Kezar Lake

WATERSHED ASSOCIATION

P.O. Box 88, Lovell, ME 04051 www.klwa.us

CLIMATE CHANGE OBSERVATORY

2015 ANNUAL REPORT

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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, 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 six-member steering committee and is funded through a Sally Mead Hands Foundation grant, generous donations, and the KLWA General Fund. The formulation of the CCO was 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 first CCO Annual Report, which is published in early fall following the busy summer when climate change-related activities are at their peak. The purpose of this report is to summarize CCO activities for the past year and to make recommendations based on the analysis of climate change-induced annual trends for available data. These data were presented by major ecological zone: water, atmosphere, and land.

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

- **Developed climate change webpages** for the KLWA website (klwa.us) to showcase observed trends in several indicator categories, but most especially water quality.
- **Purchased 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.
- **Conducted a culvert survey** that identified 15 of 211 culverts as high priority for replacement.
- **Collected sediment core samples** for historical water quality analysis by Dr. Lisa Doner from Plymouth State University.
- **Hosted a graduate summer intern** that helped research and compile key climate change data for the CCO webpages.
- **Attended four major regional or national conferences** that enhanced CCO member knowledge of climate change and promoted CCO activities to the public.
- **Attended multiple meetings with project partners**, including the Town of Lovell and Plymouth State University.
- **Obtained grant funding** from the Sally Mead Hands Foundation 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 RECOMMENDATIONS
CLIMATE	
⊗ Increased air temperatures. ⊗ Fewer extreme cold days.	⊕ Incorporate climate change language in updated municipal comprehensive plans. ⊕ Prepare municipal climate change adaptation plans. ⊕ Adopt a citizen pledge to reduce carbon footprint. ⊕ Provide incentives (e.g., tax breaks) for homeowners that reduce carbon footprint. ⊕ Review and improve energy usage of municipal buildings.
⊗ More days with 1 inch rain events. ⊗ Decreased annual snowfall.	⊕ Improve infrastructure to accommodate higher and more frequent flow volumes. ⊕ Replace the 15 high priority culverts identified by the 2015 culvert study. ⊕ Expand culvert study to include private roads. ⊕ Create a funding and assessment plan to re-assess and replace culverts in the watershed on an ongoing basis. ⊕ Develop emergency management plans based on climate projections. Include current and projected flood risk maps for residents with homes in low-lying areas. Consider requiring septic system evaluations for all homes within the projected flood zone to assess potential for failure due to rising water tables. Consider rezoning the projected flood zone for non-development.
⊗ Earlier ice-out since 1972.	⊕ Encourage establishment of a "Climate Change Adaptation" webpage on the town website that directs residents to important climate change information and the CCO webpages. ⊕ Conduct bathymetry and topographic mapping of shoreline habitats and model the effects of changing lake levels on shoreline stability.
WATER	
⊗ Stable trends in total phosphorus, chlorophyll-a, pH, and color in all waterbodies; improving trends in water clarity at Kezar Lake.	⊕ Review and update local ordinances to include better site design, low impact development, and green infrastructure principles that limit the amount of phosphorus, nitrogen, sediment, and acidic waters from reaching waterbodies.
⊗ Degrading trends in alkalinity in multiple waterbodies.	⊕ Develop an alkalinity and pH study to assess the vulnerability of waterbodies to acid rain and watershed activities.

CLIMATE CHANGE THREAT	ADAPTATION RECOMMENDATIONS
⊗ Impacted water quality at Farrington and Heald Ponds.	⊕ Target stormwater management and septic system maintenance outreach to these pond residents.
⊗ Increase in anoxic factor at the upper bay and Cushman and Horseshoe Ponds.	⊕ Protect land to ensure that development occurs in a sustainable and low-impact way to increase watershed resiliency to extreme weather events and prevent potential polluted runoff.
⊗ Increased threat from invasive aquatic plants.	⊕ Continue progressive watch programs that help prevent and control invasive plants.
⊗ Reduction in coldwater fish populations and aquatic bird species.	⊕ Classify streams based on climate resiliency for supporting coldwater fish species. This will help target streams in need of restoration. Restoration techniques include increasing overhead vegetative cover to help cool stream water temperatures. ⊕ Encourage anglers to use non-lead sinkers by providing free samples.
⊗ Increased threat from aquatic pathogens, including bacteria, protozoa, and parasites.	⊕ Create a public notification system for swimming advisories following any instances of significant algal blooms when waters may be harmful to human health.
LAND	
⊗ Reduction in agricultural yield and plant diversity.	⊕ Develop homeowner brochure that recommends climate-hardy species and mitigation strategies for farmers and garden-enthusiasts. ⊕ Promote conservation tillage to farmers.
⊗ Shifts in the habitat ranges of native plant and bird species. ⊗ Decline in moose populations.	⊕ Conduct habitat and species-level vulnerability assessments. ⊕ Protect and restore riparian habitats by enhancing buffers that limit heat stress on species. ⊕ Develop a buffer ordinance that recommends permitted activities within buffer zone and establishes minimum buffer widths more stringent that State law. ⊕ Conserve and protect land areas that serve as wildlife corridors. ⊕ Complete a habitat analysis that prioritizes high value habitat for species most vulnerable to climate change.
⊗ Increased threat from insects and pathogens.	⊕ Disseminate public notices during peak tick and mosquito season. ⊕ Control outside firewood and other materials that potentially harbor invasive insects.

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.

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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
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** – providing historical climate data from sediment core sampling, and proving to be a source of highly-qualified graduate interns;
- **FB Environmental Associates** – provides technical advice, planning, and monitoring support for CCO activities.

CURRENT CCO ACTIVITIES (2014-2015)

The CCO has been very active during the past year from September 2014 to September 2015. 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 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 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.

CULVERT STUDY

As the magnitude and frequency of storm events change with climate change, it is especially important for municipalities to regularly inspect, replace, and maintain culverts. Culverts control the movement and direction of runoff entering Kezar Lake from the surrounding landscape. Culverts that are undersized for current or future flow volumes can cause significant erosion of streambanks and road shoulders. This eroded, phosphorus-laden material enters the stream channel and makes it way to the lake, where it can serve as fuel for algal growth. Working with the Lovell Public Works Department, FB Environmental technical staff and KLWA volunteers conducted a survey of 211 culverts on Town roads in the watershed. Fifteen culverts were selected as high priority for immediate replacement by the Town. Results and recommendations were presented to the Lovell Selectmen.

SEDIMENT CORES

Under the guidance of Dr. Lisa Doner from Plymouth State University, the CCO collected sediment core samples from Kezar Lake in February and June to establish a 150 to 250-year history of climate conditions in the lake. A detailed description and preliminary results are presented later in this report.

SUMMER INTERN

The CCO was very fortunate to have a paid intern for six weeks this summer. Chelsea Berg, a graduate student from Plymouth State University, was instrumental in researching and compiling climate change data for the KLWA webpages, leading the KLWA Old Home Days booth, and participating in water quality data collection. Depending on available funding, the CCO wishes to host an intern every summer to help with climate change research.

CONFERENCES

Members of the KLWA/CCO attended several climate change conferences throughout the year to enhance their knowledge of climate change and to promote CCO activities to the public. These conferences include:

10/23/14 Six members of KLWA/CCO and Ed Ryan (Chairman, Lovell Planning Board) attended the University of Maine Climate Change Institute's "Climate Adaptation and Sustainability Conference" in Orono, ME.

03/20/15 Attended 2015 NH Waters Conference in Bartlett, NH.

03/31/15 Attended 2015 "Maine Sustainability & Water Conference" in Augusta, ME.

08/22/15 Five members of KLWA/CCO attended Maine Lakes Conference in Naples, ME.

MEETINGS

Members of the CCO met with Lovell officials as follows:

12/03/14 Briefing to Lovell Planning Board on CCO update.

01/23/15 Met with Larry Fox to discuss culvert survey.

02/10/15 Met with Selectmen on culvert survey.

04/01/15 Met with Lovell Planning Board on culvert survey.

04/22/15 Conducted culvert survey with Larry Fox.

08/04/15 Briefing to Lovell Selectmen on culvert survey and CCO status.

08/05/15 Met with Lovell Planning Board.

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

01/22/15 Met with Dr. Lisa Doner to introduce her to the CCO, discuss core sampling, and determine a possible summer intern.

CCO Steering Committee meetings were held on **01/15/15**, **04/24/15**, and **07/08/15**.

GRANT APPLICATION AND REPORTING

The CCO submitted a required status report to the Sally Mead Hands (SMH) Foundation in February 2015. The report detailed CCO use of the 2014 grant funds. The CCO then applied for a 2015-16 grant from the SMH Foundation, which awarded the CCO with $23,000 to continue their climate change tracking efforts.

EDUCATION/COMMUNITY PROGRAMS

07/11/15 Presented CCO activities update at the KLWA Annual Meeting.

07/11/15 Presented CCO overview to the Lovell Invasive Plant Prevention Committee.

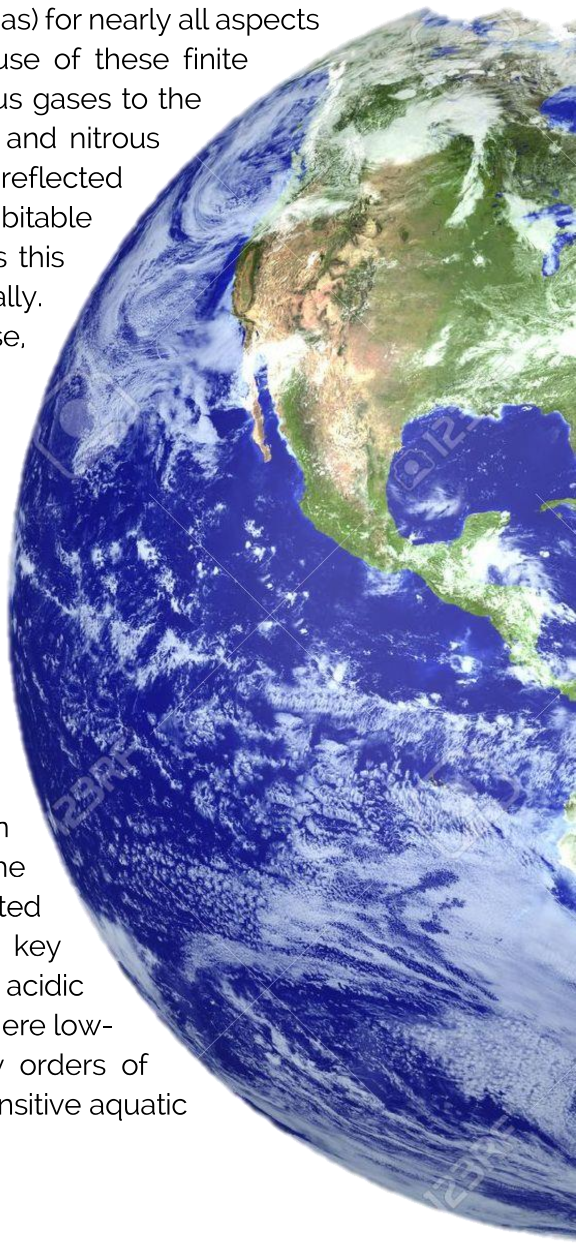
07/18/15 Established a climate change booth for Lovell Old Home Days with displays, informative hand-outs, and a water clarity participation event for children.

Great Brook outlet. Photo Credit: Jose Azel.

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.

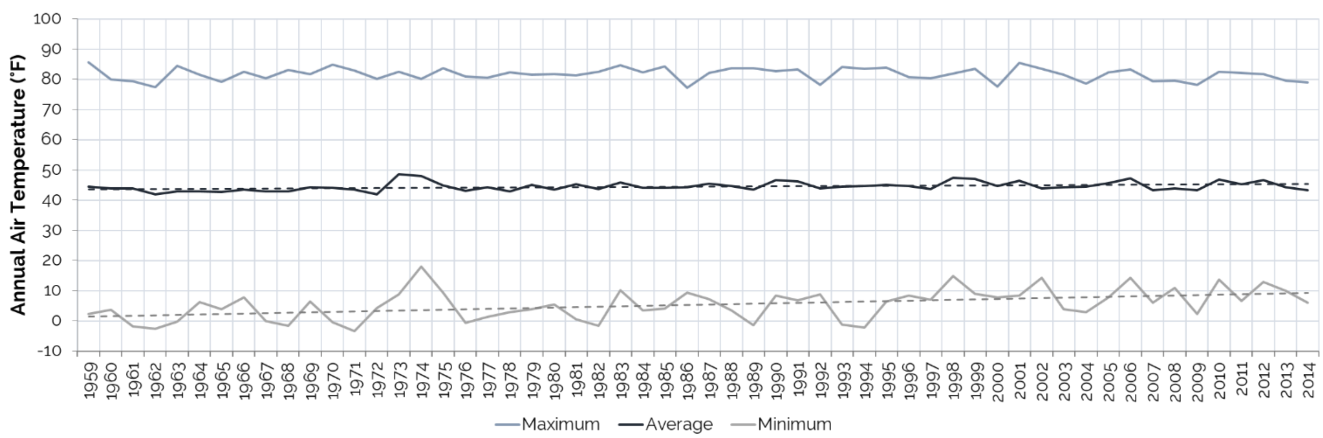
Fossil fuel combustion also emits sulfur dioxide and nitrogen oxides to the atmosphere. These gases react with water vapor, oxygen, and other gases in the atmosphere to form sulfuric and nitric acids, which fall on water and land surfaces as acid rain. Acid rain lowers the pH of aquatic and terrestrial 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 (4.3) temporarily decreases the pH of surface waters by orders of magnitude. 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 the North Conway weather station to track changes in air temperature since 1959.

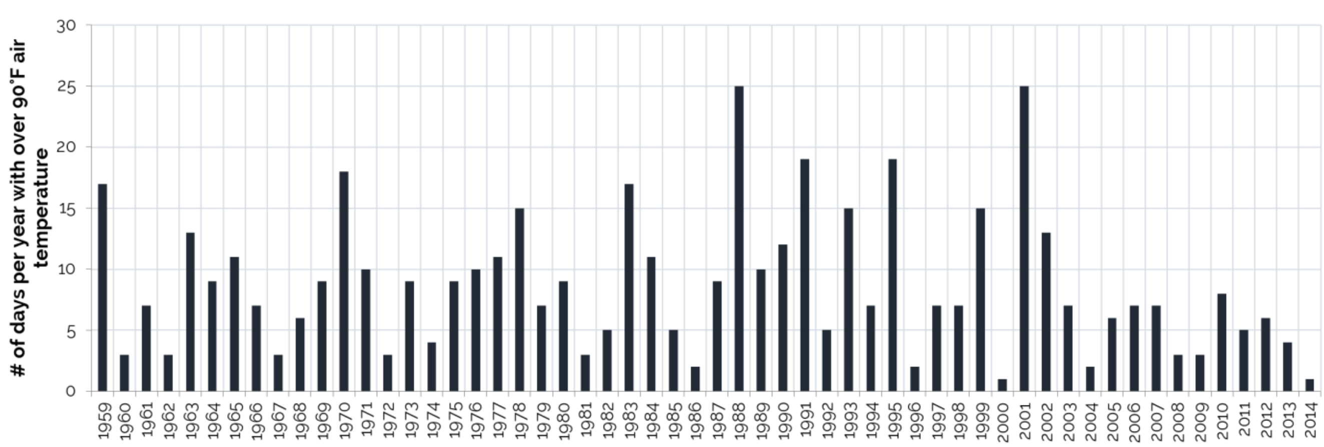
> **“AVERAGE ANNUAL TEMPERATURE ACROSS MAINE WARMED BY ABOUT 3.0 °F (1.7 °C) BETWEEN 1895 AND 2014.” - MAINE’S CLIMATE FUTURE, 2015 UPDATE**

ANNUAL AIR TEMPERATURES



Average and minimum annual air temperatures have warmed by about 1 °F and 8 °F, respectively, near North Conway, NH. Maximum annual air temperatures have remained fairly 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.

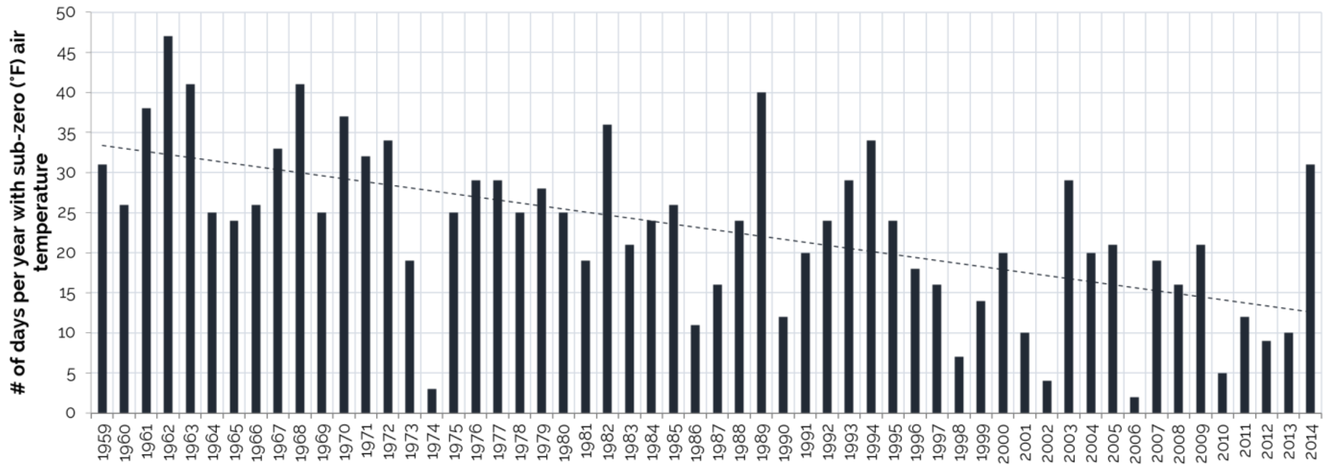
EXTREME HEAT DAYS



As air temperature rises, we can expect to see more extreme heat days. However, the North Conway weather station 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 North Conway weather station 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, but the latter half shows the number of extreme cold days declining to 15.

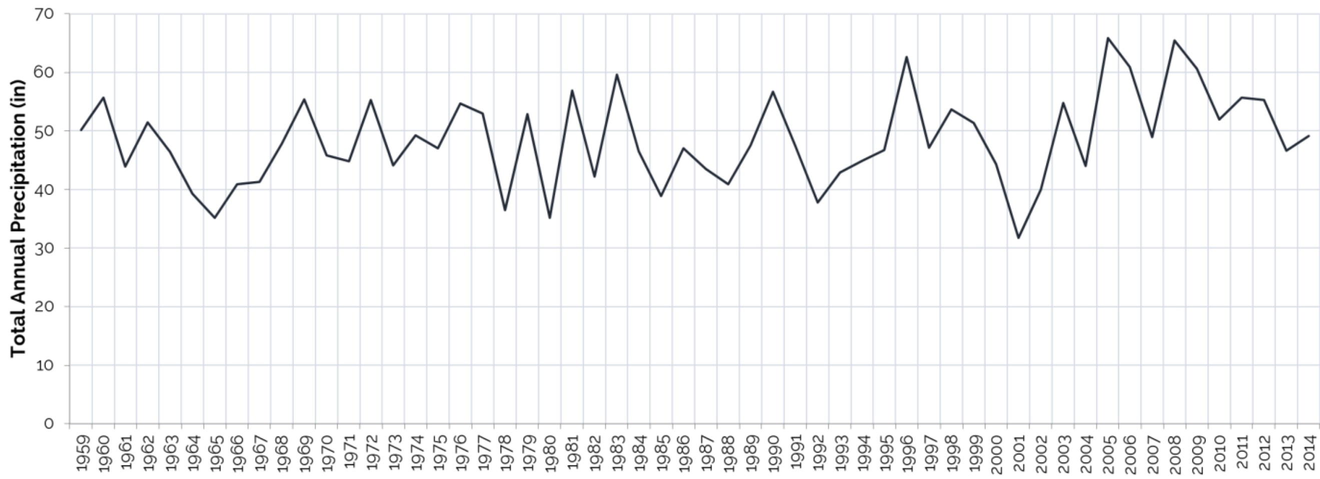
Precipitation

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

Kezar Lake in autumn. Photo Credit: Don Griggs.

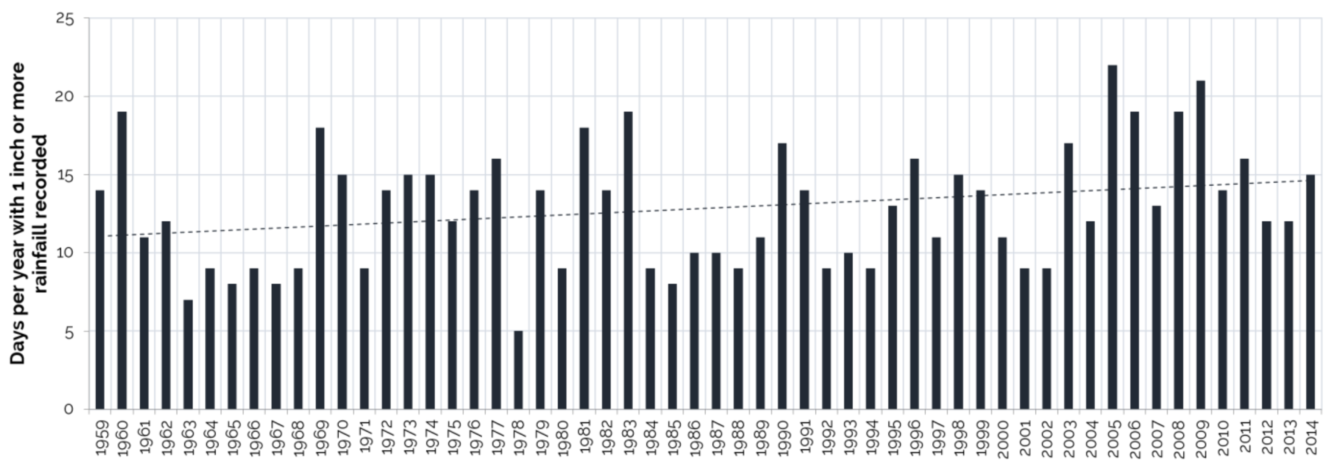
flush excess nutrients from the landscape to receiving waterbodies, including Kezar Lake, which can fuel algal production. Larger flow volumes will also threaten infrastructure, including road crossings and culverts. For the Kezar Lake watershed, we used the North Conway weather station to track changes in precipitation since 1959.

ANNUAL PRECIPITATION



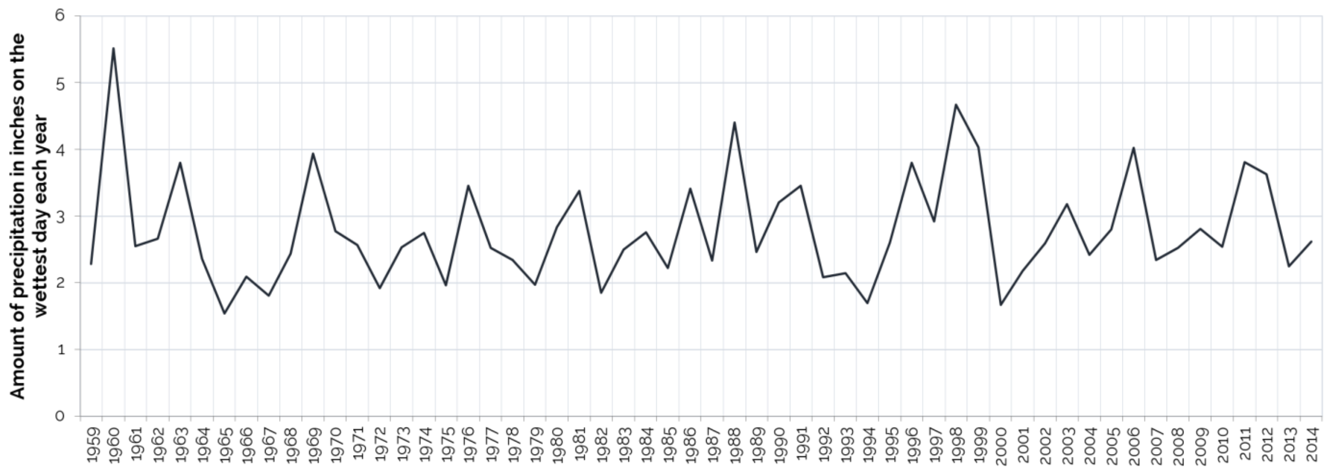
In North Conway, total annual precipitation has fluctuated greatly, but without any trend since 1959. However, three years (1996, 2005, and 2008) saw total annual precipitation above 60 inches. These were extremely wet years impacted by major storms. Total annual precipitation seems to be increasing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

ONE INCH RAIN EVENTS



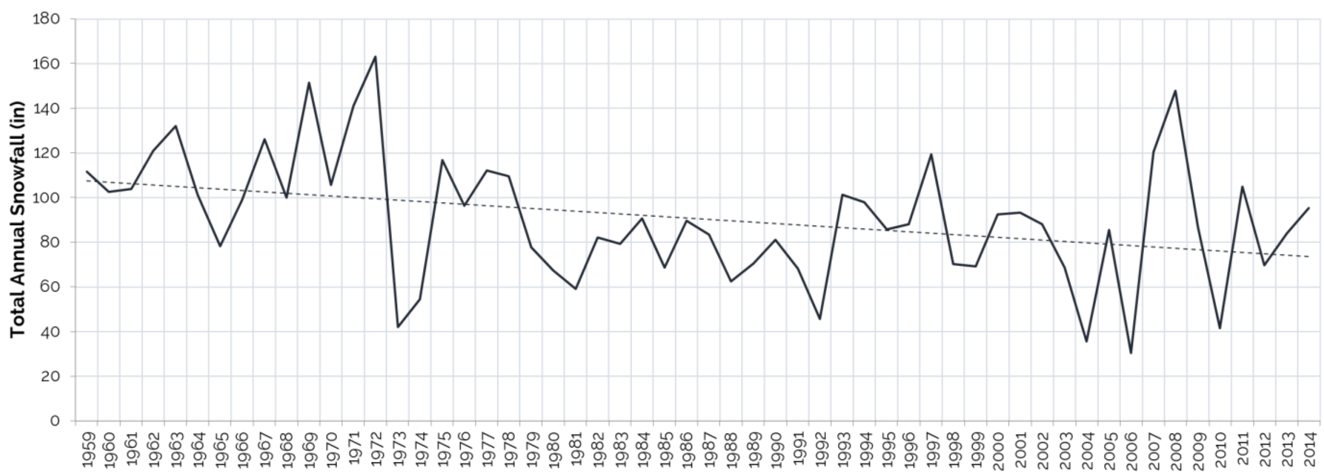
Climate change will likely cause more frequent precipitation events. For North Conway, the number of days per year receiving greater than 1 inch of rain has increased from about 12 to 15 days. The last decade shows multiple years with greater than 15 days per year with 1 inch or more of rain recorded.

WETTEST DAY OF YEAR



The intensity of extreme rain 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.

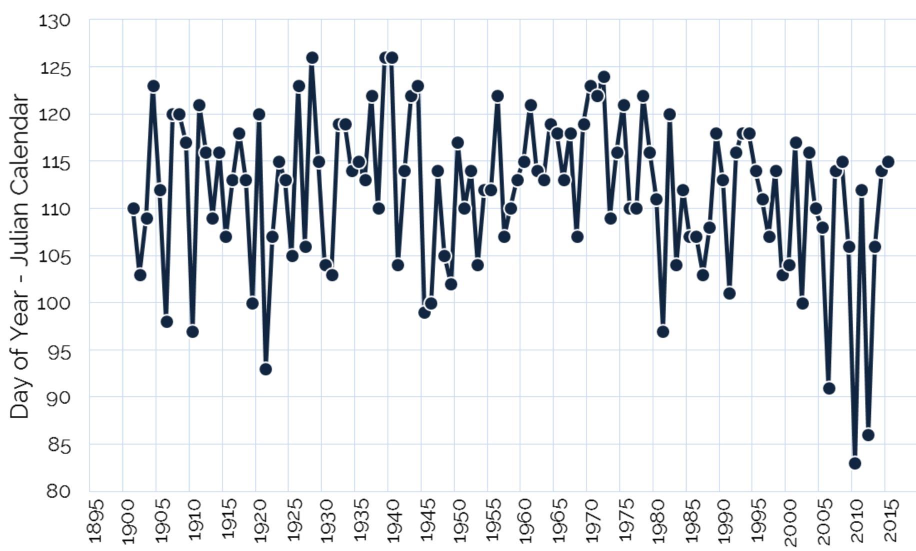
SNOWFALL ACCUMULATION



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 110 inches to less than 80 inches of snowfall per year since 1959.

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.

Kezar Lake in winter. 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 period can reveal subtle, yet steady directional changes in water quality. It is important to identify waterbodies at risk for degrading water quality as a result of climate change or development, so we can take action to combat the effects.

Statistical trend analyses (Mann-Kendall[1]) 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:

- **Total phosphorus** shows stable trends, but is elevated at Farrington and Heald Ponds.
- **Chlorophyll-a** shows stable trends, but is elevated at Farrington Pond.
- **Alkalinity** shows degrading trends at the upper bay, lower bay, and Cushman, Heald, and Horseshoe Ponds, and is critically, but naturally, low in all waterbodies.
- **pH** shows stable trends, and is low (acidic) in all waterbodies.
- **Color** shows stable trends, and is elevated at Heald Pond.
- **Water clarity** shows improving trends at Kezar Lake, and is poor (but stable) at Farrington Pond.
- **Dissolved oxygen** is regularly anoxic near the bottom in late summer at Bradley and Horseshoe Ponds.
- **Temperature** is generally good or excellent in all waterbodies.
- **Anoxic Factor** shows degrading trends at the upper bay and Cushman Pond, and is highest at Horseshoe Pond.

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

[1] 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

Water Body	Total Phosphorus	Chlorophyll-a	Alkalinity	pH	Color	Water Clarity	Dissolved Oxygen	Temp
Kezar Lake 1	Excellent, Stable	Excellent, Stable	Poor, Degrading	Good, Stable	Excellent, Stable	Excellent, Improving	Excellent	Excellent
Kezar Lake 2	Excellent, Stable	Excellent, Stable	Poor	Good	Excellent	Excellent, Improving	Excellent	Excellent
Kezar Lake 3	Good, Stable	Excellent, Stable	Poor, Degrading	Good, Stable	Excellent, Stable	Excellent, Improving	Excellent	Excellent
Bradley Pond	Good	Good	Poor	Good	Good	Good	Poor	Excellent
Cushman Pond	Good, Stable	Good, Stable	Poor, Degrading	Good, Stable	Excellent, Stable	Good, Stable	Excellent	Excellent
Farrington Pond	Poor, Stable	Poor, Stable	Poor, Stable	Good	Excellent, Stable	Poor, Stable	Good	Good
Heald Pond	Poor, Stable	Good, Stable	Poor, Degrading	Good, Stable	Poor, Stable	Good, Stable	Good	Good
Horseshoe Pond	Excellent, Stable	Good, Stable	Poor, Degrading	Good, Stable	Excellent, Stable	Excellent, Stable	Poor	Excellent
Trout Pond	Excellent	Excellent	Poor	Good	Excellent	Excellent, Stable	Good	Excellent

Key for Data Symbols – Current Conditions & Trends

CURRENT CONDITION
- EXCELLENT
- GOOD
- POOR

\+

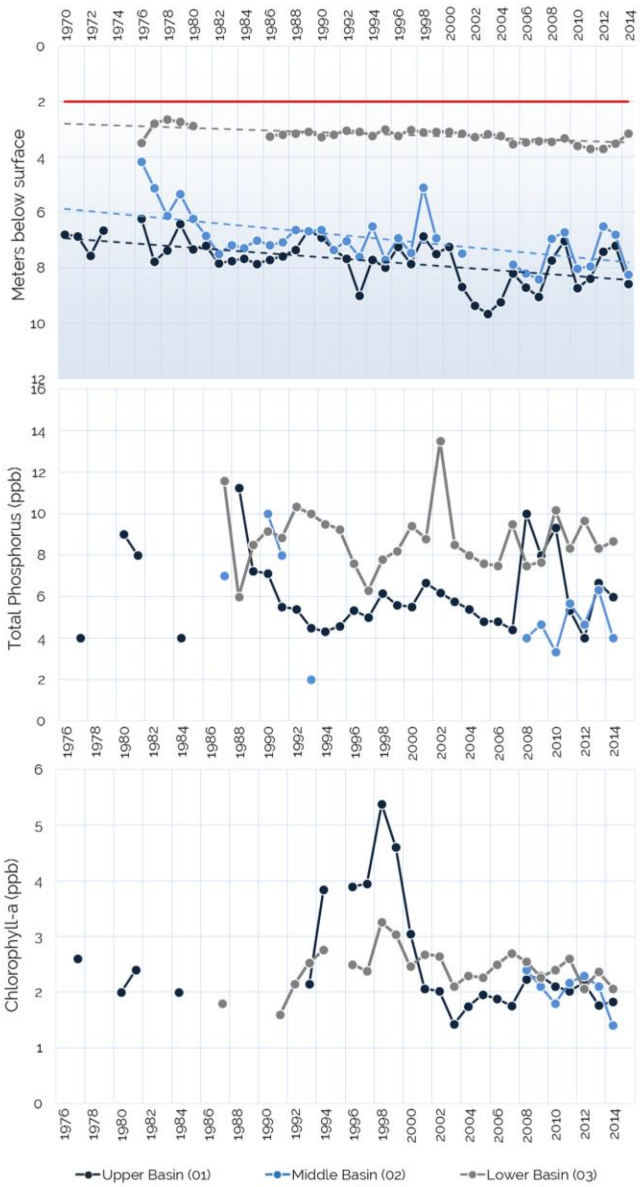
TREND
- IMPROVING
- STABLE
- DEGRADING
- PENDING

The **"Current Condition"** for each parameter is based on the data collected during the most recent sampling year compared to state or federal water quality standards. The current condition may also factor in monitoring results with respect to the state-wide average for Maine lakes.

The **"Trend"** indicates whether water quality is improving (up arrow), degrading (down arrow), or remaining stable (horizontal arrow) over time based on statistical analysis of the long-term data set for each parameter by waterbody. Stop lights provide a simple visual assessment of these trends.

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 155 feet (47 meters; FBE recorded 162 feet (49 meters) on 9/19/2011 at the upper basin) 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).



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.

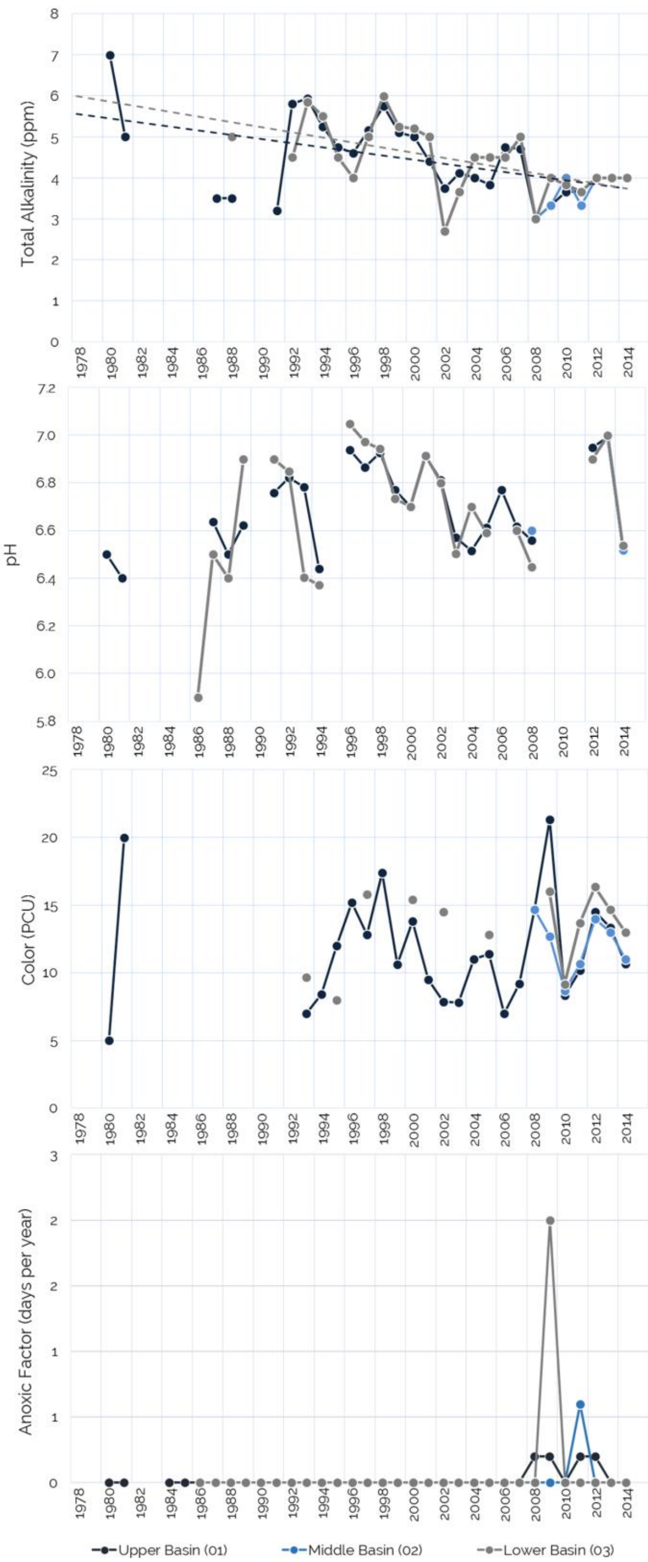
TOTAL PHOSPHORUS

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 all three basins of Kezar Lake 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 algal 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. Total alkalinity fluctuates naturally from year-to-year in response to rain. Dry years generally show lower total alkalinity; wet years generally show higher total alkalinity. The degrading trend in alkalinity is despite the increase in precipitation observed in the last century, suggesting other processes are impacting the natural level of alkalinity in the lake.

pH

Since the early 1980's, pH at all three basins of Kezar Lake has revealed no statistically significant trend over time. Generally, pH becomes more acidic as total alkalinity in the epilimnion declines. Low alkalinity make 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 all three basins of 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 stable trend in color is despite the increase in precipitation observed in the last century, suggesting that more data are needed to confirm the trend.

ANOXIC FACTOR

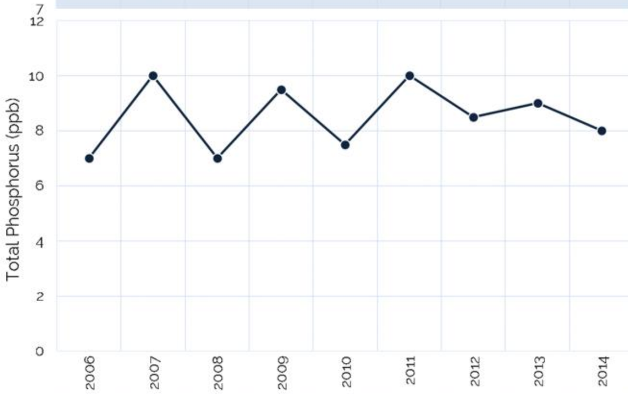
Dissolved oxygen profiles show good oxygenation throughout the water column over the collection period, which is typical of unproductive, oligotrophic lakes. While the extent and duration of anoxia (anoxic factor) is excellent at all three basins, the upper basin shows a statistically-significant (but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

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 generally remained stable. More data are needed to determine a statistically significant trend.



TOTAL PHOSPHORUS

Since 2006, total phosphorus at Bradley Pond has generally remained stable. More data are needed to determine a statistically significant trend.

CHLOROPHYLL-A

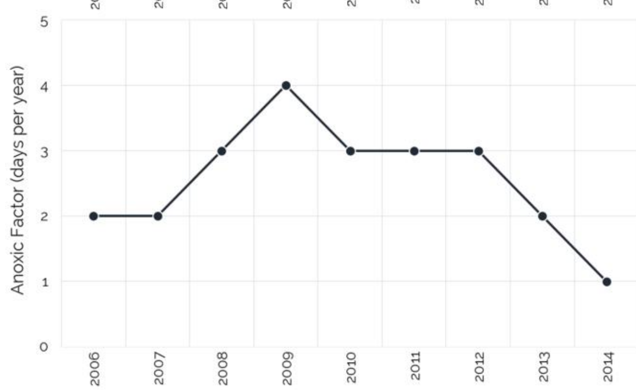
Since 2006, chlorophyll-a at Bradley Pond has ranged from about 2 to 6 ppb. More data are needed to determine a statistically significant trend. The period from 2011 to 2012 saw a marked rise in chlorophyll-a. Nutrient-rich runoff entering the lake during wetter years, combined with warmer air temperatures,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

BRADLEY POND
WATER QUALITY TRENDS

TOTAL ALKALINITY
Since 2006, total alkalinity at Bradley Pond has generally remained stable. More data are needed to determine a statistically significant trend. 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.

pH
Minimal pH data are available for Bradley Pond to make any conclusions about long-term trends, but mean annual pH falls within acceptable ranges for aquatic life. Low alkalinity make it 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.

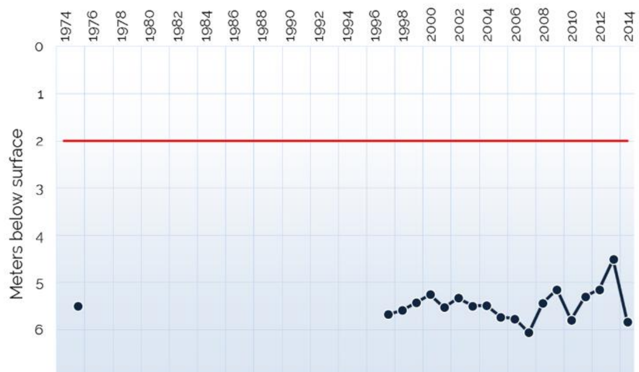
COLOR
Since 2006, color at Bradley Pond has generally remained stable. More data are needed to determine a statistically significant trend. High color was observed for 2012, likely due to the wet summer conditions. Color is highly related to summer precipitation; wetter years show higher color as more materials are washed off the landscape to the lake.



ANOXIC FACTOR
Dissolved oxygen profiles show oxygen depletion beginning 5-6 meters below the water surface, which is typical of more productive ponds. The extent and duration of anoxia (anoxic factor) is overall good at Bradley Pond. More data are needed to determine a statistically significant trend. Dissolved oxygen at depth should continue to be monitored closely in the future.

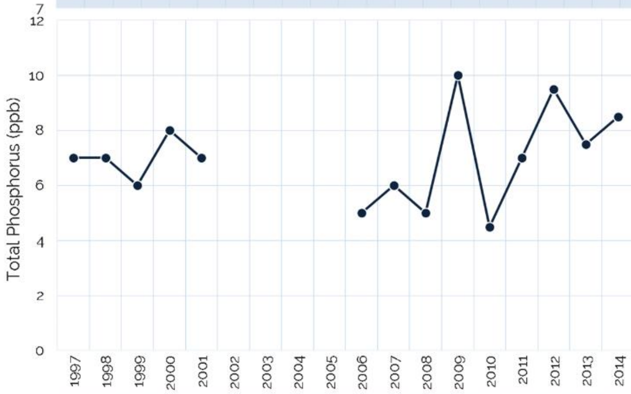
CUSHMAN POND
WATER QUALITY TRENDS

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 Variable Milfoil, which poses a threat to fish habitat. Water quality monitoring data have been collected since 1997 at Station 1 (deep spot).



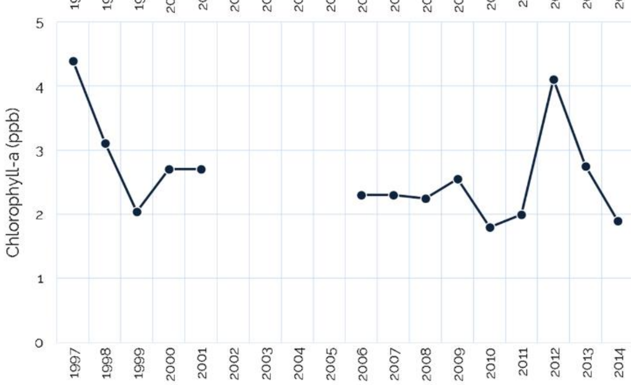
WATER CLARITY

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



TOTAL PHOSPHORUS

Since 1997, total phosphorus at Cushman Pond has remained stable with no statistically significant trend. Year-to-year variation in total phosphorus (4 to 10 ppb) is fairly large at Cushman Pond.



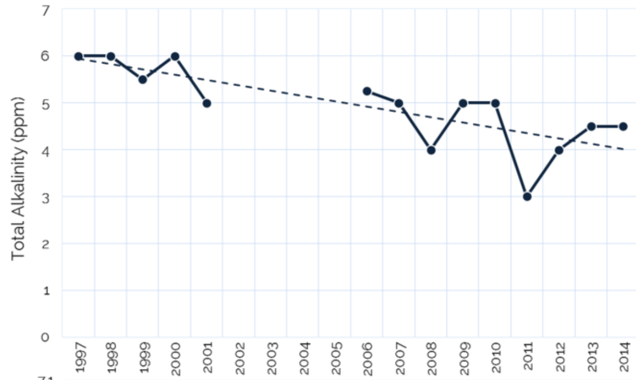
CHLOROPHYLL-A

Since 1997, chlorophyll-a at Cushman Pond has remained stable with 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 algal growth.

CUSHMAN POND
WATER QUALITY TRENDS

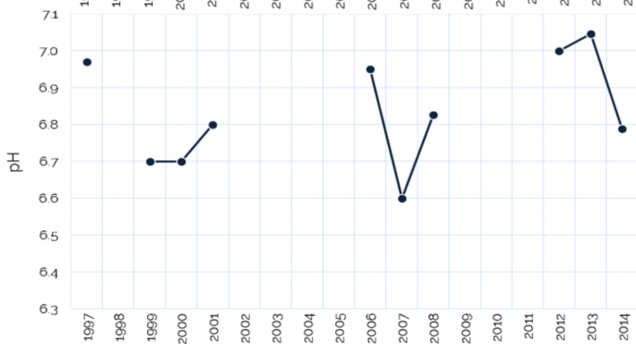
TOTAL ALKALINITY

Since 1997, total alkalinity at Cushman Pond has degraded by about 2 ppm. The degrading trend in alkalinity is despite the increase in precipitation observed in the last century, suggesting other processes are impacting the natural level of alkalinity in the pond.



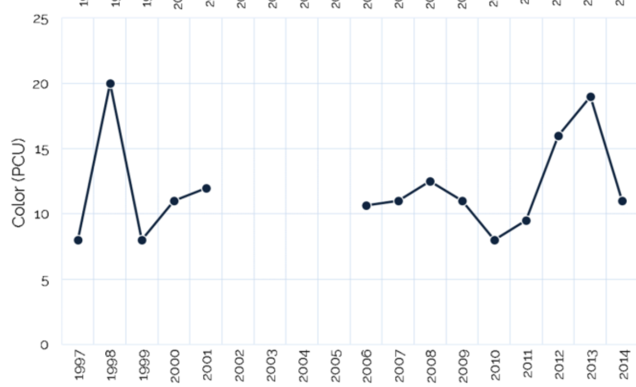
pH

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 make it 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.



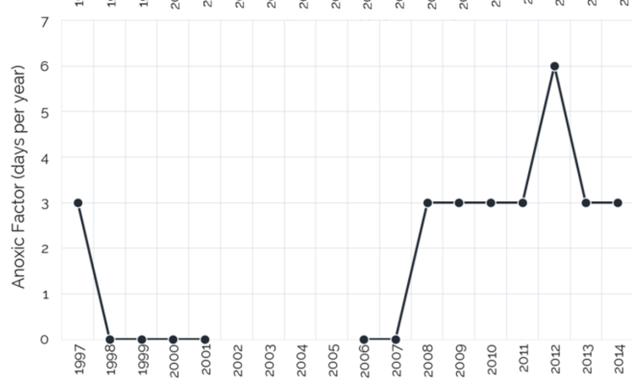
COLOR

Since 1997, color at Cushman Pond has 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 lake.



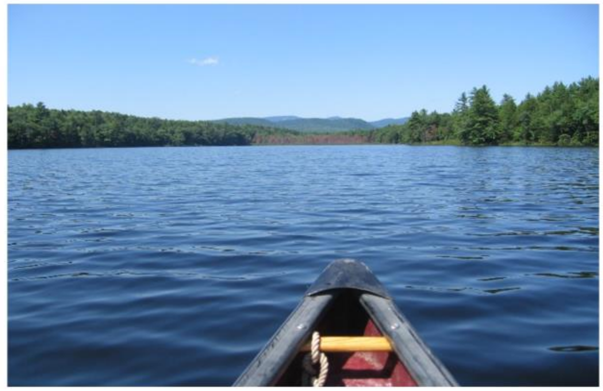
ANOXIC FACTOR

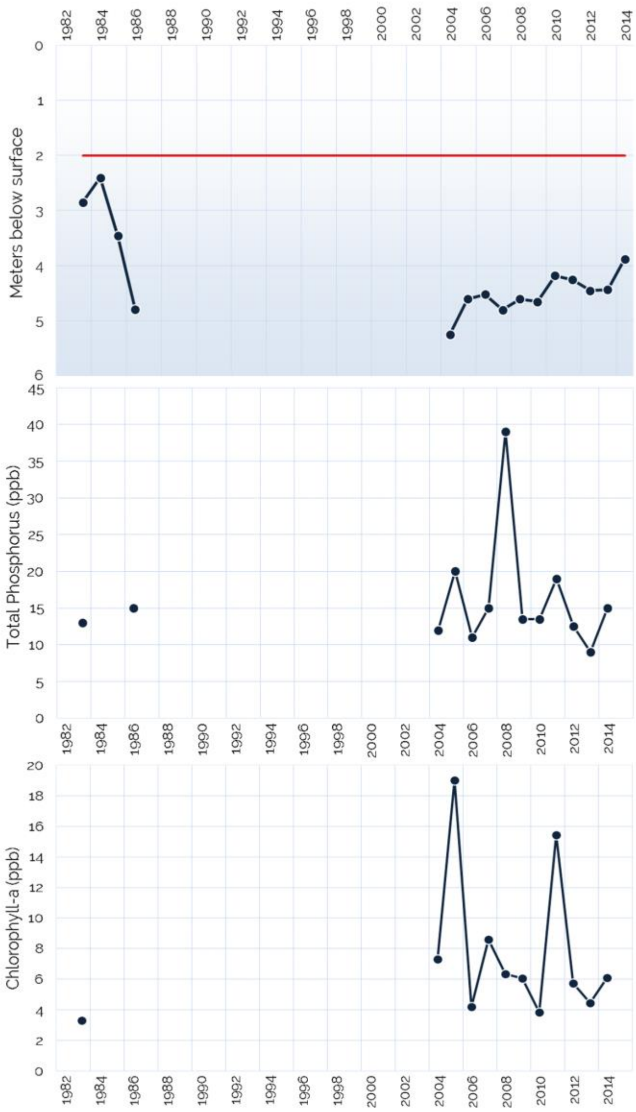
Dissolved oxygen profiles show good oxygenation throughout the water column over the collection period, with some anoxia at the bottom. While the extent and duration of anoxia (anoxic factor) is overall good, Cushman Pond shows a statistically-significant increase in anoxia over the collection period. 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 steady degradation in water clarity by more than 1 meter.

TOTAL PHOSPHORUS

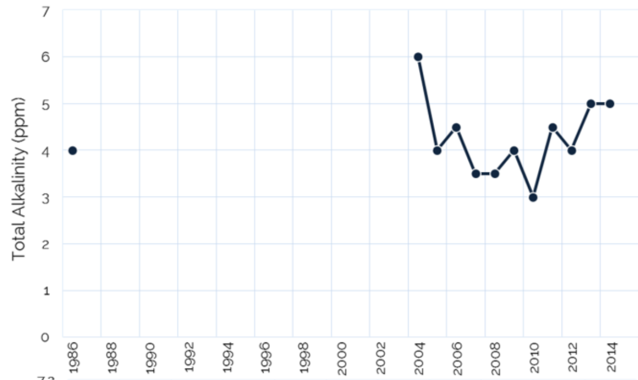
Since 1983, total phosphorus at Farrington Pond has remained stable with no statistically significant trend. Year-to-year variation in total phosphorus (10 to 40 ppb) is large at Farrington Pond, which also has the highest mean annual total phosphorus of all the ponds. The marked rise in total phosphorus 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 remained stable with no statistically significant trend, but experienced the highest concentration of chlorophyll-a of the other ponds. Sampling years 2005 and 2011 saw a marked rise in chlorophyll-a. Nutrient-rich runoff entering the lake during wetter years, combined with warmer air temperatures, can fuel algal growth. Chlorophyll-a generally increased with increasing total phosphorus.

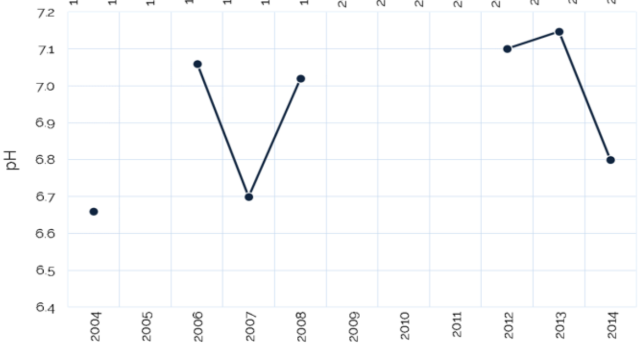
FARRINGTON POND
WATER QUALITY TRENDS

TOTAL ALKALINITY



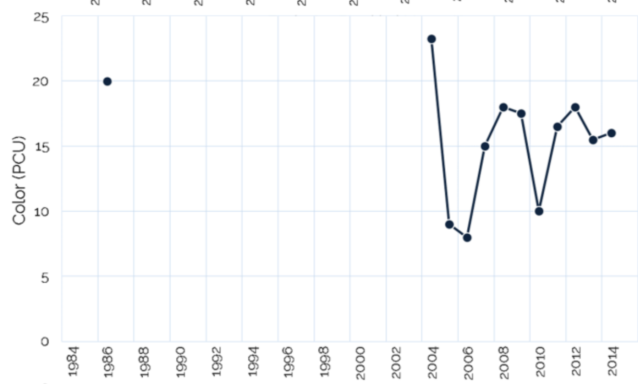
Since 1986, total alkalinity at Farrington Pond has remained stable with no statistically significant trend, unlike the other ponds that largely show degrading trends. Farrington Pond has naturally-low alkalinity (or buffering capacity) as a result of its contributing geology (i.e. granite) that lacks carbonates, bicarbonates, and carbonic acid.

pH



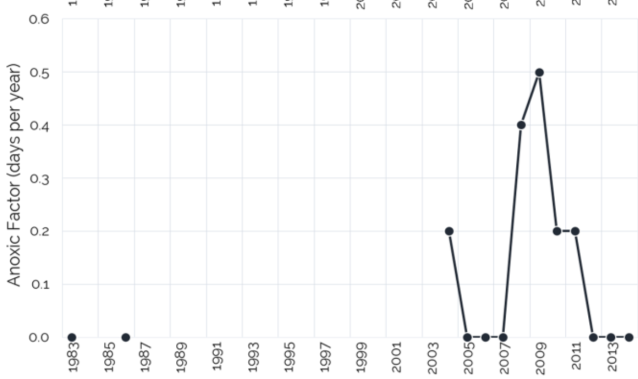
Minimal pH data are available for Farrington Pond to make any conclusions about long-term trends, but mean annual pH falls within acceptable ranges for aquatic life. Low alkalinity make it susceptible to changes in pH, particularly from acidic deposition in the form of rain or snow, which can jeopardize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

COLOR



Since 1983, color at Farrington Pond has 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 lake.

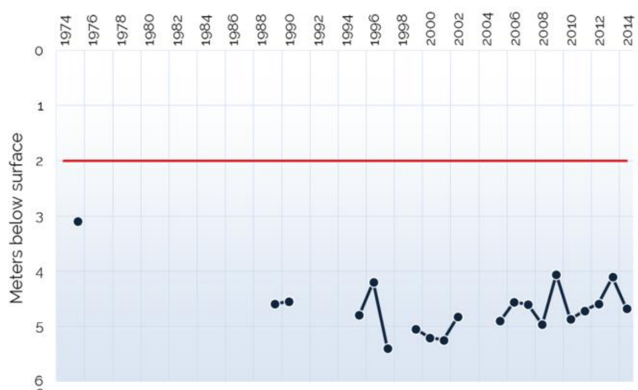
ANOXIC FACTOR



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 (anoxic factor) is overall excellent at Farrington Pond and shows no statistically-significant trend. However, dissolved oxygen at depth should continue to be monitored closely in the future.

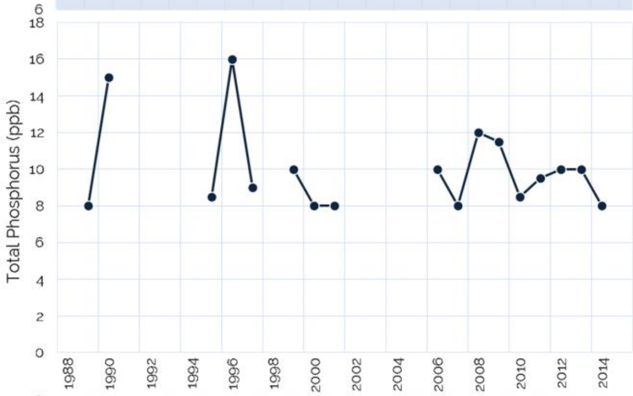
HEALD POND
WATER QUALITY TRENDS

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).



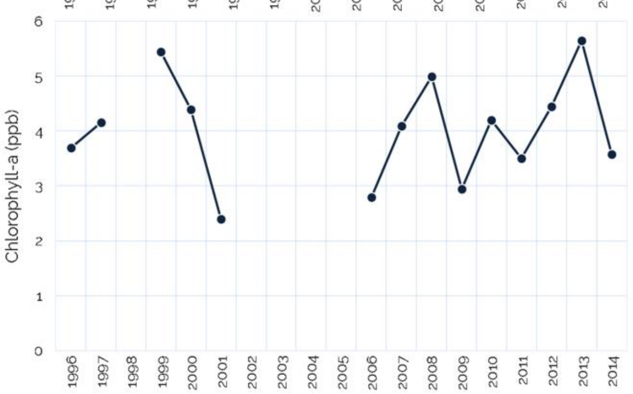
WATER CLARITY

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



TOTAL PHOSPHORUS

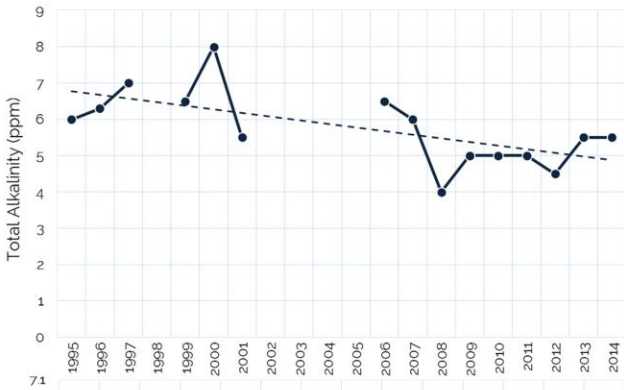
Since 1989, total phosphorus at Heald Pond has remained stable with no statistically significant trend. Higher phosphorus generally corresponds to wetter years at Heald Pond. Sediment in runoff entering the pond during rain events carries limiting nutrients. Heald Pond is highly susceptible to internal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

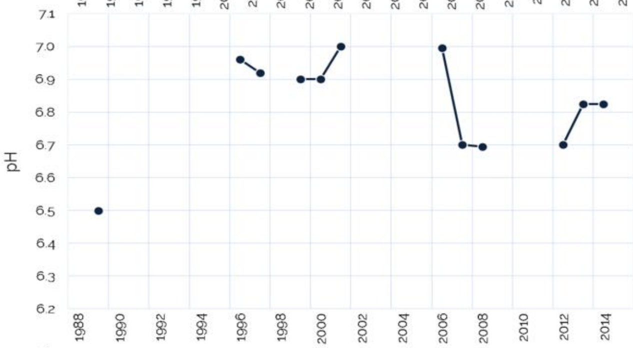


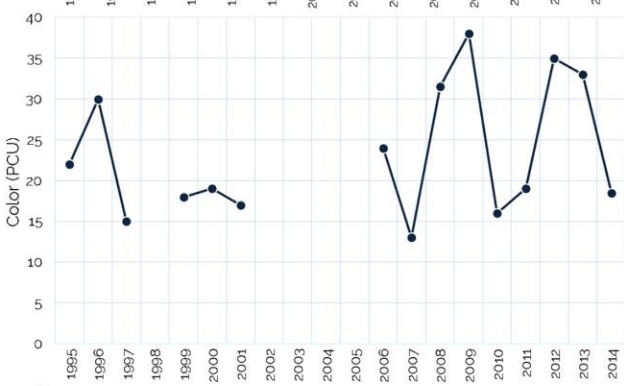
CHLOROPHYLL-A

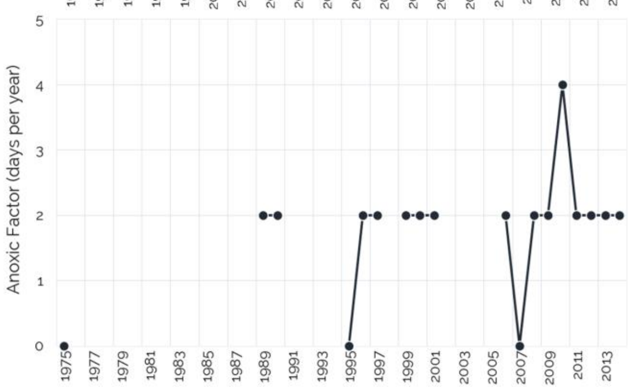
Since 1996, chlorophyll-a at Heald Pond has remained stable with no statistically significant trend. Nutrient-rich runoff entering the lake during wetter years, combined with warmer air temperatures, can fuel algal growth.

HEALD POND
WATER QUALITY TRENDS









TOTAL ALKALINITY

Since 1995, total alkalinity at Heald Pond has degraded by nearly 2 ppm. Total alkalinity fluctuates naturally from year-to-year in response to rain. Dry years generally show lower total alkalinity; wet years generally show higher total alkalinity. The degrading trend in alkalinity is despite the increase in precipitation observed in the last century, suggesting other processes are impacting the natural level of alkalinity in the pond.

pH

Since 1989, pH at Heald 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 make it 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 1995, color at Heald Pond has remained stable with no statistically significant trend, but consistently experienced the highest 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 FACTOR

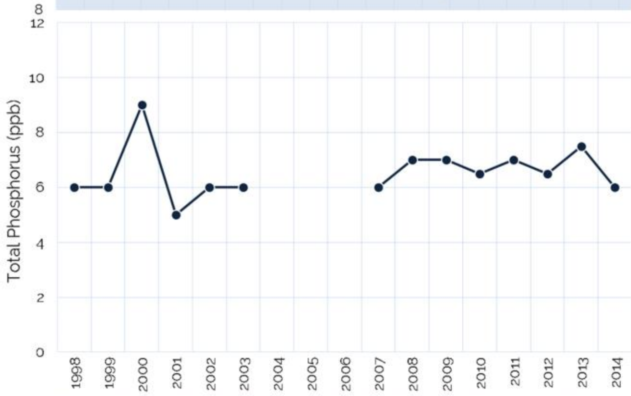
Dissolved oxygen profiles show good oxygenation throughout the water column over the collection period, with some anoxia at the bottom. The extent and duration of anoxia (anoxic factor) is overall good at Heald Pond and shows no statistically-significant trend. However, dissolved oxygen at depth should 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).

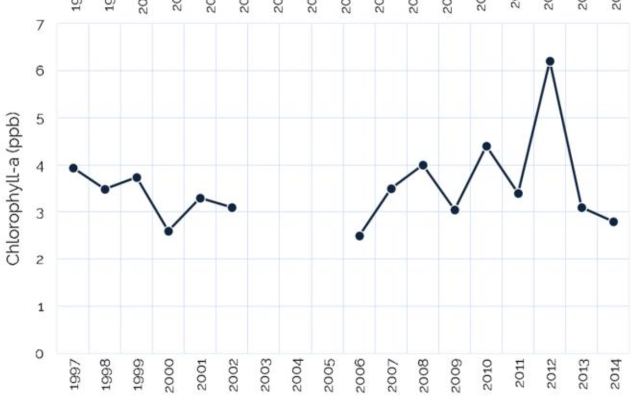
WATER CLARITY

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



TOTAL PHOSPHORUS

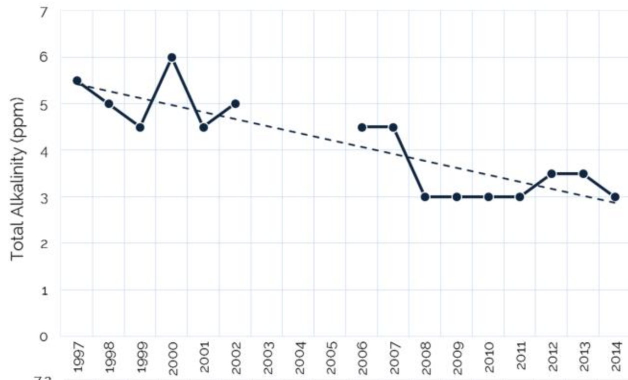
Since 1998, total phosphorus at Horseshoe Pond has remained stable with no statistically significant trend. Horseshoe Pond experiences consistently low phosphorus compared to the other ponds.

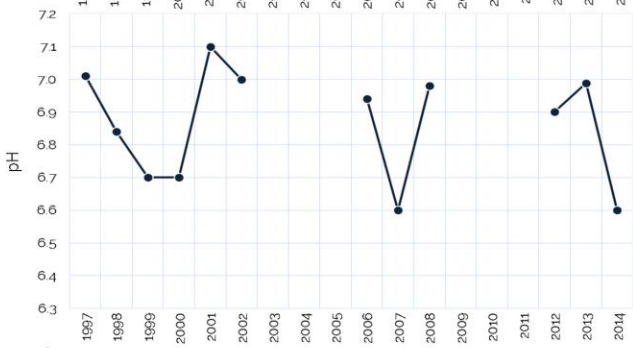


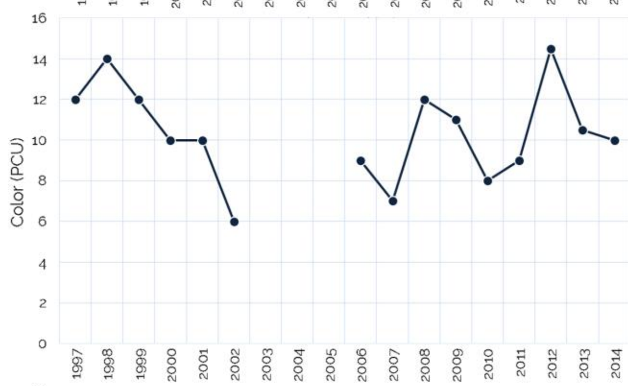
CHLOROPHYLL-A

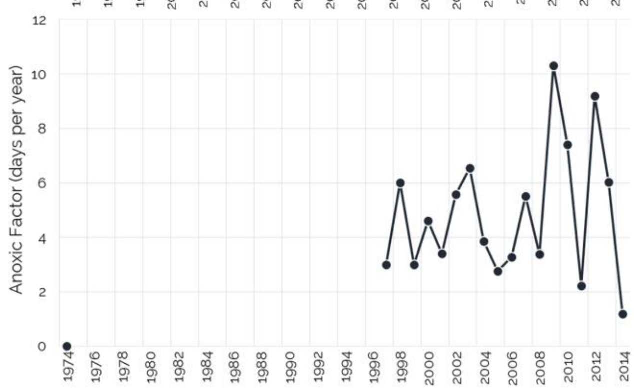
Since 1997, chlorophyll-a at Horseshoe Pond has remained stable with no statistically significant trend. Sampling year 2012 saw a marked rise in chlorophyll-a. Nutrient-rich runoff entering the lake during wetter years, combined with warmer air temperatures, can fuel algal growth.

HORSESHOE POND
WATER QUALITY TRENDS









TOTAL ALKALINITY

Since 1997, total alkalinity at Horseshoe Pond has degraded by more than 2 ppm. Total alkalinity fluctuates naturally from year-to-year in response to rain. Dry years generally show lower total alkalinity; wet years generally show higher total alkalinity. The degrading trend in alkalinity is despite the increase in precipitation observed in the last century, suggesting other processes are impacting the natural level of alkalinity in the pond.

pH

Since 1997, pH at Horseshoe Pond has revealed no statistically significant trend over time. Mean annual pH falls within acceptable ranges for aquatic life. Low alkalinity make it 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 FACTOR

Dissolved oxygen profiles show oxygen depletion from 8 to 12 meters below the water surface in late summer. The extent and duration of anoxia (anoxic factor) is overall poor at Horseshoe Pond and shows no statistically-significant trend. 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 remained stable with no statistically significant trend.

TOTAL PHOSPHORUS

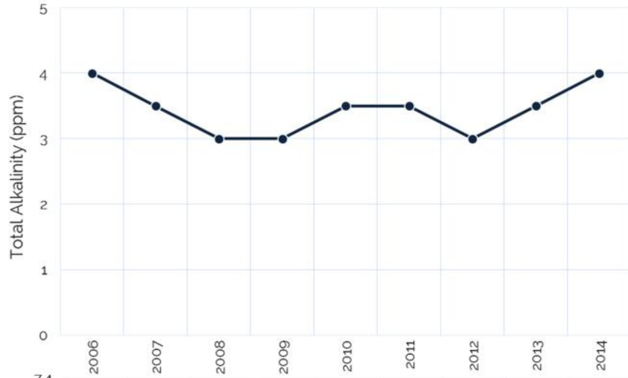
Since 2006, total phosphorus at Trout Pond has generally remained stable. More data are needed to determine a statistically significant trend.

CHLOROPHYLL-A

Since 2006, chlorophyll-a at Trout Pond has ranged from about 1 to 4 ppb. More data are needed to determine a statistically significant trend. Trout Pond experiences the lowest concentration of chlorophyll-a compared to the other ponds.

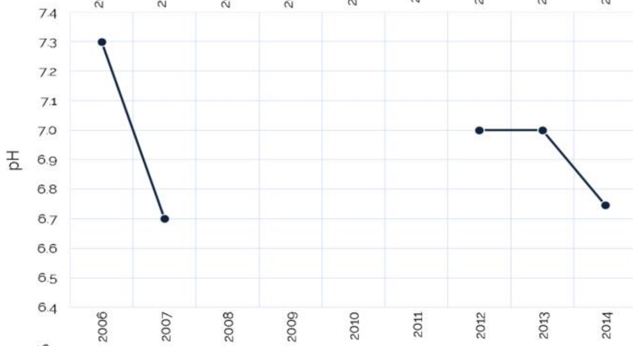
TROUT POND
WATER QUALITY TRENDS

TOTAL ALKALINITY



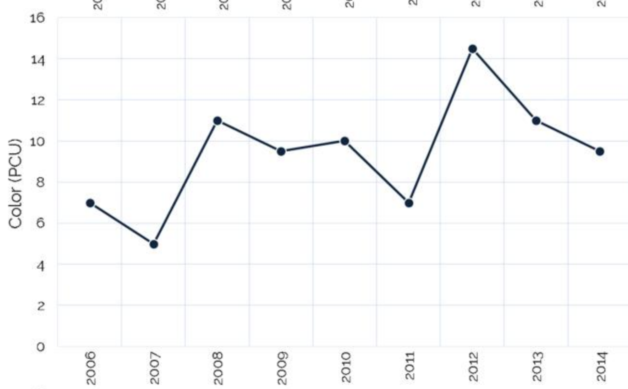
Since 2006, total alkalinity at Trout Pond has generally remained stable. More data are needed to determine a statistically significant trend. Trout Pond has naturally-low alkalinity (or buffering capacity) as a result of its contributing geology (i.e. granite) that lacks carbonates, bicarbonates, and carbonic acid.

pH



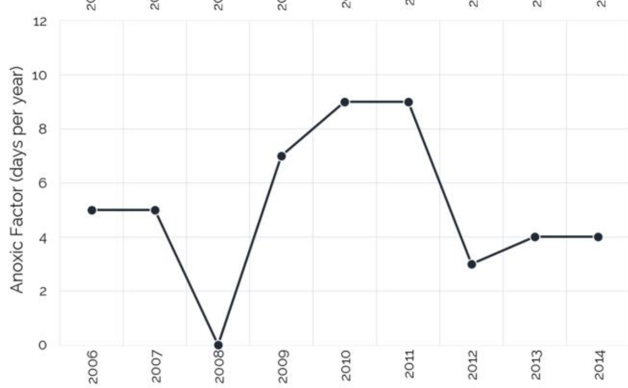
Minimal pH data are available for Trout Pond to make any conclusions about long-term trends, but mean annual pH falls within acceptable ranges for aquatic life. Low alkalinity make it susceptible to changes in pH, particularly from acidic deposition in the form of rain or snow, which can jeopardize the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

COLOR



Since 2006, color at Trout Pond has generally remained stable. More data are needed to determine a statistically significant trend. High 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.

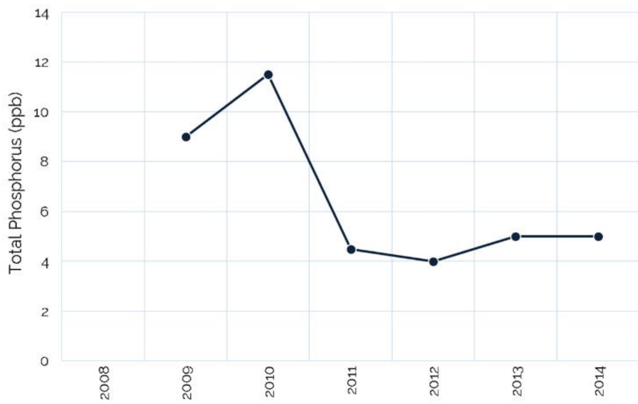
ANOXIC FACTOR



Dissolved oxygen profiles show oxygen depletion beginning 15 meters below the water surface. The extent and duration of anoxia (anoxic factor) is overall good at Trout Pond. More data are needed to determine a statistically significant trend. Dissolved oxygen at depth should continue to be monitored closely in the future.

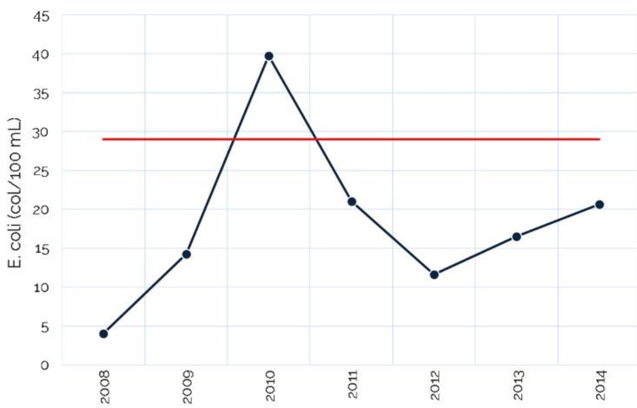
GREAT BROOK
WATER QUALITY TRENDS

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.



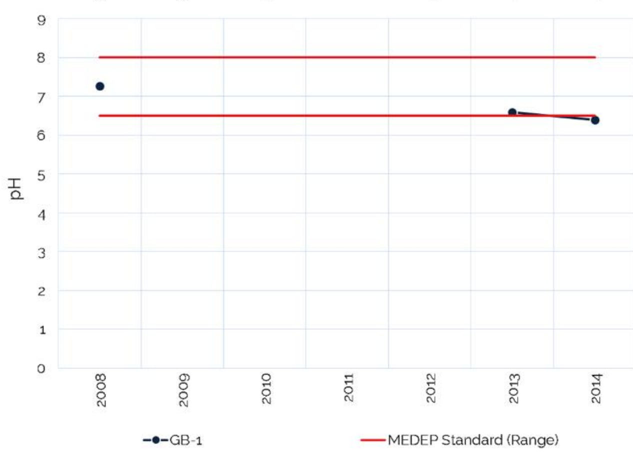
TOTAL PHOSPHORUS

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



E. COLI

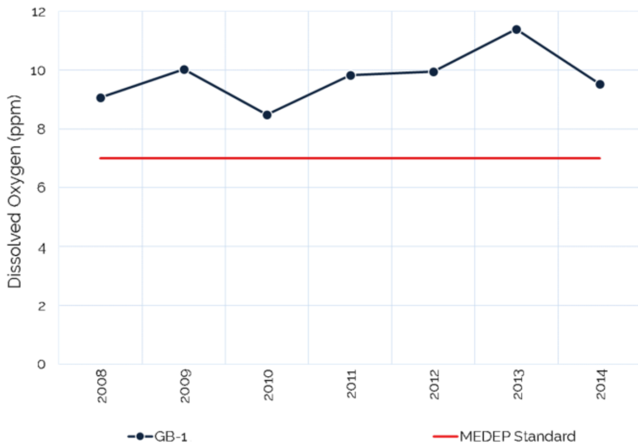
Since 2008, E. coli at Great Brook has been less than the Class A stream geometric mean of 29 col/100mL, with the exception of 2010.



pH

Minimal pH data are available for Great Brook, but generally pH falls within the range suitable for aquatic life. In 2014, Great Brook experienced pH below 6.5, the recommended lower limit for pH.

GREAT BROOK
WATER QUALITY TRENDS



DISSOLVED OXYGEN

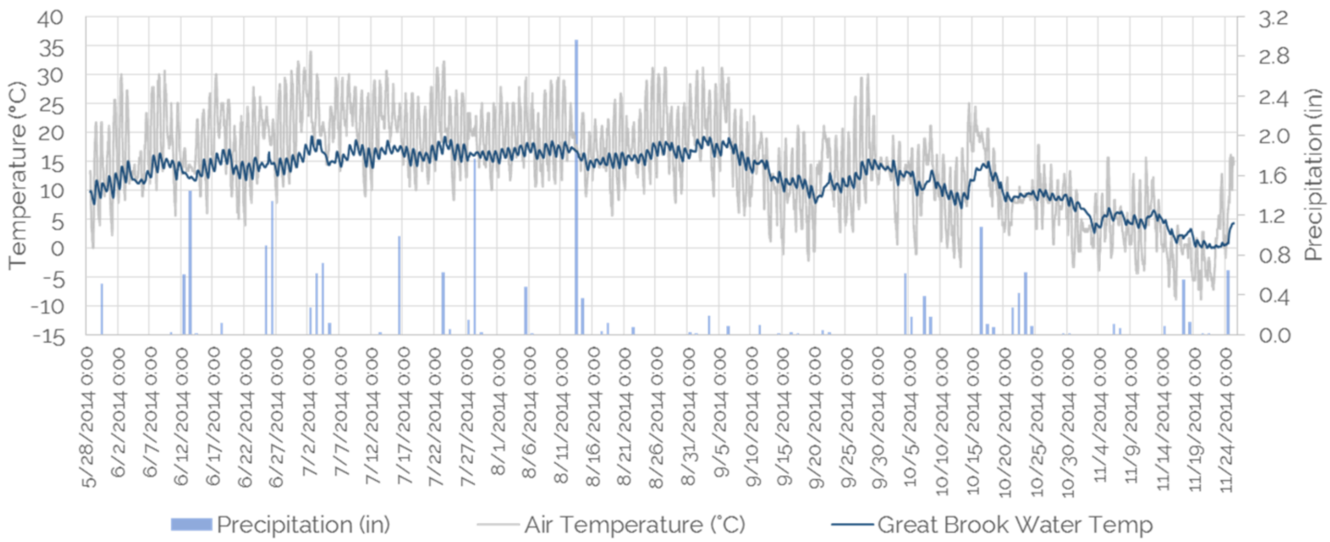
Dissolved oxygen at Great Brook remains above the Maine DEP standard of 7 ppm for Class A streams.

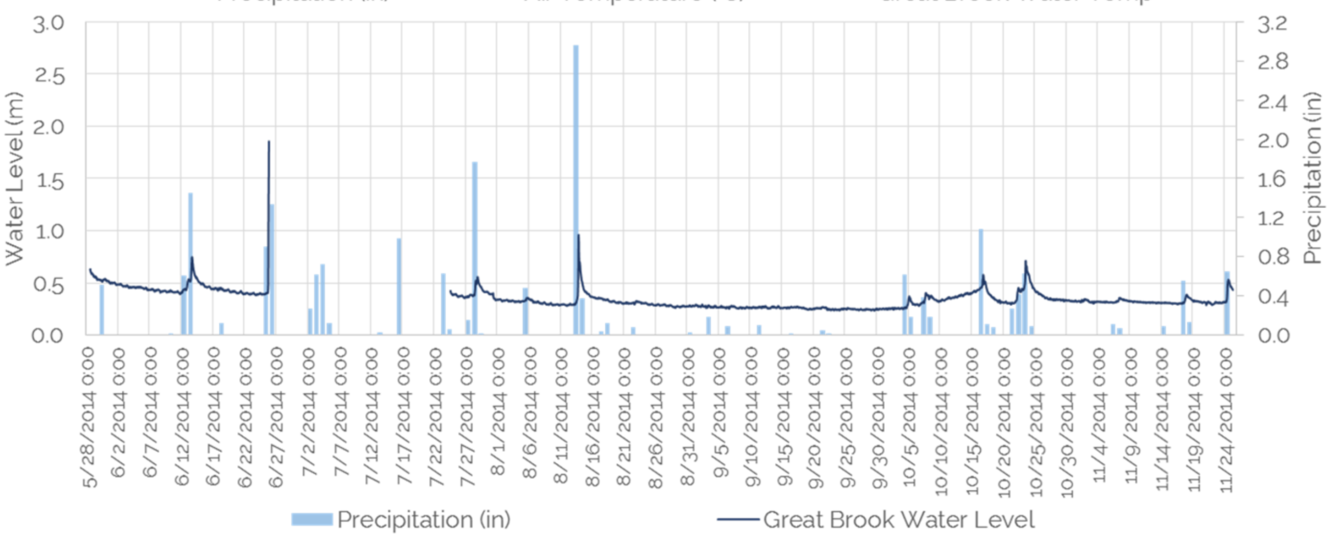
WATER TEMPERATURE

Water temperature increased at Great Brook from May to August 2014 and then steadily declined until retrieval in November 2014, following closely with observed air temperature.

STREAM FLOW

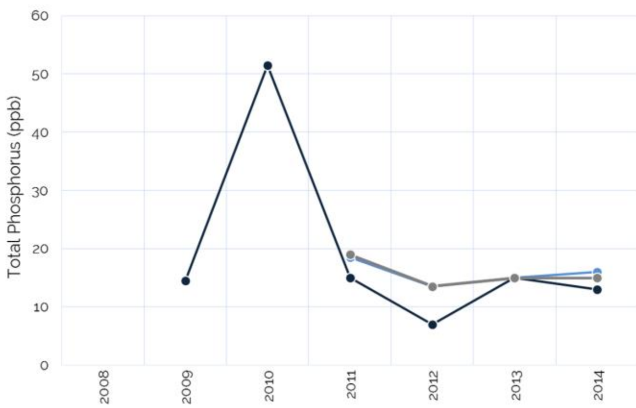
Water level data collected at Great Brook in 2014 showed that the stream responds quickly to precipitation.





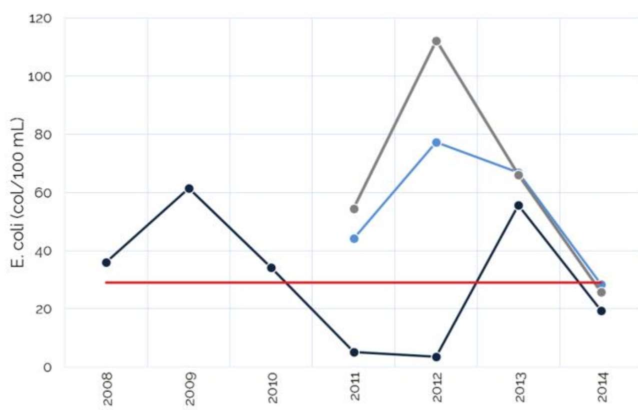
BOULDER BROOK
WATER QUALITY TRENDS

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.



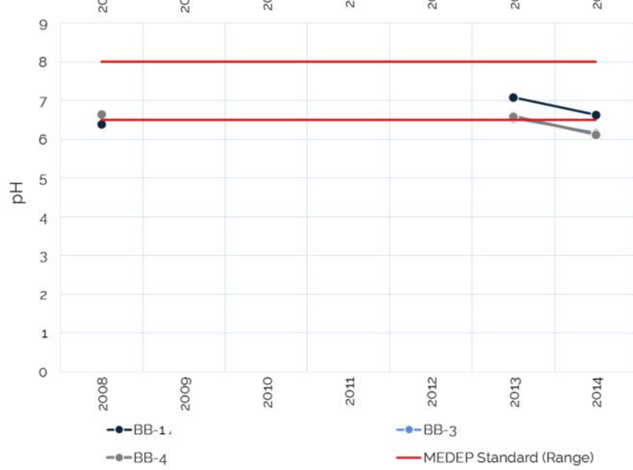
TOTAL PHOSPHORUS

Since 2009, total phosphorus at Boulder Brook has generally remained below 20 ppb, with the exception of 2010 at 51 ppb. Heavy rains may have washed excess phosphorus-laden sediment from the landscape to the stream.



E. COLI

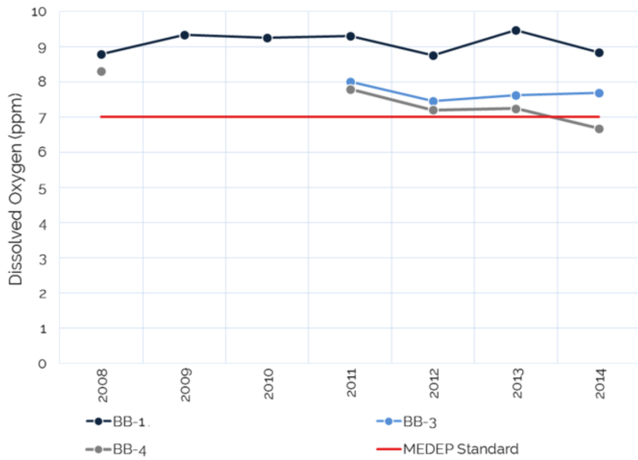
Since 2008, E. coli at Boulder Brook has largely exceeded the Class A stream geometric mean of 29 col/100mL.



pH

Minimal pH data are available for Boulder Brook, but generally pH falls within the range suitable for aquatic life. In 2014, BB-4 (upstream of Rt. 5) experienced pH below 6.5, the recommended lower limit for pH.

BOULDER BROOK
WATER QUALITY TRENDS

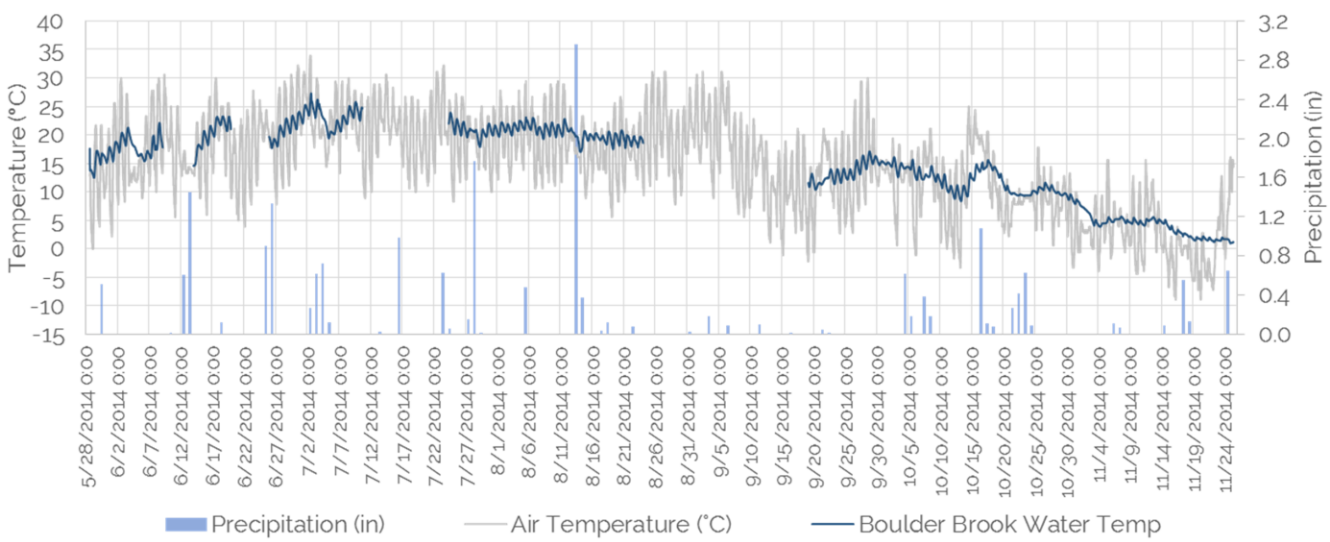


DISSOLVED OXYGEN

Dissolved oxygen at Boulder Brook generally remains above the Maine DEP standard of 7 ppm for Class A streams, with the exception of BB-4 (upstream of Rt. 5) in 2014.

WATER TEMPERATURE

Water temperature increased at Boulder Brook from May to August 2014 and then steadily declined until retrieval in November 2014, following closely with observed air temperature. Boulder Brook experienced some of the highest water temperatures compared to the other streams, particularly from May to September.



BEAVER BROOK
WATER QUALITY TRENDS

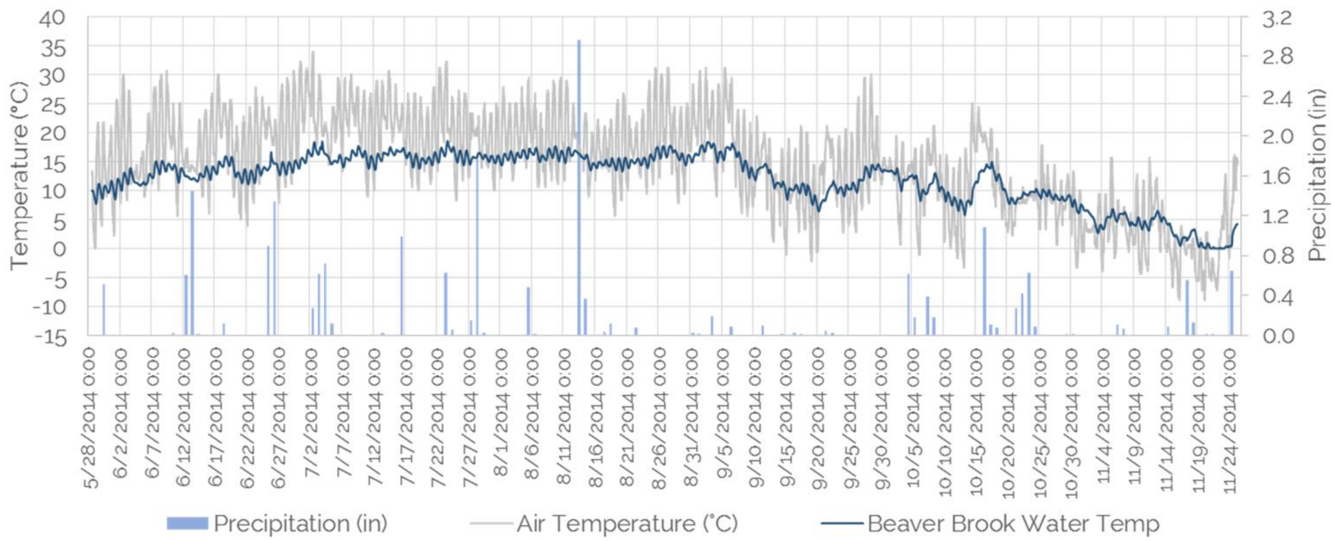
Beaver Brook is a major tributary to Great Brook, located on the northwest end of Kezar Lake off West Stoneham Road. Beaver Brook drains a portion of the White Mountain National Forest. Water quality monitoring data have been collected since 2014.

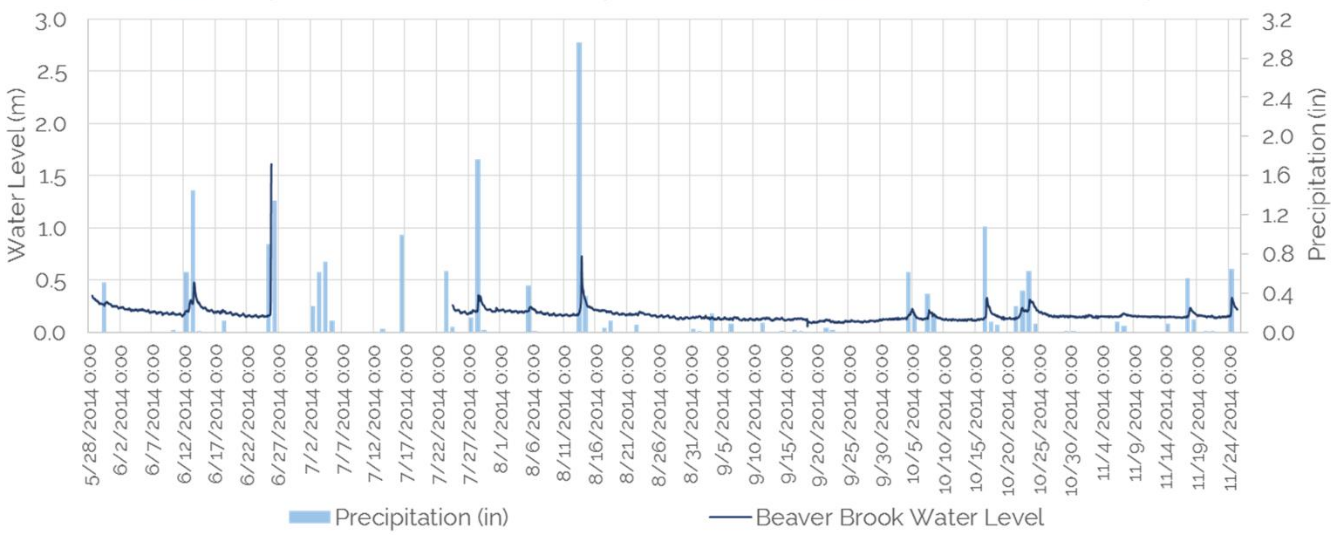
WATER TEMPERATURE

Water temperature increased at Beaver Brook from May to August 2014 and then steadily declined until retrieval in November 2014, following closely with observed air temperature.

STREAM FLOW

Water level data collected at Beaver Brook in 2014 showed that the stream responds quickly to precipitation.



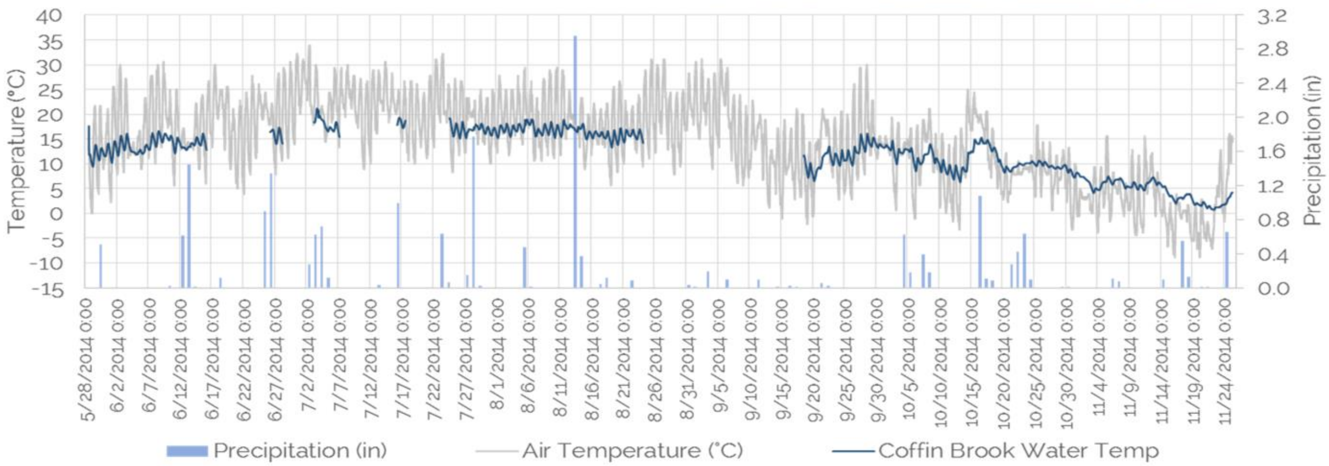


COFFIN BROOK
WATER QUALITY TRENDS

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 increased at Coffin Brook from May to August 2014 and then steadily declined until retrieval in November 2014.

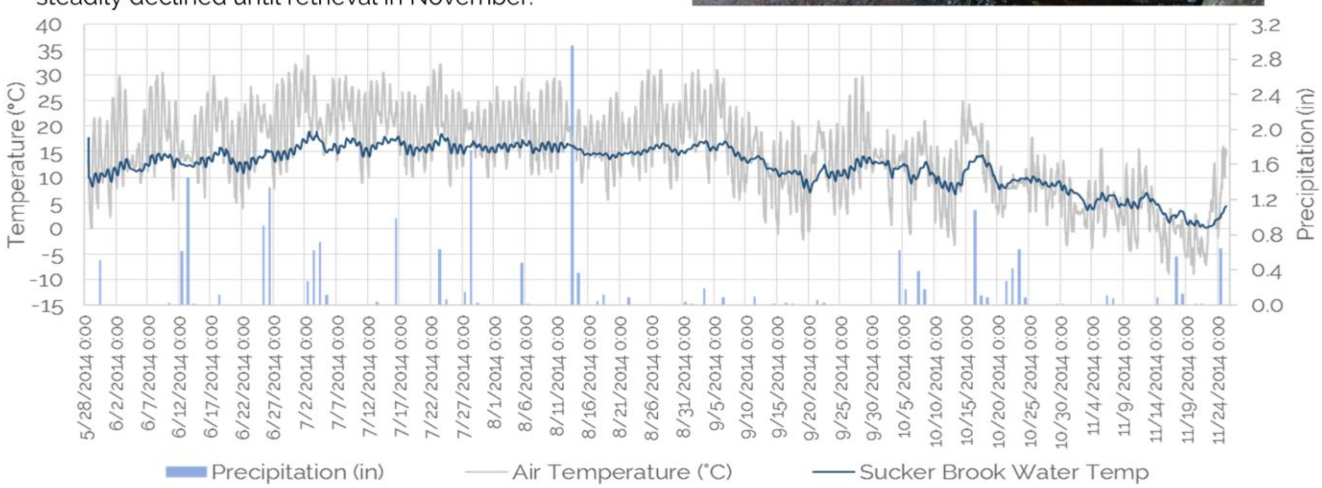


SUCKER BROOK
WATER QUALITY TRENDS

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 increased at Sucker Brook from May to August 2014 and then steadily declined until retrieval in November.

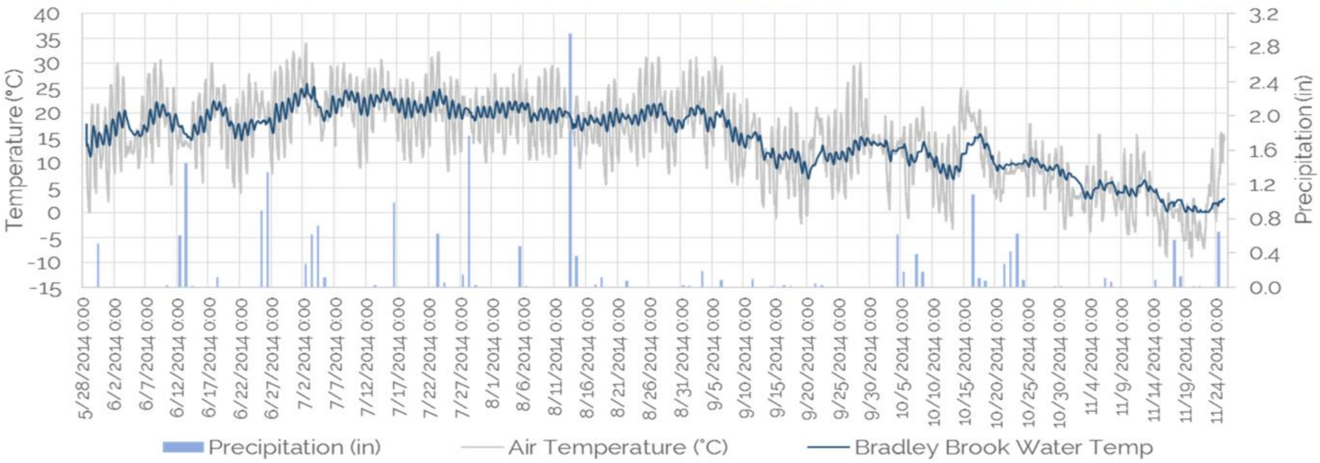


BRADLEY BROOK
WATER QUALITY TRENDS

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

WATER TEMPERATURE

Water temperature increased at Bradley Brook from May to August 2014 and then steadily declined until retrieval in November.

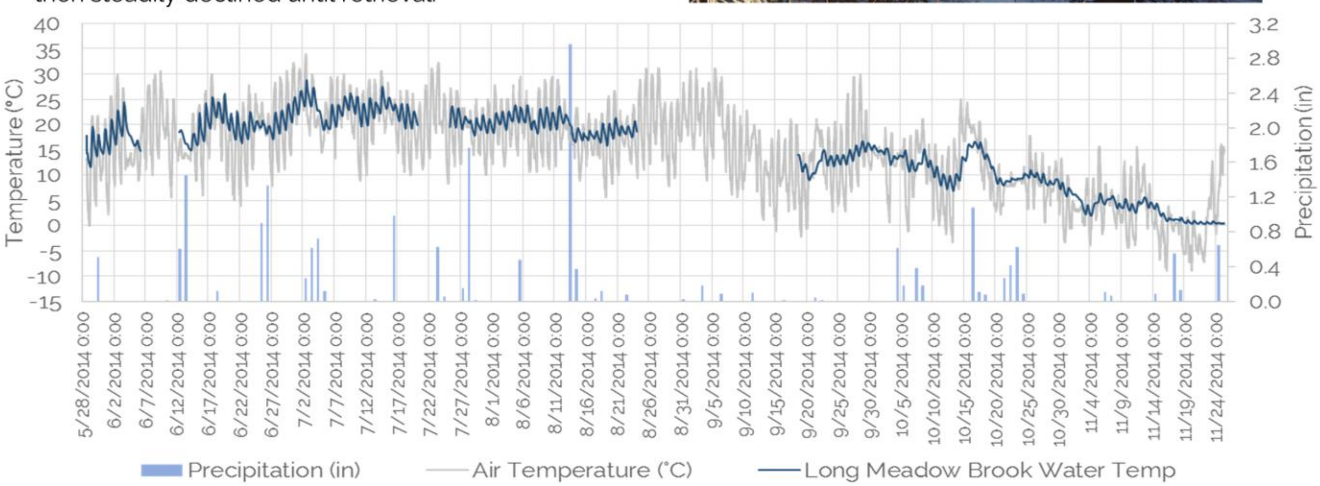


LONG MEADOW BROOK
WATER QUALITY TRENDS

Long Meadow Brook 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 increased at Long Meadow Brook from May to August 2014 and then steadily declined until retrieval.



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 water temperature in each of the three lake basins and Horseshoe Pond. Through this collaboration, KLWA hopes to continue collecting water temperature data through automatic sampling techniques.

OTHER AQUATIC INDICATORS

Sediment Core Samples

To understand the effects of climate change on lake ecosystems, it is common practice to compare past climate conditions with current ones. Since we generally lack instrumental climate data for times before the 20th century, scientists can make use of concepts in geology and biology, along with lake sediment cores, to create approximations of the missing climate data. This approach relies on previously-tested and well-understood relationships between particular aspects of climate, such as average monthly temperature or precipitation, and lake conditions, such as productivity (Chlorophyll-a concentrations), temperature stratification (thermocline depth), oxygen distribution, and particulate inflows (turbidity). Since the sediments that accumulate at the bottom of a lake are the result of the biological, geological, and climatological changes within the lake's watershed, we can then analyze those sediments for their carbon content, mineralogy, and particle-size to infer past lake productivity, stratification, oxygenation, and particulate inflows.

Sediment cores from the bottom of a lake provides information about what the conditions were in a lake over the past several centuries. Photo Credit: KLWA/CCO.

The ongoing study at Kezar Lake aims to assess both current and past relationships between climate and water quality using paleolimnological methods that assess changes in lake condition over the last few hundred years. This study will better connect water quality with climate and land use and will help determine stressors that put Kezar Lake water quality at greatest risk for future impairment.

Sediment cores were collected from the deepest location in two basins at the northern end of the lake near the Great Brook outlet and the 155-ft deep spot in the upper bay, using a hand-held "surface corer" that collects an entire sequence of sediment without disturbing the sediment-water interface (top-most material in contact with the lake water). The top of the core represents modern material and sequentially deeper sediments in the core represent progressively older material. These collection events were well-attended by KLWA, CCO, and watershed residents, which showcases the genuine community interest in protecting their treasured water resources.

Core samples were freeze-dried and analyzed for organic content by burning the samples in a furnace and weighing the difference before and after, a process called loss-on-ignition (LOI). Planned analyses include 1) core dating using the radioactive element Lead-210, 2) magnetic susceptibility to assess the intensity of land erosion, and 3) sediment geochemistry to determine how the mineral composition of lake sediments has changed over time and to assess heavy metal contamination and potential resuspension, if oxygen level deplete in bottom waters.

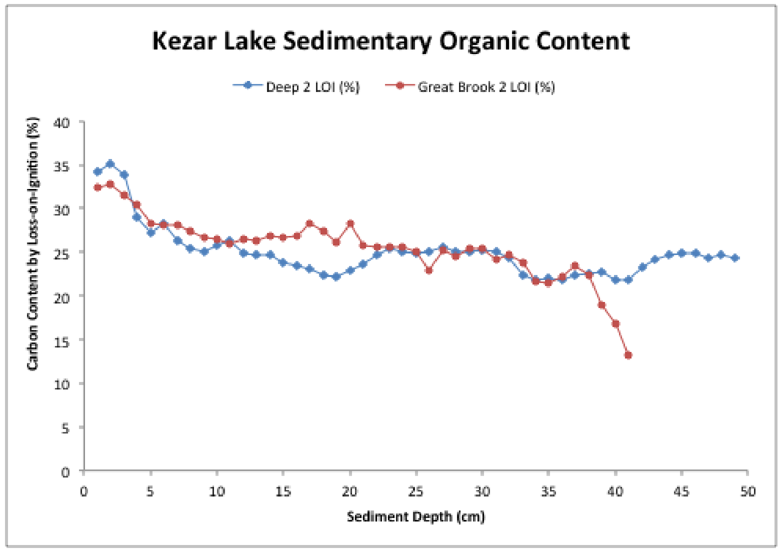


Figure 1. Changes in the amount of organic matter accumulating in the sediments over time at the deep spot of the upper bay of Kezar Lake and at the Great Brook outlet.

Preliminary results are presented here, pending further analyses. Since the two sites are similar despite differences in depth and shoreline condition, results indicate that algal growth is the dominant source of carbon in the sediments (Figure 1). However, it appears that the Great Brook outlet periodically receives more carbon from streams or upslope sources (i.e., 10-20 cm). This could be a result of logging and subsequent slash coming down Great Brook. It also appears that the Great Brook outlet experienced increased mineral sedimentation long ago because the carbon content decreases at the bottom of the core. This could be from turbid stream flows entering the lake from Great Brook.

Results also show recent increases in zinc and lead at the deep spot of Kezar Lake (Figure 2). Further analyses will help us understand the reason for and source of these heavy metal increases.

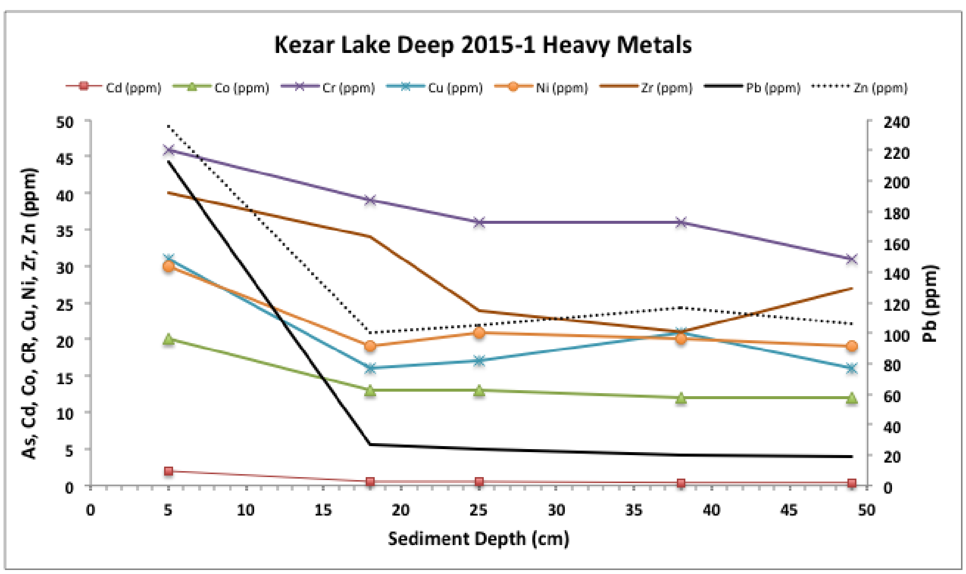
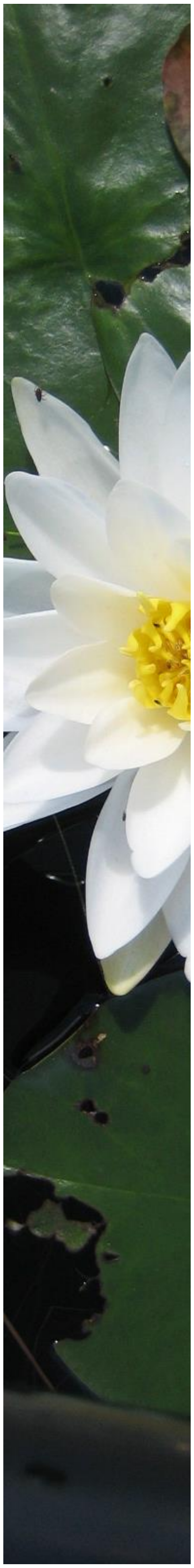


Figure 2. Geochemistry results for the deep spot of the upper bay of Kezar Lake and at the Great Brook outlet. Cd=cadmium, Co=cobalt, Cr=Chromium, Cu=copper, Ni=nickel, Zr=zirconium, Pb=lead, and Zn=zinc.



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.

Fish

Fish 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.

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.

Water Lily. Photo Credit: Don Griggs.

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*[2]. This will serve as an excellent resource for the CCO as they formulate adaptation strategies.

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.

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.

Tree canopy. Photo Credit: Jose Azel.

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

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.

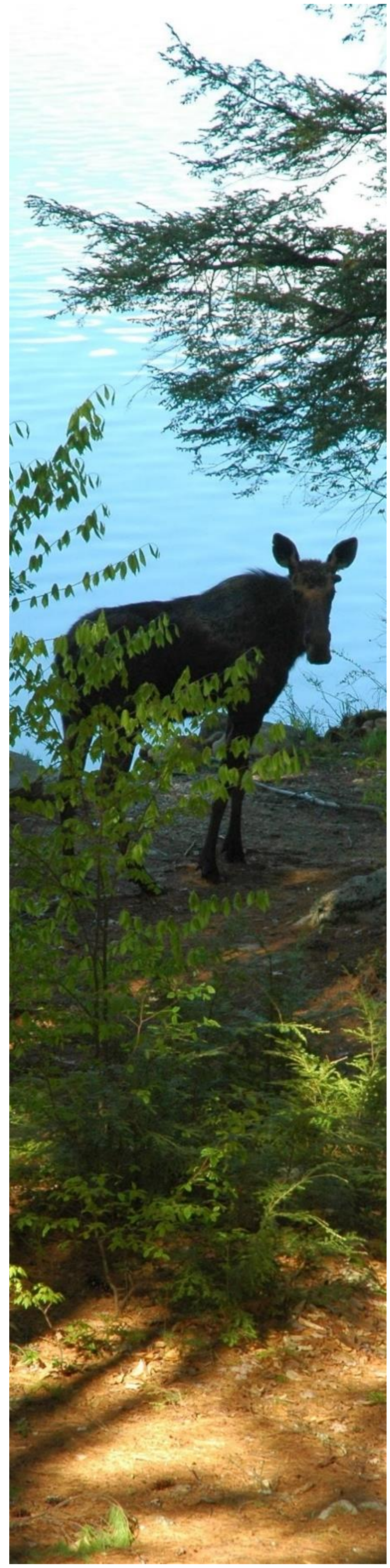
Mammals

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. The observed decline of moose in Maine from disease or migration north is a clear signal of climate change.

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.

Climate change impacts human health, agriculture, and aquatic-terrestrial ecosystems through insect-borne diseases. Increasing air temperatures and more precipitation will increase mosquito and tick populations. The predicted northward expansion of insect-born pathogens, particularly tick-borne lyme disease and mosquito-borne encephalitis, will be harmful to the health of Maine residents.



Moose in Kezar Lake watershed.
Photo Credit: KLWA.

CLIMATE CHANGE REFERENCES

The following table provides references to key documents related to climate change.

ARTICLE TITLE	DATE	DESCRIPTION	LINK
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 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
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/
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

ARTICLE TITLE	DATE	DESCRIPTION	LINK
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/
The interactive effects of excess reactive nitrogen and climate change on aquatic ecosystems and water resources of the United States	2012	Some major adverse effects include harmful algal blooms, hypoxia of fresh and coastal waters, ocean acidification, long-term harm to human health, and increased emissions of greenhouse gases	http://download.springer.com/static/pdf/867/art%253A10.1007%252Fs10533-012-9788-y.pdf?originUrl=http%3A%2F%2Flink.springer.com%2Farticle%2F10.1007%2Fs10533-012-9788-y&token2=exp=1433858939~acl=%2Fstatic%2Fpdf%2F867%2Fart%25253A10.1007%25252Fs10533-012-9788-y.pdf%3ForiginUrl%3Dhttp%253A%252F%252Flink.springer.com%252Farticle%252F10.1007%252Fs10533-012-9788-y*~hmac=b250b59a30b9eaabc6aae12dc3c53a5a168c049416f03051d01a234bfb108515
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
Lakes and Reservoirs as Sentinels, Integrators, and Regulators of Climate Change	2009	Lakes and reservoirs comprise a geographically distributed network of the lowest points in the surrounding landscape that make them important sentinels of climate change. Their physical, chemical, and biological responses to climate provide a variety of information-rich signals.	http://www.aslo.net/lo/toc/vol_54/issue_6_part_2/2273.pdf

ARTICLE TITLE	DATE	DESCRIPTION	LINK
Lakes and streams as sentinels of environmental change in terrestrial and atmospheric processes	2008	The metabolism of inland waters provides a fundamental metric of cross-ecosystem connectivity that responds to natural and human disturbances across scales, from changes in riparian zones to global-scale climate change	http://www.k-state.edu/doddslab/journalarts/williamson%20et%20al%20free%202008.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
Potential Changes in Suitable Habitat for 134 Tree Species in the Northeastern United States	2008	Predict that oak-hickory will increase and spruce-fir will decrease.; suitable habitat will diminish for sugar maple, red maple, black cherry, balsam fir, red spruce, yellow birch, quaking aspen, white pine, eastern hemlock, American beech, and white ash	http://www.ucsusa.org/assets/documents/global_warming/pdf/miti/iverson_et_al.pdf
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

ARTICLE TITLE	DATE	DESCRIPTION	LINK
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
Potential Effects Of Climate Change on Birds of the Northeast	2008	Large changes in bird communities of the northeast are likely to result from climate change, and these changes will be most dramatic under a scenario of continued high emissions.	http://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/pdf/miti/rodenhouse_et_al.pdf
Climate Change Vulnerability of the US Northeast Winter Recreation - Tourism Sector	2008	This study examined the vulnerability of the two largest winter recreation industries, snowmobiling and alpine skiing, to four climate change scenarios for the 21st century. Under all scenarios, natural snow became an increasingly scarce resource.	http://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/pdf/miti/scott_et_al.pdf
Projected Change in Climate Thresholds in the Northeastern U.S.: Implications for Crops, Pests, Livestock, and Farmers	2008	This study examined the potential impact of the IPCC scenarios on NE agriculture, finding longer and frost free growing seasons that will cause temperature stress and promote weeds, insects, disease, or other risk factors.	http://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/pdf/miti/wolfe_et_al.pdf
Climate Change, Aerobiology, and Public Health in the Northeast United States	2008	This study shows potentially more pollen and fungal spores that could create more associated allergic disease in NE.	http://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/pdf/miti/ziska_et_al.pdf

ARTICLE TITLE	DATE	DESCRIPTION	LINK
Landscaping at the Waters Edge: An Ecological Approach	–	Applying the principles of ecological landscaping will support wildlife and plant diversity and maintain or even improve water quality in our lakes	http://extension.unh.edu/resources/files/Resource004159_Rep5940.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
Global Warming Effects Lakes and Rivers	–	Displacement of cold-water species, dead zones, effects on reproduction, stress, and disease	http://www.climatehotmap.org/global-warming-effects/lakes-and-rivers.html
Inland Waters Biodiversity - What's the Problem?	–	Inland waters: Threats to biodiversity, impacts of climate change, future scenarios	https://www.cbd.int/waters/problem/

FUTURE PLANS

CCO plans for the 2015-2016 year 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.
- Complete the sediment core dating and analysis.
- 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.
- Employ a 2016 graduate summer intern to further climate change work.

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, 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 great work, the following adaptation strategies are recommended for the Kezar Lake watershed community:

ADAPTATION RECOMMENDATIONS

- Incorporate climate change language in updated municipal comprehensive plans.
- Prepare municipal climate change adaptation plans.
- Adopt a citizen pledge to reduce carbon footprint.
- Provide incentives (e.g., tax breaks) for homeowners that reduce carbon footprint.
- Review and improve energy usage of municipal buildings.

- Improve infrastructure to accommodate higher and more frequent flow volumes.
- Replace the 15 high priority culverts identified by the 2015 culvert study.
- Expand culvert study to include private roads.
- Create a funding and assessment plan to re-assess and replace culverts in the watershed on an ongoing basis.

ADAPTATION RECOMMENDATIONS

- Develop emergency management plans based on climate projections. Include current and projected flood risk maps for residents with homes in low-lying areas. Consider requiring septic system evaluations for all homes within the projected flood zone to assess potential for failure due to rising water tables. Consider rezoning the projected flood zone for non-development.
- Encourage establishment of a "Climate Change Adaptation" webpage on the town website that directs residents to important climate change information and the CCO webpages.
- Conduct bathymetry and topographic mapping of shoreline habitats and model the effects of changing lake levels on shoreline stability.
- Review and update local ordinances to include better site design, low impact development, and green infrastructure principles that limit the amount of phosphorus, nitrogen, sediment, and acidic waters from reaching waterbodies.
- Develop an alkalinity and pH study to assess the vulnerability of waterbodies to acid rain and watershed activities.
- Target stormwater management and septic system maintenance outreach to Farrington and Heald Pond residents.
- Protect land to ensure that development occurs in a low-impact way to increase watershed resiliency to extreme weather events and prevent potential polluted runoff.
- Continue progressive watch programs that help prevent and control invasive plants.
- Classify streams based on climate resiliency for supporting coldwater fish species. This will help target streams in need of restoration. Restoration techniques include increasing overhead vegetative cover to help cool stream water temperatures.
- Encourage anglers to use non-lead sinkers by providing free samples.
- Create a public notification system for swimming advisories following any instances of significant algal blooms when waters may be harmful to human health.
- Develop homeowner brochure that recommends climate-hardy species and mitigation strategies for farmers and garden-enthusiasts.
- Promote conservation tillage to farmers.
- Conduct habitat and species-level vulnerability assessments.
- Protect and restore riparian habitats by enhancing buffers that limit heat stress on species.
- Develop a buffer ordinance that recommends permitted activities within buffer zone and establishes minimum buffer widths more stringent that State law.
- Conserve and protect land areas that serve as key wildlife corridors or large habitat blocks for species movement.
- Complete a habitat analysis of the watershed that prioritizes high value habitat based on species most vulnerable to climate change.
- Disseminate public notices during peak tick and mosquito season.
- Control outside firewood and other materials that potentially harbor invasive insects.

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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 such as 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 TP values. 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, 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 taken with a long tube in order to determine average nutrient concentration in the epilimnion.

pH: The standard measure of the acidity or alkalinity 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 sediment. Since algae are usually the most common factor, transparency is an indirect measure of algal populations.

Thermocline: The uppermost point in the water column where the temperature drops at least a degree Celsius 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. It is generally present in small amounts and limits plant growth in freshwater ecosystems. As phosphorus increases, the amount of algae generally increases. Humans can add phosphorous to a lake through stormwater runoff, lawn or garden fertilizers, and leaky or poorly maintained septic tanks.

Trophic State Indicators: A scale from 0 to 100+, which ranks lakes for productivity. The low (zero) end of the scale supports very little algae, has excellent water quality (oligotrophic) and the high end 100+ is eutrophic and very productive. TSI can be calculated from the Secchi disk, Chl-a or TP results and requires at least five months of data per year. Lakes with TSI values greater than 65 may support algal blooms, while values over 100 indicate extreme productivity and annual algae blooms. TSI values can be used to compare lakes with similar water color and track water quality trends within a lake.

Watershed: A area in which all land and water drain or flow toward a central collector, such as a stream, river, or lake at a lower elevation.