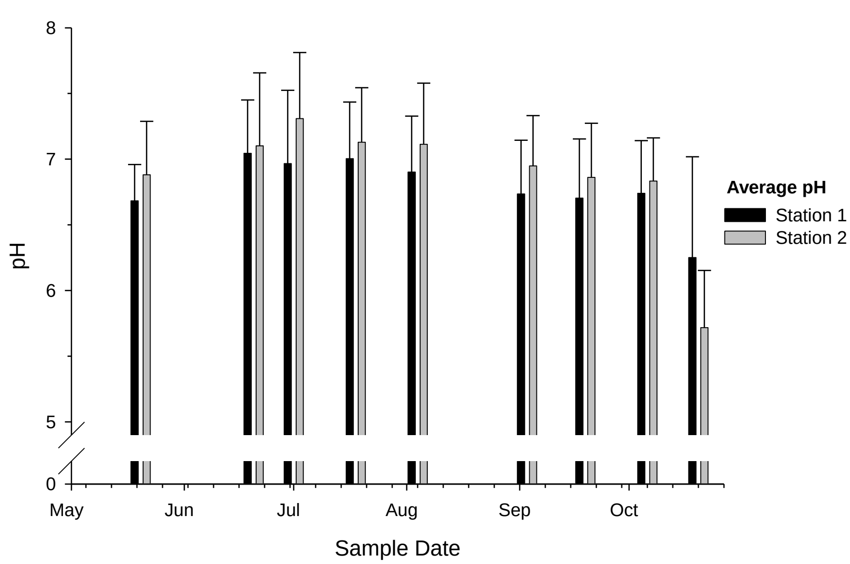
Total Chlorophyll. Chlorophyll profiles in Lake Rescue in 2008 indicated that algal concentrations likely remained very low in the main basin (Station 1) for the entire monitoring season. Average chlorophyll concentrations recorded at Station 1 in 2008 were 2.7 +/- 2.8 ug/l, and 7.2 +/- 7.0 ug/l at Station 2. Chlorophyll concentrations at Station 2 were greatest near 4 m in July. This is likely due to warming of the surface waters, as this is the period when surface waters were warmest.



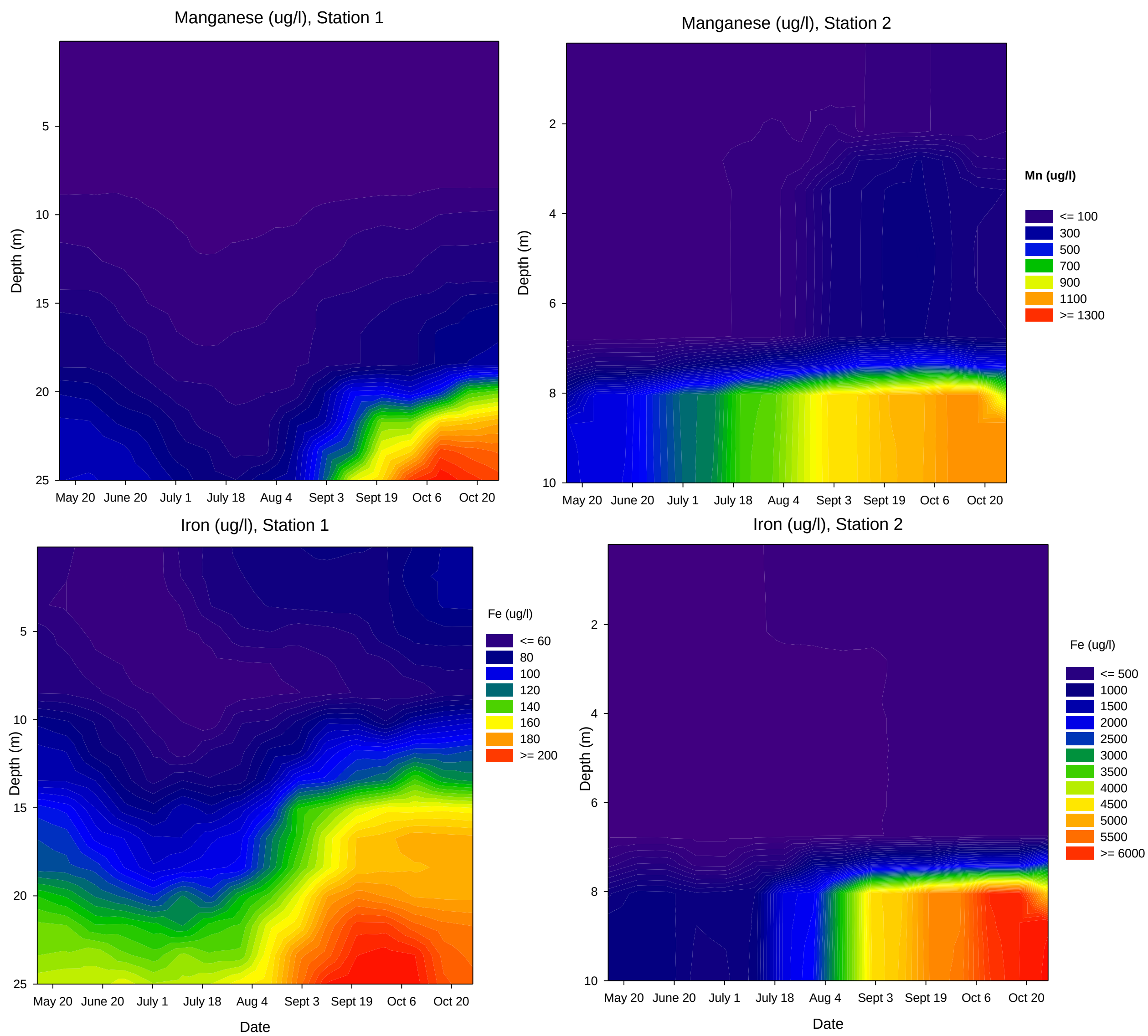


pH. Acidity levels in Lake Rescue are close to neutral. pH decreased slightly from a high of to 7.8 on July 1 in the surface waters to a low of 5.2 on October 20 at 14 m at station 1. This low pH at the end of the season is expected due to the low dissolved oxygen conditions. The figure below illustrates the mean (average) pH concentrations throughout the water column for each DEC sampling visit. The error bars represent 1 standard deviation from the mean.

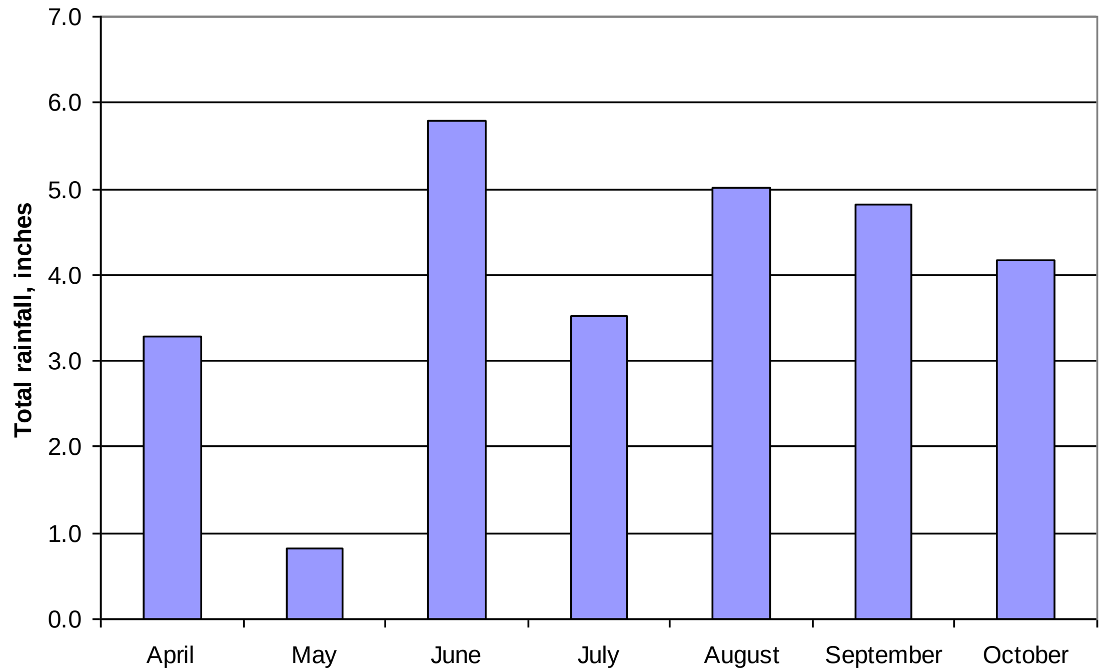
Average pH by sampling date for Stations 1 and 2 at Lake Rescue, 2008



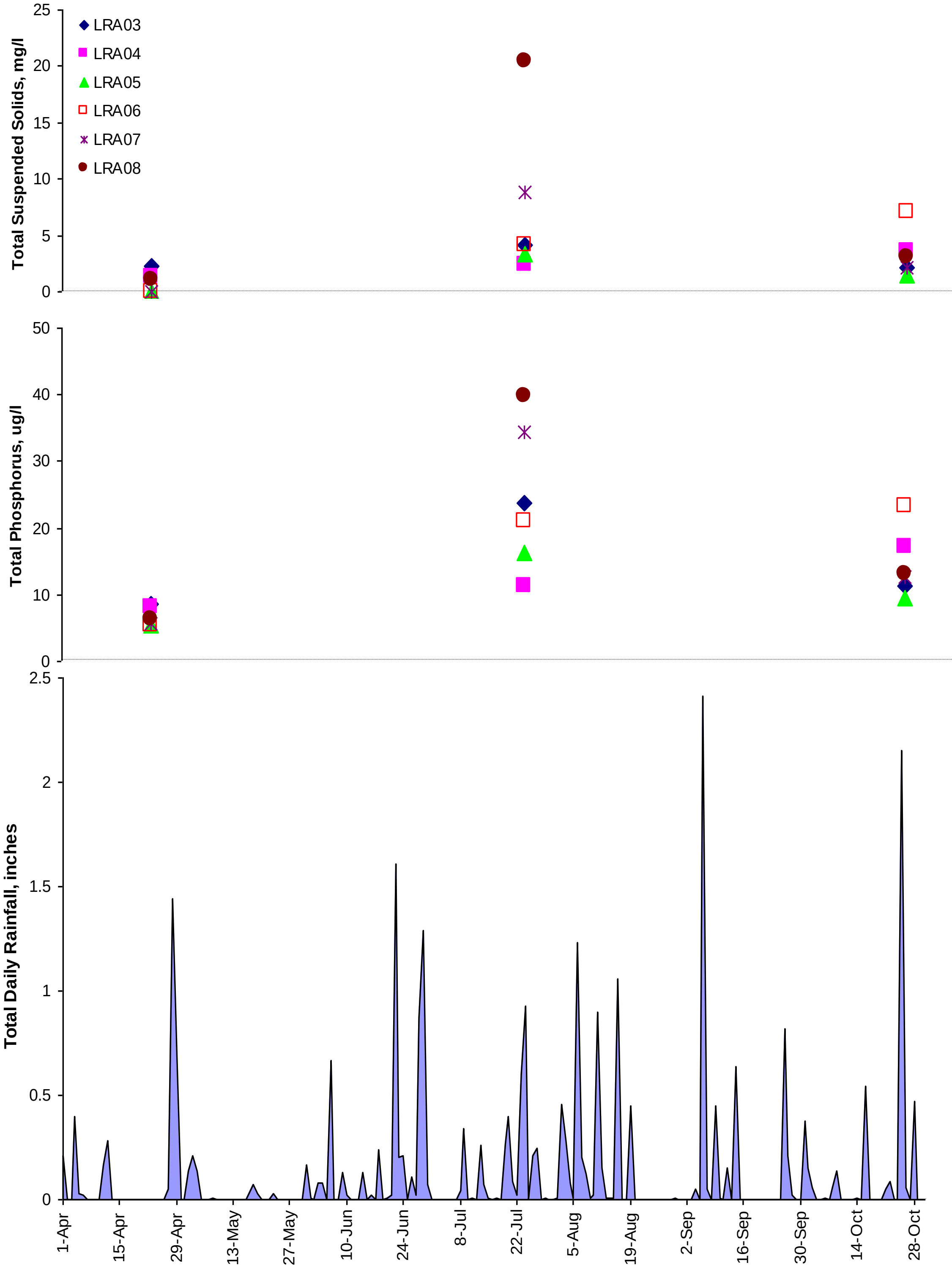
Iron and manganese. In low oxygen conditions, manganese and iron are released from the sediments, as is phosphorus. At station 1, this release does not happen until September, when the oxygen levels had been depleted, and then concentrations of both iron and manganese below 20 meters in depth increased substantially from the ambient conditions when the water is well-oxygenated. The oxygen depletion observed at Station 2 for the entire monitoring season triggers the release of these metals into the water column much earlier in the year, and for a longer duration. These events are illustrated in the figures below. Please note that the scaling for iron is different between stations 1 and 2.



Tributary data. Nutrient influxes from tributaries are often related to pulses in flows that correspond to precipitation events. Heavy precipitation events that generate excessive overland runoff into the tributary (and eventually the lake downstream) contribute large concentrations of nutrients. The figure below illustrates the total rainfall (in inches) during the summer sampling season at the Springfield airport, located approximately 12 miles from Lake Rescue.



Large, sudden influxes of water into a tributary can greatly increase the sediment load a tributary is carrying to a lake. With the increased sediment load are nutrients that are often closely associated with sediments, such as phosphorus. The correlation between increasing suspended sediment and increasing total phosphorus in the water column has been well-documented. The figure below of the data from the 2008 LRA tributary sampling program illustrates this relationship between rainfall, the ensuing increase in suspended solids, and the corresponding increase in total phosphorus for the July 24, 2008 sampling event. The other two sampling events, occurring on April 23 and October 26, sampled conditions at baseflow after several days of minimal precipitation. LRA sites 07 and 08 are much higher in all three analytes for the July 24 high-flow event than the other four monitoring sites. Turbidity results from these sampling events are not illustrated, but follow a similar trend.


Total Suspended Solids, mg/l
25
20
15
10
5
0
LRA03
LRA04
LRA05
LRA06
LRA07
LRA08
Total Phosphorus, ug/l
50
40
30
20
10
0
Total Daily Rainfall, inches
2.5
2
1.5
1
0.5
0
1-Apr
15-Apr
29-Apr
13-May
27-May
10-Jun
24-Jun
8-Jul
22-Jul
5-Aug
19-Aug
2-Sep
16-Sep
30-Sep
14-Oct
28-Oct

Summary

The results from the 2008 VT DEC monitoring program indicate that Lake Rescue is a mesotrophic lake. The main basin, where Station 1 is located, did not experience deep water anoxic conditions until later in the summer sampling season. The water temperature at Station 1 remained fairly stable throughout the season, not warming above 8 ^{o}C (46 ^{o}F) in waters deeper than 8 meters (26 ft). pH, a measurement of acidity, began to dip below 6.5 in late summer. Typically, pH levels below 6.0 are cause for concern as this is the point at which many biota are affected by acidic waters. Nutrient levels (phosphorus and nitrogen) remained fairly low, even under anoxic conditions when phosphorus is often released from the sediments. Similarly, chlorophyll concentrations, an indicator of algal growth in the water column, were low throughout the water column for the entire season. Secchi measurements were also relatively stable throughout the year, with the exception of an apparent clearing event in mid-September, when Secchi depths reached their maximum for the year at 5.7 m (19 ft). This clearing event may be due to a change in the algal population as the surface water temperatures began to cool down from the summer highs. Concentrations of iron and manganese at station 1 remained low in a majority of the water column, with concentrations somewhat increasing near the bottom, between 20-28 m (66-92 ft) in late summer as oxygen levels became depleted.

Monitoring at Station 2 in the smaller basin of Lake Rescue, also known as “Round Pond”, yielded somewhat different water chemistry results that those of the main basin. Temperatures throughout the water column were warmer at station 2, although this is not surprising as this station is only 12 meters (40 ft) deep. As with the main basin, Round Pond experienced thermal stratification between 4-6 meters (13-20 ft) deep for most of the sampling season. Water temperatures below this stratification layer were typically 8 ^{o}C or colder. Waters below the thermal stratification layer became anoxic very quickly in the season and remained so for the duration of the monitoring season in 2008. Water deeper than 8 m often held less than 2 mg/l of dissolved oxygen, well below levels needed by most fishes for survival. These prolonged anoxic conditions also affected the chemistry of the bottom waters. Phosphorus, iron, and manganese were all significantly higher in concentration in the lower waters of Round Pond than they were in the main basin of Lake Rescue. Iron concentrations were on average about 10 times greater at Station 2 than they were at Station 1. Chloride concentrations were also substantially greater in lower waters of Round Pond. This may be due to influxes from tributaries that empty into Round Pond that carry increased sediment loads, including road salt, metals, and nutrients. Chlorophyll increased in the mid-level waters during July, probably as a result of nutrients working their way into the upper water column from the sediments, and the warmer water temperatures observed in late June and early July. The pH, however, was relatively stable throughout the water column, moving towards stronger acidity near the end of the monitoring season, when the pH of the entire water column dropped into the 6.4-6.6 range after the water column began to de-stratify thermally due to the cooling of the surface waters. Water clarity (Secchi measurements) at Station 2 followed a similar trend to that of Station 1, averaging about 4 m for most of the sampling season with the exception of mid-September, when the deepest Secchi measurements were recorded during a clearing event as the surface waters began to cool. For brevity, calcium and magnesium were not illustrated in this document, but these tests indicated that concentrations of both calcium and magnesium followed similar trends to those to iron and manganese for both stations 1 and 2. Station 1 had very low concentrations of both metals, and station 2 had similarly low concentrations in the surface waters, with slightly higher concentrations closer to the sediments.

Data collected from the tributaries illustrate that, as sampling in 2007 indicated, LRA sites 07 and 08 contribute significantly more sediment and phosphorus during heavy rainfall events than the other four tributaries that were monitored by the LRA. Loadings from these tributaries are cause for concern as they contribute nutrients to the water column in the main lake, and may add to the increasing nutrient concentrations in the deep waters of Station 1.

Several VT DEC crews have noted the increasing levels of shoreline development and removal of the shoreline buffer around the perimeter of the lake. Many studies (including some in Vermont) have demonstrated the value of shoreline buffers in protecting the quality of the aquatic habitat in the shallow waters of the pond, as well as the terrestrial habitat along the waters' edge. Removal of the shoreline buffer has been shown to increase sunlight penetration into the water column and increase sedimentation into the lake. As discussed above, increasing sedimentation into the lake increases the nutrients that are available to the water column; the addition of more sunlight warms the water more quickly, and more light is available for photosynthesis, allowing more aquatic plants to grow along the shoreline. This increased growth and productivity of the lake ultimately contributes to lake eutrophication and reduces the overall health of the lake.

In conclusion, Lake Rescue is a healthy lake that is experiencing stressors typical of many lakes in Vermont. Sedimentation and increased nutrient influxes from stormwater runoff due to improperly culverted roads and development of lands within the watershed, as well as increased shoreline development are currently two of the major stressors to lakes in the northeastern United States. These stressors can be mitigated, however with proper stormwater management practices and education of shoreline homeowners toward the importance of maintaining established buffers along their lakeshores.