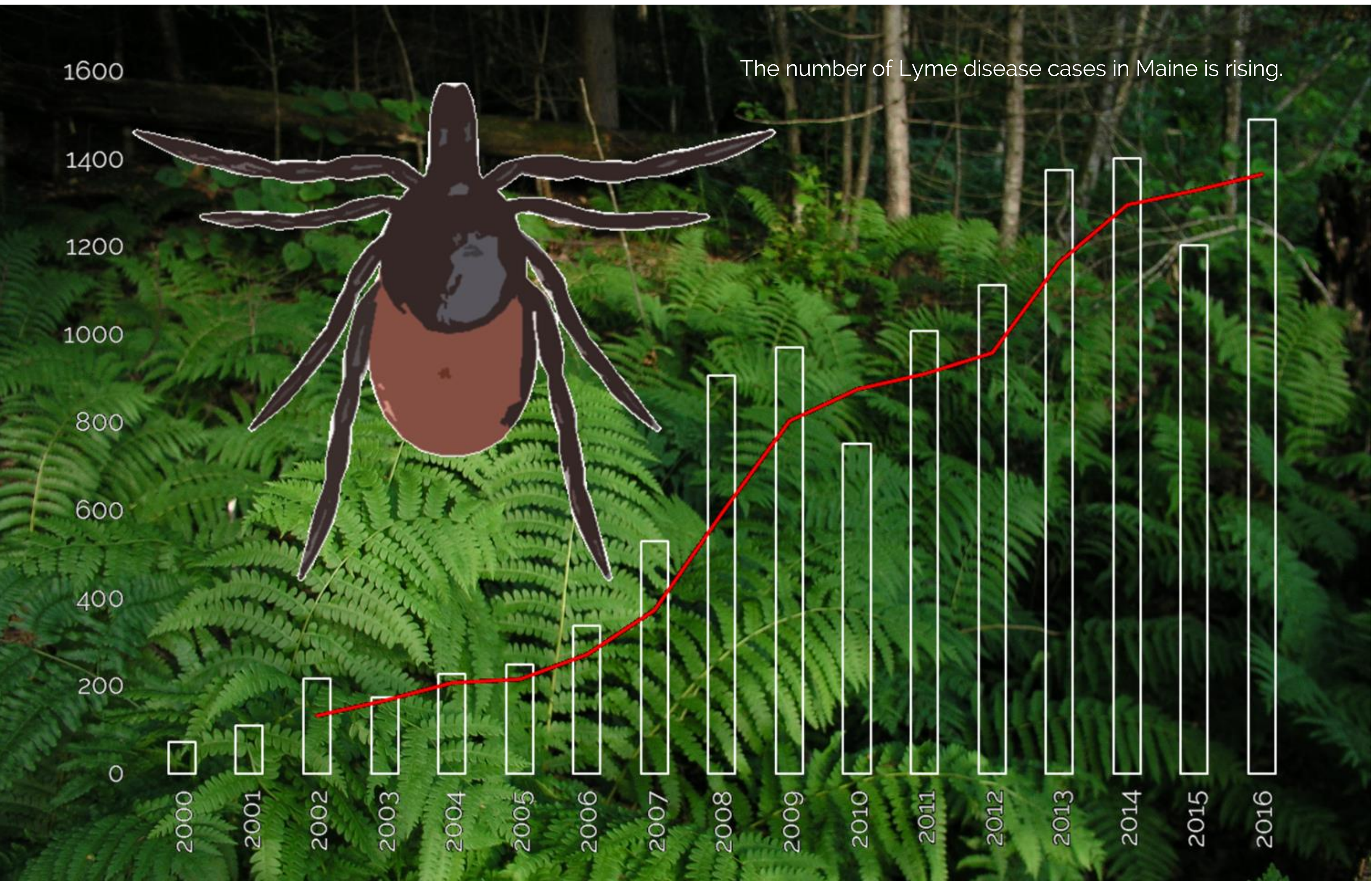
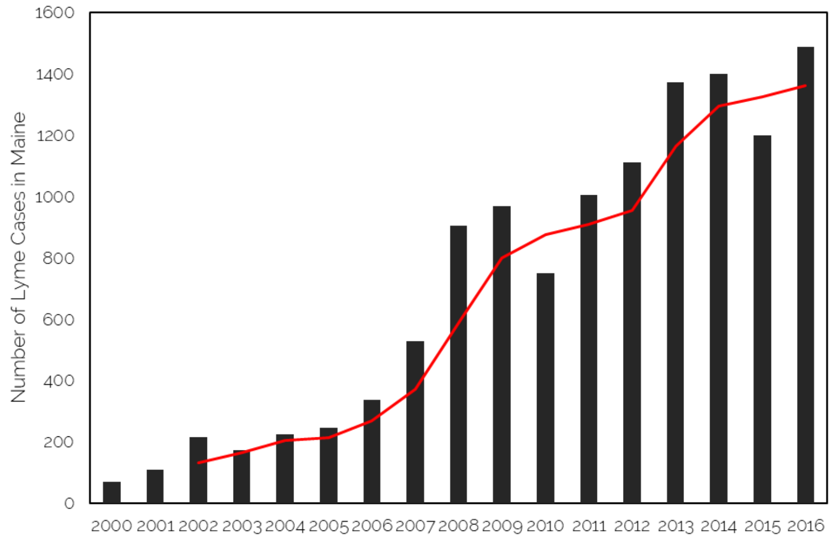
Kezar Lake
WATERSHED ASSOCIATION
P.O. Box 88, Lovell, ME 04051 www.klwa.us

CLIMATE CHANGE OBSERVATORY



2017 ANNUAL REPORT

ABOUT THE COVER



The number of Lyme disease cases in Maine is rising. Data were obtained from the Centers for Disease Control and Prevention (CDC).

The Climate Change Observatory chose to feature ticks in the 2017 Annual Report because climate change is likely driving the growing tick population in the State of Maine and thus the increased risk of human exposure to disease-carrying ticks.

The Maine Center for Disease Control and Prevention (Maine CDC) data shows that the number of reported Lyme disease cases in Maine is increasing. This increase in reported cases is likely due to a combination of climate-induced factors. Warming air temperatures (especially in winter), more precipitation, a longer growing season, and a proliferation of their primary hosts (mice, chipmunks, and other small mammals) are promoting the northern migration of and thus increasing populations of disease-carrying ticks in the State. Although deer, moose, and other large mammals are also hosts to ticks, small mammals are considered their primary hosts and generate a far greater threat to humans because small mammals live closer to where we live, work, and play.

Deer ticks carrying Lyme disease can be found in wooded areas or open, grassy areas, especially along the edges of forests. To best control tick populations around your property, clear brush and leaves and deter deer, mice, and chipmunks. Be vigilant in checking for ticks and seek immediate medical help if you were bitten by a deer tick. Lyme disease can be easily treated with antibiotics, but if left untreated, can cause severe illness, arthritis and neurological problems.

There are several other tick-borne diseases that threaten public health and may increase with a changing climate. These include anaplasmosis, babesiosis, ehrilichiosis, powassan virus, spotted fever rickettsiosis, as well as other less common diseases. Each of these has shown an increase over the years, especially anaplasmosis.

For more information on prevention and treatment, please visit https://www.cdc.gov/ticks and http://www.maine.gov/dacf/php/gotpests/bugs/ticks.htm.

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CONTRIBUTING AUTHORS: **LAURA DIEMER** (FB Environmental Associates), **DON GRIGGS** (KLWA/CCO), **TYLER SIMONDS** (KLWA Intern), **LISA DONER** (Plymouth State University), **WES HUNTRESS** (KLWA/CCO)

Design by Laura Diemer (FB Environmental Associates)

EXECUTIVE SUMMARY

Climate change is threatening the current balance of ecological systems across the globe. In New England, we can expect warmer air temperatures, more intense and frequent precipitation events, increased flooding, reduced snow cover duration, enhanced species migration and extirpation (including increased prevalence of disease-carrying ticks), and earlier lake ice-out. Lakes can provide early indications of climate change effects and have been identified as "sentinels of climate change" by the scientific community.

The Kezar Lake Watershed Association (KLWA) recognized the critical need to protect and monitor its valuable natural resources in the face of climate change. As a result, KLWA established a Climate Change Observatory (CCO), whose objective is to analyze the long-term effects of climate change on atmospheric, aquatic, and terrestrial ecosystems in the Kezar Lake watershed. The CCO is led by a seven-member steering committee and is funded through a grant, generous donations, and the KLWA General Fund. The formulation and operation of the CCO is made possible through the expert guidance of collaborating partners, including the Greater Lovell Land Trust, the U.S. Forest Service, the University of Maine Climate Change Institute, the Maine Department of Inland Fisheries & Wildlife, Manomet Center for Conservation Sciences, Plymouth State University Center for the Environment, and FB Environmental Associates.

The mission of the Climate Change Observatory is to observe, measure, and analyze long-term climate change trends and to address their impact on the waters, lands, and wildlife of the Kezar Lake watershed.

This document is the third CCO Annual Report, which is published annually to highlight the previous year's activities and monitoring results and to make recommendations based on the analysis of climate change-induced annual trends for available data. These data are presented by major ecological zone: climate, water, and land.

The CCO has accomplished the following climate change activities in the watershed in 2017:

- **Developed climate change webpages** for the KLWA website (klwa.us) to showcase observed trends in several indicator categories, but most especially water quality.
- **Deployed data loggers** to monitor water temperature and water level in several tributaries draining to Kezar Lake, as well as in the lower bay and in the outlet stream to the lake. This effort was expanded to include vertical profile monitoring of dissolved oxygen and temperature in the deep-spot of the upper and lower bays.
- **Installed a state-of-the-art weather station and web camera** on Kezar Lake for tracking local weather conditions.
- **Initiated multi-year loon study** to track the health of loon populations and their habitats.
- **Conducted a baseline acidity study of the tributaries** to better track future changes in water quality impacting fish and other sensitive aquatic life.
- **Hosted a graduate summer intern** that helped research and compile key climate change data for the CCO webpages and report.
- **Attended multiple meetings with project partners**, including the Town of Lovell and PSU.
- **Obtained grant funding** to continue climate change tracking efforts in the watershed.
- **Participated in multiple education and community outreach events** to promote CCO activities.

ANNUAL REPORT ON OBSERVED THREATS & RECOMMENDATIONS

CLIMATE CHANGE THREAT	ADAPTATION & MITIGATION RECOMMENDATIONS
ACTIONS FOR THE TOWN OF LOVELL	
⊗ Increased air temperatures, fewer extreme cold days, more frequent precipitation events, earlier ice-out since 1972, and decreased annual snowfall. ⊗ Potential degradation of stable or improving trends in water clarity, total phosphorus, chlorophyll-a, and dissolved oxygen.	⊕ Improve infrastructure (roads, ditches, swales, culverts) to accommodate higher and more frequent stormwater flow volumes. ⊕ Replace the remaining high priority culverts identified by the 2015 culvert study. ⊕ Establish a Climate Change Information link on the town website that links residents to important climate change information and the KLWA/CCO webpages. ⊕ In developing the next Comprehensive Plan: 1) include provisions to deal with projected climate change-induced weather events and conditions (e.g., upgrading infrastructure); 2) include language that ensures development occurs in a sustainable and low-impact way to increase watershed resiliency to extreme weather events and prevent potential polluted runoff; 3) include current and projected flood risk maps for residents with homes in low-lying areas; 4) consider rezoning the projected flood zone for non-development; 5) add Low Impact Development (LID) description to ordinance and require LID in site design, especially for lots with >20% imperviousness; 6) increase setback distances to at least 100 ft. around vernal pools, streams, and wetlands; and 7) encourage conservation subdivisions, where applicable, with common open space and require land trusts or conservation organizations (not homeowner's associations) to undertake stewardship of common open space in conservation subdivisions. ⊕ Review and update local septic ordinances to include the following: 1) require septic systems to be evaluated and upgraded to current code or replaced, as needed, for any sale or exchange of property ownership or upon a system failure; 2) require proof of septic system pump-outs every 3 years (unless given an approved waiver for limited use). ⊕ Conduct a shoreline survey of properties on Kezar Lake and ponds to identify conduits of stormwater runoff (e.g., driveways, boat ramps) and develop specific recommendations for mitigation of erosion.
⊗ Increased threat from invasive aquatic plants.	⊕ Continue the outstanding progressive watch programs that help prevent and control invasive plants.
⊗ Reduction in aquatic bird species, esp. loons.	⊕ Post signage to encourage anglers to use non-lead sinkers and to retrieve fishing line caught in shoreline vegetation. Install "Get the Lead Out" boxes at Town landings for disposing of lead-based fishing gear. Keep at least 200-foot distance from loons and their nest.

CLIMATE CHANGE THREAT	ADAPTATION & MITIGATION RECOMMENDATIONS
ACTIONS FOR KLWA	
⊗ Potential degradation of stable or improving trends in water clarity, total phosphorus, chlorophyll-a, and dissolved oxygen.	⊕ Target stormwater management and septic system maintenance outreach to shorefront and riverfront residents. ⊕ Advocate and publicize the merits of achieving LakeSmart certification through the State of Maine. ⊕ Advocate and publicize the specific recommendations for sustainable lake shore living in the KLWA's Lake Dweller's Handbook.
⊗ Degrading trends in alkalinity and pH in multiple waterbodies.	⊕ Conduct another alkalinity and pH study to better assess the vulnerability of waterbodies to acid rain and watershed activities across years.
⊗ Reduction in coldwater fish populations.	⊕ Continue monitoring stream conditions for supporting coldwater fish species (e.g., temperature, flow, and population size). This will help target streams in need of restoration. Restoration techniques include increasing overhead vegetative cover to help cool stream water temperatures. ⊕ Petition IF&W to make Kezar Lake catch and release only for certain sensitive fish species. Debar all fish hooks and ensure proper fishing line strength to avoid fish injury and entanglement.
⊗ Increased threat from insects and pathogens.	⊕ Contact the Maine Center for Disease Control and Prevention to determine how public notices will be issued during peak tick and mosquito season to warn residents of potential diseases, including Lyme and follow-up to see that people in Lovell receive these notices.
ACTIONS FOR GREATER LOVELL LAND TRUST	
⊗ Shifts in the habitat ranges of native plant, bird, and mammal species.	⊕ Continue to conserve and protect land areas that serve as wildlife corridors.

INTRODUCTION

In 2013, the Kezar Lake Watershed Association (KLWA) established a Climate Change Observatory (CCO) to observe, measure, and analyze long-term climate change trends and to address their impact on the waters, lands, and wildlife of the Kezar Lake watershed. The CCO is building upon decades of limited local data by expanding data collection activities in the Kezar Lake watershed. These data collection activities target current community interests that were identified during a Community Values Form hosted by the CCO in July 2014. The purpose of this work is to provide the public, local government, and other stakeholder organizations with 1) ongoing information related to the effects of climate change on community interests and 2) recommendations for mitigating or adapting to these potential effects.

This document is the third CCO Annual Report, which is published annually to highlight the previous year's activities and monitoring results and to make recommendations based on the analysis of climate change-induced annual trends for available data. These data are presented by major ecological zone: climate, water, and land.

CLIMATE CHANGE OBSERVATORY MANAGEMENT AND DIRECTION

The CCO is funded by a combination of grant, donations, and the KLWA General Fund. CCO activities are guided by a Steering Committee that reports to the KLWA President and supervises the activities of the CCO, by providing direction, setting goals, establishing priorities, and allocating funds.

Current Steering Committee Members

Don Griggs, Director	Bob Winship	Eric Ernst
Heinrich Wurm	Ray Senecal	
Lucy LaCasse	Wes Huntress	

PARTNERS AND COLLABORATING ORGANIZATIONS

The CCO collaborates with federal and state government agencies, universities, and private organizations that are involved in climate change activities. CCO members meet and exchange ideas and data with these partners on a regular basis. The recommendations and guidance the CCO has received from these collaborating partners have been immensely helpful in formulating climate change monitoring plans and activities.

Our Partners Include:

- **Greater Lovell Land Trust** – shares our vital interest in the future of our watershed;
- **U.S. Forest Service** – established a water quality data exchange plan for streams within the watershed in the White Mountain National Forest (24% of our watershed);
- **University of Maine Climate Change Institute** – provides access to internationally-acclaimed experts studying climate science;
- **Maine Department of Inland Fisheries & Wildlife** – conducts research on the effects of climate change on fisheries and wildlife;

- **Manomet Center for Conservation Sciences** – provides technical experts on climate change effects on land and water;
- **Plymouth State University Center for the Environment** – provides historical climate data from sediment core sampling, as well as a source of highly-qualified graduate interns;
- **FB Environmental Associates** – provides technical advice, planning, and monitoring support for CCO activities.

CURRENT CCO ACTIVITIES (2017)

The CCO was very active in 2017. These activities have bolstered community involvement and awareness of climate change in the Kezar Lake watershed. Our work has received support and commendations from several regional environmental organizations in Maine.

WEB SITE DEVELOPMENT

A major effort over the past year has been the continued development of webpages for the KLWA website (klwa.us) that tell the story of climate change trends for a variety of data collected within or near the Kezar Lake watershed. This website successfully summarizes the voluminous data collected over several decades in a format that is readily accessible and understandable to the public. Because of the extensive and local data available on water quality for Kezar Lake and six ponds within the watershed, most of the initial effort was placed on water quality. However, the CCO was also able to collect and summarize general climate information for the area, as well as the effects of climate change on many key wildlife and plant species. Website development will be an ongoing effort by the CCO and one of the primary methods of data communication with the public.

DATA COLLECTION

The CCO purchased, engineered, and installed a state-of-the-art weather station and web camera on the edge of Kezar Lake just south of Boulder Brook. Collecting local weather data will greatly improve the accuracy of our water quality data analyses that are dependent on temperature and precipitation readings. The weather station data and webcam images are also an important service that KLWA provides to the community.

The CCO deployed data loggers that continuously collect water temperature and water level data in two streams draining to Kezar Lake, as well as in the lower bay and in the outlet stream of the lake. Five other streams draining to Kezar Lake are continuously monitored for water temperature. The CCO and its partners are currently working to establish a stage-discharge relationship for three sites so that water level can be converted to flow data. Climate change is likely to impact water temperature and stream flow greatly; thus, establishing a monitoring program that evaluates these parameters annually will provide insight to how the watershed responds to climate change.

KLWA deployed dissolved oxygen and temperature data loggers in the deep spot of the upper and lower bays. With high-resolution data from continuous loggers, we can pinpoint spring and fall turnover, determine the onset of thermal stratification, and determine the extent and duration of anoxia. By tracking these parameters over time, we can measure whether these indices are shifting because of climate change or other human disturbances within the watershed.

Concerned with long-term degrading trends in alkalinity and recent degrading trends in pH in surface waters of the Kezar Lake watershed, KLWA conducted a baseline acidity study of the tributaries to Kezar Lake to better track future changes in water quality impacting fish and other sensitive aquatic life. Results showed that acidification is a potential issue for aquatic life in waters of the Kezar Lake watershed and reduction in snowpack because of climate change may be further exacerbating observed degrading trends in acidity metrics.

SEDIMENT CORES

Under the guidance of Dr. Lisa Doner from Plymouth State University, the CCO collected several sediment cores from Kezar Lake in 2015, partially analyzed and dated some of the core samples, and established a 1,000-year history of climate conditions in the lake. A summary description and preliminary results were presented in the 2016 Annual Report. Further analyses and dating of the cores will be dependent on new funding.

SUMMER INTERN

The CCO was very fortunate, once again, to have a paid intern for six weeks this summer. Tyler Simonds, a graduate student from Plymouth State University, was instrumental in researching and compiling climate change data for the KLWA webpages, including tick disease research, and participating in water quality data collection. The CCO will not host an intern in 2018.

MEETINGS

Members of the CCO met with Lovell officials as follows:

03/01/17 Met with Planning Board to present 2016 Annual Report.

05/09/17 Met with Lovell Selectmen to present 2016 Annual Report.

Members of the CCO met with Plymouth State University staff as follows:

10/16/17 Met with Dr. Lisa Doner in Plymouth, NH to discuss future collaboration opportunities.

CCO Steering Committee meetings were held on **02/27/17**, and **05/08/17**.

GRANT APPLICATION AND REPORTING

The CCO submitted a required status report on our 2016 grant in February 2017. The report detailed CCO use of the 2016 grant funds. The CCO then applied for a 2017-18 grant and was awarded $15,000 to continue our climate change tracking efforts.

The CCO facilitated a grant request to the Stephen and Tabitha King Foundation titled "Sustaining Loons in the Kezar Lake Watershed: A Community Response" to study our loons and establish a baseline for tracking future trends. We received a grant of $40,000 for a 2-year project to document the nesting behavior and breeding and rearing activities of our loons and to identify actions that we can take to foster their longevity. We consider the loons one of the "indicator species" of climate change.

EDUCATION/COMMUNITY PROGRAMS

07/08/17 Presented CCO activities update at the KLWA Annual Meeting.

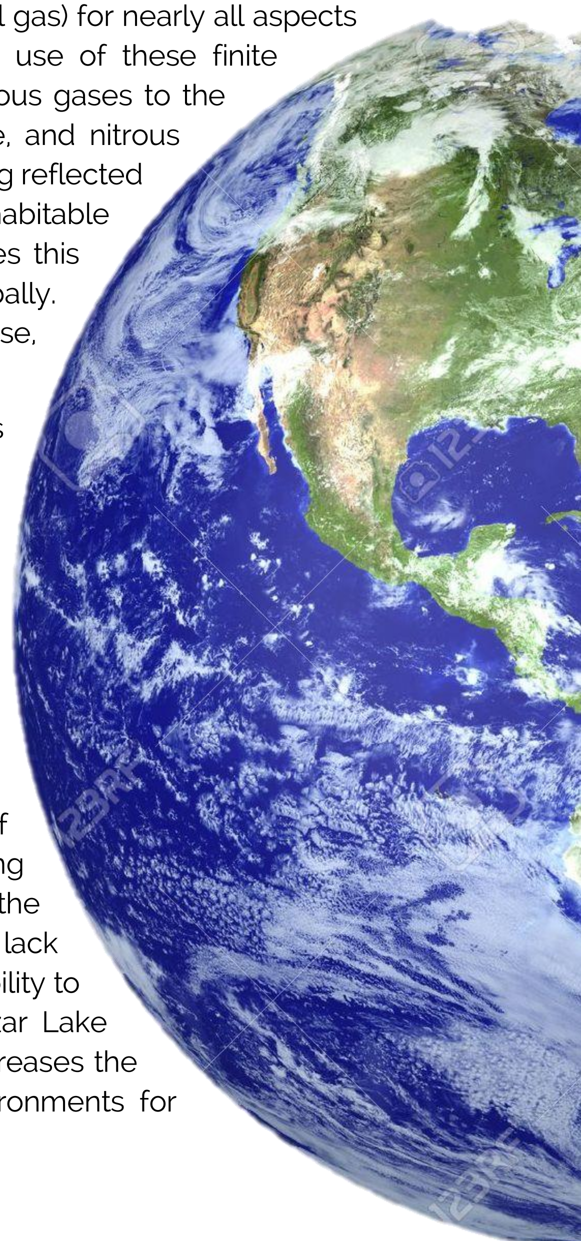
07/15/17 Established a climate change booth for Lovell Old Home Days with displays, informative hand-outs, and a water clarity participation event for children.

Kezar Lake. Photo Credit: Don Griggs.

ANNUAL REPORT ON OBSERVED TRENDS

CLIMATE

Air Pollutants



We rely on the burning of fossil fuels (i.e., gasoline, coal, and natural gas) for nearly all aspects of our everyday lives. This heightened energy demand for and use of these finite resources over the last century has introduced an excess of noxious gases to the atmosphere. Some of these gases (e.g., carbon dioxide, methane, and nitrous oxide), also known as greenhouse gases, are responsible for trapping reflected heat from the earth's surface. This process is vital to maintaining a habitable planet, but excess greenhouse gases in the atmosphere enhances this effect by trapping more heat and increasing air temperatures globally. Warmer air temperatures impact rain and snow patterns, sea level rise, and species migrations.

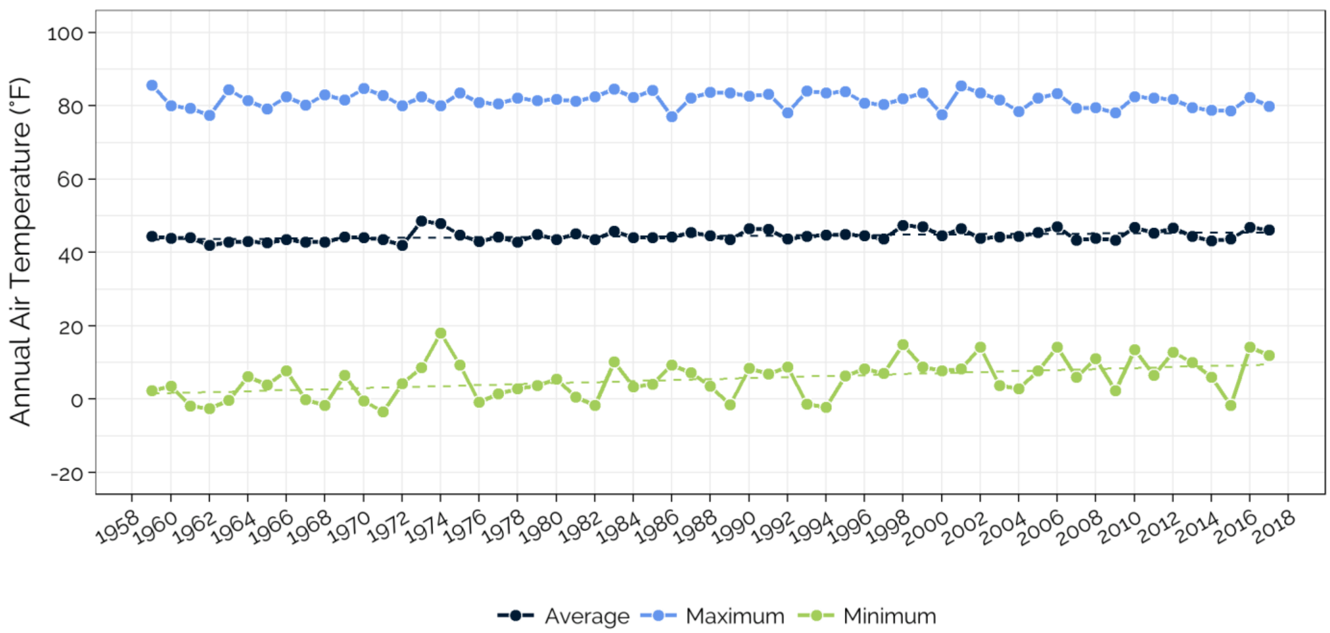
Fossil fuel combustion also emits sulfur dioxide and nitrogen oxides to the atmosphere. These gases react with water vapor, oxygen, and other gases in the atmosphere to form sulfuric and nitric acids, which fall on water and land surfaces as acid rain. Acid rain lowers the pH of aquatic and terrestrial systems, causing reduced reproductive capacity of sensitive aquatic organisms, lower body weight of fish, decreased species diversity, and forest mortality. Substantial effort was made to reduce acid rain deposition through the 1970 Clean Air Act, which established national ambient air quality standards for controlling these noxious emissions. While emissions have decreased, and the damaging short-term effects of acid rain have been minimized, many waterbodies are still recovering from the long-term effects of acidification. In particular, the northeastern United States has thin soils with granite geology that lack carbonates, a key component of a system's buffering capacity or ability to neutralize acidic compounds. We see this in streams of the Kezar Lake watershed where low-pH rain (5.0) temporarily, but drastically, decreases the pH of surface waters. These swings in pH create stressful environments for sensitive aquatic organisms.

Air Temperature

Climate change is expected to increase global air temperatures, an effect that we have already observed in the last century. An important point to understand about climate change is the difference between "climate" and "weather." Climate change observations and predications are based on "climate," which is long-term averages of weather observations across regional or global space. For example, the State of Maine has seen a 3 °F increase in annual air temperatures in the last century and we expect an additional 1.4 to 3.0 °F increase in annual air temperatures by 2040. Local weather observations may deviate from this general trend from season to season or year to year, depending on a suite of local variables. For the Kezar Lake watershed, we used CONWAY 1 N, NH US (ID# GHCND:USC00271732) and NORTH CONWAY, NH US (ID#GHCND:USC00275995) weather stations from the NOAA National Centers for Environmental Information (NCEI) to track changes in air temperature since 1959[1].

> **"AVERAGE ANNUAL TEMPERATURE ACROSS MAINE WARMED BY ABOUT 3.0 °F (1.7 °C) BETWEEN 1895 AND 2014." - MAINE'S CLIMATE FUTURE, 2015 UPDATE**

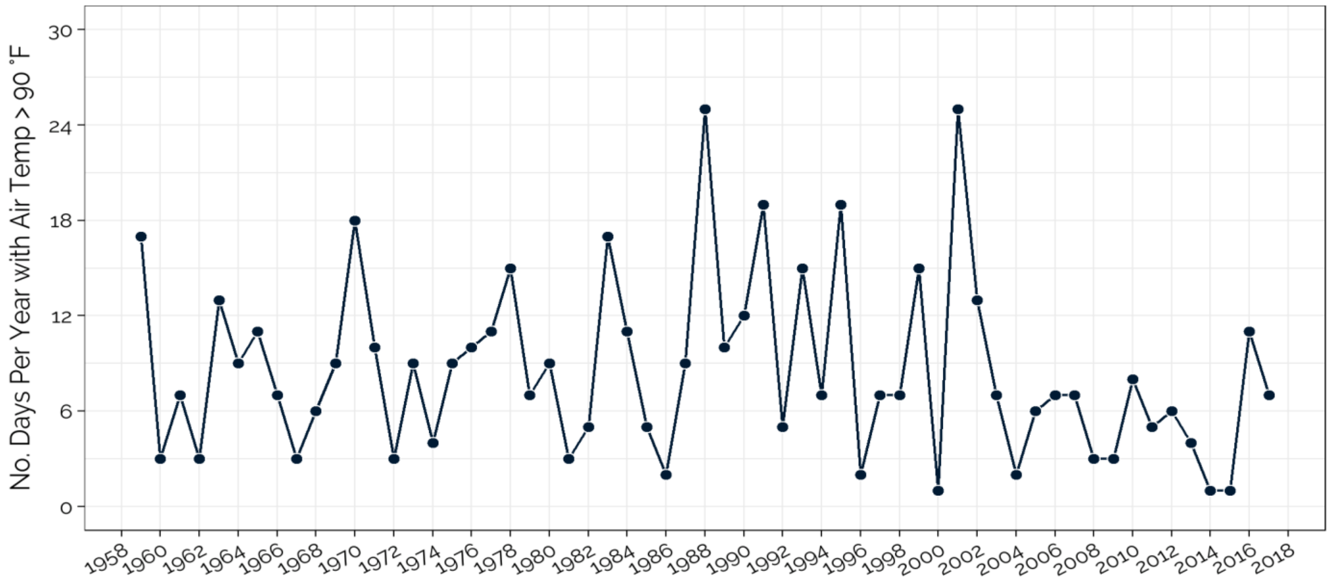
ANNUAL AIR TEMPERATURES



Average and minimum annual air temperatures have warmed by about 1 °F and 8 °F, respectively, near Conway-North Conway, NH. Maximum annual air temperatures have remained stable. In 1960, the minimum, average, and maximum annual air temperatures were 4 °F, 44 °F, and 80°F, respectively. This compares with higher minimum, average, and maximum annual air temperatures observed in 2012: 13 °F, 47 °F, and 82°F.

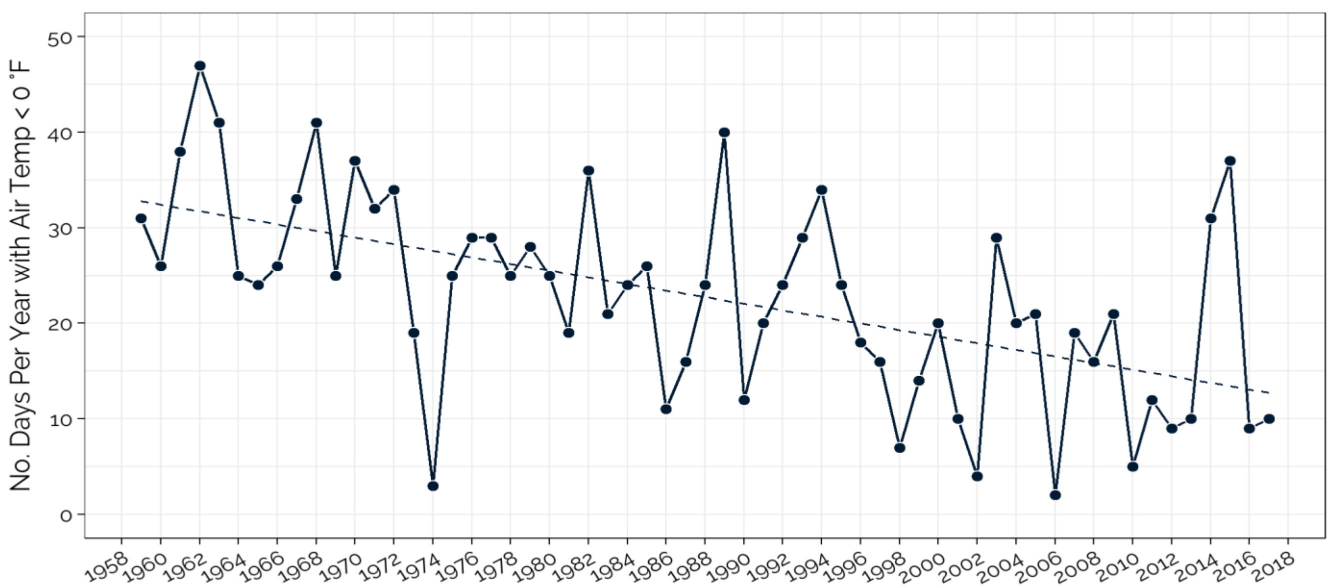
[1] These stations have collected significantly more data than more local stations, including Creeper Hill (2008-present), and therefore, were determined to be a more appropriate dataset for the assessment of long-term climate change in the area. In 2016, KLWA analyzed other long-term weather data from Auburn and Bridgton, ME weather stations (1955-present) and found similar trends in weather compared to the Conway-North Conway stations, further confirming the Conway-North Conway stations as likely representative of the area.

EXTREME HEAT DAYS



As air temperature rises, we can expect to see more extreme heat days. However, the Conway-North Conway weather data since 1959 show no trend in the number of days per year with air temperatures over 90 °F. In fact, the number of extreme heat days seems to have declined in the last decade. Several climate models show that the northeast will not experience as dramatic an increase in extreme heat days as the southern and middle portions of the United States.

EXTREME COLD DAYS

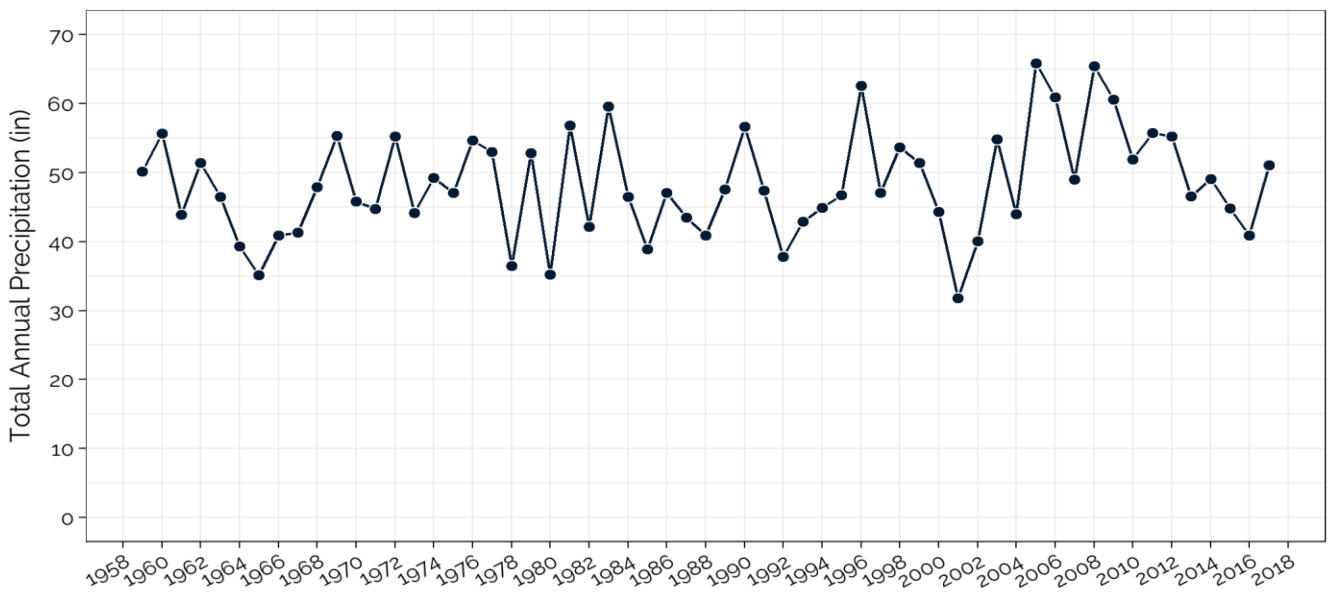


As air temperature rises, we can expect to see less extreme cold days. As expected, the Conway-North Conway weather data since 1959 show a statistically significant decrease in the number of days per year with air temperatures below 0 °F. The first half of the record shows the number of extreme cold days around 25-30, but the latter half shows the number of extreme cold days declining to around 10-15.

Precipitation

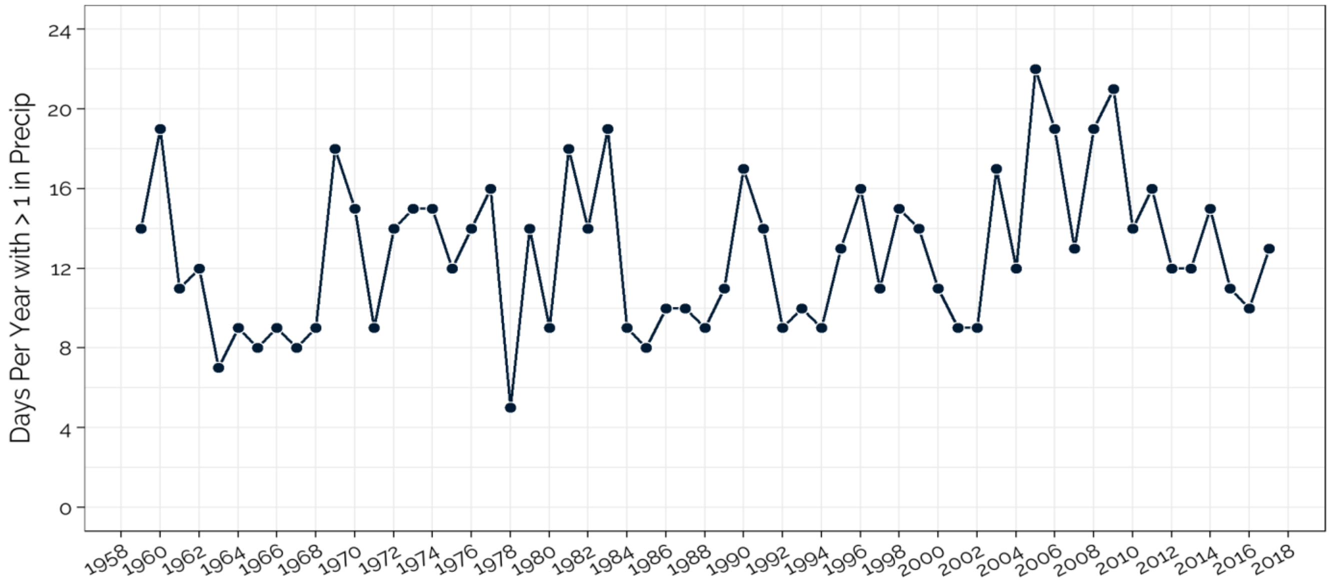
Warming air temperatures have impacted rain and snow patterns across the globe. In Maine, total annual precipitation has increased by 6 inches (13%) since 1895 and is predicted to increase an additional 5-10% by 2050. The distribution of this precipitation is highly variable; some models predict more rain in interior Maine, while historic observations show more rain along the coast. Extreme precipitation events will also likely increase in frequency and duration, particularly along the coast and in the western mountains. Maine has seen a decrease in snowfall accumulations by 1 inch and a decrease in snowpack duration by two weeks since 1895. More frequent and intense rain events will flush excess nutrients from the landscape to receiving waterbodies, including Kezar Lake, which can fuel algae production. Larger flow volumes will also threaten infrastructure, including road crossings and culverts. For the Kezar Lake watershed, we used the North Conway weather station to track changes in precipitation since 1959.

ANNUAL PRECIPITATION



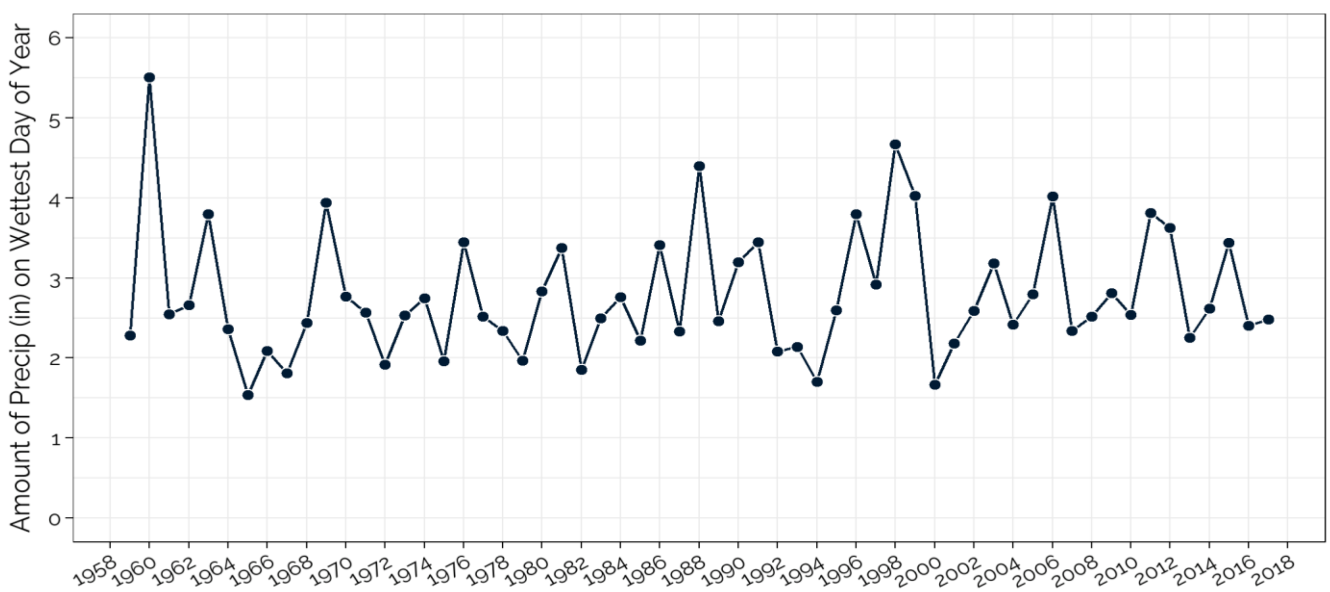
In North Conway, total annual precipitation has fluctuated greatly, but without any trend since 1959. However, three years (1996, 2005, and 2008) saw total annual precipitation above 60 inches. These were extremely wet years impacted by major storms. Total annual precipitation seems to be decreasing in the last decade but may be rebounding with a wetter 2017.

ONE INCH PRECIPITATION EVENTS



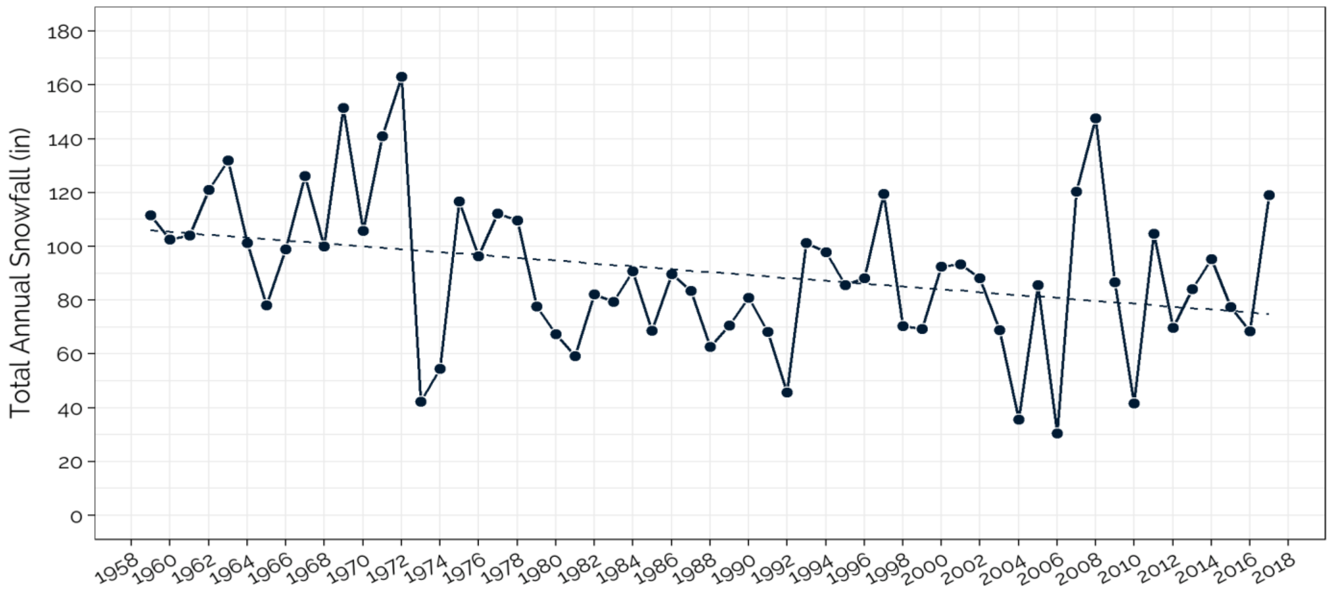
Climate change will likely cause more frequent precipitation events. For North Conway, the number of days per year receiving greater than 1 inch of precipitation has been highly variable; however, the last decade shows multiple years with greater than 12 days per year with 1 inch or more of precipitation recorded.

WETTEST DAY OF YEAR

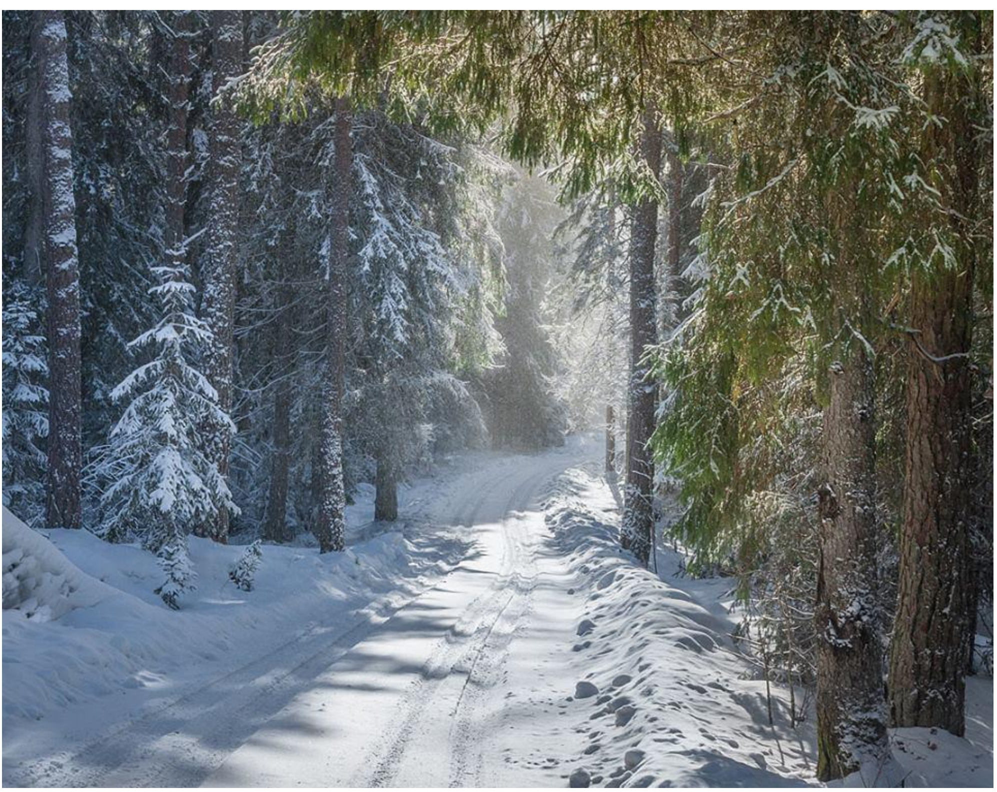


The intensity of extreme precipitation events is illustrated by finding the day from each year with the largest amount of precipitation. Since Maine has an extensive coastline, extreme precipitation events are often related to Atlantic storms. For instance, the extreme precipitation day for 1960 (5.5 inches) coincides with Hurricane Donna. The wettest day of the year precipitation amounts varied considerably throughout the record for North Conway, and no trend was observed.

SNOWFALL ACCUMULATION



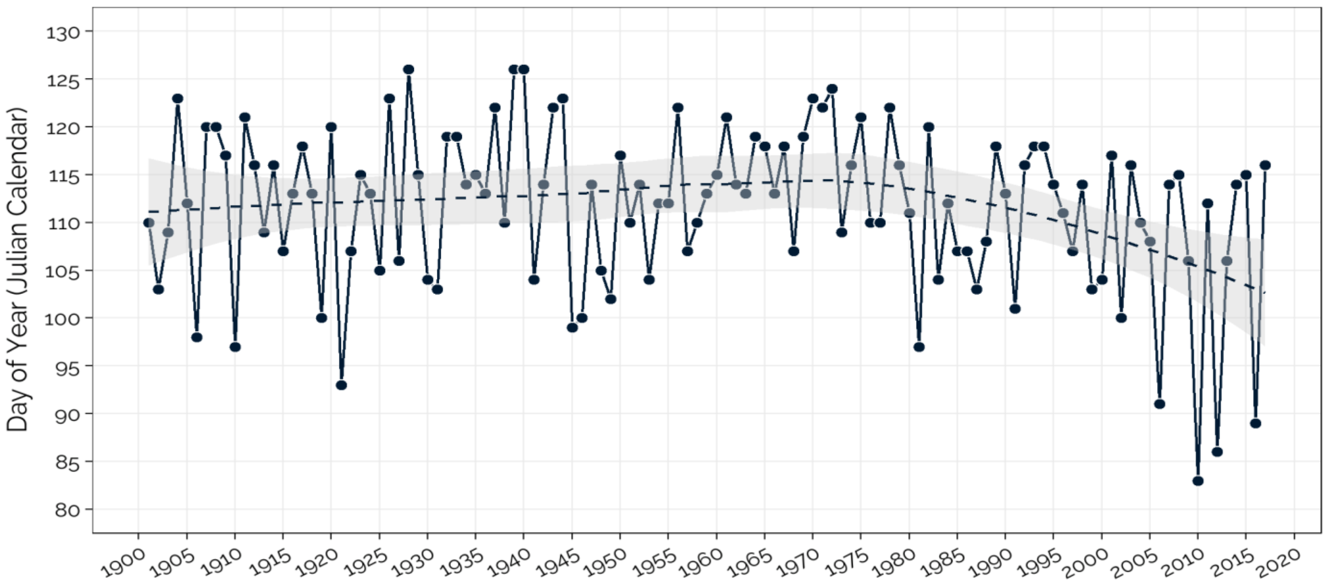
As air temperatures increase, climate change models predict less snowfall and reduced snowpack duration. Maine has already shown a statistically significant trend of decreased annual snowfall between 1950 and 2000. For North Conway, total annual snowfall has declined from an average of 105 to 70 inches of snowfall per year since 1959.



Kezar Lake watershed in winter. Photo Credit: KLWA (left); Don Griggs (right).

Ice-Out

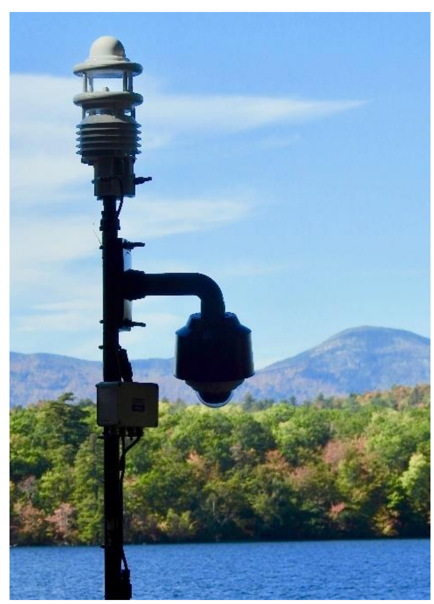
Ice-out data has been collected for Kezar Lake since 1901, providing over a century of information about changes in the seasonal duration of winter snowpack and ice. Ice-out refers to the day when all ice covering Kezar Lake has broken up and melted. This marks the beginning of spring when the entire lake is exposed to direct sunlight, which stimulates lake productivity and drives the critical process of spring turnover.



Although some years within the last decade showed abnormally early ice-out dates, no statistically significant trend was found for all data since 1901. The increasing variability and abnormally early ice-out dates within the last few decades should be monitored closely in the future to confirm the trend. Early ice-out is directly linked to warming air temperatures and changes in seasonality.

KLWA Weather Station

In August-September 2017, the CCO purchased, engineered, and installed a state-of-the-art weather station and web camera on the edge of Kezar Lake just south of Boulder Brook. Collecting local weather data will greatly improve the accuracy of our water quality data analyses that are dependent on temperature and precipitation readings. The weather station data and webcam images are also an important service that KLWA provides to the community.

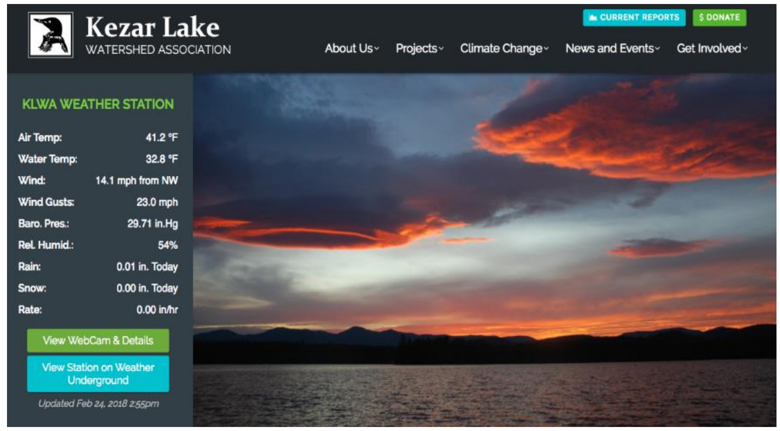


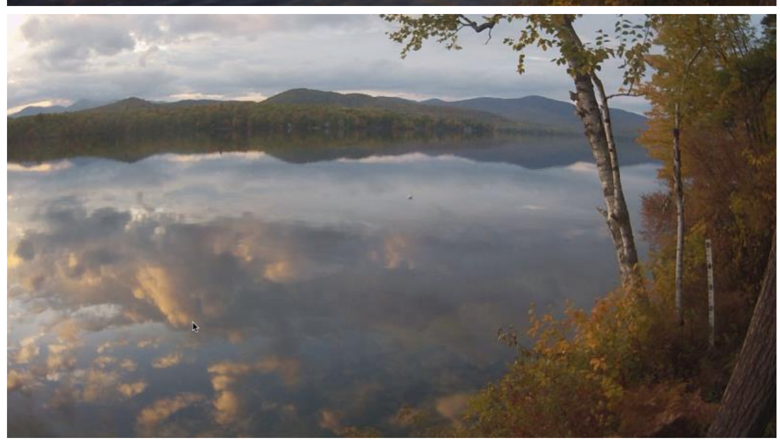
KLWA Weather Station. Photo Credit: Don Griggs.

Our weather station is a Columbia Weather Systems Pulsar 600 with an Axis M-3025 VE HD dome camera. The weather station has no moving parts, which means it can collect weather data during snow and freezing temperatures. It measures rain and snow (both rate and accumulation) with Doppler radar; wind speed and direction with ultrasonic sensors; lake water temperature with a sensor placed three feet below the water's (or ice's) surface; and air temperature, barometric pressure, and relative humidity. The webcam has a west and north view of the lake and the western mountains (from Baldface to Speckled Mountains).

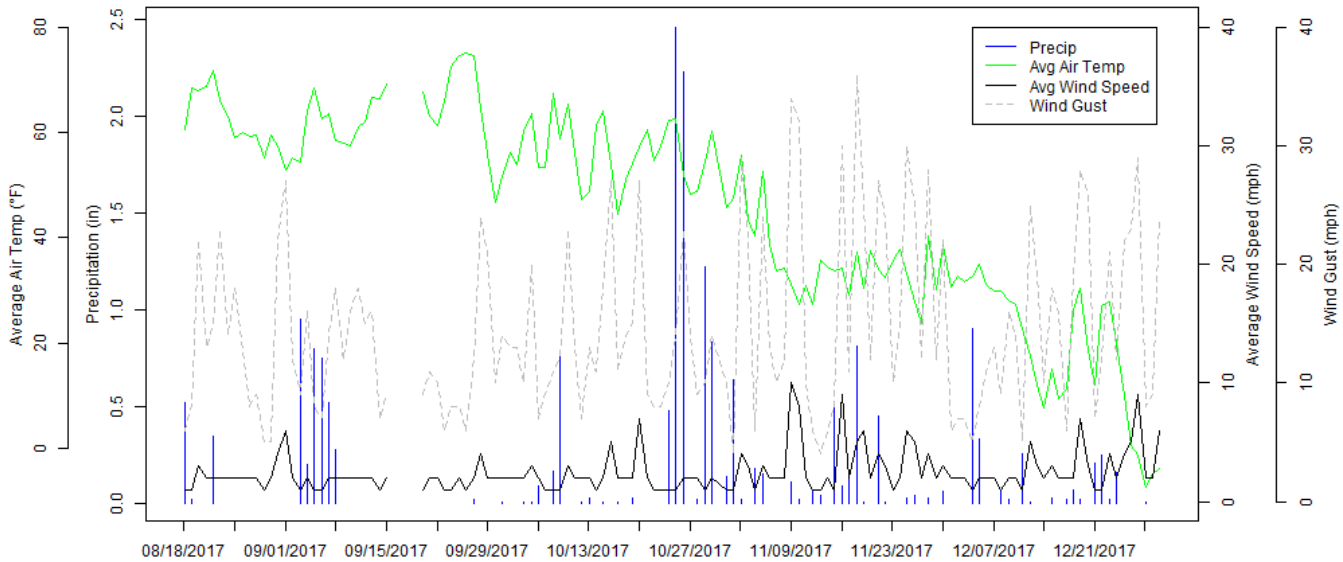
The current weather summary (updated every minute) is showcased on the KLWA website home page (klwa.us). Links from the home page to more detailed weather station information, including high-definition webcam photos, are provided. Weather Underground (KMELOVEL4) provides historical data and forecasts for the next ten days, along with other astronomical and almanac data for Lovell, ME. Lake water temperature data are only provided on the KLWA Weather Station webpages.

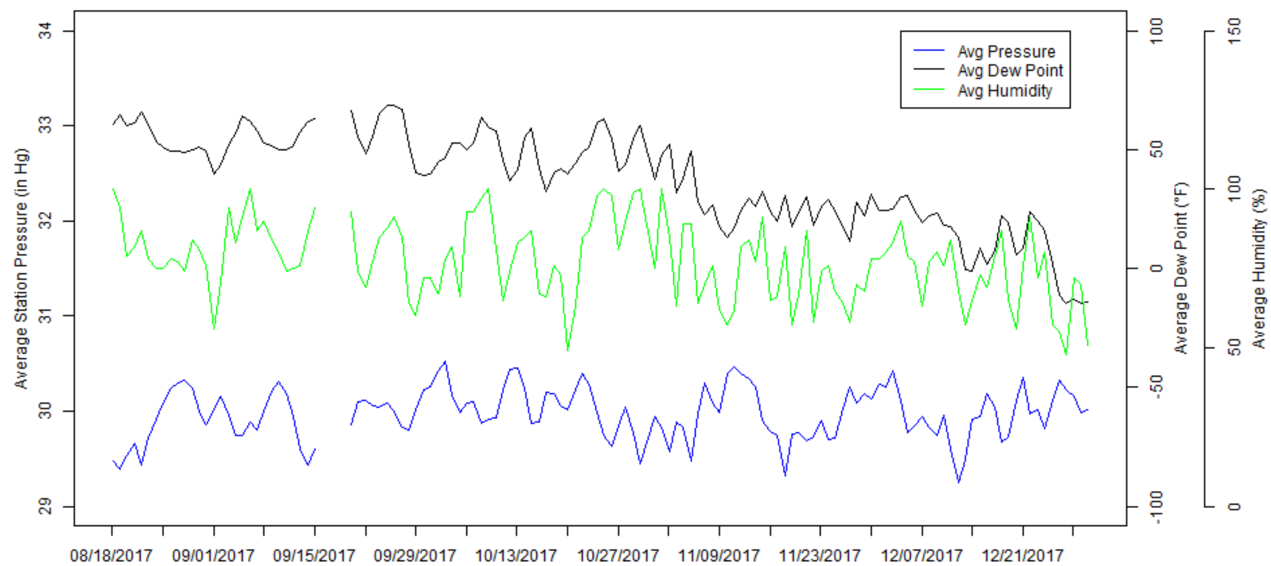
Since the weather station data and webcam images are accessible from the KLWA website and Weather Underground, these data and images can be viewed at anytime from anywhere over the internet on a computer, smart phone, or tablet. The KLWA and CCO are pleased to offer this service to all who live in, visit, or care about what is happening weather-wise in Lovell and on Kezar Lake. The CCO intends to use collected weather data over the years to create trend-lines that will give an accurate view of weather-related climate changes within our watershed. °





KLWA Weather Station data are displayed on the KLWA website home page (klwa.us), with links to more detailed weather station information through KLWA's website or Weather Underground (top). The webcam provides high-definition photos year-round: summer, fall, and winter examples are shown from middle top to bottom.
Design Credit: Level8 & Troy Web Consulting.





Summary of average daily KLWA Weather Station data for 2017. The station went live on 08/18/17. No data were collected by the station from 09/16-9/19/17 due to massive power outages across the State. These data can be used for water quality analyses and can provide residents with accurate local weather info.

KLWA CCO volunteers installing the KLWA weather station on the east shore of Kezar Lake (south of Boulder Brook). Photo Credit: Don Griggs.

WATER

Water Quality

Water quality data has been collected in the Kezar Lake watershed since 1970. These data provide a wealth of long-term information from which we can judge the health of the lake, ponds, and streams in the watershed. Because water quality can fluctuate significantly from year-to-year depending on local conditions and activities within the watershed, analyzing data over a longer time can reveal subtle, yet steady directional changes in water quality. It is important to identify waterbodies at risk for degrading water quality because of climate change or development, so we can take action to combat the effects.

Statistical trend analyses (Mann-Kendall[2]) were performed on annual water quality data for all available water quality parameters at all monitored waterbodies in the Kezar Lake watershed. A summary of current conditions and trends are as follows:

- **Water clarity** shows improving trends at Kezar Lake; water clarity at the ponds are stable and meet DEP mesotrophic guidelines.
- **Total phosphorus** and **Chlorophyll-a** show no trends and meet DEP mesotrophic guidelines in all waterbodies. Chlorophyll-a at the upper bay is improving.
- **Alkalinity** shows degrading trends at the upper bay, lower bay, Cushman Pond, and Horseshoe Pond (though improving at the middle bay), and is critically, but naturally, low in all waterbodies. Recent 10-year trends show improving conditions for alkalinity at Farrington, Heald, and Trout Ponds.
- **pH** shows degrading trends at Heald and Horseshoe Ponds and is low (acidic) in all waterbodies.
- **Color** shows no trends and meets DEP mesotrophic guidelines in all waterbodies.
- **Dissolved oxygen** is regularly anoxic near the bottom in late summer at Bradley, Horseshoe, and Trout Ponds.
- **Temperature** is generally good or excellent in all waterbodies, though Kezar Lake shows a warming trend in surface waters.
- **Anoxic Extent** shows a degrading trend at the upper bay and is highest at Horseshoe Pond.

A list of water quality definitions is provided in Appendix A. The following section showcases annual historical and continuous data for Kezar Lake, six ponds, seven tributaries, and the outlet stream.

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[2] Mann-Kendall trend tests were performed on annual water quality data to determine trends over time. Dotted trend lines were added where statistically significant. Sample stations with less than 10 years of data cannot be analyzed for statistically significant trends (too few data points). Data obtained from Maine DEP and FB Environmental Associates.

Summary of Current Conditions & Trends

Lakes and Ponds

Water Body	Water Clarity	Total Phosphorus	Chlorophyll-a	Anoxic Extent	Temp	pH	Alkalinity	Color
Kezar Lake Upper Bay	Excellent, Improving	Excellent, Stable	Excellent, Improving	Good, Degrading	Good, Degrading	Excellent, Stable	Poor, Degrading	Excellent, Stable
Kezar Lake Middle Bay	Excellent, Improving	Excellent, Stable	Excellent, Stable	Excellent, Stable	Excellent, Stable	Excellent	Good, Improving	Excellent, Stable
Kezar Lake Lower Bay	Excellent, Improving	Excellent, Stable	Excellent, Stable	Excellent, Stable	Good, Degrading	Excellent, Stable	Poor, Degrading	Excellent, Stable
Bradley Pond	Excellent, Stable	Excellent, Stable	Excellent, Stable	Excellent, Stable	Excellent, Stable	Excellent	Good, Stable	Excellent, Stable
Cushman Pond	Excellent, Stable	Excellent, Stable	Excellent, Stable	Excellent, Stable	Excellent, Stable	Excellent, Stable	Good, Degrading	Excellent, Stable
Farrington Pond	Excellent, Stable	Excellent, Stable	Excellent, Stable	Excellent, Stable	Excellent, Stable	Excellent, Stable	Good, Stable	Excellent, Stable
Heald Pond	Excellent, Stable	Excellent, Stable	Excellent, Stable	Excellent, Stable	Excellent, Stable	Good, Degrading	Excellent, Stable	Excellent, Stable
Horseshoe Pond	Excellent, Stable	Excellent, Stable	Excellent, Stable	Good, Stable	Excellent, Stable	Good, Degrading	Poor, Degrading	Excellent, Stable
Trout Pond	Excellent, Stable	Excellent, Stable	Excellent, Stable	Good, Stable	Excellent, Stable	Excellent	Good, Stable	Excellent, Stable

Brooks and Streams

Water Body	Total Phosphorus	pH	Dissolved Oxygen	E.coli	Temp	Flow
Great Brook	Excellent	Excellent	Excellent, Stable	Excellent	Excellent	Excellent
Boulder Brook	Excellent	Excellent	Excellent	Good	Excellent	
Beaver Brook					Excellent	Excellent
Lower Bay					Excellent	Excellent
Kezar Outlet Stream					Excellent	Excellent
Coffin Brook					Excellent	
Bradley Brook					Excellent	
Sucker Brook					Excellent	
Long Meadow Brook					Excellent	

Key for Data Symbols – Current Conditions & Trends

CURRENT CONDITION: EXCELLENT / GOOD / POOR

+

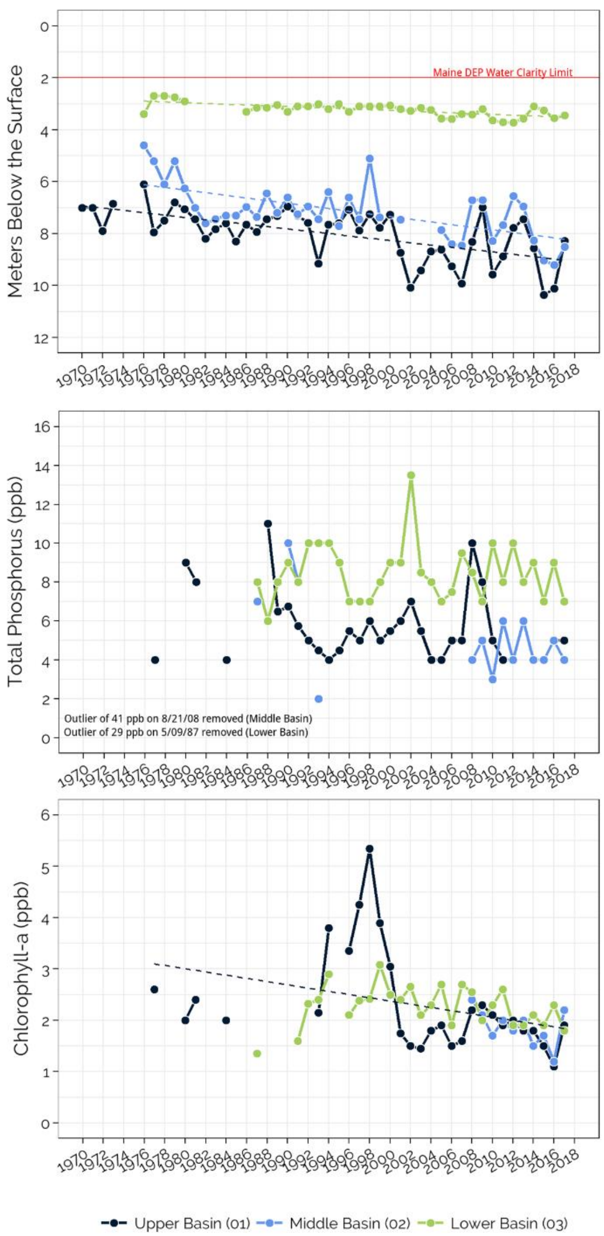
TREND: IMPROVING / STABLE / DEGRADING / PENDING

The **"Current Condition"** for each parameter is based on the data collected during the most recent decade and current year compared to state or federal water quality criteria or recommendations and detection of a statistically-significant trend. Stop lights provide a simple visual assessment of overall waterbody condition by parameter.

The **"Trend"** indicates whether water quality is improving (up arrow), degrading (down arrow), or remaining stable with no trend (horizontal arrow) over time based on statistical analysis of the long-term data set for each parameter by waterbody.

KEZAR LAKE
WATER QUALITY TRENDS

Kezar Lake (Midas #0097) is a non-colored waterbody located in the Town of Lovell, Oxford County, Maine. The lake stretches 9 miles from north to south, covering 2,665 acres (4.16 square miles) and has a maximum depth of 160 feet (49 meters) and a mean depth of 34 feet (10 meters). Water quality monitoring data have been collected since 1970 at Station 1 (upper), 1976 at Station 2 (middle), and 1976 at Station 3 (lower). Note: "stoplight" symbols ordered from left to right show status of upper, middle, and lower basins.



WATER CLARITY

Since the early 1970's, water clarity at all three basins of Kezar Lake has improved with the upper and middle basins improving by nearly 1 meter. The slight, but statistically significant, improvement at the lower basin is an artifact of changing lake depth since nearly all readings hit bottom.

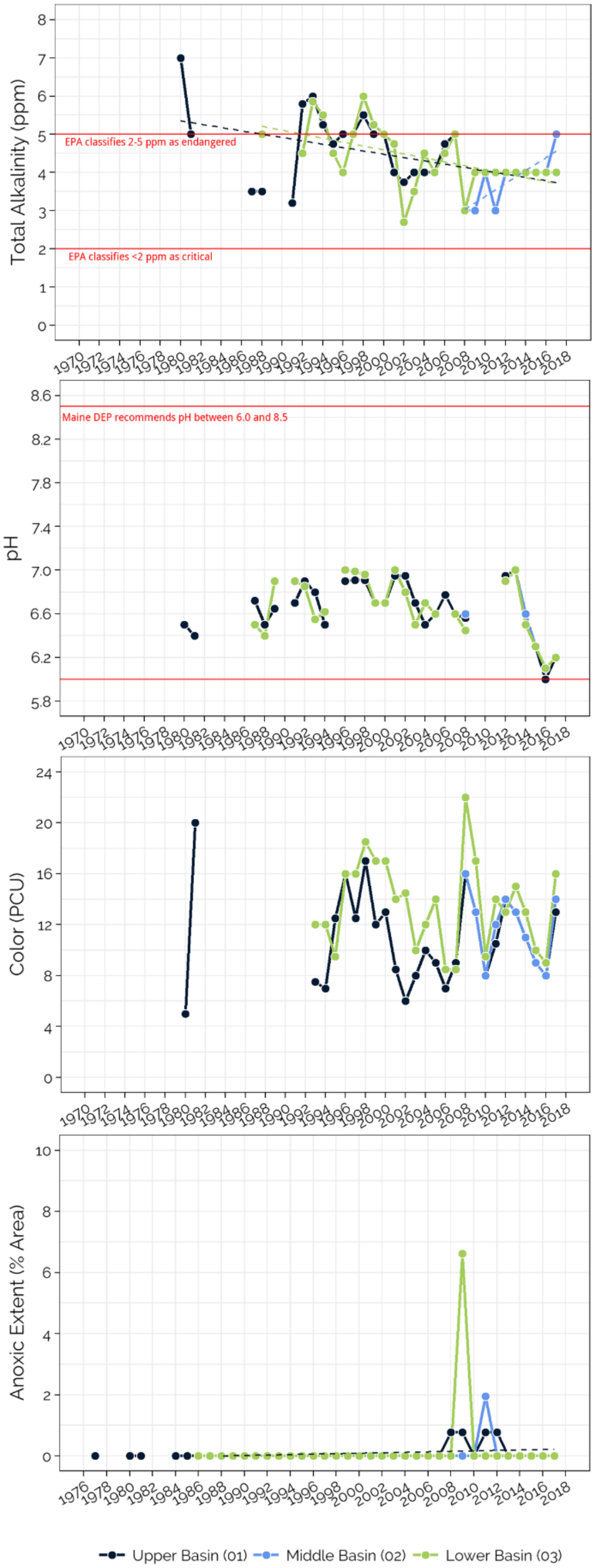
TOTAL PHOSPHORUS

Since the late 1970's, total phosphorus at all three basins of Kezar Lake has revealed no statistically significant trend over time. The generally higher median annual total phosphorus observed at the lower basin is an artifact of its shallow depth, where wave action can disturb bottom sediments that release phosphorus into the water column.

CHLOROPHYLL-A

Since the late 1970's, chlorophyll-a at the upper basin of Kezar Lake has improved, while chlorophyll-a at the middle and lower basins has revealed no statistically significant trend over time. The period from 1994 to 1999 saw a marked rise in chlorophyll-a at the upper basin, but chlorophyll-a has remained below 3 ppb since then. Nutrient-rich runoff entering the lake during wetter years, combined with warmer air temperatures, can fuel algae growth.

KEZAR LAKE
WATER QUALITY TRENDS



TOTAL ALKALINITY

Since the early 1980's, total alkalinity at the upper and lower basins of Kezar Lake has degraded by nearly 3 ppm, while total alkalinity at the middle basin has improved by 2 ppm. The region has naturally-low alkalinity (or buffering capacity) as a result of its contributing geology (i.e., granite) that lacks carbonates, bicarbonates, and carbonic acid.

pH

Since the early 1980's, pH at Kezar Lake has revealed no statistically significant trend over time. Generally, pH becomes more acidic as total alkalinity in the epilimnion declines. Low alkalinity makes Kezar Lake susceptible to changes in pH, particularly from acidic deposition in the form of rain or snow, which can jeopardize the health of freshwater fish species.

COLOR

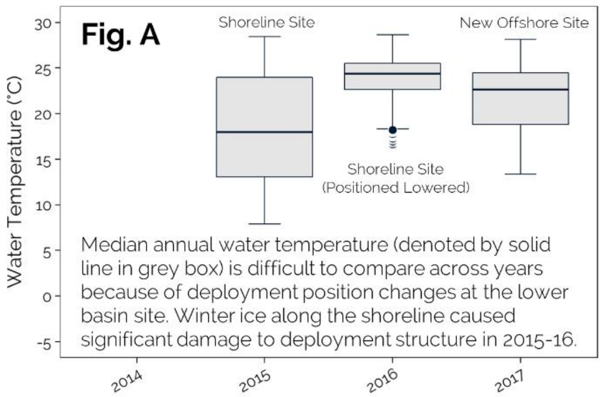
Since the early 1980's, color at Kezar Lake has revealed no statistically significant trend over time. Color is highly related to summer precipitation; wetter years show higher color as more materials are washed off the landscape to the lake. The lack of trend in color is despite the increase in regional precipitation observed in the last century, suggesting that more data are needed to confirm the trend.

ANOXIC EXTENT

Dissolved oxygen profiles show good oxygenation throughout the water column over the collection period. While the extent and duration of anoxia is good or excellent at all three basins, the upper basin shows a statistically-significant (but very slight) increase in anoxia within a meter of the bottom. This should continue to be monitored closely in the future.

LOWER BAY
WATER QUALITY TRENDS

The lower bay is the southernmost basin of Kezar Lake. The sensor was deployed on Heinrich Wurm's property just offshore of the western rocky shoreline of the lake. Water quality monitoring data have been collected since 2015.



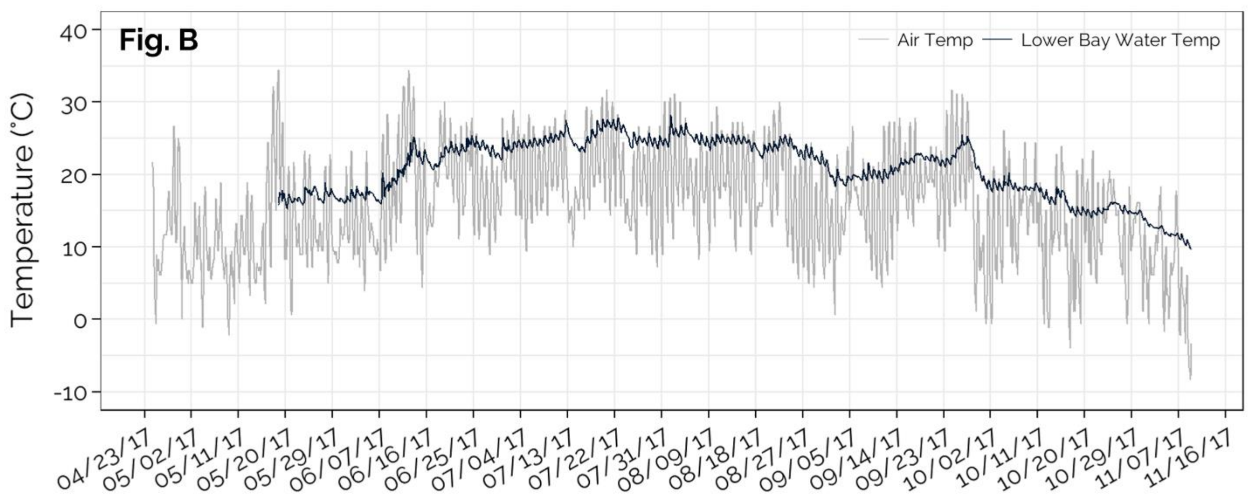
Median annual water temperature (denoted by solid line in grey box) is difficult to compare across years because of deployment position changes at the lower basin site. Winter ice along the shoreline caused significant damage to deployment structure in 2015-16.

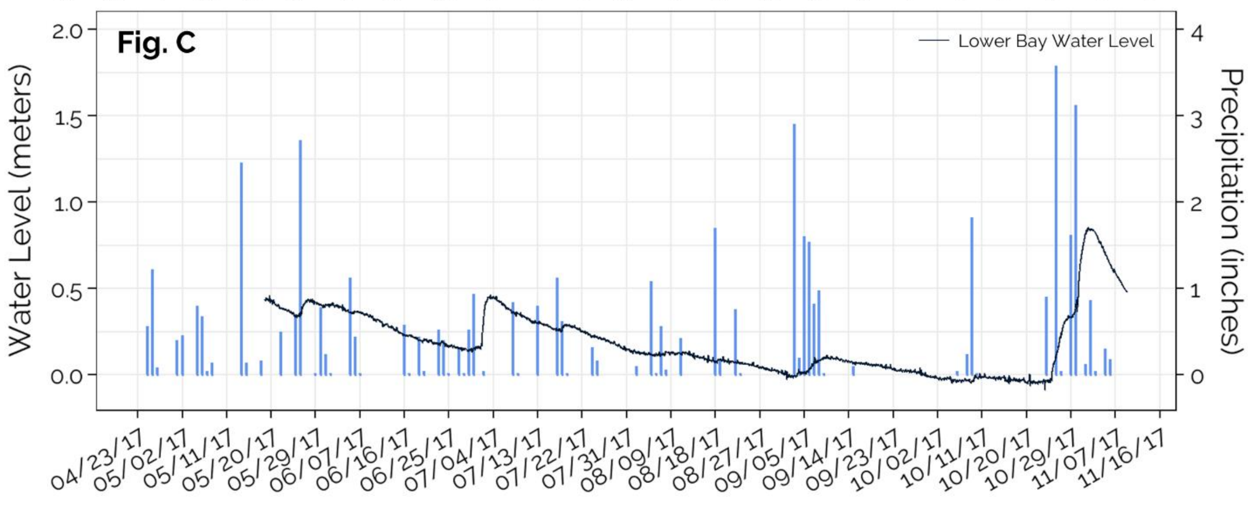
WATER TEMPERATURE

Water temperature (Fig. B) in 2017 followed closely with air temperature (hourly data obtained from NOAA NCEI for Fryeburg, ME).

LAKE SURFACE WATER HEIGHT

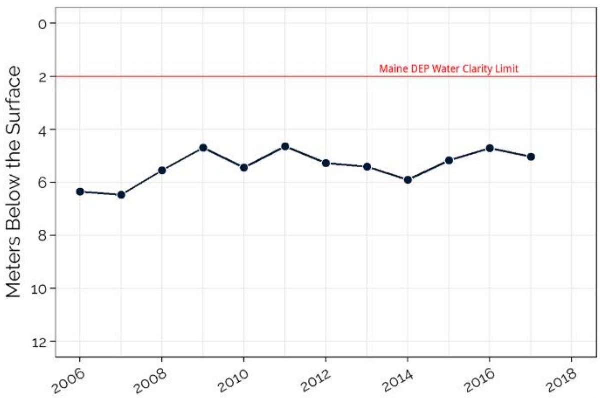
Water level data (Fig. C) collected at the lower bay showed that lake level steadily declined from May to October due to evaporation and then responded quickly (by rising) to large precipitation events in late fall.





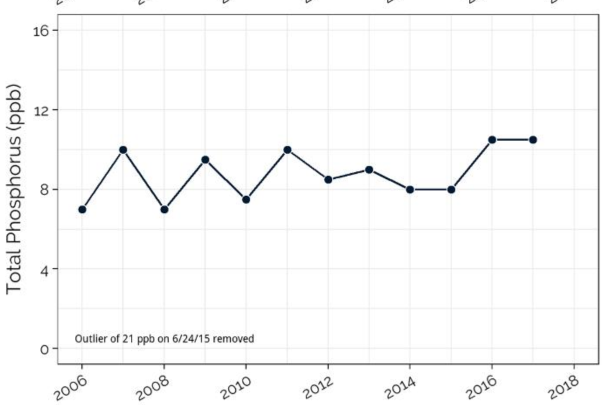
BRADLEY POND
WATER QUALITY TRENDS

Bradley Pond (Midas #3220) is a non-colored waterbody located in the Town of Lovell, Oxford County, Maine. Covering 35 acres (0.05 square miles) with a maximum and mean depth of 29 and 10 feet (9 and 3 meters), respectively, the pond drains to Heald Pond, which in turn drains to a tributary to Boulder Brook and eventually Kezar Lake. Water quality monitoring data have been collected since 2006 at Station 1 (deep spot).



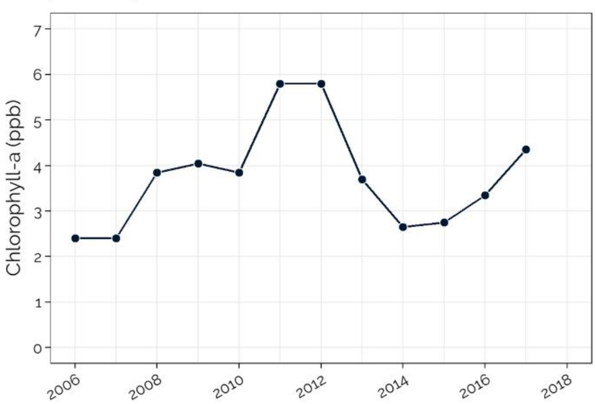
WATER CLARITY

Since 2006, water clarity at Bradley Pond has remained stable.



TOTAL PHOSPHORUS

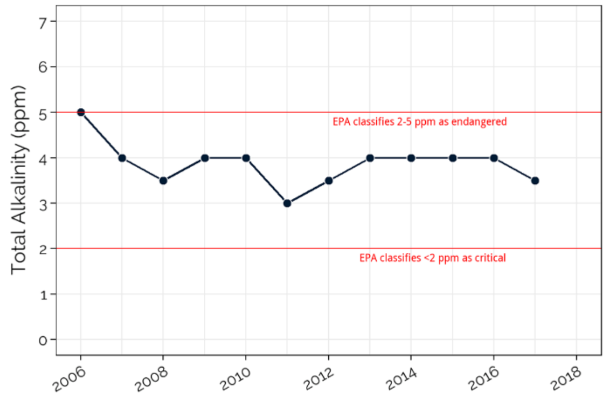
Since 2006, total phosphorus at Bradley Pond has remained stable, but 2016 and 2017 experienced the highest annual total phosphorus on record.



CHLOROPHYLL-A

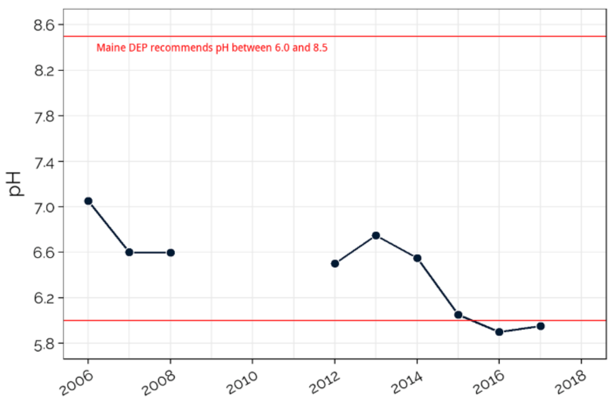
Since 2006, chlorophyll-a at Bradley Pond has ranged from about 2 to 6 ppb. The period from 2011 to 2012 saw a marked rise in chlorophyll-a. Nutrient-rich runoff entering the lake during wetter years, combined with warmer air temperatures, can fuel algae growth.

BRADLEY POND
WATER QUALITY TRENDS



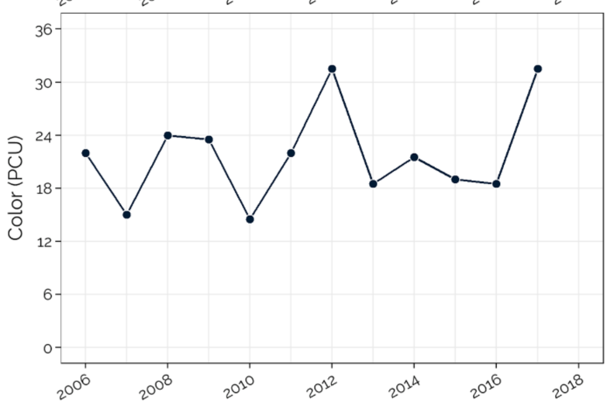
TOTAL ALKALINITY

Since 2006, total alkalinity at Bradley Pond has remained stable. Bradley Pond has naturally-low alkalinity (or buffering capacity) as a result of its contributing geology (i.e., granite) that lacks carbonates, bicarbonates, and carbonic acid. These low concentrations make Bradley Pond susceptible to changes in pH, particularly from acidic deposition in the form of rain or snow, which can jeopardize the health of freshwater fish species.



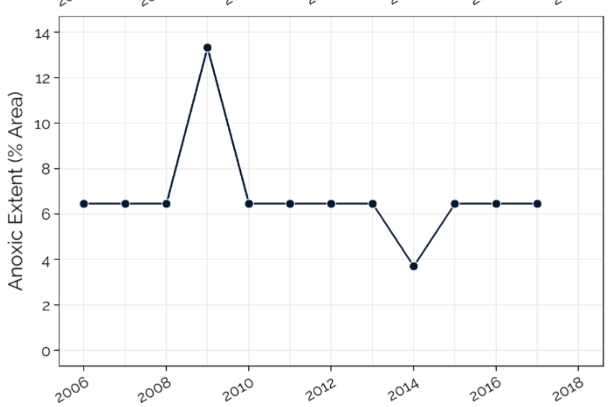
pH

Minimal pH data are available for Bradley Pond to make any conclusions about long-term trends, but mean annual pH fell below the recommended optimal range in both 2016 and 2017.



COLOR

Since 2006, color at Bradley Pond has revealed no statistically-significant trends. High color was observed for 2012 and 2017, due in part to wetter summer conditions. Color is highly related to summer precipitation; wetter years show higher color as more materials are washed off the landscape and into the pond.



ANOXIC EXTENT

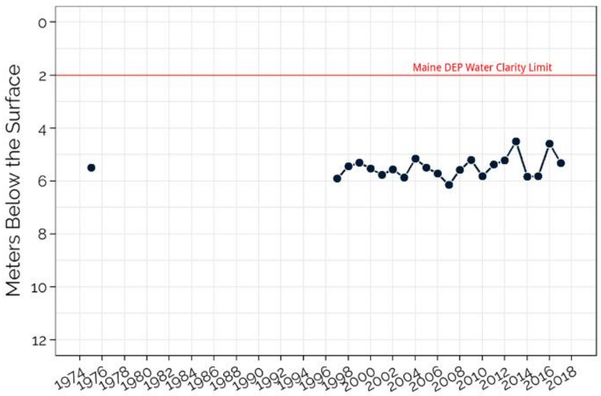
Dissolved oxygen profiles show oxygen depletion beginning 5-6 meters below the water surface (within a few meters of the bottom). The extent and duration of anoxia is overall excellent at Bradley Pond (affecting <10% of pond area). Dissolved oxygen at depth should continue to be monitored closely in the future.

CUSHMAN POND
WATER QUALITY TRENDS

Cushman Pond (Midas #3224) is a non-colored waterbody located in the Town of Lovell, Oxford County, Maine. Covering 37 acres (0.06 square miles) with a maximum and mean depth of 21 and 15 feet (6 and 5 meters), respectively, the pond drains to Heald Pond, which in turn drains to a tributary to Boulder Brook and eventually Kezar Lake. Cushman Pond is impacted by Variable Milfoil, which poses a threat to fish habitat. Water quality monitoring data have been collected since 1997 at Station 1 (deep spot).

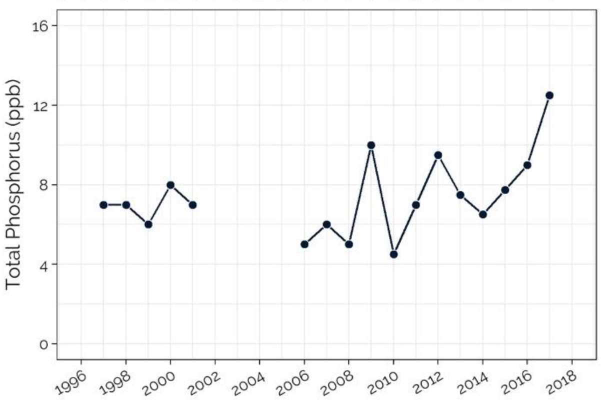
WATER CLARITY

Water clarity at Cushman Pond has remained stable with no statistically significant trend.



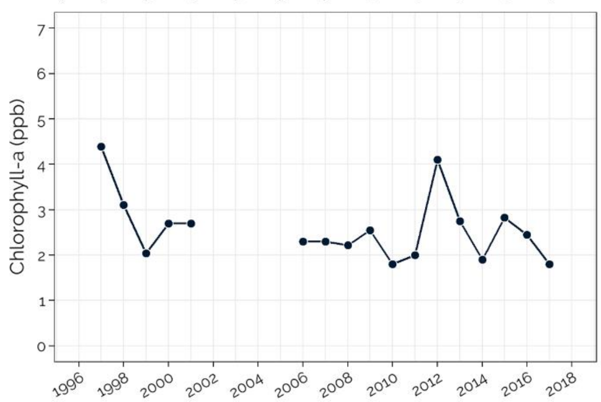
TOTAL PHOSPHORUS

Since 1997, total phosphorus at Cushman Pond has revealed no statistically significant trend. Year-to-year variation in total phosphorus (4 to 12 ppb) is large and hit a record high in 2017. The increase in annual total phosphorus since 2014 should be monitored closely.

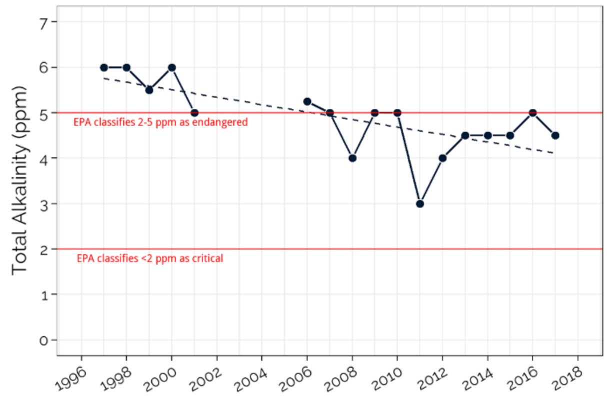


CHLOROPHYLL-A

Since 1997, chlorophyll-a at Cushman Pond has revealed no statistically significant trend. Sampling years 1997 and 2012 saw a rise in chlorophyll-a. Nutrient-rich runoff entering the lake during wetter years, combined with warmer air temperatures, can fuel algae growth.

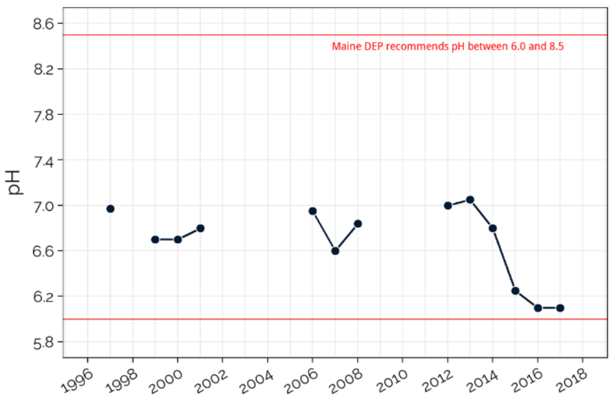


CUSHMAN POND
WATER QUALITY TRENDS



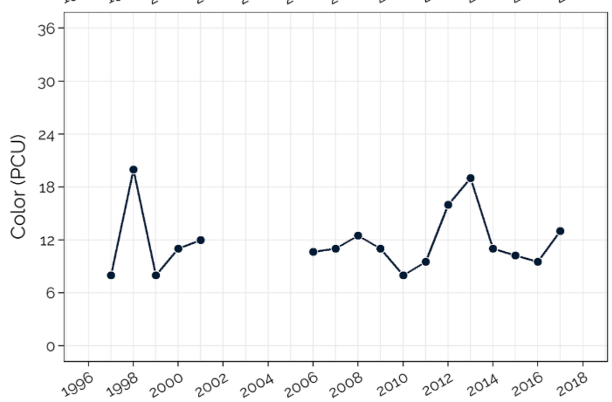
TOTAL ALKALINITY

Since 1997, total alkalinity at Cushman Pond has degraded by about 2 ppm. The region has naturally-low alkalinity (or buffering capacity) as a result of its contributing geology (i.e., granite) that lacks carbonates, bicarbonates, and carbonic acid.



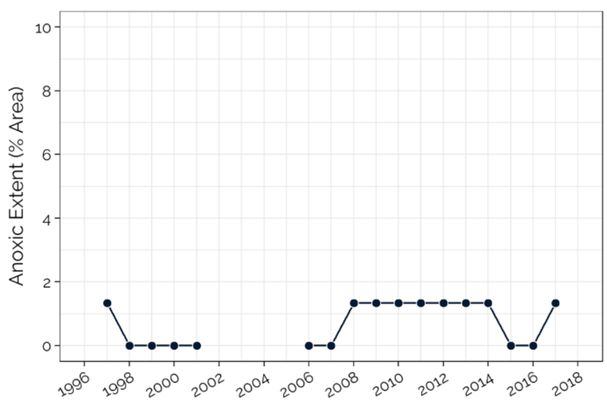
pH

Since 1997, pH at Cushman Pond has revealed no statistically significant trend over time. Mean annual pH falls within acceptable ranges for aquatic life. More consistent data are needed to confirm long-term trends. Low alkalinity makes Cushman Pond susceptible to changes in pH, particularly from acidic deposition in the form of rain or snow, which can jeopardize the health of freshwater fish species.



COLOR

Since 1997, color at Cushman Pond has revealed no statistically significant trend. Color is highly related to summer precipitation; wetter years show higher color as more materials are washed off the landscape to the pond.

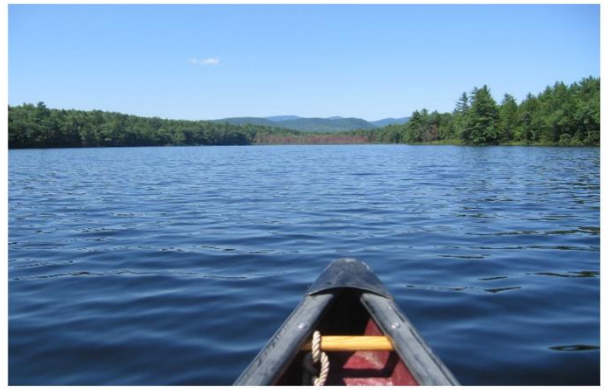


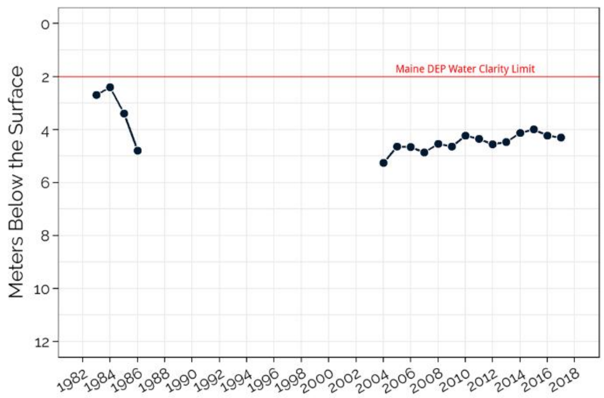
ANOXIC EXTENT

Dissolved oxygen profiles show good oxygenation throughout the water column over the collection period, with some anoxia at the bottom. The extent and duration of anoxia is overall excellent at Cushman Pond (affecting <10% of pond area). Dissolved oxygen at depth should continue to be monitored closely in the future.

FARRINGTON POND
WATER QUALITY TRENDS

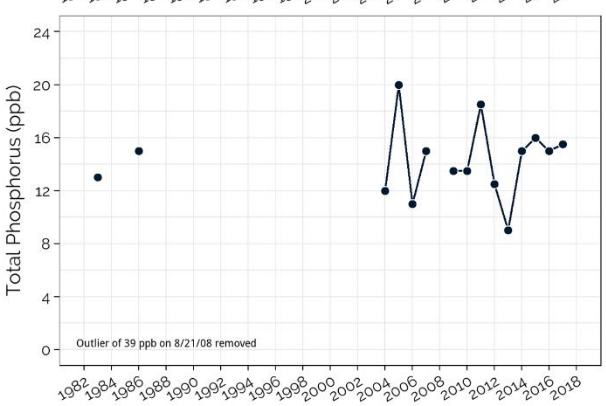
Farrington Pond (Midas #3200) is a non-colored waterbody located in the Town of Lovell, Oxford County, Maine. Covering 57 acres (0.09 square miles) with a maximum and mean depth of 15 and 5 feet (5 and 2 meters), respectively, the pond drains directly to Kezar Lake. Water quality monitoring data have been collected since 1983 at Station 1 (deep spot).





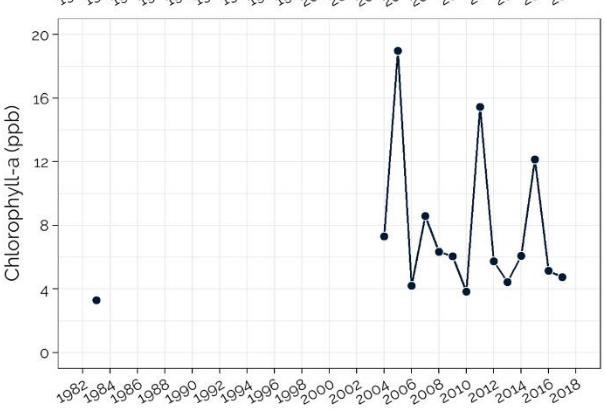
WATER CLARITY

Since 1983, water clarity at Farrington Pond has revealed no statistically significant trend, but data collected since 2004 show a possible degradation in water clarity by about 1 meter.



TOTAL PHOSPHORUS

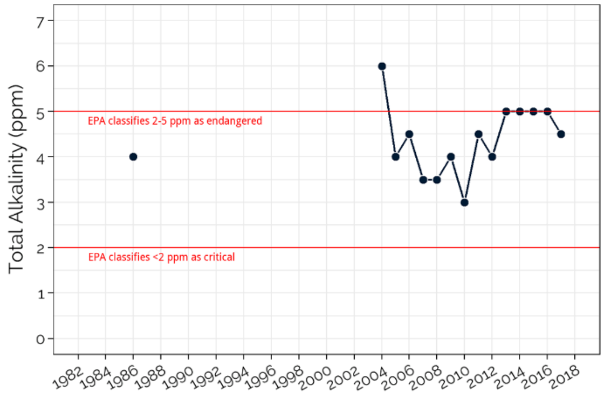
Since 1983, total phosphorus at Farrington Pond has revealed no statistically significant trend. Year-to-year variation in total phosphorus (10 to 20 ppb) is large at Farrington Pond, which also has the highest mean annual total phosphorus of all the ponds. The marked rise in total phosphorus observed in 2008 reflects nutrient-laden sediment in runoff entering the lake during this very wet year. Farrington Pond is highly susceptible to internal loading of phosphorus due to its shallow depth, where disturbance of bottom sediments can release phosphorus into the water column.



CHLOROPHYLL-A

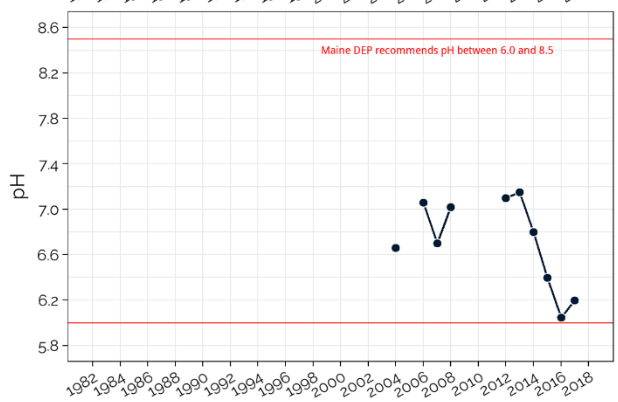
Since 1983, chlorophyll-a at Farrington Pond has revealed no statistically significant trend, and typically experiences the highest annual concentration of chlorophyll-a of the other ponds. Sampling years 2005, 2011, and 2015 saw a marked rise in chlorophyll-a. Nutrient-rich runoff entering the lake during wetter years, combined with warmer air temperatures, can fuel algae growth. Chlorophyll-a generally increases with increasing total phosphorus.

FARRINGTON POND
WATER QUALITY TRENDS



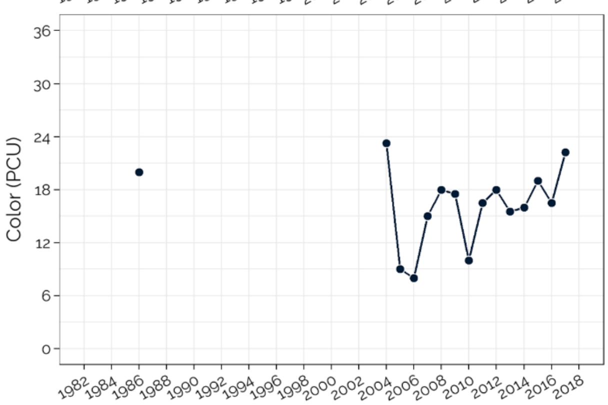
TOTAL ALKALINITY

Since 1986, total alkalinity at Farrington Pond has revealed no statistically significant trend, unlike the other ponds that largely show degrading trends (and may actually be improving in the last 10 years). The region has naturally-low alkalinity (or buffering capacity) as a result of its contributing geology.



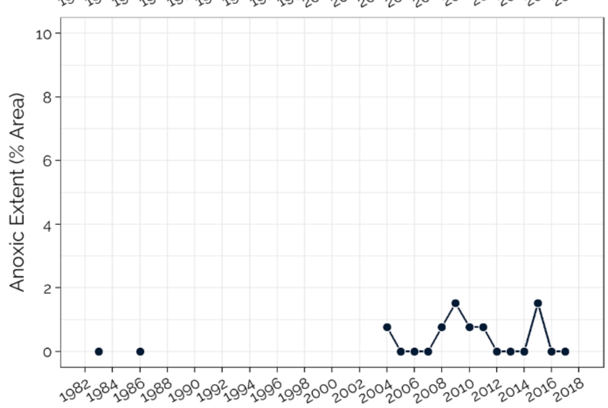
pH

Since 2004, pH at Farrington Pond has revealed no statistically significant trend. Mean annual pH falls within acceptable ranges for aquatic life. Low alkalinity makes Farrington Pond susceptible to changes in pH, particularly from acidic deposition in the form of rain or snow, which can jeopardize the health of freshwater fish species.



COLOR

Since 1983, color at Farrington Pond has revealed no statistically significant trend, though year-to-year variation is large (~8 to 23 PCU). Color is highly related to summer precipitation; wetter years show higher color as more materials are washed off the landscape to the lake.

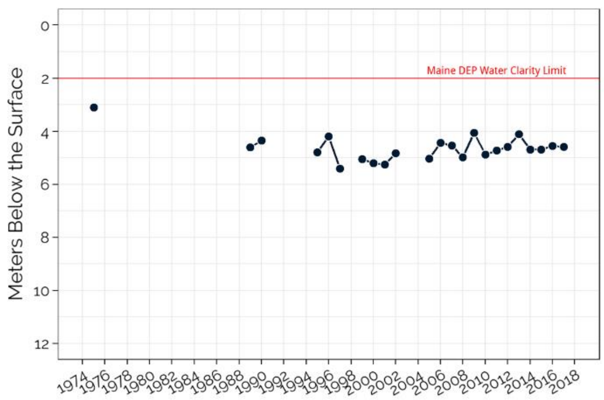


ANOXIC EXTENT

Dissolved oxygen profiles show good oxygenation throughout the water column over the collection period, with some anoxia at the bottom. The extent and duration of anoxia is overall excellent at Farrington Pond (affecting <10% of pond area). Dissolved oxygen at depth should continue to be monitored closely in the future.

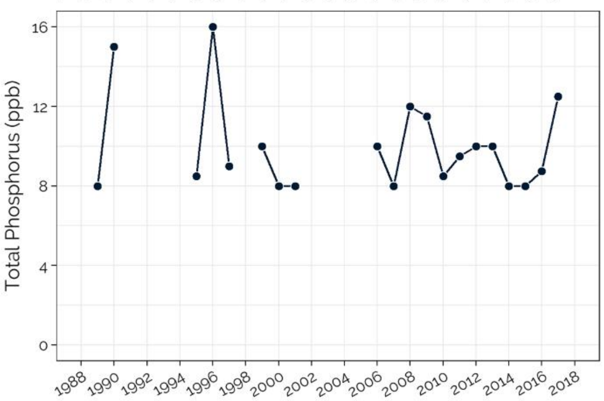
HEALD POND
WATER QUALITY TRENDS

Heald Pond (Midas #3222) is a non-colored waterbody located in the Town of Lovell, Oxford County, Maine. Covering 106 acres (0.17 square miles) with a maximum depth of 17 feet (5 meters), the pond drains directly to Kezar Lake through a tributary to Boulder Brook. Water quality monitoring data have been collected since 1975 at Station 1 (deep spot).



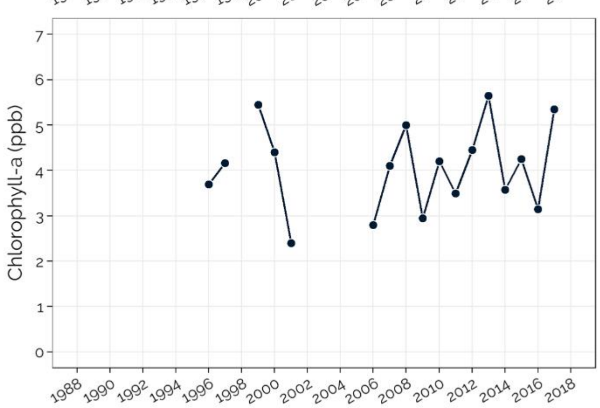
WATER CLARITY

Since 1975, water clarity at Heald Pond has remained stable with no statistically significant trend, but data collected since 2000 show a possible degradation in water clarity by nearly 1 meter.



TOTAL PHOSPHORUS

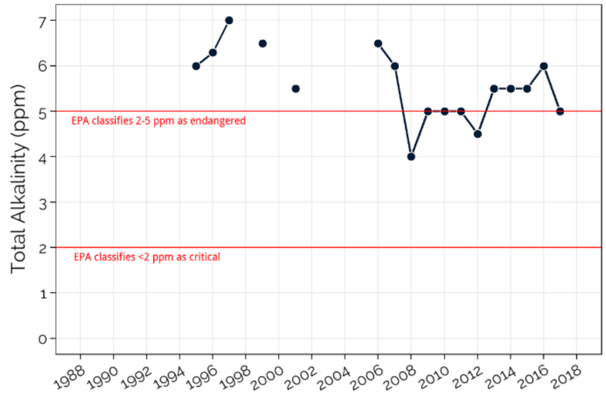
Since 1989, total phosphorus at Heald Pond has revealed no statistically significant trend. Higher phosphorus generally corresponds to wetter years at Heald Pond. Sediment in runoff entering the pond during rain events carries limiting nutrients. Heald Pond is highly susceptible to internal loading of phosphorus due to its shallow depth, where disturbance of bottom sediments can release phosphorus into the water column.



CHLOROPHYLL-A

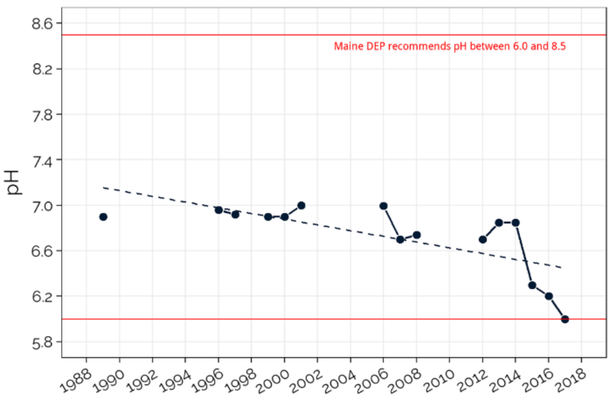
Since 1996, chlorophyll-a at Heald Pond has revealed no statistically significant trend. Nutrient-rich runoff entering the lake during wetter years, combined with warmer air temperatures, can fuel algae growth.

HEALD POND
WATER QUALITY TRENDS



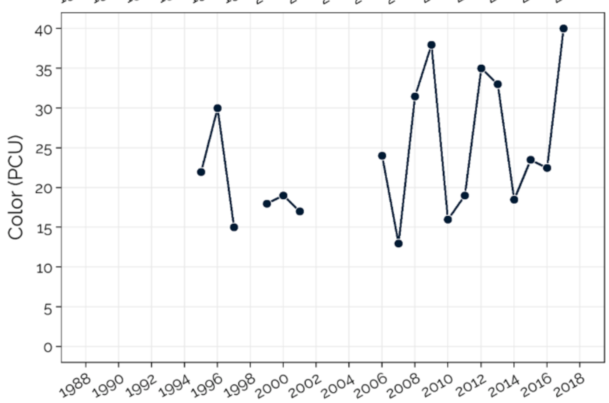
TOTAL ALKALINITY

Since 1995, total alkalinity at Heald Pond has revealed no statistically significant trend. Heald Pond experiences the highest (best) annual alkalinity compared to the other ponds. However, Heald Pond is still susceptible to changes in pH, particularly from acidic deposition in the form of rain or snow, which can jeopardize the health of freshwater fish species.



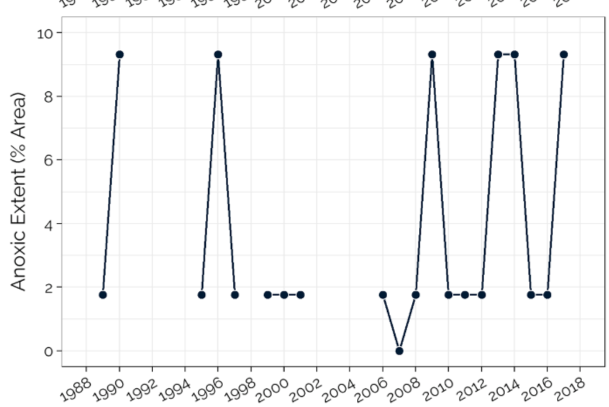
pH

Since 1989, pH at Heald Pond has degraded by about 1.0. Mean annual pH falls within acceptable ranges for aquatic life, but hit a record low in 2017. More consistent data are needed to confirm long-term trends.



COLOR

Since 1995, color at Heald Pond has revealed no statistically significant trend. Heald Pond consistently experiences the highest annual color compared to the other ponds. Color is highly related to summer precipitation; wetter years show higher color as more materials are washed off the landscape to the lake.

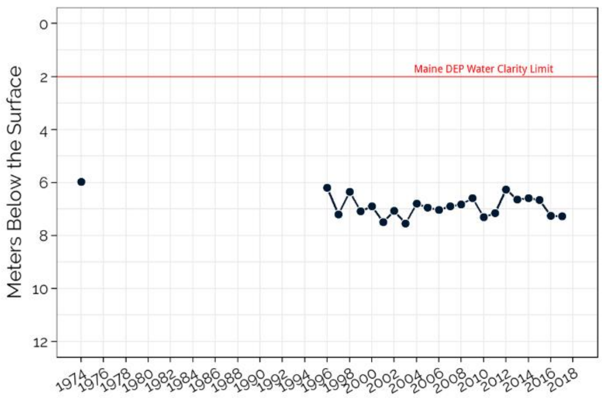


ANOXIC EXTENT

Dissolved oxygen profiles show good oxygenation throughout the water column over the collection period, with some anoxia at the bottom. The extent and duration of anoxia is overall excellent at Heald Pond (affecting <10% of pond area). Dissolved oxygen at depth should continue to be monitored closely in the future.

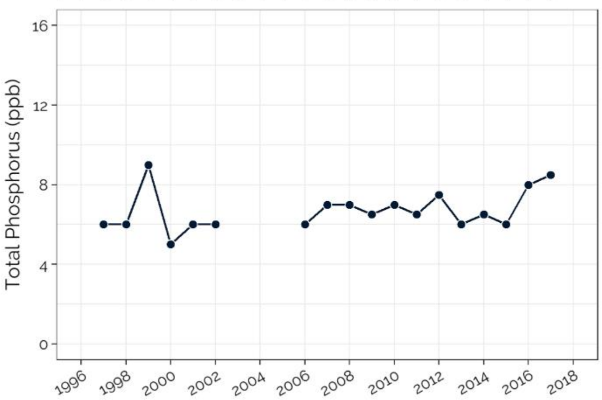
HORSESHOE POND
WATER QUALITY TRENDS

Horseshoe Pond (Midas #3196) is a non-colored waterbody located in the Town of Lovell and Stoneham, Oxford County, Maine. Covering 136 acres (0.20 square miles) with a maximum and mean depth of 40 and 12 feet (12 and 4 meters), the pond drains to Moose Pond, which in turn drains directly to Kezar Lake. Water quality monitoring data have been collected since 1974 at Station 1 (deep spot).



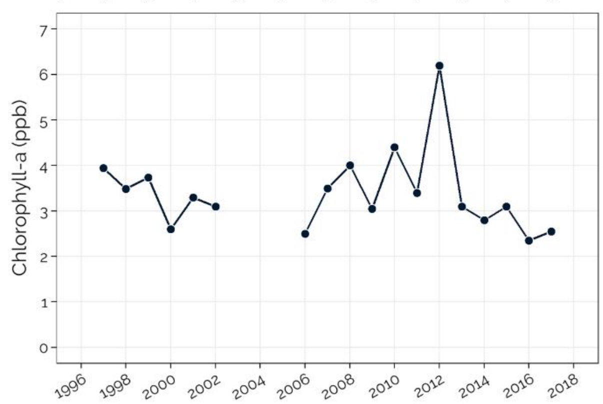
WATER CLARITY

Since 1974, water clarity at Horseshoe Pond has remained stable with no statistically significant trend.



TOTAL PHOSPHORUS

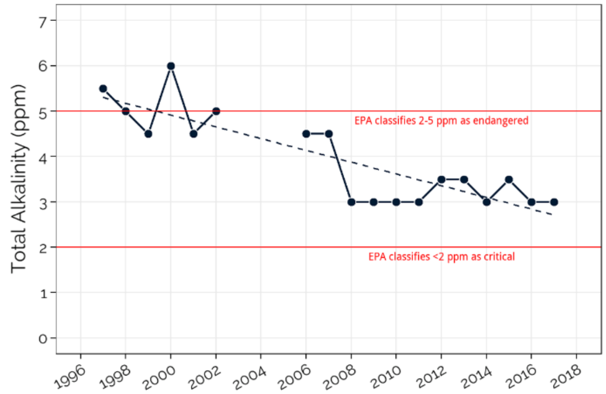
Since 1998, total phosphorus at Horseshoe Pond has remained stable with no statistically significant trend. Horseshoe Pond experiences consistently low phosphorus compared to the other ponds.



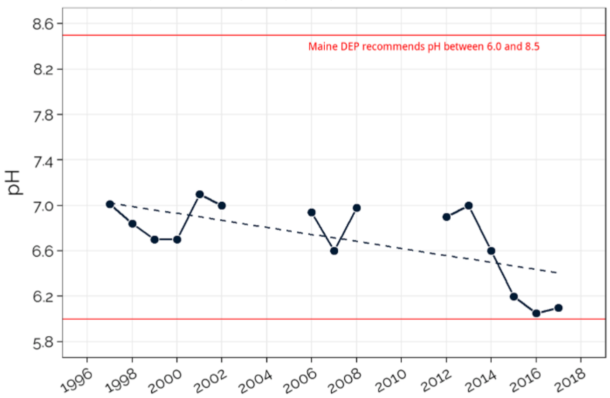
CHLOROPHYLL-A

Since 1997, chlorophyll-a at Horseshoe Pond has revealed no statistically significant trend. Sampling year 2012 saw a marked rise in chlorophyll-a. Nutrient-rich runoff entering the lake during wetter years, combined with warmer air temperatures, can fuel algae growth.

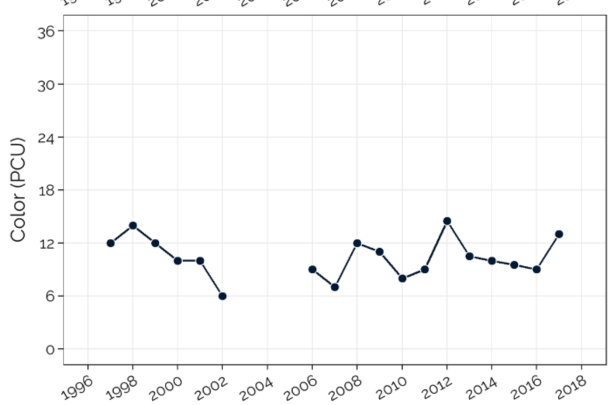
HORSESHOE POND
WATER QUALITY TRENDS



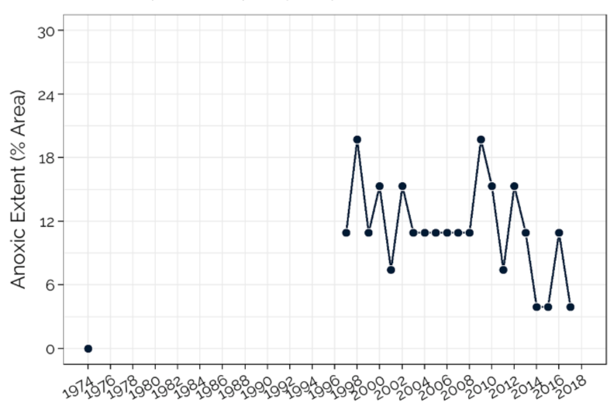
TOTAL ALKALINITY
Since 1997, total alkalinity at Horseshoe Pond has degraded by more than 2 ppm. Horseshoe Pond experiences the lowest (worst) alkalinity compared to the other ponds. The region has naturally-low alkalinity (or buffering capacity) as a result of its contributing geology.



pH
Since 1997, pH at Horseshoe Pond has degraded by nearly 1.0. Mean annual pH falls within acceptable ranges for aquatic life, but hit record low in 2016. Low alkalinity makes Horseshoe Pond susceptible to changes in pH, particularly from acidic deposition in the form of rain or snow, which can jeopardize the health of freshwater fish species.



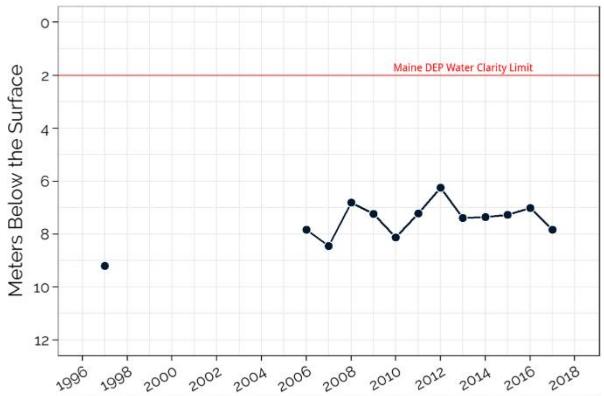
COLOR
Since 1997, color at Horseshoe Pond has remained stable with no statistically significant trend. Color is highly related to summer precipitation; wetter years show higher color as more materials are washed off the landscape to the pond.



ANOXIC EXTENT
Dissolved oxygen profiles show oxygen depletion from 8 to 12 meters below the water surface in late summer. The extent and duration of anoxia is overall good at Heald Pond (sometimes affecting >10% of pond area). Dissolved oxygen at depth should continue to be monitored closely in the future.

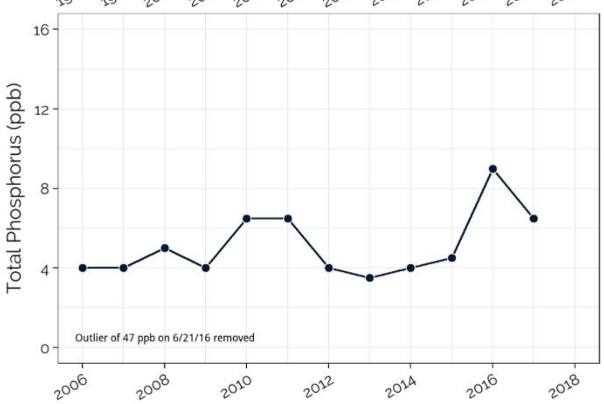
TROUT POND
WATER QUALITY TRENDS

Trout Pond (Midas #3212) is a non-colored waterbody located in the Town of Stoneham, Oxford County, Maine. Covering 64 acres (0.10 square miles) with a maximum and mean depth of 68 and 27 feet (21 and 8 meters), respectively, the pond drains to Cushman Pond, which in turn drains to Heald Pond, then to a tributary to Boulder Brook and eventually Kezar Lake. Water quality monitoring data have been collected since 1997 at Station 1 (deep spot).



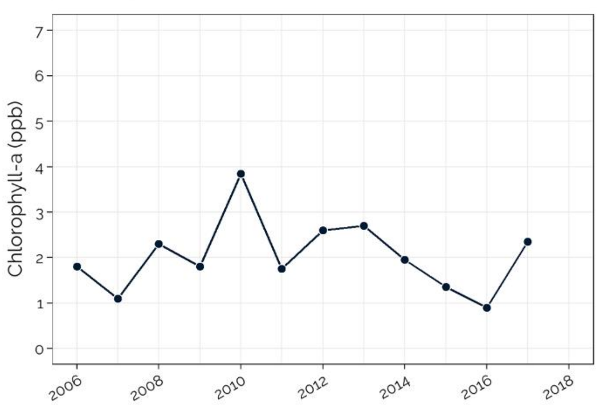
WATER CLARITY

Since 1997, water clarity at Trout Pond has revealed no statistically significant trend, though there appears to be a possible degradation in water clarity of nearly 1 meter. Trout Pond has the deepest water clarity compared to the other ponds.



TOTAL PHOSPHORUS

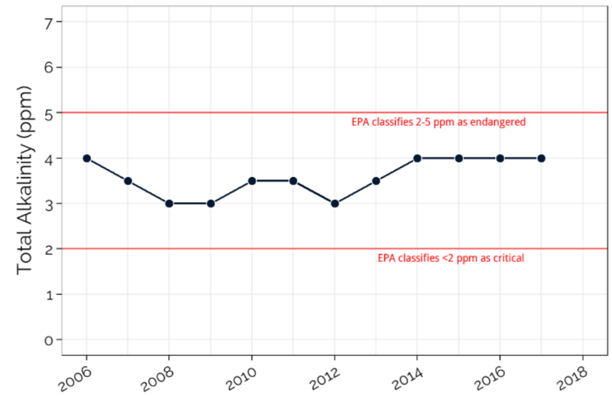
Since 2006, total phosphorus at Trout Pond has revealed no statistically significant trend. Trout Pond experiences the lowest concentration of total phosphorus compared to the other ponds.



CHLOROPHYLL-A

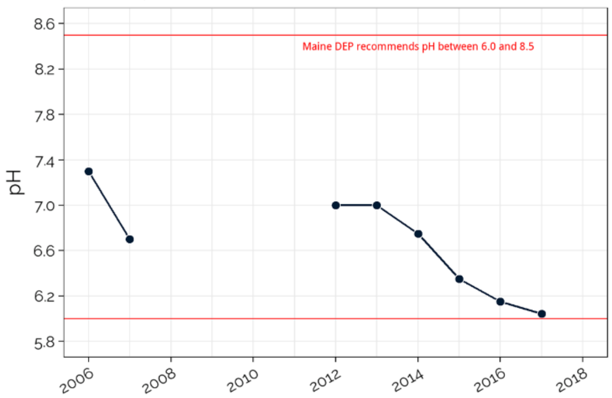
Since 2006, chlorophyll-a at Trout Pond has ranged from about 1 to 4 ppb. Trout Pond experiences the lowest concentration of chlorophyll-a compared to the other ponds.

TROUT POND
WATER QUALITY TRENDS



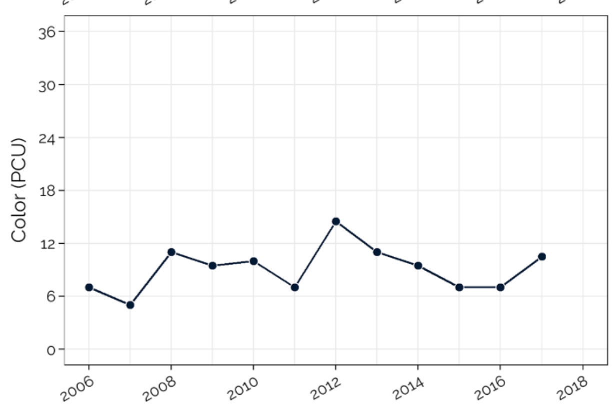
TOTAL ALKALINITY

Since 2006, total alkalinity at Trout Pond has generally remained stable. The region has naturally-low alkalinity (or buffering capacity) as a result of its contributing geology (i.e., granite) that lacks carbonates, bicarbonates, and carbonic acid.



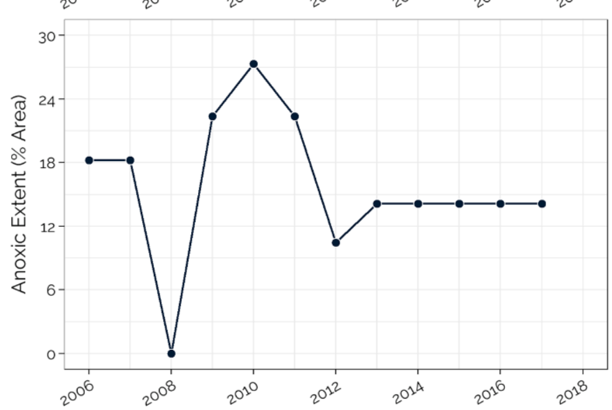
pH

Minimal pH data are available for Trout Pond to make any conclusions about long-term trends, but mean annual pH falls within acceptable ranges for aquatic life, but hit a record low in 2017. Low alkalinity makes Trout Pond susceptible to changes in pH, particularly from acidic deposition in the form of rain or snow, which can jeopardize the health of freshwater fish species.



COLOR

Since 2006, color at Trout Pond has generally remained stable. Trout Pond has the lowest (best) color compared to the other ponds. Higher color was observed for 2012, likely due to the wet summer conditions. Color is highly related to summer precipitation; wetter years show higher color as more materials are washed off the landscape to the pond.

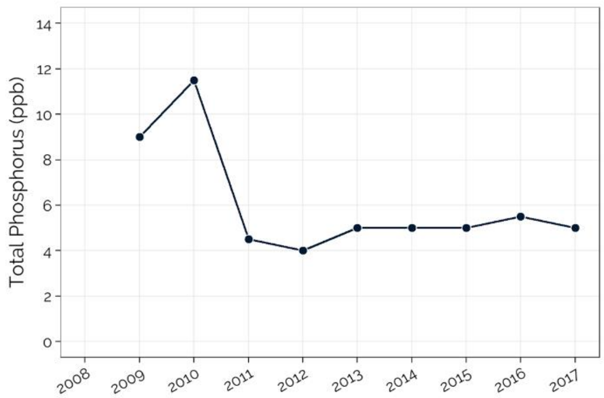


ANOXIC EXTENT

Dissolved oxygen profiles show oxygen depletion beginning at 15 meters below the water surface. The extent and duration of anoxia is overall good at Trout Pond (typically affecting >10% of pond area). Dissolved oxygen at depth should continue to be monitored closely in the future.

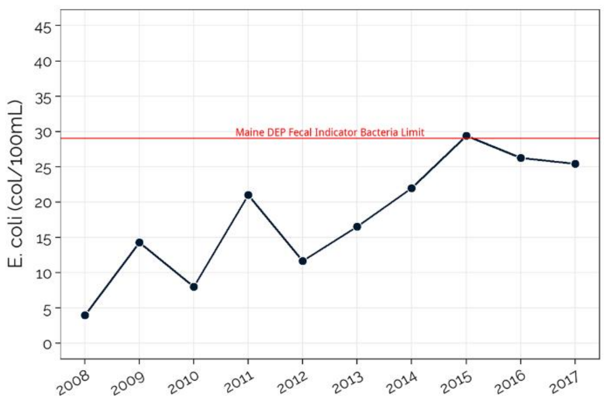
GREAT BROOK
WATER QUALITY TRENDS

Great Brook is located on the northwest end of Kezar Lake off West Stoneham Road. Great Brook drains a large portion of the White Mountain National Forest. Water quality monitoring data have been collected since 2008.



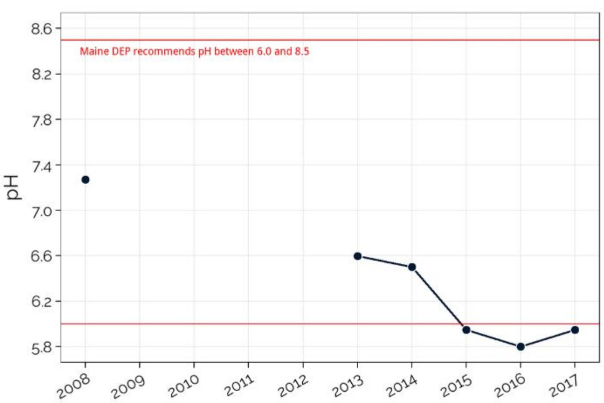
TOTAL PHOSPHORUS

Since 2009, total phosphorus at Great Brook has remained below 12 ppb.



E. COLI

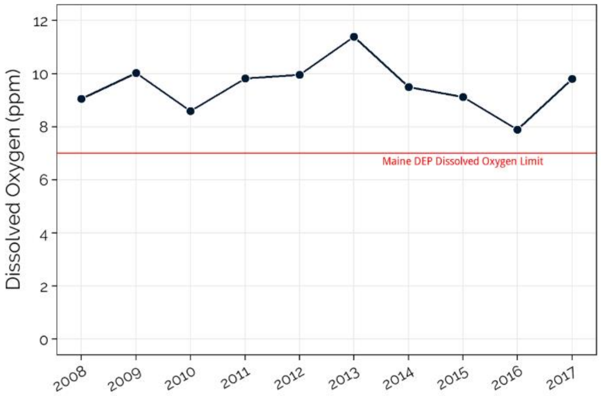
Since 2008, E. coli at Great Brook has been less than the Class A stream geometric mean of 29 col/100mL, with the exception of 2015 (30 col/100mL).

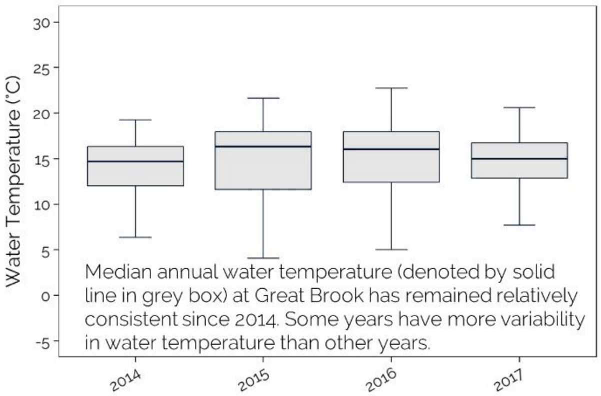


pH

Minimal pH data are available for Great Brook, but pH fell below the range suitable for aquatic life from 2015-2017.

GREAT BROOK
WATER QUALITY TRENDS





DISSOLVED OXYGEN

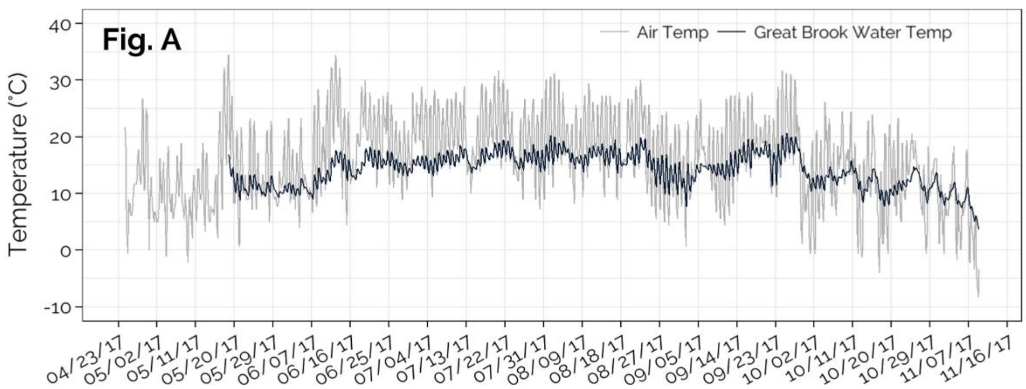
Dissolved oxygen at Great Brook remains above the Maine DEP standard of 7 ppm for Class A streams. Note that dissolved oxygen readings are collected mid-day and do not represent the lowest oxygen readings for that day. Dissolved oxygen is typically lowest in early morning when decomposition processes dominate over photosynthesis.

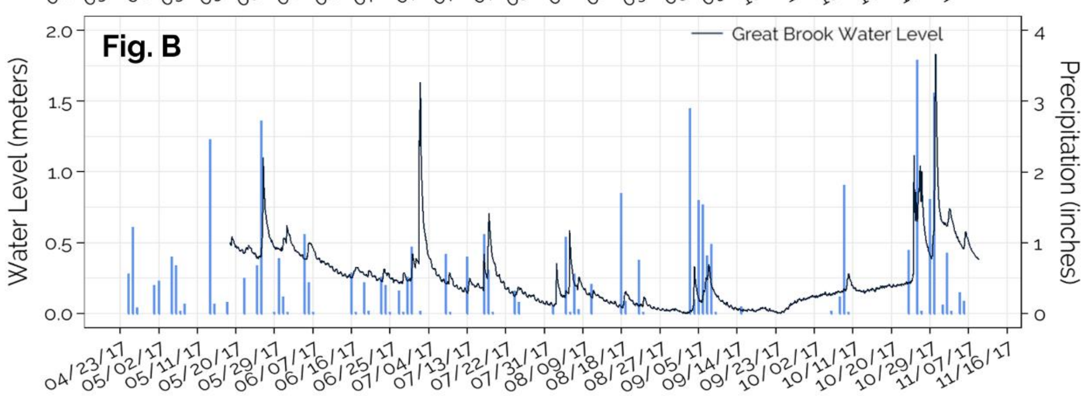
WATER TEMPERATURE

Water temperature in 2017 (Fig. A) increased at Great Brook from May to August and then steadily declined until retrieval in November, following closely with observed air temperature. (hourly data obtained from NOAA NCEI for Fryeburg, ME).

STREAM FLOW

Water level data in 2017 (Fig. B) collected at Great Brook shows that the stream responds quickly to precipitation (daily data obtained from Creeper Hill, Weather Underground).



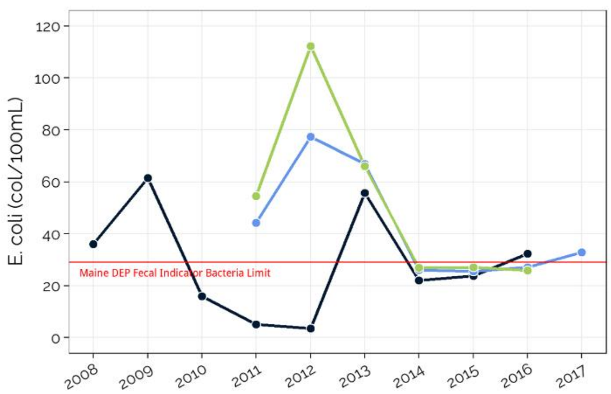


BOULDER BROOK
WATER QUALITY TRENDS

Boulder Brook drains an area that includes Bradley, Trout, Cushman, and Heald Ponds. Boulder Brook crosses under Route 5 north of Center Lovell, and flows past the Boulder Brook Club before entering the east side of Boulder Brook at the swimming area. Water quality monitoring data have been collected since 2008 at multiple stations (BB-1, BB-2, BB-3, and BB-4) along Boulder Brook. Only BB-3 was sampled in 2017.

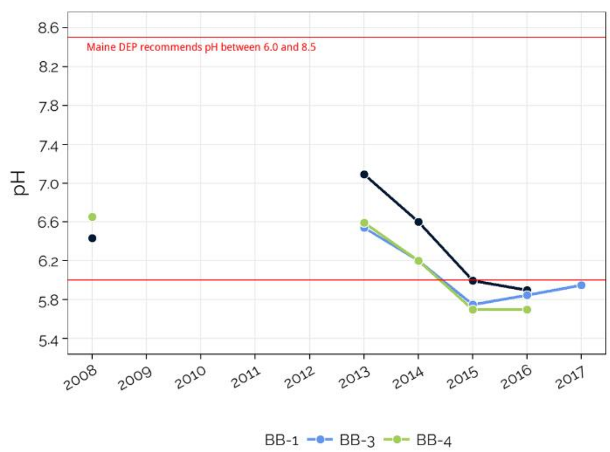
TOTAL PHOSPHORUS

Total phosphorus in Boulder Brook in 2016 was elevated despite dry summer conditions and hit record low in 2017.



E. COLI

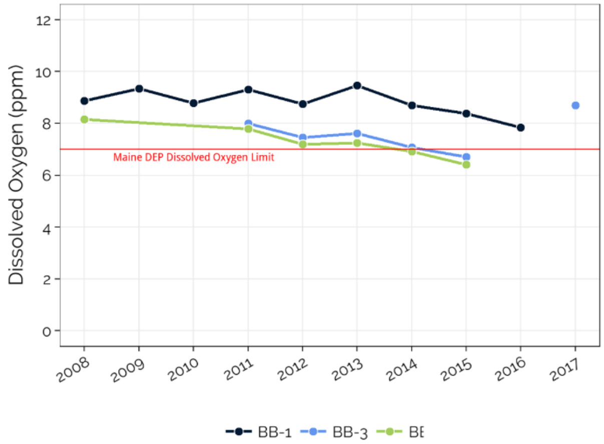
Since 2008, E. coli at Boulder Brook has largely exceeded the Class A stream geometric mean of 29 col/100mL.



pH

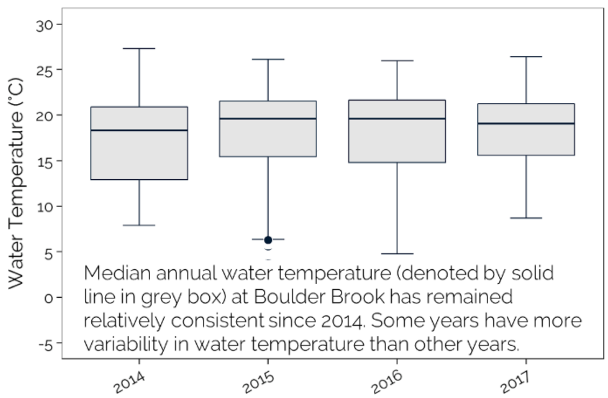
Minimal pH data are available for Boulder Brook, but pH fell within the range suitable for aquatic life up until 2015 when pH dropped below 6.0. Low pH (acidic) waters can threaten fish and other aquatic life.

BOULDER BROOK
WATER QUALITY TRENDS



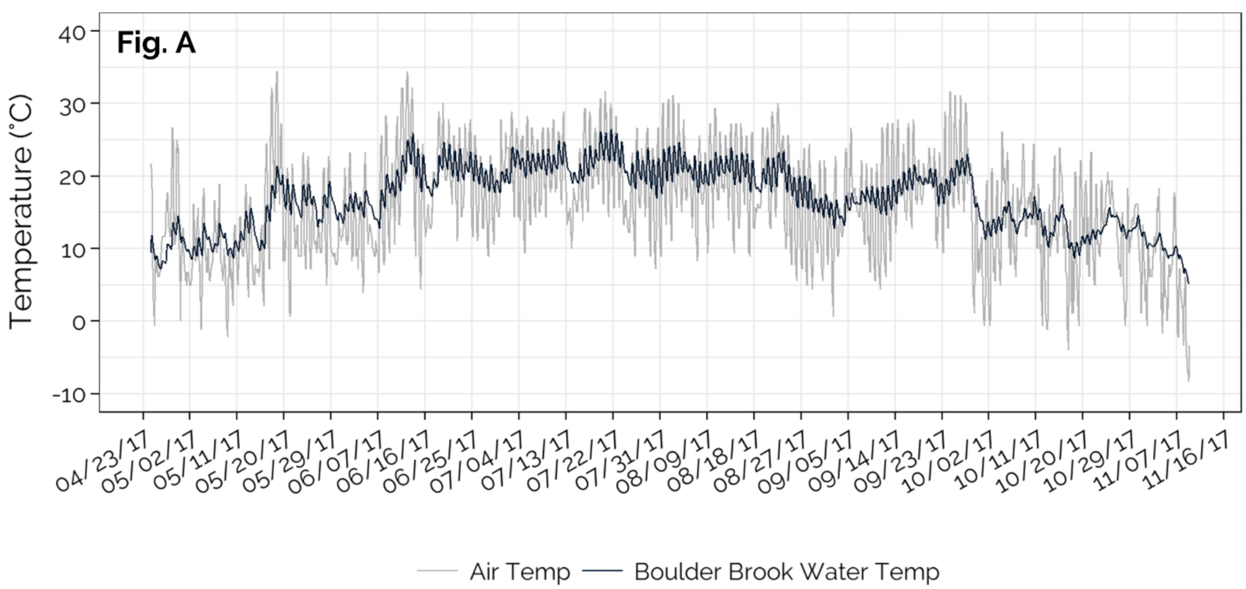
DISSOLVED OXYGEN

Dissolved oxygen at Boulder Brook generally remains above the Maine DEP standard of 7 ppm for Class A streams, with the exception of 2014-2015. Note that dissolved oxygen readings are collected mid-day and do not represent the lowest oxygen readings for that day. Dissolved oxygen is typically lowest in early morning when decomposition processes dominate over photosynthesis.



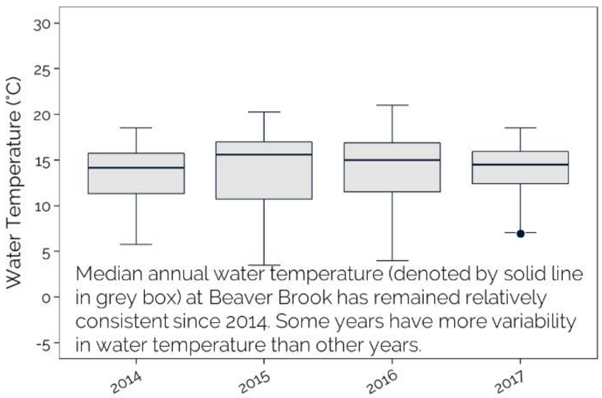
WATER TEMPERATURE

Water temperature in 2017 (Fig. A) increased at Boulder Brook from May to August and then steadily declined until retrieval in November, following closely with observed air temperature (hourly data obtained from NOAA NCEI for Fryeburg, ME). Boulder Brook experienced some of the highest water temperatures compared to the other streams. July to August 2017 showed water temperatures frequently above 24 °C, which may threaten coldwater fish species.



BEAVER BROOK
WATER QUALITY TRENDS

Beaver Brook is a major tributary to Great Brook, located on the northwest end of Kezar Lake off West Stoneham Road. Beaver Brook drains a portion of the White Mountain National Forest. Water quality monitoring data have been collected since 2014.



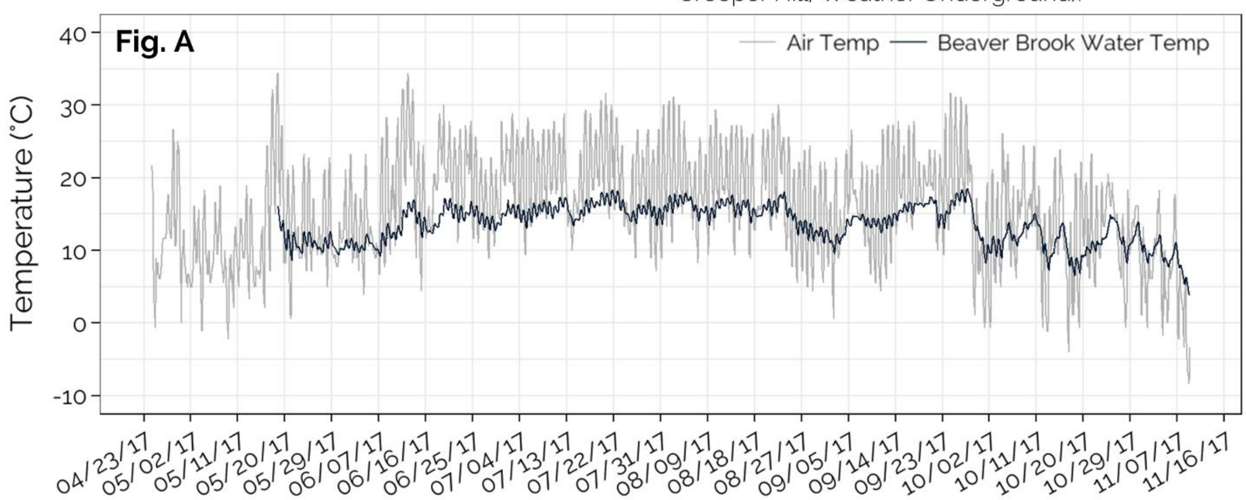
Median annual water temperature (denoted by solid line in grey box) at Beaver Brook has remained relatively consistent since 2014. Some years have more variability in water temperature than other years.

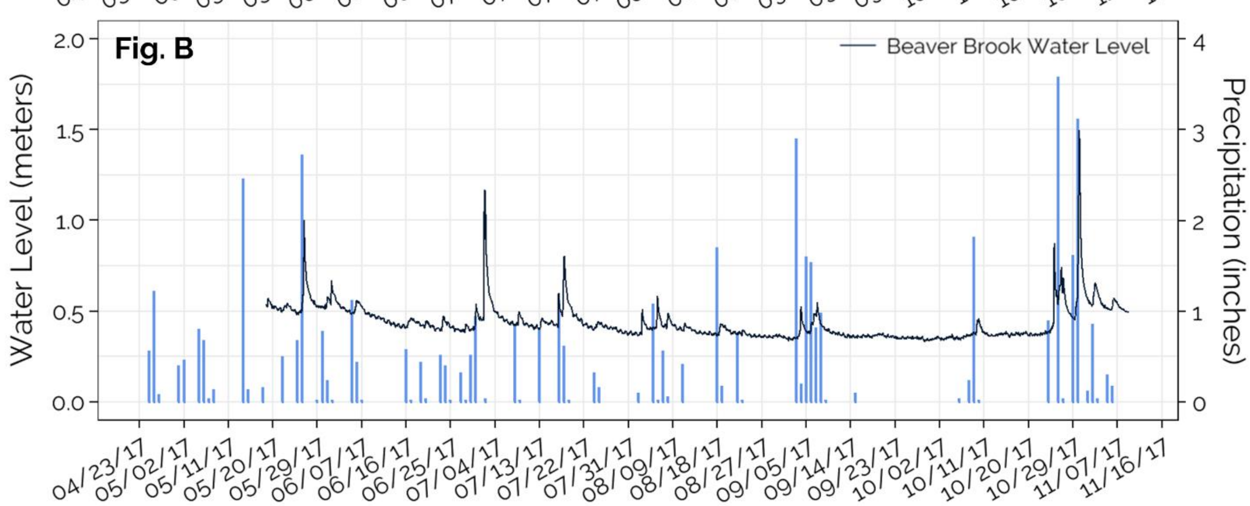
WATER TEMPERATURE

Water temperature in 2017 (Fig. A) increased at Beaver Brook from May to August and then steadily declined until retrieval in November, following closely with air temperature (data obtained from NOAA NCEI for Fryeburg, ME).

STREAM FLOW

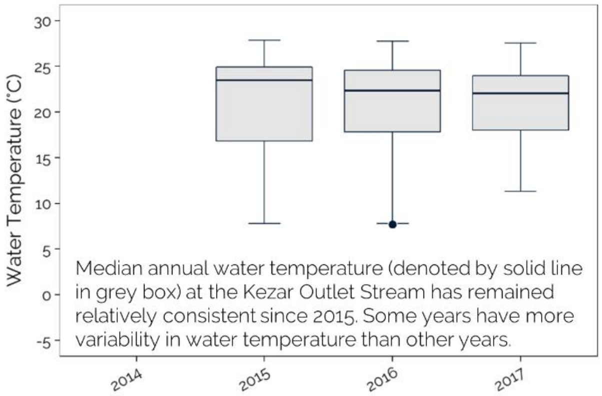
Water level data in 2017 (Fig. B) collected at Beaver Brook shows that the stream responds quickly to precipitation (data obtained from Creeper Hill, Weather Underground).





KEZAR OUTLET STREAM
WATER QUALITY TRENDS

The Kezar Outlet Stream flows south from the lower bay of Kezar Lake. The stilling well was attached to an old fish dam structure just upstream of Harbor Road. Water quality monitoring data have been collected since 2015.



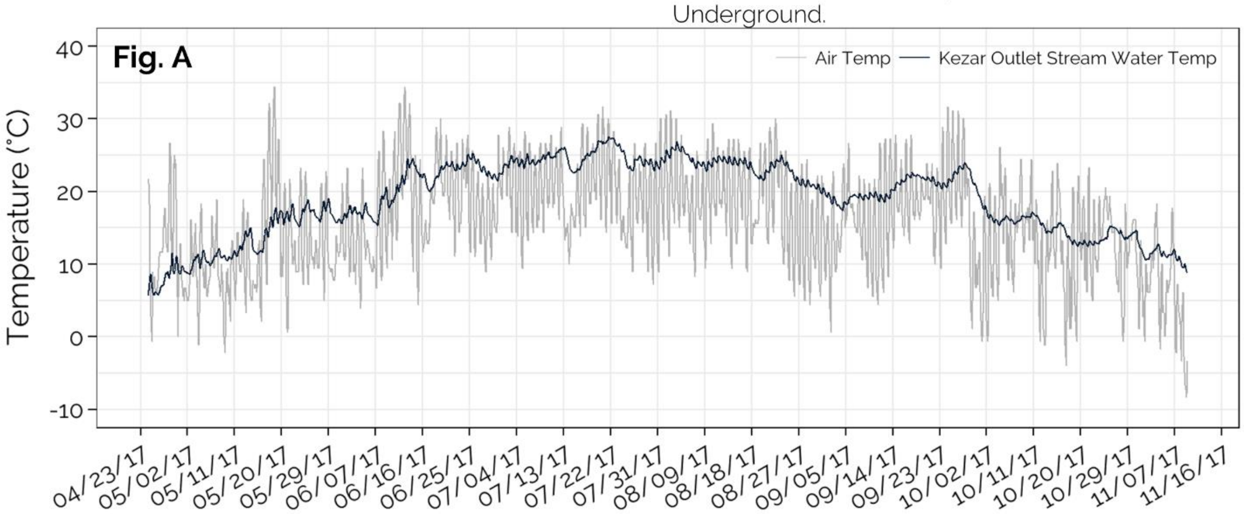
Median annual water temperature (denoted by solid line in grey box) at the Kezar Outlet Stream has remained relatively consistent since 2015. Some years have more variability in water temperature than other years.

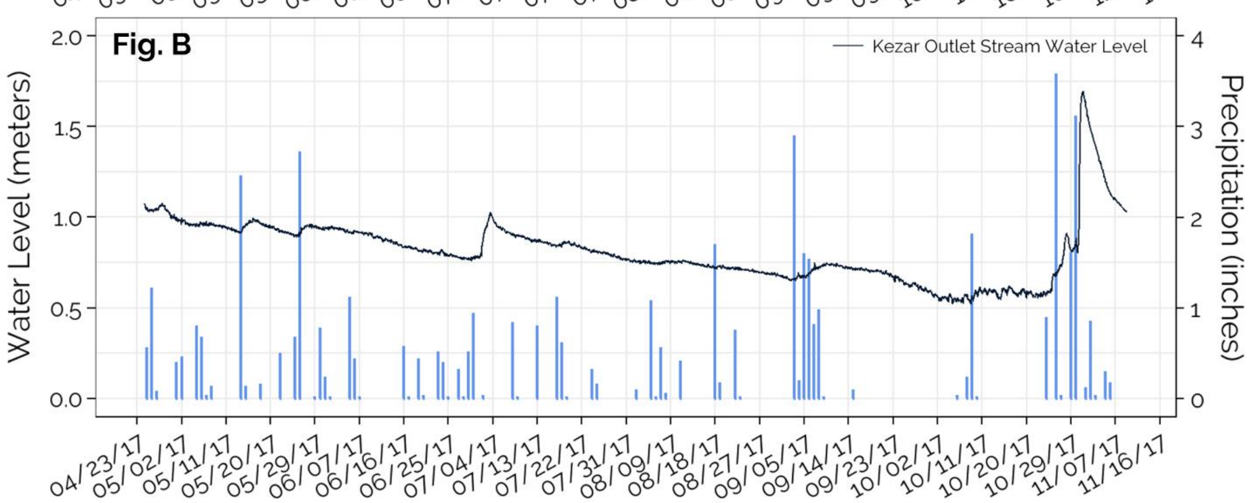
WATER TEMPERATURE

Water temperature in 2017 (Fig. A) followed closely with air temperature (data obtained from NOAA NCEI for Fryeburg, ME).

STREAM FLOW

The large, but delayed volume of water flowing from the lake through the Kezar Outlet Stream allowed water level (Fig. B) to increase and decrease much more gradually compared to headwater streams. Precipitation data obtained from Creeper Hill, Weather Underground.



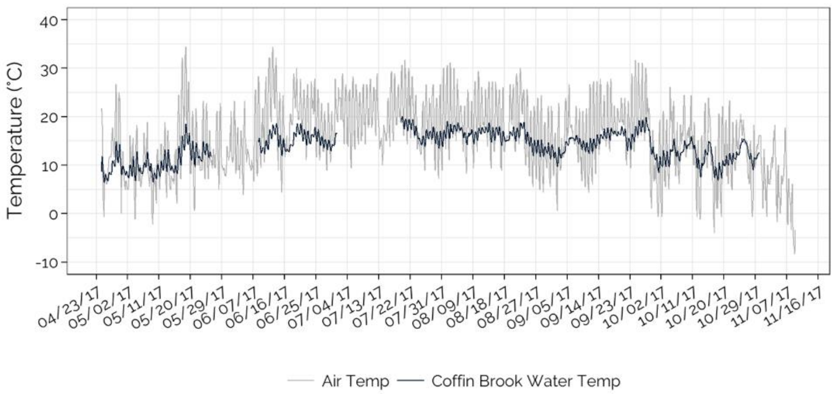


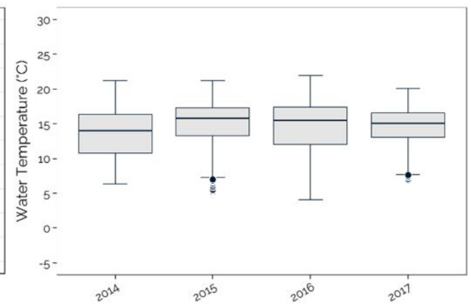
COFFIN BROOK
WATER QUALITY TRENDS

Coffin Brook drains to the eastern side of the upper basin of Kezar Lake, crossing Rt. 5 just south of West Stoneham Road. Water quality data have been collected since 2014.

WATER TEMPERATURE

Water temperature in 2017 (below, left fig.) increased at Coffin Brook from May to August and then steadily declined until retrieval in November, closely tracking air temperatures (data obtained from NOAA NCEI).





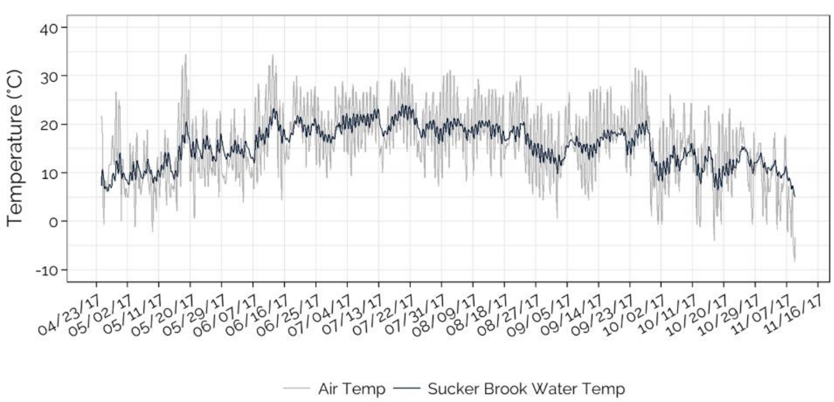
Median annual water temperature (denoted by solid line in grey box) at Coffin Brook has remained relatively consistent since 2014. Some years have more variability in water temperature than other years.

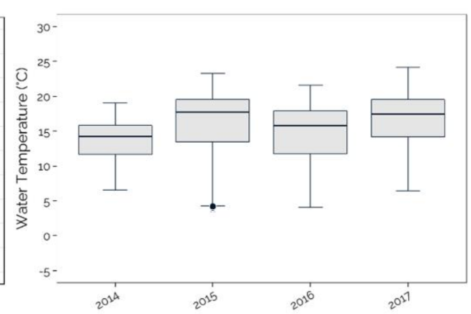
SUCKER BROOK
WATER QUALITY TRENDS

Sucker Brook begins at the outlet to Horseshoe Pond and drains to the western side of the lower basin of Kezar Lake after converging with Bradley Brook. Water quality data have been collected since 2014.

WATER TEMPERATURE

Water temperature in 2017 (below, left fig.) increased at Sucker Brook from May to August and then steadily declined until retrieval in November, closely following air temperatures (data obtained from NOAA NCEI).





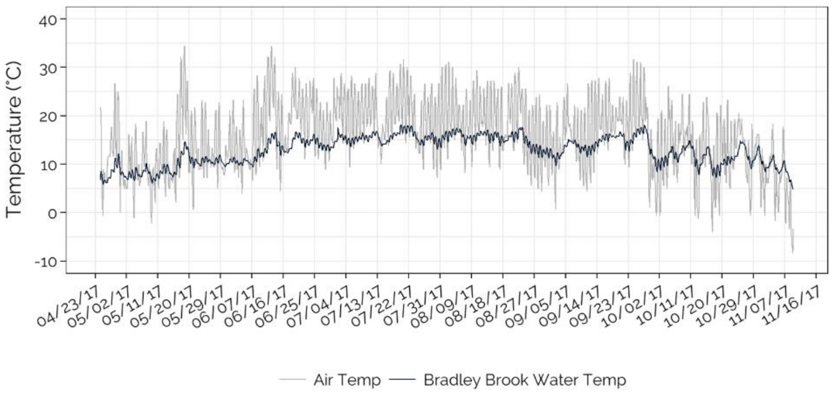
Median annual water temperature (denoted by solid line in grey box) at Sucker Brook has been more variable since 2014 than other streams.

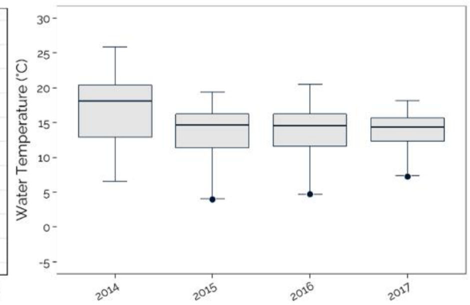
BRADLEY BROOK
WATER QUALITY TRENDS

Bradley Brook is a tributary that drains to the western side of the lower basin of Kezar Lake. Water quality data have been collected since 2014.

WATER TEMPERATURE

Water temperature in 2017 (below, left fig.) increased at Bradley Brook from May to August and then steadily declined until retrieval in November, closely following air temperatures (data obtained from NOAA NCEI).





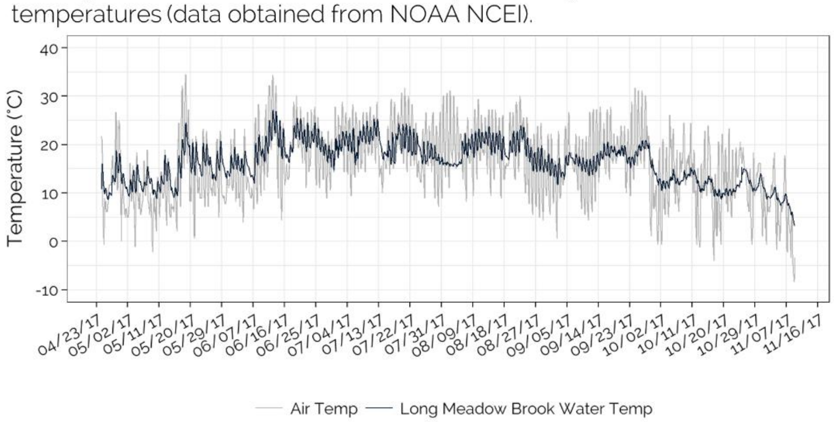
Median annual water temperature (denoted by solid line in grey box) at Bradley Brook has remained relatively consistent since 2015. Some years have more variability in water temperature than other years.

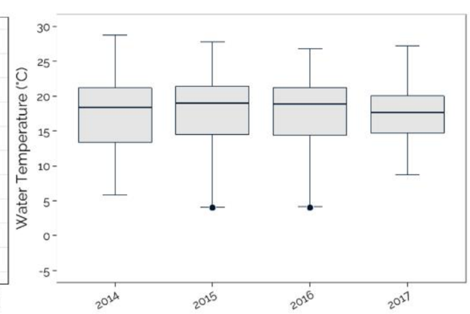
LONG MEADOW BROOK
WATER QUALITY TRENDS

Long Meadow Brook is a tributary that drains through a large wetland complex to the southwestern side of the lower basin of Kezar Lake. Water quality data have been collected since 2014.

WATER TEMPERATURE

Water temperature in 2017 (below, left fig.) increased at Long Meadow Brook from May to August and then steadily declined until retrieval, closely following air temperatures (data obtained from NOAA NCEI).





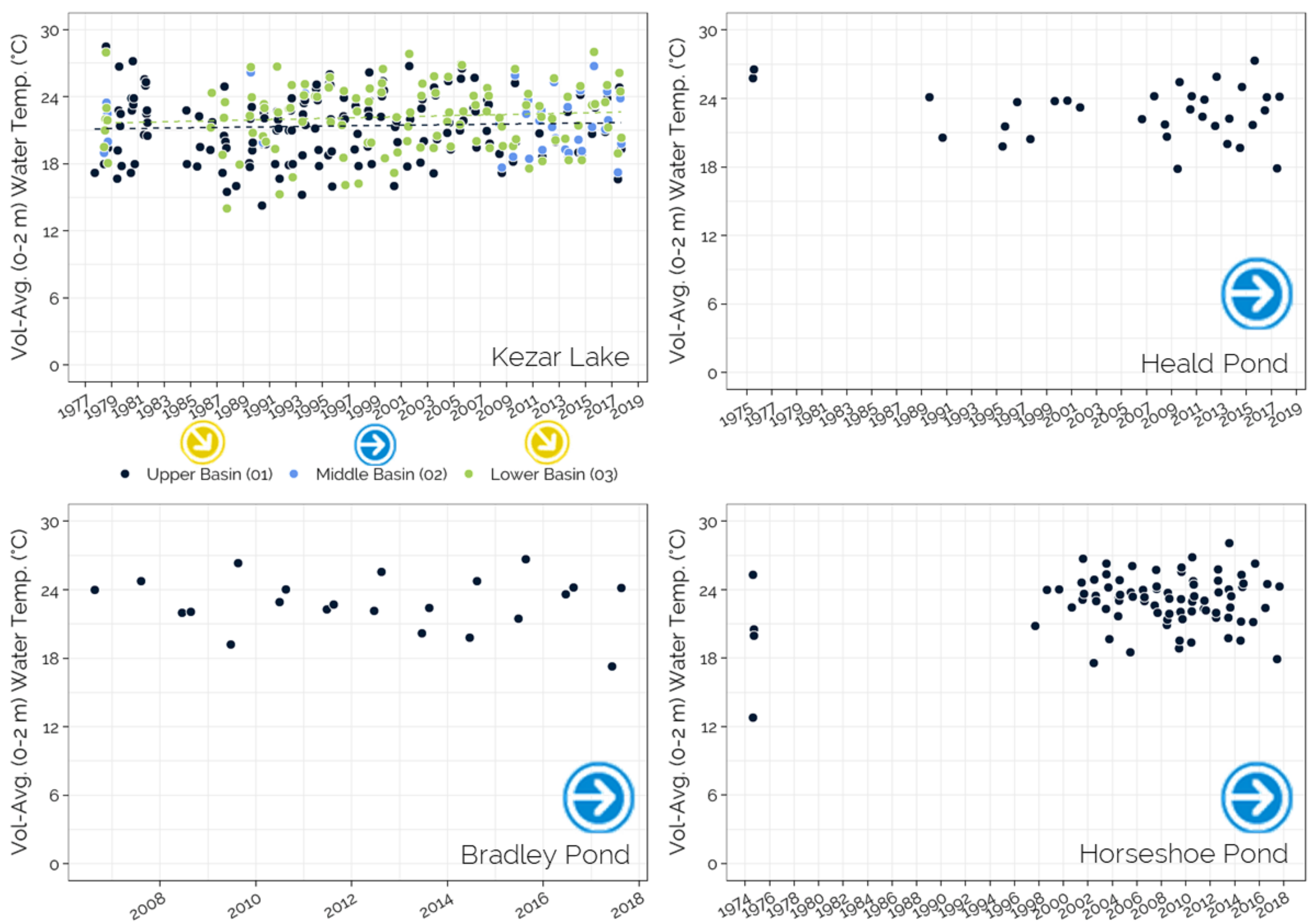
Median annual water temperature (denoted by solid line in grey box) at Long Meadow Brook has remained relatively consistent since 2014. Some years have more variability in water temperature than other years.

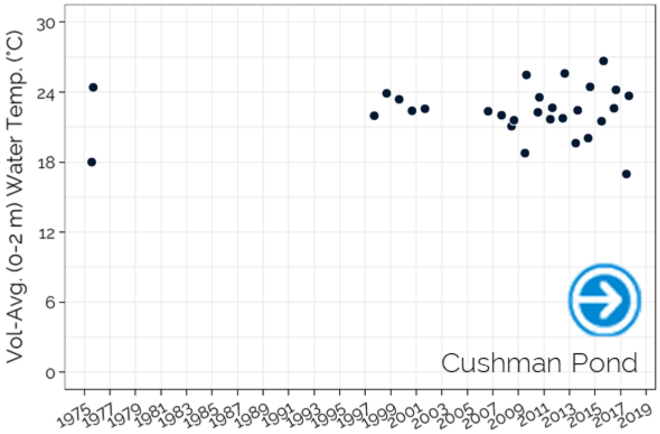
LAKE SURFACE WATER TEMPERATURE

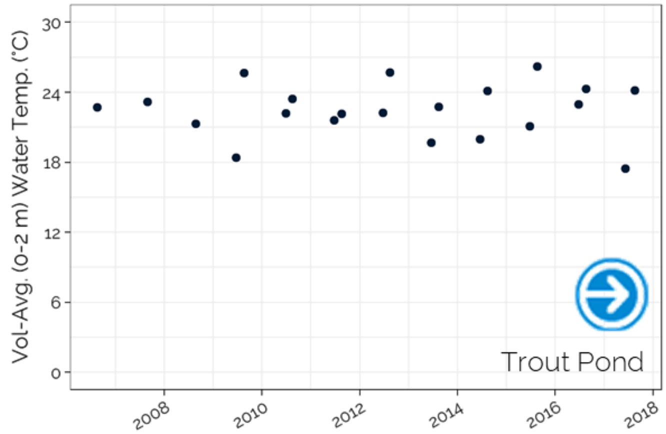
Climate change is predicted to increase surface water temperatures at a much faster rate than the observed increase in air temperature. Temperature affects the density of water (e.g., cooler water sinks), the solubility of gases (e.g., cooler water holds more dissolved oxygen), the rate of chemical reactions, and the activity of aquatic organisms (e.g., metabolic growth rates peak at different temperatures for different species; some species such as trout and salmon prefer cooler, more oxygen-rich waters; others such as bass prefer warmer waters). Thus, water temperature serves as a critical indicator of climate change impacts to ecological systems.

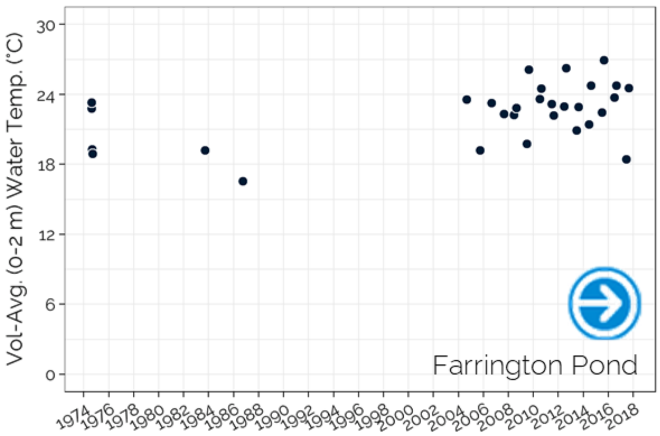
Volume-weighted average surface water temperature (0-2 m) for each profile measurement was calculated using rLakeAnalyzer. This method allows comparison of surface water temperatures across multiple waterbodies with different morphological characteristics. Mann-Kendall trend tests were performed on annual water quality data to determine trends over time. Dotted trend lines were added where statistically significant.

The volume-weighted average surface water temperature for the top 2 meters showed a statistically significant increasing (degrading) trend of about 0.5-1 ˚C at both the upper and lower basin of Kezar Lake. This is likely a signal of climate change; correlations with air temperature and precipitation may help tease out the relative contribution of weather variables on lake surface temperature. All other waterbodies showed no statistically-significant trend in water temperature over the available record.









LAKE MONITORING BUOYS

Climate change will alter the physical, chemical, and biological processes within surface waters of the Kezar Lake watershed. The culmination of the impact of these processes can be readily observed in dissolved oxygen and water temperature within the vertical profile of the water column. With high-resolution data from continuous loggers, we can pinpoint spring and fall turnover, determine the onset of thermal stratification, and determine the extent and duration of anoxia. By tracking these parameters over time, we can measure whether these indices are shifting because of climate change or other human disturbances within the watershed.

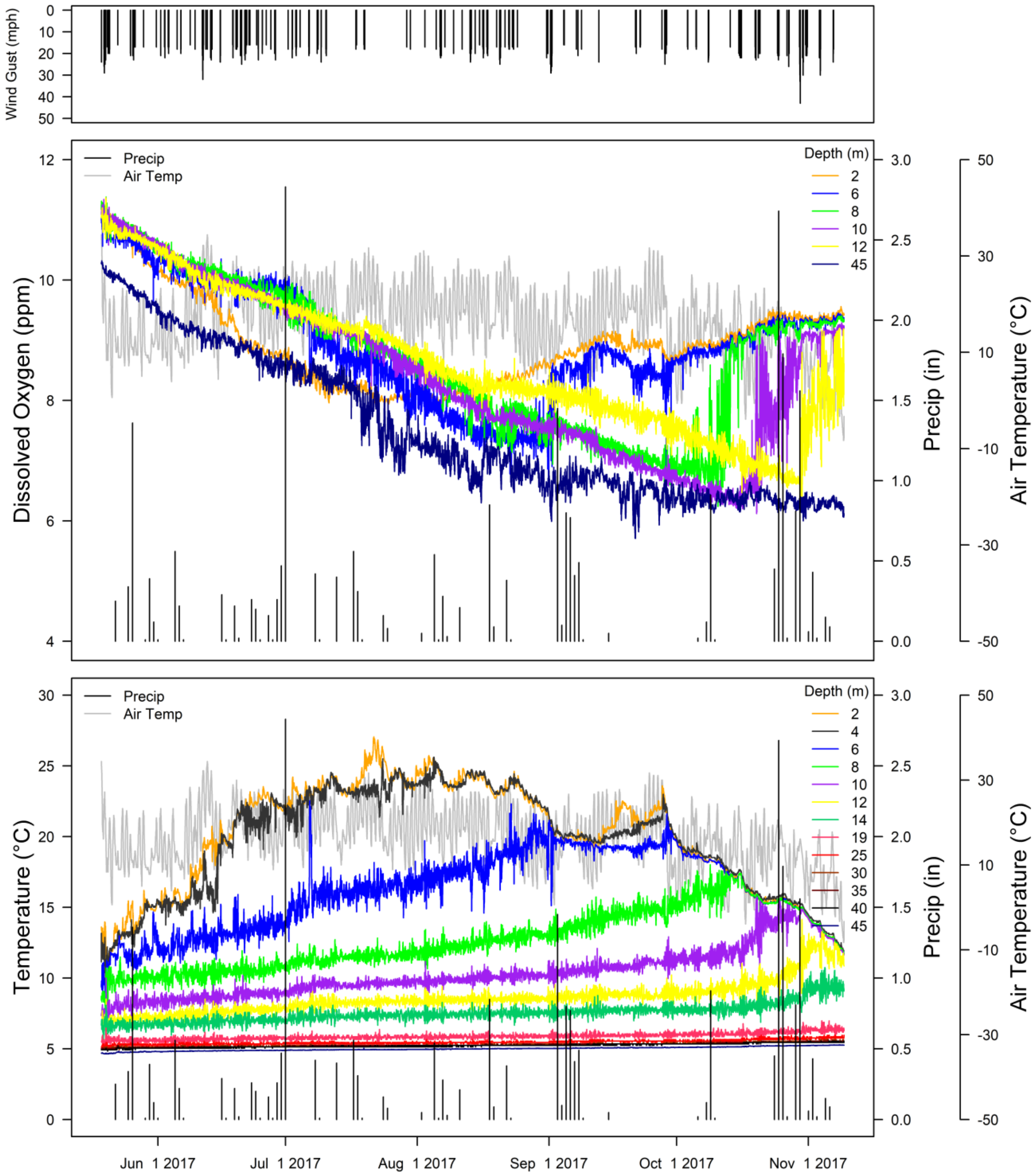
Buoy deployed at the lower basin in 2017. Photo Credit: FBE.

FB Environmental Associates, with assistance from KLWA, deployed monitoring buoys with Onset HOBO® continuous logging devices for temperature and dissolved oxygen at the upper and lower basins. The lower basin also included a conductivity sensor; conductivity can serve as a surrogate measure for the ionic materials (including nutrients) present in water. These buoy-logger systems were deployed from May to November and left intact with logging temperature sensors over winter. Refer to the 2017 Kezar Lake Water Quality Monitoring Report for further details on deployment configuration and maintenance methods.

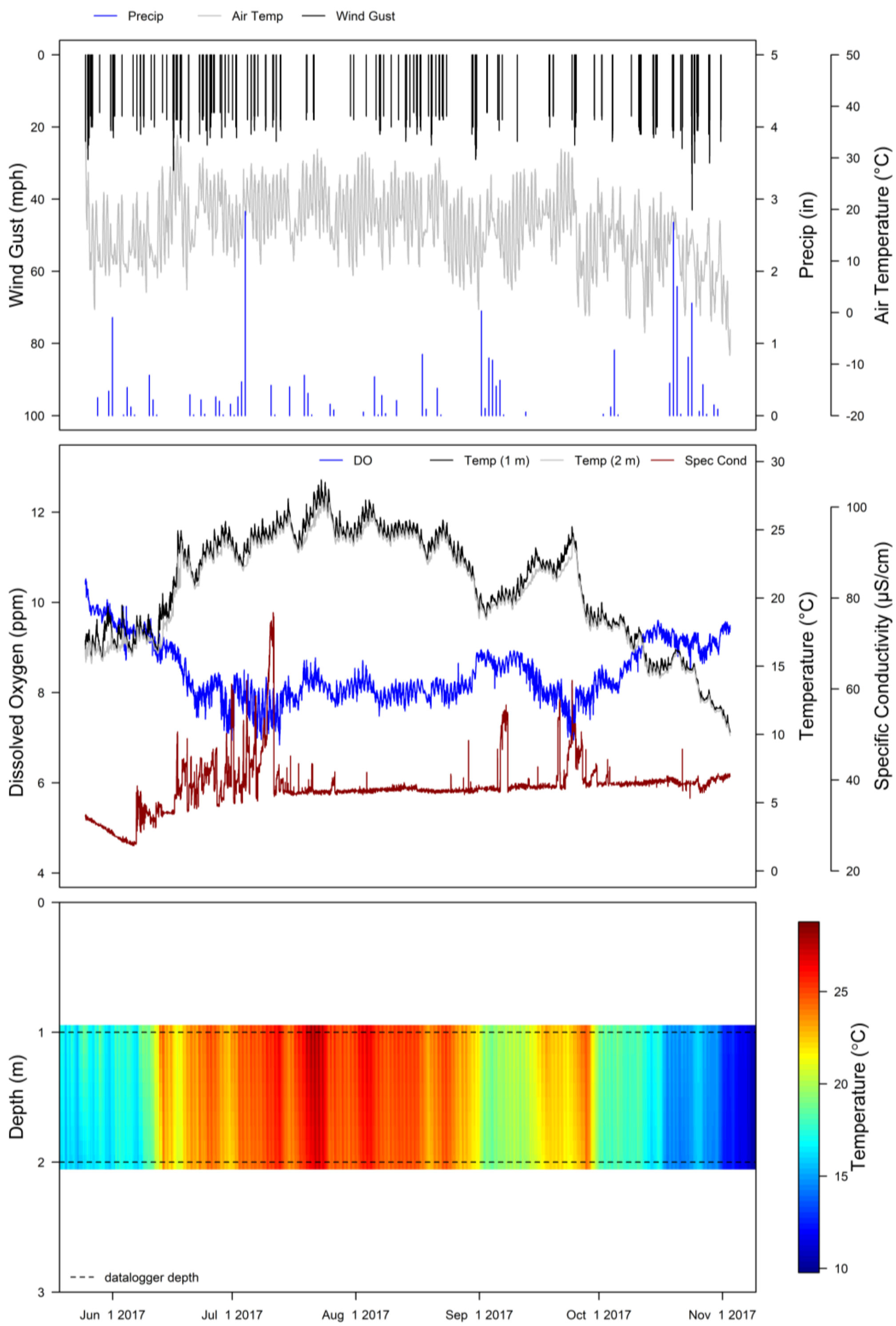
These data will serve as a baseline for future comparisons of water quality to assess long-term changes in temperature and dissolved oxygen. Until more data are collected over the next few years to begin to account for interannual variability, no major conclusions or analyses can be made on this limited dataset aside from general patterns.

- DO at the upper basin gradually declined at all depths from supersaturation in early May to 6-9 ppm in mid- to late-August, at which point the upper layers from the surface down to 6 meters began to steadily increase in oxygen (possibly due to wind action and/or biological processes as algae growth peaked in the water column). The upper 2 meters were regularly oxygenated by wind action.
- Temperature data at the upper basin showed that the onset of stratification occurred around the day of deployment in May. The water column in the upper 14 meters continued to stratify with warm surface waters reaching a maximum of 27.1˚C at 2 meters depth on 7/21/2017. Following a large storm event in early September that forced upper lake mixing, temperature of depths down to 6 meters converged.
- As air temperatures declined into the fall and large storm events (wind and rain) occurred, subsequently deeper layers began to mix with upper layers until dissolved oxygen and temperature readings converged (down to 10 meters). The 45-meter-depth logger was still gradually declining in oxygen and water temperature were stable as the lake had not yet experienced complete fall turnover by 11/9/2017.
- Surface waters at the lower basin reached a maximum of 28.7˚C at 1-meter depth on 7/21/2017. Temperature and dissolved oxygen displayed an inverse relationship throughout the deployment (e.g., as temperature rose, oxygen declined). Warmer waters hold less oxygen and stimulate algae/plant growth, the organic material of which can be decomposed via oxygen consumption.
- Conductivity at the lower basin was highly erratic in June, suggesting that ions in soil were easily activated during rain events and following the spring snowmelt period. An apparent delay in conductivity response in the lower basin following large rain events suggests that the spikes in conductivity were likely sourced from the upper basin (and the headwaters of the watershed). A large 2.8" storm in late June pushed a large slug of ion-rich water from the landscape to the lake. This storm may have depleted soil ion stock since subsequent storm events did not produce as high of a response in conductivity. The cause of the prolonged spike in conductivity in late September is unknown and unassociated with a storm (unless very localized). The Kezar Outlet Stream did back up into Kezar Lake in the fall, depositing a large plume of sediment. It may also be due to wind or wave action (from motorized boats). It also

corresponded with a peak in temperature and reduction in dissolved oxygen; thus, an algae bloom may have been captured in the conductivity readings during that time.



Hourly maximum wind gust (top), and dissolved oxygen (middle) and temperature (bottom) readings taken every 15 minutes during the summer at various depths at the deep spot of Kezar Lake's upper basin. Precipitation, air temperature, and wind gust data were obtained from NOAA NCEI station at Fryeburg. Interpolated dissolved oxygen and temperature data were not included here. Refer to the 2017 Kezar Lake Water Quality Report.

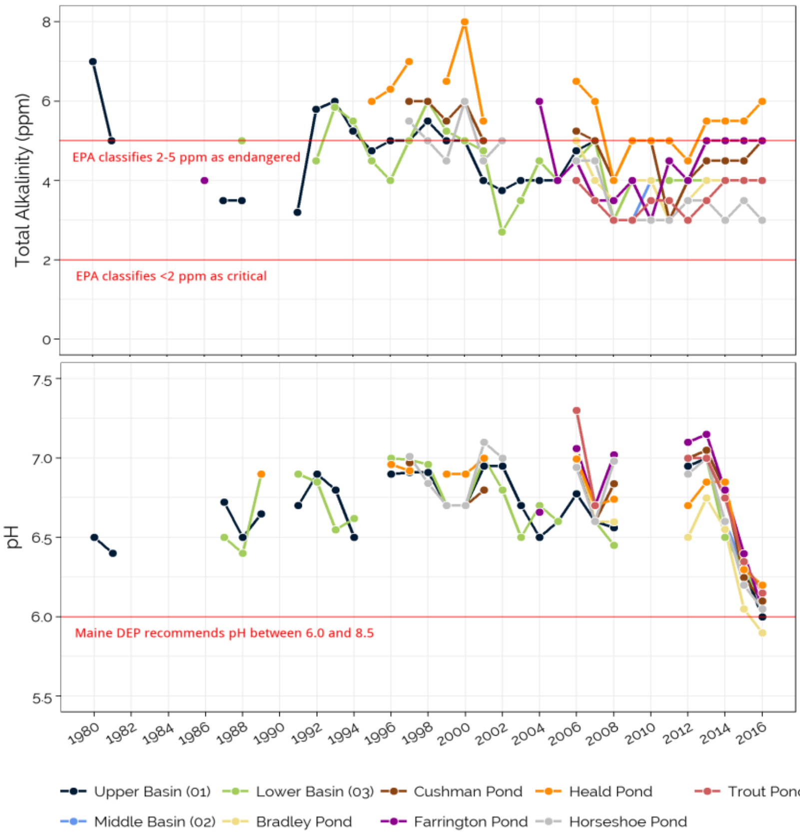


Hourly maximum wind gust, air temperature, and precipitation (top). Dissolved oxygen, temperature, and specific conductivity readings taken every 15 minutes during the summer at 2 meters depth (temperature also included 1 meter depth) at the deep spot of Kezar Lake's lower basin (middle). Interpolation of temperature readings taken every 15 minutes during the summer at 1 and 2 meters depth at the deep spot of Kezar Lake's lower basin (bottom). Precipitation, air temperature, and wind gust data were obtained from NOAA NCEI station at Fryeburg. Red coloring represents warm surface waters in the lake.

BASELINE ACIDITY STUDY

Due to its natural granitic geology, Kezar Lake and its ponds suffer from extremely low alkalinity (typically < 5 ppm), which has significantly degraded by 1 ppm or more in the last few decades at Kezar Lake, Cushman Pond, and Horseshoe Pond. Without adequate alkalinity to remove excess hydrogen ions in rain (~ pH 5.0) or acidic groundwater, pH in surface waters can fall below levels deemed safe for aquatic life (pH 6.0-8.5).

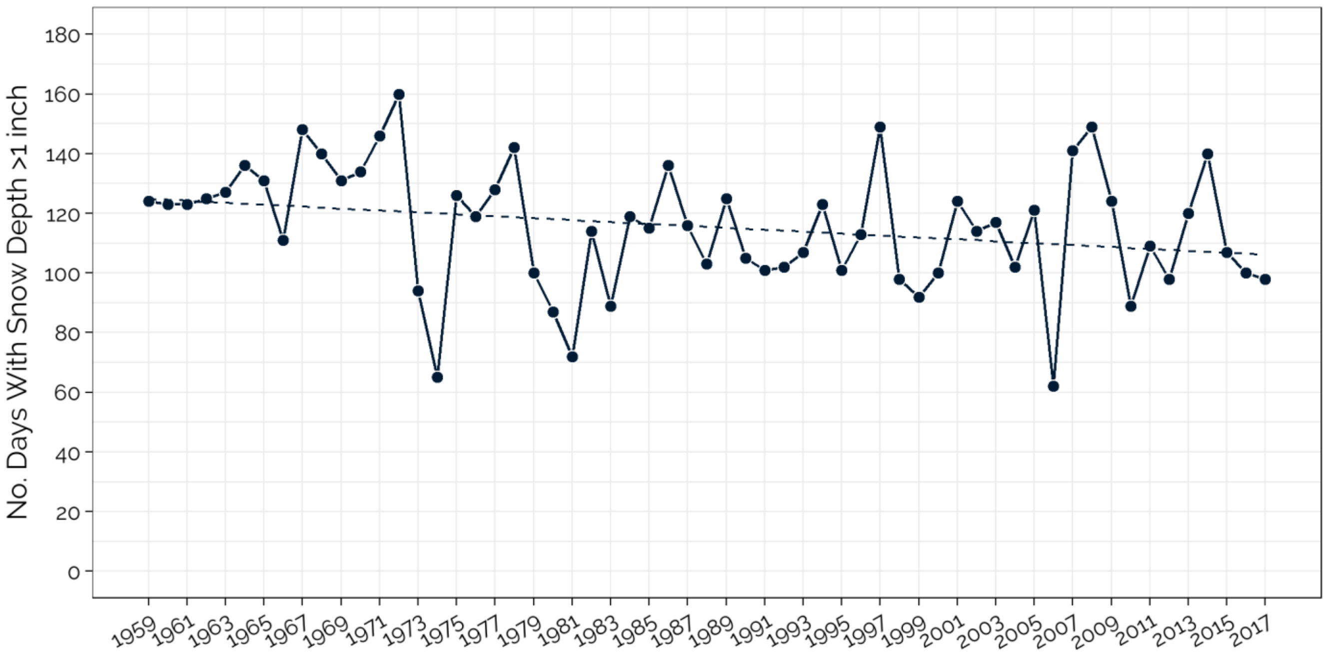
pH in Kezar Lake and its ponds over the same period shows a statistically significant decline at both Heald and Horseshoe Ponds. While most waterbodies with a longer record showed recovery from acidification following the Clean Air Act Amendments of 1990, pH in waterbodies of the Kezar Lake watershed, including tributaries, has shown a marked decline since 2014, without an obvious cause.



Mean annual total alkalinity (top) and pH (bottom) from 1980-2016 in Kezar Lake and six ponds.

One theory is that the recent chronic acidification observed from 2014-2016 in the surface waters of the Kezar Lake watershed may be the result of multiple back-to-back mild winters with little snow cover. Over the available long-term record for North Conway, NH (1959-2017), the number of days with snowpack depth greater than 1 inch significantly declined by about 10 days. This reduction in snowpack depth comes as temperatures and precipitation (as rain, not snow) increase with climate change. Long-term pH data are insufficient to adequately correlate annual pH with number of days with snowpack depth greater than 1 inch, but the recent rapid decline in annual pH in Kezar Lake and the ponds occurred after mild winters in 2014-2016.

Reduction in snowpack duration results in loss of soil CO_2 (degassing from soil horizons to the atmosphere) and thus lower alkalinity in spring runoff, leaving these systems more vulnerable to acidification. Drought (as we have experienced in the last few summers) can also lower water tables and result in evaporative concentration of acid deposition and slowed rates of mineral weathering of buffering elements, causing enhanced acidification. Acidification leaches critical nutrients like calcium (Ca^{+2}) and magnesium (Mg^{+2}) and increases the availability of toxic metals like aluminum (Al), causing reduced reproductive capacity of sensitive organisms, lower body weight of fish, decreased species diversity, and forest mortality.



Number of days with snowpack depth of more than one inch. Data taken from the NOAA National Climatic Data Center for station CONWAY 1 N, NH US (ID# GHCND:USC00271732) for 1959-73 and station NORTH CONWAY, NH US (ID#GHCND:USC00275995) for 1974-present. Mann-Kendall trend test was performed. Statically-significant trend is shown as dotted trend line.

In response to concerns of the impacts of acidification, KLWA obtained funding for a study that determined a baseline for acidity metrics, including alkalinity, pH, Al, and Ca^{2+}, for eight major tributary streams to Kezar Lake. Refer to the 2017 Kezar Lake Watershed Baseline Acidity Study: A Report on the Current State of Tributary Acidity to Kezar Lake for details on methodology.

Results showed that aquatic life in the tributaries to Kezar Lake may be impacted by low alkalinity, pH, and Ca^{2+}, and elevated Al, especially during episodic (rainfall or snowmelt) acidification events.

Future studies in the Kezar Lake watershed should build on the existing baseline data set for acidity metrics to track changes in these metrics over time.

ADDITIONAL WATER TEMPERATURE MONITORING

In partnership with Prof. Daniel Buckley from the University of Maine at Farmington, KLWA participates in a high-resolution lake temperature monitoring study that uses Onset HOBO sensors to record water temperature in over 30 Maine lakes. These automated thermometers were installed to gather data on surface water temperature in each of the three lake basins and Horseshoe Pond (at docks along the shorelines). Through this collaboration, KLWA hopes to continue collecting water temperature data through automatic sampling techniques.

OTHER AQUATIC INDICATORS

Sediment Core Study

One of the most effective ways to understand the long-term effects of climate change on lake ecosystems is to compare past conditions with current ones. Since sediments that accumulate at the bottom of a lake are the result of the biological, geological, and climatological changes within each lake's watershed, they provide a sequential record of past conditions in lake productivity, stratification, oxygenation, and material inflows from streams and watershed runoff. The sediment core study of Kezar Lake aimed to better link water quality with climate and land use and to determine which stressors have put Kezar Lake water quality at greatest risk for future impairment.

A full description of preliminary results was presented in the 2016 CCO Annual Report. No new analyses were completed in 2017, so only a summary of major findings is presented below.

SUMMARY

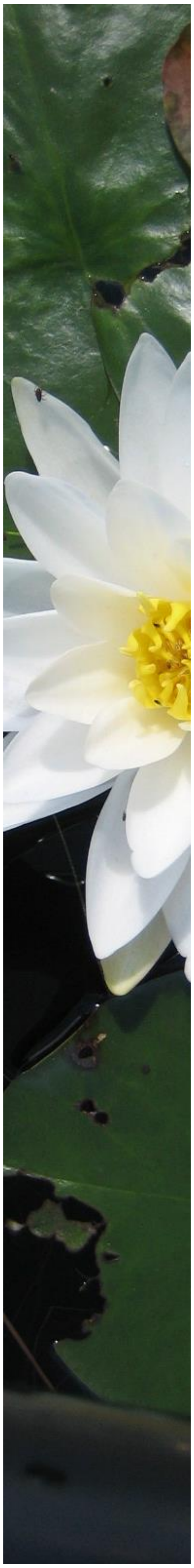
- Natural processes affecting water quality within the Kezar Lake watershed were relatively stable until the Europeans arrived in the 1800's.
- The Europeans logged forests, plowed fields, raised farm animals, trapped beavers, and built roads, resulting in significant changes to the landscape.
- The Industrial Age added other stressors and pollutants, such as acid rain, heavy metals from the burning of fossil fuels, chemicals from fertilizers and other uses, and high-powered boats that create wakes and disturb bottom sediments.
- The synergistic effect of human activities and rising temperatures due to climate change is having a measurable impact on our environment.

MAJOR STUDY FINDINGS

- Between A.D. 2000-2015, the sediment accumulation rate and organic content of both the deep spot of Kezar Lake and the area near Great Brook increased dramatically, likely the result of intensified watershed runoff and erosion due to climate change effects of more frequent and more violent storms. This recent intensification of larger-scale flood and erosion events caused a notable increase in particle-size and decrease in aluminum concentrations in lake bottom sediments at both sites.
    - **An alternative hypothesis for the increase in organic content in Kezar Lake may be enhanced soil organic matter solubility following recovery from acid rain deposition. Studies of acid-sensitive lakes in the northeast show increasing in-lake dissolved organic carbon (DOC) concentrations with decreasing sulfate deposition. DOC serves as an energy source for microbes, which may also help explain the observed change in sediment-core algal community composition since 2008. This theory is complicated by DOC's other abilities to bind with trace metals, such as Al, and photodegrade in surface waters (releasing Al to settle on lake bottom).**
- Preliminary diatom results indicate that a marked change in algal composition accompanied the increase in sediment accumulation rates after 2008. This supports the idea that the lake is not currently as stable as it was just a decade ago.
- The particle-size record at the deep spot of Kezar Lake suggests that no large-scale events have occurred in the Kezar Lake watershed since the large hurricanes in the 1600's, despite forest clearances in the 1800's and fires in the 1930's. The Great Brook core record showed the influence of many smaller-scale events that are most likely associated with minor flood events.
- The deep spot of Kezar Lake showed a steady rise in lead and zinc from the burning of coal and gasoline since the 1800's, then a sharp decline in the 1970's after the ban of leaded gas.

The Great Brook core record did not show as sharp a decline in lead and zinc as at the deep spot, which may indicate a continued source of heavy metal contamination from dredged or disturbed lake sediments with legacy contamination.


Sediment core collection in June 2015 (left) and February 2015 (right). Photo Credit: KLWA.



Aquatic Plants

Warming water temperatures, longer growing seasons, and changing precipitation patterns will cause shifts in the extent and abundance of native aquatic plant species. Many aquatic plant species that thrive under cooler conditions will die out, giving opportunity for southern plant species to take root. This will cause a gradual change in aquatic plant species composition and distribution within the lake and ponds. Different aquatic plant species have varying levels of nutrient and water needs, a change in which will alter cycling dynamics within the lake and ponds. An immediate threat to Kezar Lake is the invasion of non-native plants that can outcompete native plants. This threat is being addressed by the Lovell Invasive Plant Prevention Committee (LIPPC). A list of aquatic plants native to waterbodies within the Kezar Lake watershed was compiled using data collected by the Lake and Watershed Management Association from 2011-2015, as well as published survey reports funded by the LIPPC. Cushman Pond has already been invaded by variable-leaf milfoil and efforts to eradicate this invasive have taken place over the last 20 years.

Fish

Fish, especially land-locked salmon, are a keystone species for the Kezar Lake fishing community, who have relied on abundant populations of coldwater fish for their recreational enjoyment. These coldwater fish species are extremely sensitive to changes in water temperature and chemistry. Coldwater fish will seek cold, deep areas of lakes, ponds, and streams to avoid warm surface waters in late summer. This can be problematic in productive lakes that have depleted oxygen in bottom waters, leaving little habitat for these fish species to survive. pH is particularly critical to fish species and other aquatic life as it affects their metabolic functioning and reproductive capacity. This is a concern for Kezar Lake and its ponds given the naturally-low buffering capacity of the soil and water in the watershed. Low-pH rain (4.3) will temporarily decrease the pH of surface waters, placing significant stress on aquatic organisms residing in those waters. If climate change enhances the frequency and duration of precipitation events, then sensitive fish populations may face high disturbance, low pH environments that may be fatal. Because of this, fish can be a good indicator of climate change and should be monitored.

Aquatic Birds

Warmer air temperatures, variable precipitation patterns, and changes in vegetation will very likely reduce the abundance and diversity of aquatic bird species, including the iconic common loon. Earlier snowmelt means changes in seasonal duration and timing, which greatly impacts life cycles, including growth and survival rates of loons and other bird species. Monitoring these populations will help assess the effects of climate change on native species in the watershed.

Maine Audubon is partnering with the University of Maine to increase loon observations

Water Lily. Photo Credit: Don Griggs.

and track changes in hatching and maturation times. Since it is possible that observations may underestimate the true number of loons, a pilot detectability study will also be conducted to determine if the results represent actual number of loons in the survey area. Loon counts are done on a specific day, and the observers record the adults and chicks seen in their count area for a half hour period in the morning, which may miss the count of known loons in the area.

Overall, the adult loon population at Kezar Lake has been constant with some annual changes in the last 30 years (Fig. 1). The chick population shows a statistically-significant, but slight decline (based on Mann Kendall Trend Test) over the observation period. This could be an artificial decline because the chicks were not visible during the count period or an actual decline because chicks are being killed by eagles. Over 29 years of observations show an increase in eagle nesting population at Kezar Lake. Several eagle attacks on chicks have been observed over the last few years; most attacks were unsuccessful, but at least two did capture a chick.

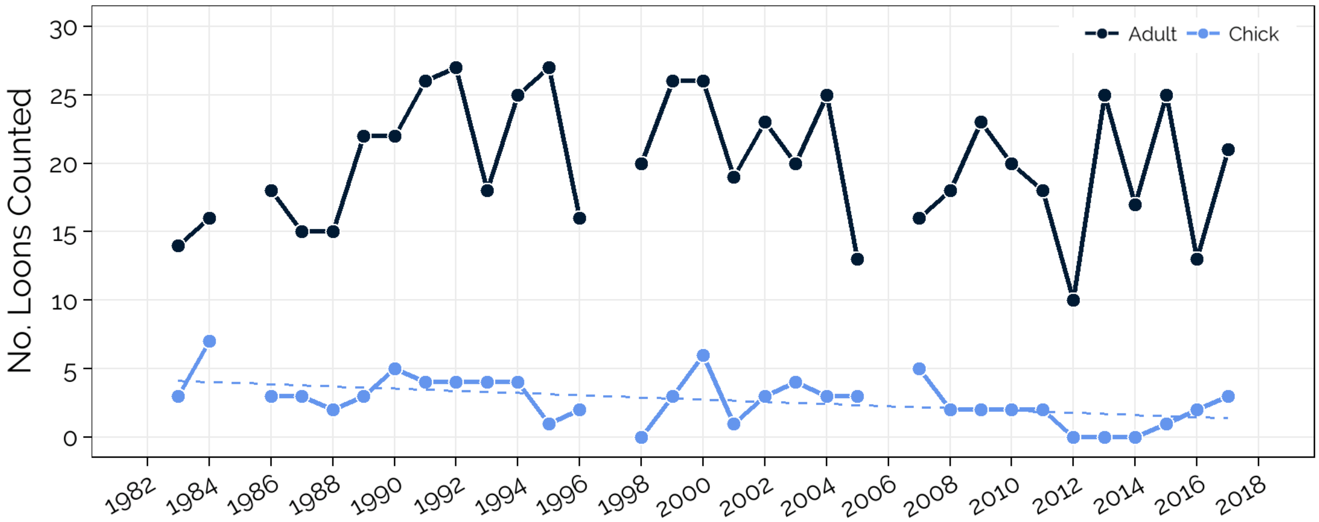


Fig. 1. Annual loon counts for adult and chick populations observed at Kezar Lake from 1983-2016.

Loon on Kezar Lake. Photo Credit: Conary.

The ponds have a much sparser data set:

- Based on 14 non-consecutive years of observations, Horseshoe Pond hosts an annual chick population varying from zero to three, and Farrington Pond hosts a few adult loons with only two chicks seen in 2016.
- Based on 18 non-consecutive years of observations, Heald Pond hosts an annual adult population varying from zero to three. The first and only chick was documented in 2015.
- Based on 29 years of non-consecutive observations, Cushman Pond hosts an annual adult population varying from zero to three. The first and only two chicks were documented in 2011.
- Based on 10 non-consecutive years of observations, Trout Pond hosts an annual adult population varying from zero to two. The first and only two chicks were documented in 2017.
- No surveys have been done on Bradley Pond.

Estimation of loon population in southern Maine conducted by the Maine Audubon show an increase in loon population despite climate change impacts. The study suggests that if lakes are clear, the food supply is abundant, and any adverse human impacts are avoided, the loon population will likely remain stable and/or increase.

In 2017, the CCO in collaboration with KLWA's Fisheries and Loon Committee embarked on an ambitious grant request to develop an inventory of the Common Loon within the watershed. Having recovered in part from lead and mercury exposure over the last few decades, loons and their breeding habitats are now threatened by climate change. With generous support from the Stephen and Tabitha King Foundation, our goal is to conduct a multi-year study of breeding pairs, nesting success, and chick survival. Our first two successful loon bandings occurred in summer 2017 and kicked off the study, which is of great interest to local and seasonal residents on our lake and ponds.

Fish survey on Great Brook in 2017. Photo credit: Don Griggs.

SPECIAL REPORT: Climate Change Impact on Loons

Mark A. Pokras, DVM, *Associate Professor Emeritus, Wildlife Clinic & Center for Conservation Medicine, Cummings School of Veterinary Medicine, Tufts University*

Climate change is likely to impact the well-being of our loons, sooner or later. Dr. Mark Pokras, who consulted on our loon study, has offered some observations on how loons are likely to be impacted by variations in ambient air temperature and increased pathogens because of climate change.

Dr. Pokras is concerned about our loons' ability to tolerate higher air temperatures. On water, loons can dilate blood vessels on their feet and dump excess body heat into the water, but on land during nesting, loons, chicks, and developing eggs become less tolerant of or adaptive to elevated air temperatures. Adult loons have thick, insulating plumage that allows them to stay warm in icy lake waters in early spring and frigid oceans in winter, but that may become too much insulation when sitting on nests out of water in warmer summer months. Loons can erect their feathers, alter posture, or vasodilate the vessels in their foot webbing to try to dissipate some heat when on land, but observers have noticed more adult loons on nests vigorously panting to try to cool themselves. If adult loons leave their nests to cool off in the water, this leaves the developing eggs more susceptible to predators and overheating (especially with their dark shells).

Successful incubation and hatching of eggs must occur within a narrow range of temperature and humidity so that the developing eggs can breathe and metabolize. Gas and water vapor must be able to move back and forth through the eggshell and shell membranes to support adequate respiration, growth, and development of the embryo. The size and number of microscopic pores in eggshells that allow this diffusion of gases are specifically adapted to the loons' metabolic needs and determine the preferred range of temperature and humidity for loon egg incubation. Environmental contaminants that bioaccumulate in adult loons can alter egg properties, such as the size and number of pores or the thickness of shells, and lead to embryonic death. Increasing air temperatures can speed up embryo metabolism needs, triggering increased rates of gas and water vapor diffusion through the eggshell. If increased metabolic needs outstrip the permeable capacity of the eggshells, developing embryos will die. If air temperatures increase too quickly for a species to evolve, then we might expect more embryonic deaths, most likely late in development. For example, for some ducks and geese, optimal incubation temperature is around 37.7 °C with 50-55% humidity. Air temperatures just a couple of degrees higher can kill embryos in 15-30 minutes, depending on the species and stage of development.

Changes in air temperatures and moisture can also increase the potential for infectious diseases and parasites. Several studies support the observation that southern pathogens and parasites, some of which carry diseases, are moving north into new territory. Mosquitoes, biting flies, and ticks are most prone to migrate and spread diseases. In recent years, a significant increase in the incidence of avian malarial parasites in loons (with one direct mortality) and thorny-headed worms (*Acanthocephala)* have been documented. Preliminary evidence shows that fungal respiratory disease may be increasing in loons. The first case of a fatal fungal disease, *Cryptococcus*, was reported in New York. There is speculation that some parasites (like thorny-headed worms) are being carried in by invertebrate hosts introduced to New England lakes. These pathogenic risks to loons are still unknown but will likely have a significant impact on New England loon populations. We must be vigilant in keeping watch over the health of the loons and notify officials of any cases so that the spread of these pathogens and parasites can be tracked.

Zooplankton

Zooplankton play an important role in a lake's ecosystem and are useful indicators of food web stability. As microscopic animals that consume phytoplankton, zooplankton serve as a valuable food source for fish. KLWA supported a study of zooplankton in Kezar Lake from 2004-2007, the results of which were published in a 2008 article titled, "Cladoceran and copepod zooplankton abundance and body size in Kezar Lake, Maine (MIDAS 0097)" by Nichole M. Cousins and Katherine E. Webster from the School of Biology and Ecology at the University of Maine, Orono. The results of the study show that the zooplankton population in Kezar Lake was consistent during the sampling period and can be used as a baseline for future studies. The CCO supports future zooplankton studies to assess long-term trends in zooplankton population because of climate change or other environmental stressors.

Crayfish

KLWA supported a brief study of crayfish in Kezar Lake in August-September 2008. The study was conducted by Dr. Karen Wilson at the University of Southern Maine. The study found three native species and caught a total of 29 crayfish, which were mostly found around rocky islands. The spatial and temporal sample size were too small to gain any significant conclusions on population size, species composition, or size trends. No evidence of invasive crayfish was found. Anecdotal evidence suggests that the crayfish population has declined in Kezar Lake. The CCO supports a new, more comprehensive, crayfish study in the future.

Pathogens

Warmer water temperatures, along with increased population growth, will increase the risk of aquatic pathogens, including bacteria, protozoa, and parasites. While it is difficult to control the spread of these pathogens due to climate change, we can make sure proper waste disposal techniques are used for all existing and future development in the watershed and along the shoreline of Kezar Lake and its ponds.

LAND

Climate affects the abundance, extent, and diversity of all life on the planet – plants and trees, birds, mammals, and insects and pathogens. As the climate changes, terrestrial species will need to adapt to or move from these changing environments. Two-thirds of Maine's animal and plant species are predicted to be at risk from climate stress. We can watch for change in these populations as indicators of climate change. The CCO intends to collaborate with existing phenology networks across the country to better understand the periodic plant and animal life cycle events and how these are influenced by seasonal and interannual variations in climate, as well as habitat factors.

An outstanding, detailed climate change vulnerability assessment of Maine's wildlife species of greatest conservation need has been published by the Manomet Center for Conservation Sciences, titled *Climate Change and Biodiversity in Maine: Vulnerability of Habitats and Priority Species*[3]. This will serve as an excellent resource for the CCO as we formulate adaptation strategies.

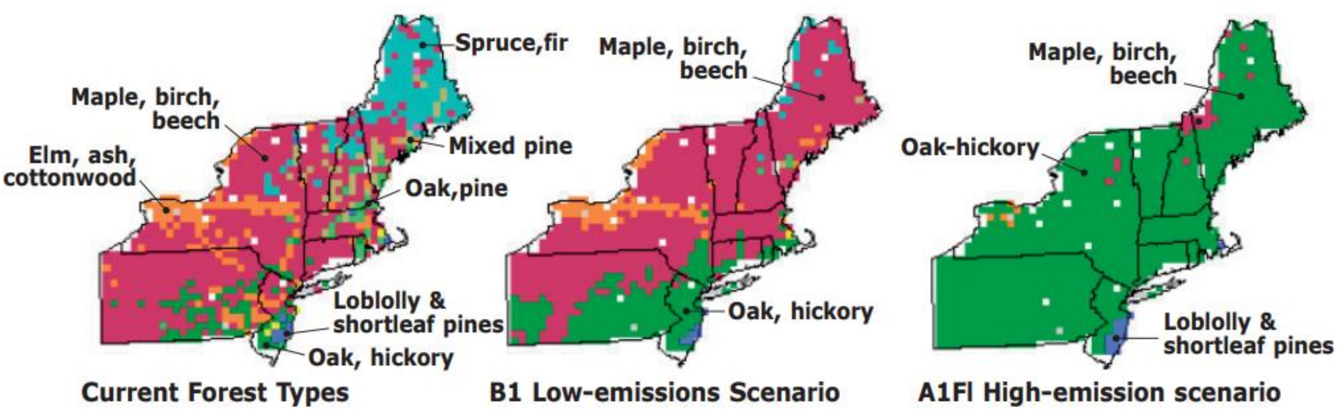
[3] https://www.manomet.org/sites/default/files/publications_and_tools/2013%20BwH%20Vulnerability%20Report%20CS5v7_0.pdf

Plants & Trees

Earlier and warmer summers will lengthen the growing season, but potentially more days above 90 degrees and variable precipitation patterns may mitigate any benefits for farming in the region. Watermelon, tomatoes, peppers, peaches, and others will benefit from higher air temperatures, but corn, wheat, and oats will have lower yields. Cabbage, potato, apples, blueberries, and winter wheat that need cool weather and cold winters will also decline. Flowering, fruit set, and seed production will decline in many species due to loss of pollinators.

Tree canopy. Photo Credit: Jose Azel.

Warming air temperatures and changing precipitation patterns will cause shifts in the geographic extent of native plant and tree species in the area. Many plant and tree species that thrive under cooler, drier conditions will die out, giving opportunity for southern plant and tree species to take root. This will cause a gradual change in plant and tree species composition and distribution within the watershed. For example, spruce and fir will move farther north and to higher elevations. The sap season for maples will come earlier and sugar maples may be restricted to northern Maine. Different plant and tree species have varying levels of nutrient and water needs, a change in which will alter ecosystem cycling dynamics.



Adapted from Rustad et al. (2014), Figure 7. **Current and projected suitable habitat for major forest types in New England under low and high emissions scenarios. Under the low emissions scenario, conditions will favor maple-birch-beech forests, while under the high emissions scenario, conditions will favor oak-hickory forests. Kezar Lake watershed is currently in an area dominated by mixed pine, oak-pine, and maple-birch-beech. This will transition to maple-birch-beech and oak-hickory under various climate change scenarios.**

University of Maine studies over the last 30 years show that, due to increased temperatures and precipitation, the abundance of beech trees have increased in abundance at the expense of birch and maple in the forests of the northeast, notably in the White Mountains, echoing other work that environmental changes are squeezing out important tree species. Beech, often used for firewood, is a less valuable a commodity than hardwoods used for furniture and flooring.

Joshua Halman, a Forest Health Specialist with the Vermont Department of Forest, Parks and Recreation, has been monitoring trees in Underhill State Park for 25 years by recording color change and leaf drop. These data show that the timing of peak color and leaf drop have come later in the season by about eight days in the last 25 years. Comparable data are not available for Lovell; however, Underhill State Park is at approximately the same latitude, and therefore, can be extrapolated as relevant to the White Mountain National Forest and the Kezar Lake watershed.

In 2004, a survey was undertaken to document non-native and invasive species on all GLLT-owned properties. Surveys documented the presence of non-native species sheep sorrel (*Rumex acetosella*) and coltsfoot (*Tussilago farfara*). While some might consider these plants to be invasive, they are not often targeted for management efforts. Later that year, GLLT conducted surveys in the town targeting areas where invasive plants would most likely occur, such as power lines, roadsides, logging roads, informal camping spots, playing fields, and disturbed areas. Japanese knotweed (*Fallopia japonica*), sheep sorrel, coltsfoot, black locust (*Robinia pseudoacacia*), and non-native honeysuckle (*Lonicera sp.*) were detected during these surveys. Of all observed non-native plants, Japanese knotweed was observed to be the most pervasive. GLLT also surveyed 12 private properties, which revealed the presence of additional non-native invasive plants, including Japanese barberry (*Berberis thunbergii*), non-native honeysuckle, autumn olive (*Elaeagnus umbellata*), asiatic bittersweet (*Celastrus orbiculatus*), and purple loosestrife (*Lythrum salicaria*). Anecdotally, Tom Henderson of GLLT reports that an infestation of purple loosestrife was also found on a member's property, but was eradicated. Other non-native, invasive plant species known to occur in neighboring towns include glossy false buckthorn (*Frangula alnus*) and yellow iris (*Iris pseudacorus*).

Birds

Bird counts and movements can be monitored easily and can serve as an indicator of climate change. Changes in air temperatures and precipitation amounts can shift habitat ranges and limit mating and nesting seasons. Late spring storms can kill migrating birds and cause behavioral shifts. Available food sources can change, forcing birds to find new suitable habitat. Birds in the Kezar Lake watershed that are most likely to decline due to climate change include the Black-capped Chickadee (Maine State Bird), Evening Grosbeak, Ruffed Grouse, Wood Thrush, and all high-elevation species. Birds that may increase or move into Maine include the Tufted Titmouse, Canada Goose, House Finch, Brown-headed Nuthatch, and Loggerhead Shrike.

Long-term (1966-2010) and short-term (2000-2010) population trends based on data from the North American Breeding Bird Survey for 5 songbird species in Maine (and likely within the Kezar Lake watershed) showed two species declining (Barn swallow and Bobolink), one species stable (Ovenbird), and two species increasing (Northern Cardinal and Tufted titmouse). Under the high emissions scenario, western Maine is projected to show a net increase in bird species richness as a warming climate allows southern species to invade (Rustad et.al. (2014).

Mammals, Reptiles, and Amphibians

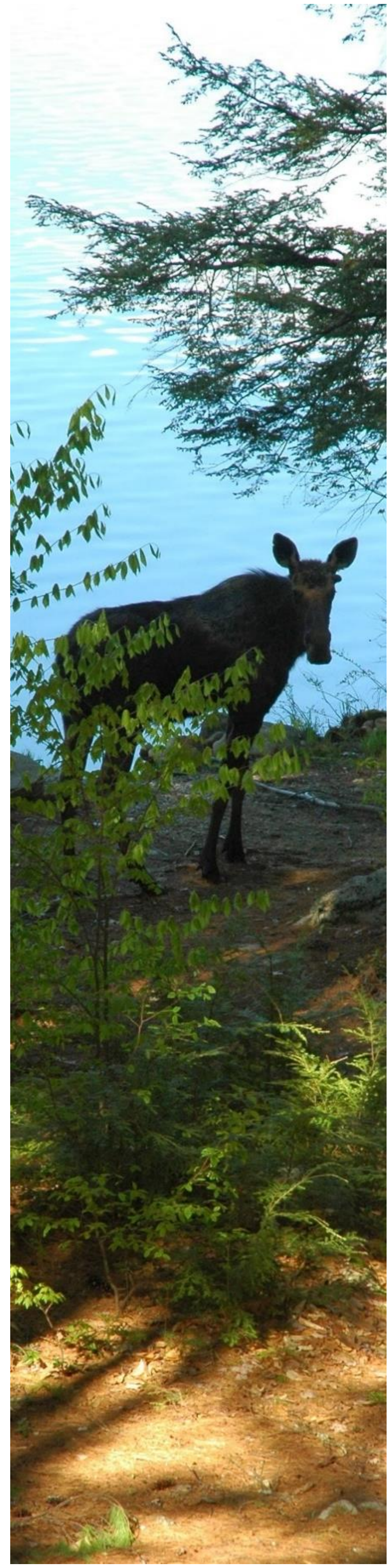
Moose are an iconic mammal in Maine and a local inhabitant of the Kezar Lake watershed. This iconic species is vulnerable to heat stress and ticks that proliferate following mild winters. Moose studies have shown that ticks are killing 70% of calves in Maine and New Hampshire due to mild winters. The observed decline of moose in Maine from disease or migration north is a clear signal of climate change.

Attempts by the KLWA to find detailed information on historical moose populations in Lovell were not successful (this included an evaluation of the Statewide permit and harvest data). The last estimate of moose population was in 2012 when the State of Maine reported a population of 76,000. While hunting permit numbers are not linearly related to the total population, Maine Inland Fisheries and Wildlife (MIFW) reports moose harvests by individual towns. Very few moose harvests have been recorded in Lovell with the maximum in 2009 at only two individuals. Moose are also unevenly distributed throughout the State and primarily occupy the commercial forestlands in northern Maine. The State division that includes Lovell (Division 15) receives 25 permits per year and reports approximately a 50% success rate (ranging from 24% - 60% historically).

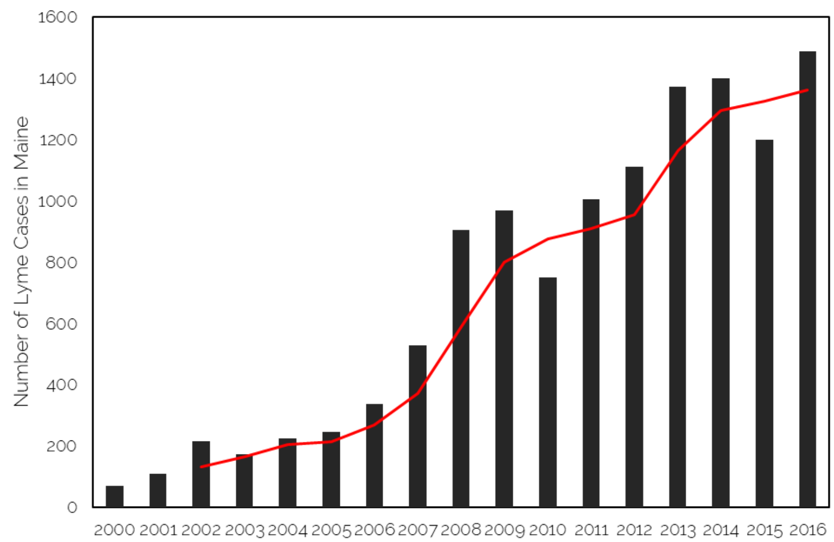
Detailed Statewide information is needed to make assessments of the moose population in Lovell. Unfortunately, data on other mammals, such as bear, deer, and wild turkey are also limited. Generally, bat populations are declining from white nose syndrome (some areas like Vermont by as much as 90% in the last decade). MIFW has more information regarding these mammals on their website.

Insects & Pathogens

The movement of warmer and wet weather pests into New England are a signal of climate change. Migratory insects will arrive earlier with earlier snowmelt and rising air temperatures, and insects only marginally-adapted to the region will begin to invade as the climate warms. Increases in balsam woolly adelgid, spruce budworm, Beech bark disease, and winter moth will adversely affect tree populations. Inadequate winter chill will adversely affect agriculture by increasing populations of insects and disease, including flea beetle and Steward's wilt. Wetter conditions will increase the likelihood of white pine needle disease caused by pathogenic fungi.



Moose in Kezar Lake watershed. Photo Credit: KLWA.



The number of Lyme disease cases in Maine is rising. Data were obtained from the Centers for Disease Control and Prevention (CDC).

The Maine Center for Disease Control and Prevention (Maine CDC) data shows that the number of reported Lyme disease cases in Maine is increasing. This increase in reported cases is likely due to a combination of climate-induced factors. Warming air temperatures (especially in winter), more precipitation, a longer growing season, and a proliferation of their primary hosts (mice, chipmunks, and other small mammals) are promoting the northern migration of and thus increasing populations of disease-carrying ticks in the State. Although deer, moose, and other large mammals are also hosts to ticks, small mammals are considered their primary hosts and generate a far greater threat to humans because small mammals live closer to where we live, work, and play.

Deer ticks carrying Lyme disease can be found in wooded areas or open, grassy areas, especially along the edges of forests. To best control tick populations around your property, clear brush and leaves and deter deer, mice, and chipmunks. Be vigilant in checking for ticks and seek immediate medical help if you were bitten by a deer tick. Lyme disease can be easily treated with antibiotics, but if left untreated, can cause severe illness, arthritis and neurological problems.

There are several other tick-borne diseases that threaten public health and may increase with a changing climate. These include anaplasmosis, babesiosis, ehrilichiosis, powassan virus, spotted fever rickettsiosis, as well as other less common diseases. Each of these has shown an increase over the years, especially anaplasmosis.

For more information on prevention and treatment, please visit https://www.cdc.gov/ticks and http://www.maine.gov/dacf/php/gotpests/bugs/ticks.htm.

CLIMATE CHANGE REFERENCES

The following table provides references to key documents related to climate change. The subsequent table contains links to important climate change websites that are applicable to the Kezar Lake CCO.

ARTICLE TITLE	DATE	DESCRIPTION	LINK
EPA Climate Change Indicators in the US	2016	Communicates information on the science and impacts of climate change, assesses trends in environmental quality, and informs decision-making	https://www.epa.gov/sites/production/files/2016-08/documents/climate_indicators_2016.pdf
Maine's Climate Future	2015	Assessment of climate change and key indicators in Maine	http://cci.siteturbine.com/uploaded_files/climatechange.umaine.edu/files/MainesClimateFuture_2015_Update2.pdf
Climate Change in Southern New Hampshire	2014	Describes how the climate of southern NH has changed over the past century and how the future climate of the region will be affected by a warmer plant due to human activities	https://sustainableunh.unh.edu/sites/sustainableunh.unh.edu/files/images/southernnhclimateassessment2014.pdf
Climate Change and Biodiversity in Maine: Vulnerability of Habitats and Priority Species	2014	Summarizes a climate change vulnerability assessment of Maine's wildlife Species of Greatest Conservation Need, state-listed Threatened or Endangered plant species, and Key Habitats of the Maine Comprehensive Wildlife Conservation Strategy	https://www.manomet.org/sites/default/files/publications_and_tools/2013%20BwH%20Vulnerability%20Report%20CS5v7_0.pdf
IPCC Climate Change 2014 Synthesis Report	2014	Observed changes and their causes; Future climate change, risks and impacts; Future pathways for adaptation, mitigation and sustainable development	https://www.ipcc.ch/report/ar5/syr/
Climate Change Profound Impacts on Lakes in Europe	2014	Coldwater fish species such as trout and whitefish are declining dramatically due to climate warming and nutrient enrichment	http://voices.nationalgeographic.com/2014/07/21/climate-change-already-having-profound-impacts-on-lakes-in-europe/

ARTICLE TITLE	DATE	DESCRIPTION	LINK
Lakes as Sentinels of Climate Change	2014	Lakes are effective sentinels for climate change because they are sensitive to climate, respond rapidly to change, and integrate information about changes in the catchment	http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2854826/
Lakeshore & Rivershore Climate Assessment	2013	Strategies to address vulnerabilities	http://extension.unh.edu/resources/files/Resource004598_Rep6566.pdf
Lake Ice	2013	Ice formation and breakup dates are relevant indicators of climate change	http://www.epa.gov/climatechange/pdfs/lake-ice_documentation.pdf
Evolutionary and plastic responses of freshwater invertebrates to climate change: realized patterns and future potential	2013	Temperature increase and associated ecological challenges such as changes in predation rates	http://onlinelibrary.wiley.com/doi/10.1111/eva.12108/epdf
Warming Lakes: Effects of Climate Change seen on Lake Tahoe	2012	Extended lake stratification season is a concern for water quality	http://voices.nationalgeographic.com/2012/10/17/warming-lakes-effects-of-climate-change-seen-on-lake-tahoe/
Allied attack: climate change and eutrophication	2011	Global warming and eutrophication in fresh and coastal waters may mutually reinforce the symptoms they express and thus the problems they cause	https://www.fba.org.uk/journals/index.php/IW/article/viewFile/359/263
Climate Change and Vermont's Waters	2011	Flooding, water quality, dissolved oxygen, drought; short term mitigation options	http://www.anr.state.vt.us/anr/climatechange/Pubs/AdaptationWP_ClimateChangeandWaterReources.pdf
People and Nature Adapting to a Changing Climate: Charting Maine's Course	2010	Discusses the impacts of climate change on Maine communities and suggests that early planning and adaptive actions are likely to be cost effective.	http://www.maine.gov/dacf/municipalplanning/docs/People%20and%20Nature%20Adapting%20to%20Climate%20Change.pdf

ARTICLE TITLE	DATE	DESCRIPTION	LINK
Sensitivity of future ozone concentrations in the Northeast U.S. to regional climate change	2008	NE predictions: warmer/less cloudy summers, increased biogenic emissions, and increased ozone concentrations	http://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/pdf/miti/kunkel_et_al.pdf
Emissions Mitigation Opportunities and Practice in Northeastern United States	2008	Emission reductions in NE, with a 3% reduction recommended with individuals choosing personal BMPS and technologies; action vs inaction debated as well	http://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/pdf/miti/moomaw_and_johnston.pdf
Adaptation to Climate Change in the Northeast United States: Opportunities, Processes, Constraint	2008	How to plan for climate change	http://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/pdf/miti/moser_et_al.pdf
Potential Effects of Climate Change and Rising CO2 on Ecosystem Processes in Northeastern U.S. Forests	2008	A look into the range of possible outcomes under different warming scenarios.; factors of interest: forest growth, carbon exchange, water runoff, nitrate leaching, etc.	http://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/pdf/miti/ollinger_et_al.pdf
Confronting Climate Change in the US Northeast	2007	The Northeast Climate Impacts Assessment (NECIA) is a collaborative effort between the Union of Concerned Scientists (UCS) and a team of independent experts to develop and communicate a new assessment of climate change and associated impacts on key climate-sensitive sectors in the northeastern United States	http://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/pdf/confronting-climate-change-in-the-u-s-northeast.pdf
A Shoreland Homeowner's Guide to Stormwater Management	-	Cost effective options for Best Management Practices to mitigate stormwater runoff	http://nhlakes.mylaketown.com/uploads/tinymce/nhlakes/Stormwater%20Guides/HomeownersStormwaterGuide.pdf

FUTURE PLANS

CCO plans for 2018 include the following activities:

- Continue to develop and expand the climate change portion of the KLWA website to include more trend data, especially information on parameters for climatology, flora, and fauna. Continue to improve the easy public access to climate change data and trends for the Kezar Lake watershed.
- Continue to participate in water quality monitoring of the lake, ponds, and streams.
- Further expand the sediment core dating and analysis to include diatom analysis.
- Continue to collect and archive year-round local weather data and provide webcam views of the lake and land conditions as a service to the community.
- Expand our collaboration with other organizations involved with climate change monitoring and analysis.
- Continue to research and gather data pertinent to climate change in the watershed.

SUMMARY & RECOMMENDATIONS

Climate change is a real and imminent threat to our local, regional, and global ecosystems, most especially our treasured lakes. Lakes are recognized as "sentinels of climate change" because their physical, chemical, and biological responses to climate change can provide the first signal of the effects of climate change. In New England, we can expect warmer air temperatures, more intense and frequent precipitation events, increased flooding, reduced snow cover duration, enhanced species migration and extirpation (including increased prevalence of disease-carrying ticks), and earlier lake ice-out. In reaction to these predications, a Climate Change Observatory (CCO) was established with the objective to analyze the long-term effects of climate change on atmospheric, aquatic, and terrestrial ecosystems in the Kezar Lake watershed.

The CCO has accomplished a great deal since its establishment in 2013. To continue this vitally important work, the following adaptation and mitigation strategies are recommended for the Kezar Lake watershed community. Both adaptation (i.e., changing behavior/actions in response to the impacts of climate change) and mitigation (changing behavior/actions to reduce the causes of climate change) strategies are needed to effectively address climate change.

ADAPTATION & MITIGATION RECOMMENDATIONS

ACTIONS FOR THE TOWN OF LOVELL

⊕ Improve infrastructure (roads, ditches, swales, culverts) to accommodate higher and more frequent stormwater flow volumes.

⊕ Replace the remaining high priority culverts identified by the 2015 culvert study.

⊕ Establish a Climate Change Information link on the town website that links residents to important climate change information and the KLWA/CCO webpages.

⊕ In developing the next Comprehensive Plan: 1) include provisions to deal with projected climate change-induced weather events and conditions (e.g., upgrading infrastructure); 2) include language that ensures development occurs in a sustainable and low-impact way to increase watershed resiliency to extreme weather events and prevent potential polluted runoff; 3) include current and projected flood risk maps for residents with homes in low-lying areas; 4) consider rezoning the projected flood zone for non-development; 5) add Low Impact Development (LID) description to ordinance and require LID in site design, especially for lots with >20% imperviousness; 6) increase setback distances to at least 100 ft. around vernal pools, streams, and wetlands; and 7) encourage conservation subdivisions, where applicable, with common open space and require land trusts or conservation organizations (not homeowner's associations) to undertake stewardship of common open space in conservation subdivisions.

- Review and update local septic ordinances to include the following: 1) require septic systems to be evaluated and upgraded to current code or replaced, as needed, for any sale or exchange of property ownership or upon a system failure; 2) require proof of septic system pump-outs every 3 years (unless given an approved waiver for limited use).
- Conduct a shoreline survey of properties on Kezar Lake and ponds to identify conduits of stormwater runoff (e.g., driveways, boat ramps) and develop specific recommendations for mitigation of erosion.
- Continue the outstanding progressive watch programs that help prevent and control invasive plants.
- Post signage to encourage anglers to use non-lead sinkers and to retrieve fishing line caught in shoreline vegetation. Install "Get the Lead Out" boxes at Town landings for disposing of lead-based fishing gear. Keep at least 200-foot distance from loons and their nest.

ACTIONS FOR KLWA

- Target stormwater management and septic system maintenance outreach to shorefront and riverfront residents.
- Advocate and publicize the merits of achieving LakeSmart certification through the State of Maine.
- Advocate and publicize the specific recommendations for sustainable lake shore living in the KLWA's Lake Dweller's Handbook.
- Conduct another alkalinity and pH study to better assess the vulnerability of waterbodies to acid rain and watershed activities across years.
- Continue monitoring stream conditions for supporting coldwater fish species (e.g., temperature, flow, and population size). This will help target streams in need of restoration. Restoration techniques include increasing overhead vegetative cover to help cool stream water temperatures.
- Petition IF&W to make Kezar Lake catch and release only for certain sensitive fish species. Debar all fish hooks and ensure proper fishing line strength to avoid fish injury and entanglement.
- Contact the Maine Center for Disease Control and Prevention to determine how public notices will be issued during peak tick and mosquito season to warn residents of potential diseases, including Lyme and follow-up to see that people in Lovell receive these notices.

ACTIONS FOR GREATER LOVELL LAND TRUST

- Continue to conserve and protect land areas that serve as wildlife corridors.

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APPENDIX A

Anoxic Factor: a method that summarizes individual dissolved oxygen profiles as annual values that represent the extent and duration of anoxia (depth at which dissolved oxygen falls below 2 ppm) in lakes and ponds. This method normalizes complex, 2-dimensional data into a single factor that can be used to assess within-lake changes over time or compare among other waterbodies. Waterbodies can reach "tipping points," when the extent and duration of anoxia in late summer increases to a point when major ecological changes take root (e.g., algal blooms).

Chlorophyll-a (Chl-a): A measurement of the green pigment found in all plants, including microscopic plants like algae. It is used as an estimate of algal biomass; higher Chl-a equates to greater amount of algae in the lake.

Color: The influence of suspended and dissolved particles in the water as measured by Platinum Cobalt Units (PCU). A variety of sources contribute to the types and amount of suspended material in lake water, including weathered geologic material, vegetation cover, and land use activity. Colored lakes (>25 PCU) can have reduced transparency readings and increased total phosphorus concentrations. When lakes are highly colored, the best indicator of algal growth is chlorophyll-a.

Dissolved Oxygen: The concentration of oxygen that is dissolved in the water. DO is critical to the healthy metabolism of many creatures that reside in the water. DO levels in lake water are influenced by a number of factors, including water temperature, concentration of algae and other plants in the water, and amount of nutrients and organic matter that flow into the waterbody from the watershed. Too little oxygen severely reduces the diversity and abundance of aquatic communities. DO concentrations may change dramatically with lake depth. Oxygen is produced in the top portion of a lake (where sunlight drives photosynthesis), and oxygen is consumed near the bottom of a lake (where organic matter accumulates and decomposes).

Epilimnion: The top layer of lake water that is directly affected by seasonal air temperature and wind. This layer is well oxygenated by wind and wave action, except when the lake is covered by ice.

Escherichia coli (E. coli): An indicator of the presence of fecal contamination in the water.

Eutrophication: Refers to lakes with high productivity, high levels of phosphorus and chlorophyll-a, low Secchi disk readings, and abundant biomass with significant accumulation of organic matter on the bottom. Eutrophic lakes are susceptible to algal blooms and oxygen depletion in the hypolimnion.

Integrated Epilimnetic Core: A water sample that is collected with a long tube extending from the surface of the lake to the upper part of the thermocline to determine average nutrient concentration in the epilimnion.

MIDAS: unique four-digit identification code for each Maine lake.

pH: The standard measure of the acidity of a solution on a scale of 0-14. Most aquatic species require a pH between 6.5 and 8. As the pH of a lake declines, particularly below 6, the reproductive capacity of fish populations can be greatly impacted as the availability of nutrients and metals changes. pH is influenced by bedrock, acid rain or snow deposition, wastewater discharge, and natural carbon dioxide fluctuations.

Platinum Cobalt Units (PCU): A unit of measurement used to determine the color of lake water. Lake water with 30 PCU will look slightly brown or tea-colored (formerly reported as SPU - Standard Platinum Units).

Sample Station: Location where water quality readings and samples are taken. Some of the larger lakes or basins are sampled at more than one location, resulting in multiple station numbers. In lakes with more than one basin, at least one station is usually located in each basin.

Water Clarity: A vertical measure of water transparency (ability of light to penetrate water) obtained by lowering a black and white disk into the water until it is no longer visible (a.k.a., Secchi disk transparency). Measuring water clarity is one of the most useful ways to show whether a lake is changing from year to year. Changes in transparency may be due to increased or decreased algal growth, or the amount of dissolved or particulate materials in a lake, resulting from human disturbance or other impacts to the lake watershed area. Factors that affect transparency include algae, water color, and suspended sediment. Since algae are usually the most common factor, transparency is an indirect measure of algal populations.

Thermocline: The markedly cooler, dynamic middle layer of rapidly changing water temperature. The of this layer is distinguished by at least a degree Celsius change per meter of depth.

Total Alkalinity: A measure of the buffering capacity of a lake, or the capacity of water to neutralize acids. It is a measure of naturally-available bicarbonate, carbonate, and hydroxide ions in the water, which is largely determined by the geology of soils and rocks surrounding the lake. Alkalinity is important to aquatic life because it buffers against changes in pH that could have dire effects on animals and plants.

Total Phosphorus (TP): The total concentration of phosphorus found in the water, including organic and inorganic forms. TP is one of the major nutrients needed for plant growth, and is generally present in small amounts. Humans can add phosphorous to a lake through stormwater runoff, lawn or garden fertilizers, and leaky or poorly maintained wastewater disposal systems. Excess phosphorus can lead to increased plant and algae growth in lakes.

Trophic State Indicators: Indicators of biological productivity in lake ecosystems, including water clarity, total phosphorus, and chlorophyll-a. The combination of these parameters helps determine the extent and effect of eutrophication in lakes, and helps signal changes in lake water quality over time.

Watershed: An area of land that drains water to a point along or the outlet of a stream, river, or lake.