KEZAR LAKE

2016 WATER QUALITY REPORT

A REPORT ON THE WATER QUALITY OF KEZAR LAKE,
EIGHT STREAMS, AND SIX WATERSHED PONDS

PREPARED BY:
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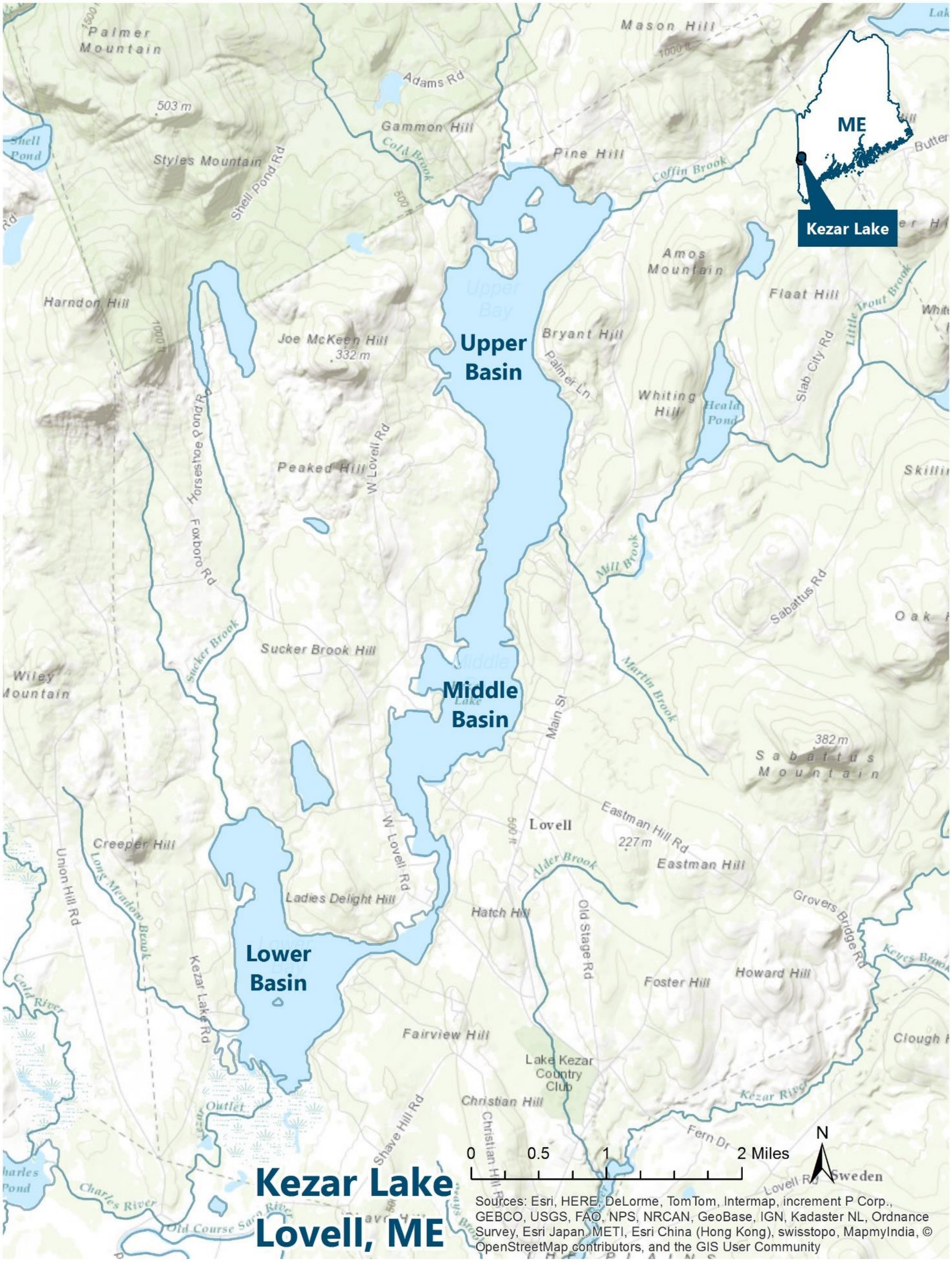
Kezar Lake
Lovell, ME
Upper Basin
Middle Basin
Lower Basin
ME
Kezar Lake
Lovell
Mason Hill
Pine Hill
Gammon Hill
Adams Rd
Coffin Brook
Cold Brook
Palmer Mountain
Styles Mountain
Shell Pond Rd
Harndon Hill
Joe McKeen Hill
Amos Mountain
Flaat Hill
Bryant Hill
Palmer Ln
Whiting Hill
Heald Pond
Slab City Rd
Little Trout Brook
Horseshoe Pond Rd
Foxboro Rd
Peaked Hill
W Lovell Rd
Mill Brook
Sabattus Rd
Sucker Brook Hill
Sucker Brook
Wiley Mountain
Martin Brook
Main St
Sabattus Mountain
Eastman Hill Rd
Eastman Hill
Creeper Hill
Union Hill Rd
Long Meadow Brook
Ladies Delight Hill
Alder Brook
Hatch Hill
Old Stage Rd
Grovers Bridge Rd
Kezar Lake Rd
Foster Hill
Howard Hill
Cold River
Fairview Hill
Lake Kezar Country Club
Clough Hill
Christian Hill
Christian Hill Rd
Shave Hill Rd
Kezar Outlet
Kezar River
Fern Dr
Lovell Rd
Sweden
Charles River
Old Course Saco River
0 0.5 1 2 Miles
N
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

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February 2017

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Kezar Lake Watershed Association

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Special thanks to Jim Stone (KLWA President), Heinrich Wurm (KLWA Water Quality Program Coordinator), Don Griggs (KLWA CCO Chair), Terri Mulks (Camp Susan Curtis - Trout Pond), Ralph Tedesco (Farrington Pond), Mrs. Sundsrom (Heald Pond), the Emond Family (Horseshoe Pond), and Andy Chakoumakos (KLWA Volunteer) for providing access, time, and equipment for the 2016 water quality monitoring season.

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GLOSSARY OF KEY TERMS

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

Color: A measure of the influence of suspended and dissolved particles in water from weathered geologic material, vegetation cover, and land use activity. Colored lakes (>25 PCU) can have reduced water clarity and increased phosphorus concentrations.

Dissolved Oxygen: The concentration of oxygen dissolved in 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, amount of algae and other plants in the water, and the amount of nutrients and organic matter that flow into the waterbody from the watershed. 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 harmful pathogens from fecal contamination that can derive from a number of mammalian sources, including human, canine, and wildlife.

Eutrophication: Process by which lakes become more productive over time. Lakes with high productivity have high levels of phosphorus and chlorophyll-a, low water clarity, and abundant biomass with significant accumulation of organic matter on lake bottom. Eutrophic lakes are susceptible to algal blooms and severe oxygen depletion in the hypolimnion. Lakes naturally become more productive or "age" over thousands of years. In recent geologic time, however, humans have enhanced the rate of enrichment and lake productivity, speeding up this natural process to tens or hundreds of years.

Integrated Epilimnetic Core: A water sample that is taken with a long tube to determine average nutrient concentration from the lake surface to the top of the thermocline.

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 the deepest spot of each basin.

GLOSSARY OF KEY TERMS (CONTINUED)

Secchi Disk Transparency (SDT) or 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. Measuring water clarity is one of the most useful ways to show whether a lake is changing from year to year. Changes in water clarity 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.

Thermocline: The uppermost point in the water column where the temperature drops at least a degree Celsius per meter of depth.

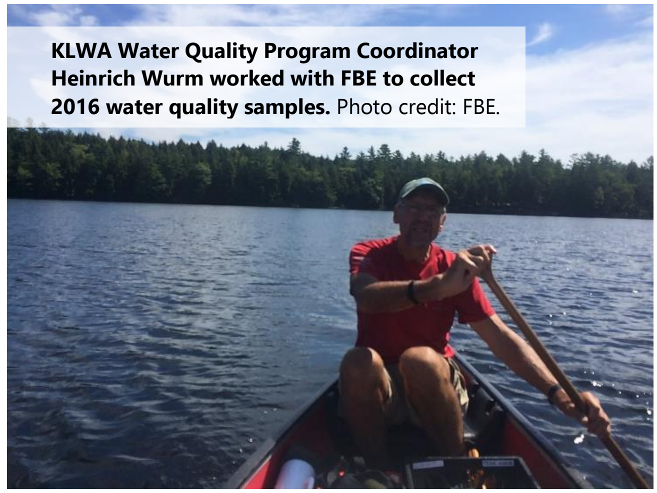
Total Alkalinity: A measure of the buffering capacity of a lake (i.e., the capacity of water to neutralize acids). The buffering capacity or the concentration of bicarbonate, carbonate, and hydroxide ions in water, is largely determined by the geology of soils and rocks surrounding the lake. Total alkalinity above 20 ppm buffers against drastic changes in pH that could impact aquatic plants and animals.

Total Phosphorus (TP): The total concentration of phosphorus found in water, including organic and inorganic forms. Phosphorus is one of the limiting nutrients needed for plant growth; as phosphorus increases, the amount of algae generally increases. Humans can add excess phosphorus to a lake through stormwater runoff, lawn or garden fertilizers, and leaky or poorly-maintained septic systems.

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

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

BACKGROUND AND METHODS



KLWA Water Quality Program Coordinator Heinrich Wurm worked with FBE to collect 2016 water quality samples. Photo credit: FBE.

This report documents the results of water quality monitoring conducted by FB Environmental Associates (FBE) for the Kezar Lake Watershed Association (KLWA) in 2016. Deep spot sample stations at the three basins of Kezar Lake were sampled on June 21, August 18, and September 15, 2016; deep spot sample stations at six ponds (Bradley, Cushman, Farrington, Heald, Horseshoe, and Trout Ponds) and two public beaches (PPB-1 and LVT-1) were sampled on June 21 and August 18, 2016; and tributary sample stations along Great Brook (GB-1) and Boulder Brook (BB-1, BB-3, and BB-4) were sampled on June 21 and September 15, 2016 (Figure 1).

- For **lake and pond deep spot monitoring**, FBE, with the help of KLWA volunteers, collected temperature and dissolved oxygen profiles, as well as integrated epilimnetic cores, or cores of water taken from the surface of the lake to the upper part of the thermocline. These water samples were analyzed for trophic state indicators (water clarity, total phosphorus, and chlorophyll-a) and chemical parameters (total alkalinity, pH, and color). Trophic state indicators are indicators of biological productivity and help determine the extent and effect of eutrophication in lakes.
- For **beach monitoring**, FBE, at the request of KLWA, sampled two public beaches twice for *Escherichia coli (E. coli)*. *E.coli* is an indicator of harmful pathogens found in fecal waste.
- For **tributary monitoring**, four sites at two tributaries (Great and Boulder Brooks) were sampled for dissolved oxygen, temperature, total phosphorus, pH, and *E.coli.* FBE also monitored water temperature and/or water level using continuous Onset® HOBO® loggers at the lower basin, Kezar outlet stream, and seven tributaries of Kezar Lake: Great, Beaver, Coffin, Boulder, Sucker, Bradley, and Long Meadow Brooks.

Sampling was conducted in accordance with standard methods and procedures for lake monitoring established by the Maine Department of Environmental Protection (Maine DEP), the US Environmental Protection Agency (USEPA), and the Maine Volunteer Lake Monitoring Program (VLMP). All lab samples were analyzed at the Health and Environmental Testing Lab (HETL) in Augusta. Background and historical information on these waterbodies can be found in previous reports (FBE, 2016; FBE, KLWA, & PSU, 2015; FBE, 2013a, 2013b).

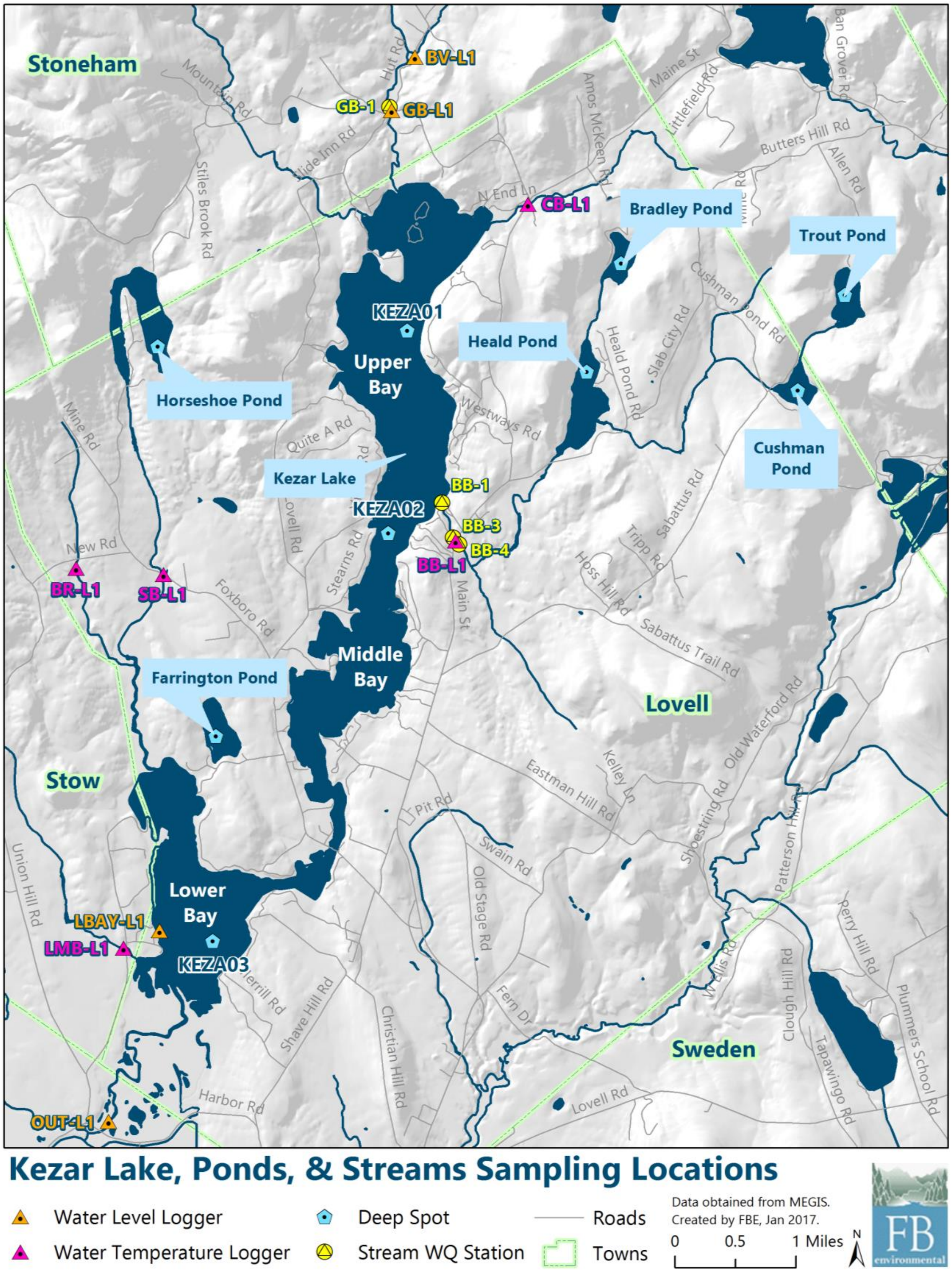
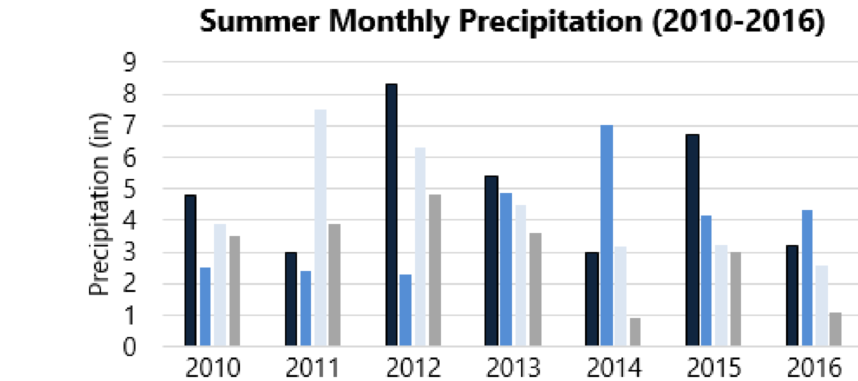


FIGURE 1. Map of lake, pond, and stream sampling locations.

WATER QUALITY MONITORING RESULTS

WEATHER

Weather is one of the major factors influencing inter-annual variability in lake water quality. Abnormally dry summer conditions (as experienced in 2016) reduce the amount of runoff, containing sediment and nutrients, to the lake and ponds, resulting in improved water quality (e.g., high water clarity, lower phosphorus, and lower chlorophyll-a or algae). Conversely, wetter years transport more material from the landscape to the lake and ponds, resulting in degraded water quality. From 2010-2016, the region experienced the lowest total summer rainfall in 2016, with only 11 inches in Fryeburg, Maine. This resulted in better-than-normal water quality for some parameters, discussed below.



	2010	2011	2012	2013	2014	2015	2016
June	4.8	3.0	8.3	5.4	3.0	6.7	3.2
July	2.5	2.4	2.3	4.9	7.0	4.2	4.3
August	3.9	7.5	6.3	4.5	3.2	3.2	2.6
September	3.5	3.9	4.8	3.6	0.9	3.0	1.1

FIGURE 2. Summer (June-September) monthly precipitation amounts from 2010-2016. Data sourced from Weather Underground for the Fryeburg, ME weather station.

KEZAR LAKE

Trophic State Indicators

Measuring water clarity is one of the most useful ways for determining if a lake is changing from year to year. Changes in water clarity may be due to a change in the amount and composition of algal communities or the amount of dissolved or particulate materials in a lake. Such changes are likely the result of human disturbance or other impacts to the lake's watershed. Water clarity varies widely in Maine lakes, ranging from 0.5 to 15.5 meters, with an average of 4.8 meters (VLMP, 2013). Generally, water clarity of 2 meters or less indicates a water quality problem and a higher potential for severe algal blooms. The Maine DEP classifies productive or eutrophic lakes as 4 meters or less, moderately productive or mesotrophic lakes as 4-7 meters, and unproductive or oligotrophic lakes as 7 meters or greater.

Since 1970, mean annual water clarity in Kezar Lake – upper basin (01) has ranged from 6.2 to 10.1 meters, with an average of 7.8 meters; Kezar Lake – middle basin (02) has ranged from 4.2 to 9.1 meters, with an average of 7.0 meters; and Kezar Lake – lower basin (03) has ranged from 2.6 to 3.7 meters, with an average of 3.2 meters. Kezar Lake is generally clearer than the average water clarity of Maine lakes and has shown an improving trend in water clarity in all three basins over the sampling record (Figure 3). In 2016, average water clarity for the upper, middle, and lower basins of Kezar Lake were 9.3, 8.4, and 3.4 meters, respectively (Figure 3). For the upper and middle basins, 2016 average water clarity were 0.81 and 0.66 meters shallower (worse) than 2015, but were still the next deepest (best) annual average since 2003 or the entire sampling record, respectively. This is attributed to the abnormally dry summer conditions in 2016, particularly in August and September (see Weather). The lower basin is very shallow (~3 meters deep); the Secchi disk is usually still visible on lake bottom. Because of this, changes in water clarity in the lower basin reflects variable lake water level only.

Since 1977, mean annual total phosphorus in Kezar Lake – upper basin (01) has ranged from 4.0 to 11.3 ppb, with an all data average of 5.9 ppb; Kezar Lake – middle basin (02) has ranged from 2.0 to 10.0 ppb, with an all data average of 5.0 ppb; and Kezar Lake – lower basin (03) has ranged from 6.0 to 13.5 ppb, with an all data average of 8.8 ppb. Kezar Lake has low phosphorus compared to average phosphorus levels in Maine Lakes (12.0 ppb) and has shown a relatively stable trend in phosphorus over the sampling record (Figure 3; VLMP, 2013). In 2016, average total phosphorus for the upper, middle, and lower basins of Kezar Lake were 4.7, 4.7, and 9.3 ppb, respectively (Figure 3). While 2015 and 2016 were excellent years for water clarity, 2016 was in line with, though generally on the lower to mid end of, historical measurements for total phosphorus.

Since 1977, mean annual chlorophyll-a in Kezar Lake – upper basin (01) has ranged from 1.1 to 5.4 ppb, with an all data average of 2.6 ppb; Kezar Lake – middle basin (02) has ranged from 1.0 to 2.4 ppb, with an all data average of 1.9 ppb; and Kezar Lake – lower basin (03) has ranged from 1.6 to 3.3 ppb, with an all data average of 2.4 ppb. Kezar Lake has low chlorophyll-a compared to average chlorophyll-a levels in Maine Lakes (5.4 ppb) and has shown a relatively stable trend in chlorophyll-a over the sampling record (Figure 3; VLMP, 2013). In 2016, average chlorophyll-a for the upper, middle, and lower basins of Kezar Lake were 1.1, 1.0, and 2.2 ppb, respectively (Figure 3). For the upper and middle basins, 2016 average chlorophyll-a was the lowest (best) annual average over the entire sampling record. For the lower basin, 2016 average chlorophyll-a was in line with historical measurements for chlorophyll-a, likely because of it shallow nature and susceptibility to algal growth due to elevated nutrients in runoff or from bottom sediments.

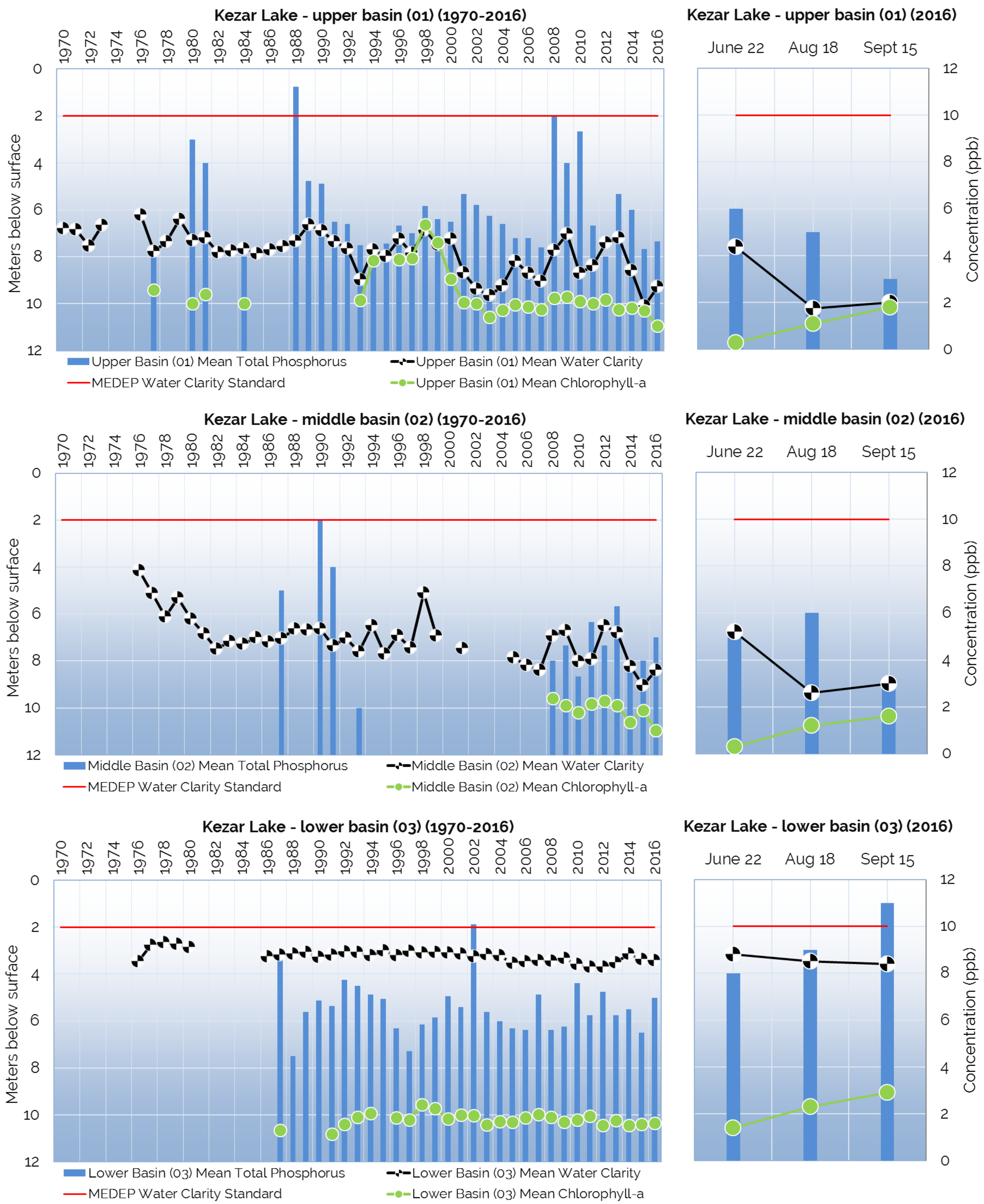


FIGURE 3. Kezar Lake water clarity, total phosphorus, and chlorophyll-a for the three basins for the entire historical record (left) and for 2016 (right). The lower basin (03) is limited by its shallow depth and the Secchi disk typically hits bottom during readings. Water clarity readings taken on June 22 were by Heinrich Wurm, KLWA.

Dissolved Oxygen & Temperature

A sunny day at the Kezar Lake upper basin in September of 2016. Photo Credit: FBE.

A common problem in Maine lakes is the depletion of dissolved oxygen (DO) in the deepest part of lakes throughout the summer months. This occurs when thermal stratification prevents warmer, oxygenated surface waters from mixing with cooler, oxygen-depleted (from chemical and biological processes) bottom waters in the lake. DO levels below 5 ppm (and water temperature above 24 °C) can stress and reduce habitat for cold-water fish. In addition, anoxia (low DO) at lake bottom can result in the release of sediment-bound phosphorus (otherwise known as internal phosphorus loading), which becomes a readily available food source for algae.

Historically, Kezar Lake has experienced some DO depletion in the upper and middle basins in summer. In 2016, DO depletion was evident at the very bottom (50 meters) in the upper basin during both the August and September sampling (3.6 ppm and 4.9 ppm, respectively; Figure 4). However, it is very likely that the sensor was sitting in bottom sediments since the depth reading was 160 feet (or 48.8 meters) during both sampling events. In 2016 (like 2014 and 2015), the entire water columns of the middle and lower basins were well oxygenated, never measuring below 7.4 ppm. Differences in profile depths at the upper and middle basins were due to gusty weather conditions (particularly for the upper basin in June) and/or difficulty in pinpointing the deep spot (particularly for the middle basin).

Temperature profiles in 2016 were generally in line with historic temperature profiles for all stations, with slightly lower 2016 surface temperatures in August and September than in 2015. Formation of the metalimnion (thermocline) began between 5 and 9 meters below the surface at the upper and middle basins (Figure 4). A thermocline cannot develop at the lower basin due to shallow water depth.

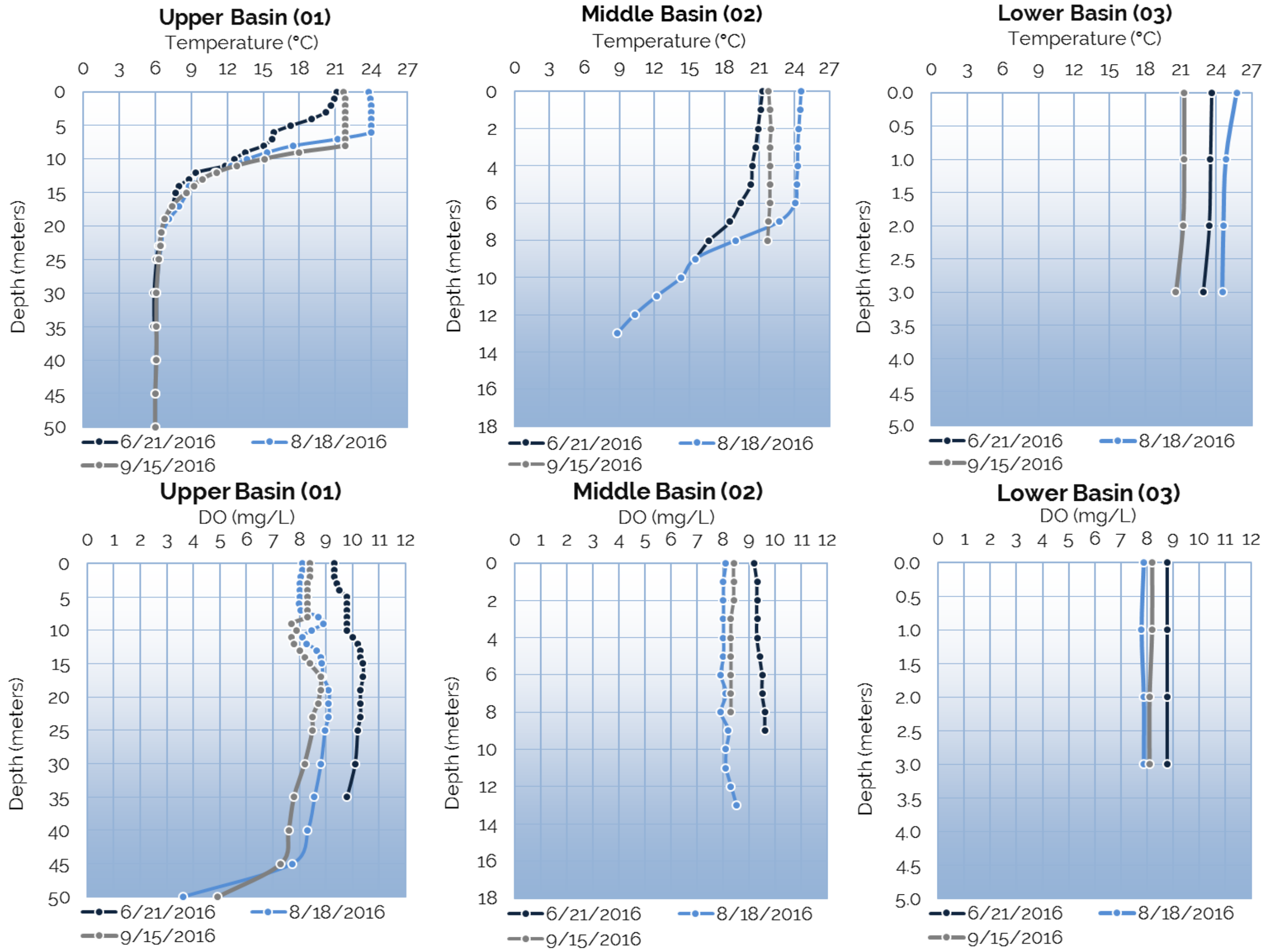


FIGURE 4. 2016 temperature (top panel) and dissolved oxygen (bottom panel) profiles for the upper, middle, and lower basins of Kezar Lake. mg/L= parts per million (ppm).

Chemical Parameters

Since 1980, mean annual total alkalinity in Kezar Lake – upper basin (01) has ranged from 3.0 to 7.0 ppm, with an all data average of 4.5 ppm; Kezar Lake – middle basin (02) has ranged from 3.0 to 4.0 ppm, with an all data average of 3.8 ppm; and Kezar Lake – lower basin (03) has ranged from 2.7 to 6.0 ppm, with an all data average of 4.5 ppm. Kezar Lake has low alkalinity compared to average alkalinity levels in Maine Lakes (11.8 ppm) and has shown a decreasing (worsening) trend in total alkalinity over the sampling record for the upper and middle basins (Table 1; VLMP, 2013). Since 2012 (including 2016), all three basins in Kezar Lake have averaged 4.0 ppm over the course of each sampling season (Table 1). Kezar Lake has critically-low alkalinity (or buffering capacity) because of its contributing geology (i.e., granite) that lacks carbonates, bicarbonates, and carbonic acid. These low levels make Kezar Lake and its inhabiting aquatic organisms susceptible to both natural and anthropogenic changes in pH (acidity), particularly from acidic deposition in the form of rain or snow.

Since 1977, mean annual pH in Kezar Lake – upper basin (01) has ranged from 6.3 to 7.0, with an all data average of 6.6; Kezar Lake – middle basin (02) has ranged from 6.3 to 7.0, with an all data average of 6.4; and Kezar Lake – lower basin (03) has ranged from 5.9 to 7.0, with an all data average of 6.6. Kezar Lake has slightly more acidic pH compared to average pH levels in Maine Lakes (6.8) and has shown no trend in pH over the sampling record (Table 1; VLMP, 2013). In 2016, pH at the upper basin averaged 6.0 and pH at the middle and lower basins both averaged 6.1. These pH values are more acidic than those measured historically and are below the Maine DEP/USEPA recommended range of 6.5 to 8.0 to support aquatic species (Table 1).

Since 1980, mean annual color in Kezar Lake – upper basin (01) has ranged from 5.0 to 21.3 PCU, with an all data average of 11.2 PCU; Kezar Lake – middle basin (02) has ranged from 8.7 to 14.7 PCU, with an all data average of 11.2 PCU; and Kezar Lake – lower basin (03) has ranged from 8.0 to 16.3 PCU, with an all data average of 14.0 PCU. Kezar Lake is a non-colored waterbody (<25 PCU) compared to average color in Maine Lakes (28.0 PCU) and has shown a relatively stable trend in color over the sampling record (Table 1; VLMP, 2013). In 2016, color at the upper, middle, and lower basins averaged 8.3, 8.7, and 10.0, respectively (Table 1). These results were slightly lower than in 2015 (9.0, 9.0, and 10.3 PCU, respectively). Historical data indicate that high color values are positively correlated to high precipitation years because of increased runoff (Figure 5). Precipitation in summer 2016 was low (11.2 inches from June to September) as were color values, which further solidifies this relationship.

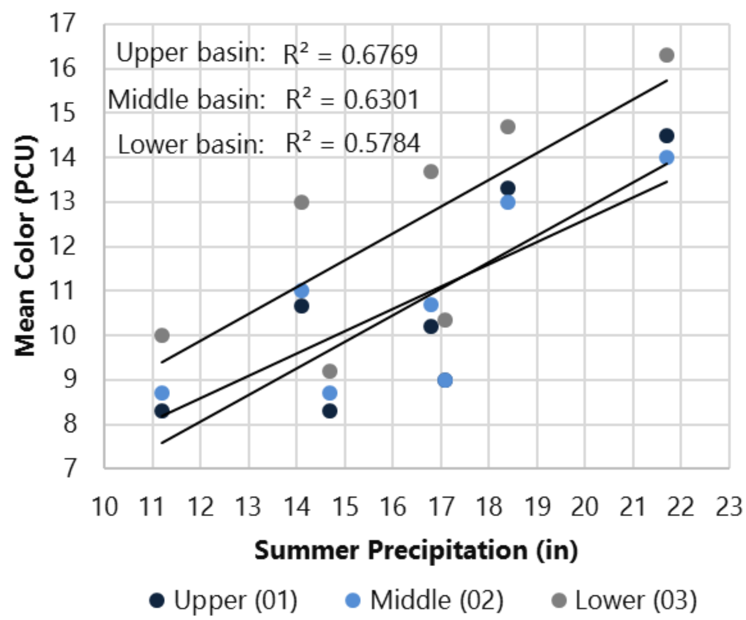


FIGURE 5. Higher summer precipitation amounts wash off more material from the landscape to the lake and contributes to higher color values. Conversely, lower summer precipitation amounts generally allow for better water clarity and reduced color.

TABLE 1. 2016 water quality monitoring results for the upper, middle, and lower basins of Kezar Lake.

DATE	STATION	WATER CLARITY (METERS)	TOTAL PHOSPHORUS (PPB)	CHLOROPHYLL-A (PPB)	ALKALINITY (PPM)	PH	COLOR (PCU)
6/21/2016	Upper (01)	7.6	6.0	0.3	4.0	6.1	10.0
	Middle (02)	6.8	5.0	0.3	4.0	6.1	11.0
	Lower (03)	3.2	8.0	1.4	4.0	6.3	12.0
8/18/2016	Upper (01)	10.3	5.0	1.1	4.0	6.0	8.0
	Middle (02)	9.4	6.0	1.2	4.0	6.1	8.0
	Lower (03)	3.5	9.0	2.3	4.0	6.1	9.0
9/15/2016	Upper (01)	10.0	3.0	1.8	4.0	6.0	7.0
	Middle (02)	9.0	3.0	1.6	4.0	6.1	7.0
	Lower (03)	3.6	11.0	2.9	4.0	6.0	9.0
2016 Mean (Kezar Lake)	Upper (01)	9.3	4.7	1.1	4.0	6.0	8.3
	Middle (02)	8.4	4.7	1.0	4.0	6.1	8.7
	Lower (03)	3.4	9.3	2.2	4.0	6.1	10.0
Historical Average[a]	Upper (01)	7.8	5.9	2.6	4.5	6.6	11.2
	Middle (02)	7.0	5.0	1.9	3.8	6.4	11.2
	Lower (03)	3.2	8.8	2.4	4.5	6.6	14.0
Maine Lakes*	**Mean**	**4.8**	**12.0**	**5.4**	**11.8**	**6.8**	**28.0**

** From Maine VLMP 2013 Lakes Report.*

[a] All data averages do not include QA/QC'd 2015 or 2016 Maine DEP or VLMP data

PONDS

The following provides a summary of historical and current water quality of the six ponds in the Kezar Lake watershed. Refer to Table 2 and Figure 6.

Bradley Pond

- Average water clarity in 2016 (4.7 meters) was the third shallowest (worst) annual average behind 2011 (4.6 meters) and 2009 (4.7 meters) and was 0.6 meters shallower (worse) than the all data average (5.3 meters). This was despite the extremely dry summer experienced throughout most of the region, which contributed to generally better water clarity in most waterbodies.
- Average total phosphorus in 2016 (10.5 ppb) was the second highest (worst) annual average behind 2015 (14.5 ppb) and was 1.1 ppb higher (worse) than the all data average (9.4 ppb). This may be tending toward a degrading trend; further monitoring will be needed.
- Average chlorophyll-a in 2016 (3.4 ppb) was 0.1 ppb lower (better) than the all data average (3.5 ppb), but higher (worse) than average chlorophyll-a measured in 2014 and 2015 (2.7-2.8 ppb).

- DO concentrations dropped below the aquatic life criterion of 5 ppm beginning at 5 or 6 meters depth on both sampling dates in 2016. Anoxia at pond bottom should continue to be monitored closely for signs of degradation (i.e., increase in the extent and duration of anoxia experienced in late summer).
- Average pH in 2016 (5.9) was the lowest (worst) annual average on record, was 0.4 lower (worse) than the all data average (6.3), and fell below the optimal aquatic life criteria range of 6.5 to 8.0. Bradley Pond has historically experienced the lowest (worst) pH, which may also be tending toward a degrading trend; further monitoring will be needed.
- Average alkalinity in 2016 (4.0 ppm) was slightly higher (better) than the all data average (3.9 ppm). Annual average alkalinity has been consistently measuring at 4.0 ppm since 2013.
- Average color in 2016 (18.5 PCU) was the lowest (best) annual average since 2013 and was 2.7 PCU lower (better) than the all data average (21.2 PCU). This is likely attributed to the extremely dry summer weather conditions that limited material runoff to the pond.

Cushman Pond

- Average water clarity in 2016 (4.6 meters) was the second shallowest (worst) annual average behind 2013 (4.5 meters) and was 0.9 meters shallower (worse) than the all data average (5.5 meters). This was despite the extremely dry summer experienced throughout most of the region, which contributed to generally better water clarity in most waterbodies.
- Average total phosphorus in 2016 (9.0 ppb) was the third highest (worst) annual average behind 2009 (10.0 ppb) and 2012 (9.5 ppb) and was 1.6 ppb higher (worse) than the all data average (7.4 ppb). This may be tending toward a degrading trend since 2006; further monitoring will be needed.
- Average chlorophyll-a in 2016 (2.5 ppb) was 0.1 ppb lower (better) than the all data average (2.6 ppb) and has remained relatively stable since 1997.
- Between 2010 and 2013, DO concentrations dropped below the aquatic life criterion of 5 ppm beginning at 6-7 meters below the surface. Since then and including 2016, no DO depletion of <5 ppm has been observed at Cushman Pond.
- Average pH in 2016 (6.1) was the lowest (worst) annual average on record, was 0.5 lower (worse) than the all data average (6.6), and fell below the optimal aquatic life criteria range of 6.5 to 8.0. This may be tending toward a degrading trend; further monitoring will be needed.
- Average alkalinity in 2016 (5.0 ppm) was slightly higher (better) than the all data average (4.7 ppm). Annual average alkalinity has been decreasing (worsening) since 1997.

- Average color in 2016 (9.5 PCU) was the lowest (best) annual average since 2011 (9.5 PCU) and was 2.3 PCU lower (better) than the all data average (11.8 PCU). This is likely attributed to the extremely dry summer weather conditions that limited material runoff to the pond.

Farrington Pond

- Average water clarity in 2016 (4.2 meters) was 0.2 meters shallower (worse) than the all data average (4.4 meters), but was deeper (better) than 2014 (4.1 meters) and 2015 (4.0 meters). This may be due to the extremely dry summer experienced throughout most of the region, which contributed to generally better water clarity in most waterbodies. Farrington Pond water clarity has occasionally been limited due to the Secchi disk hitting bottom; however, water clarity is the shallowest (worst) of the other ponds and has become consistently shallower (worse) by about 1.0 meter since 2009.
- Average total phosphorus in 2016 (15.0 ppb) was 0.3 ppb lower (better) than the all data average (15.3 ppb). Year-to-year variability in and absolute concentrations of total phosphorus in Farrington Pond is the highest (worst) compared to the other ponds. The shallow nature of this pond makes it more vulnerable to suspension of phosphorus-laden sediment because of heavy rainfall, wind storms, or watershed disturbances (e.g., shoreline development).
- Average chlorophyll-a in 2016 (5.2 ppb) was 2.3 ppb lower (better) than the all data average (7.5 ppb). Year-to-year variability in and absolute concentrations of chlorophyll-a in Farrington Pond is the highest (worst) compared to the other ponds.
- In 2016, DO concentrations did not drop below the aquatic life criterion of 5 ppm. Because Farrington Pond is so shallow, the entire water column was above 24°C in August, which would have severely limited suitable habitat for cold-water fish species that may only have survived if they sought out cooler pockets of groundwater springs.
- Average pH in 2016 (6.0) was the lowest (worst) annual average on record, was 0.5 lower (worse) than the all data average (6.5), and fell below the optimal aquatic life criteria range of 6.5 to 8.0. This may be tending toward a degrading trend since 2013; further monitoring will be needed.
- Average alkalinity in 2016 (5.0 ppm) was slightly higher (better) than the all data average (4.3 ppm).
- Average color in 2016 (16.5 PCU) was slightly higher (worse) than the all data average (16.1 PCU), but was lower (better) than 2014 (19.0 PCU) and 2015 (19.0 PCU). This is likely attributed to the extremely dry summer weather conditions that limited material runoff to the pond.

Heald Pond

- Average water clarity in 2016 (4.6 meters) was on par the all data average (4.6 meters). Water clarity is the second shallowest (worst) of the other ponds, but Heald Pond water clarity has occasionally been limited due to the Secchi disk hitting bottom.
- Average total phosphorus in 2016 (8.8 ppb) was 0.8 ppb lower (better) than the all data average (9.6 ppb). Average chlorophyll-a in 2016 (3.7 ppb) was also 0.4 ppb lower (better) than the all data average (4.1 ppb). This was likely due to the extremely dry summer experienced throughout most of the region, which contributed to generally better water clarity in most waterbodies. However, Heald Pond has the second highest (worst) all data average for total phosphorus and chlorophyll-a after Farrington Pond. The shallow nature of Heald pond makes it more vulnerable to suspension of phosphorus-laden sediment (and subsequently, algal growth) because of heavy rainfall, wind storms, or watershed disturbances (e.g., shoreline development).
- In 2016, DO concentrations dropped below the aquatic life criterion of 5 ppm beginning at 4 meters depth (but within 1-2 meters of the bottom). This has been a consistent pattern over the historical record for Heald Pond.
- Average pH in 2016 (6.2) was the lowest (worst) annual average on record, was 0.4 lower (worse) than the all data average (6.6), and fell below the optimal aquatic life criteria range of 6.5 to 8.0. Although Heald Pond has one of the highest (best) all data average pH of the other ponds, pH may be tending toward a degrading trend since 2014; further monitoring will be needed.
- Average alkalinity in 2016 (6.0 ppm) was slightly higher (better) than the all data average (5.5 ppm). Though Heald Pond holds the highest (best) all data average alkalinity of the other ponds, total alkalinity in Heald Pond has been significantly decreasing (worsening) since sampling began in 1995.
- Average color in 2016 (22.5 PCU) was slightly lower (better) than the all data average (24.0 PCU), but is the most colored waterbody of the other ponds.

Horseshoe Pond

- Average water clarity in 2016 (7.3 meters) was the deepest (best) annual average since 2010, was 0.4 meters deeper (better) than the all data average (6.9 meters), and was the deepest (best) annual average compared to the other ponds. This was likely due to the extremely dry summer experienced throughout most of the region, which contributed to generally better water clarity in most waterbodies.

- Average total phosphorus in 2016 (8.0 ppb) was the second highest (worst) annual average behind 1999 (9.0 ppb), was 1.4 ppb higher (worse) than the all data average (6.6 ppb), but was the lowest (best) annual average compared to the other ponds. Horseshoe Pond has historically experienced the lowest (best) total phosphorus after Trout Pond.
- Average chlorophyll-a in 2016 (2.4 ppb) was the lowest (best) annual average on record and was 1.1 ppb lower (better) than the all data average (3.5 ppb). Algal growth may have been limited by some other factor aside from phosphorus.
- DO concentrations dropped below the aquatic life criterion of 5 ppm beginning at 12 and 8 meters depth in June and August 2016, respectively. In 2015, DO concentrations were <5 ppm only in August, suggesting that the pond experienced prolonged anoxia in 2016 compared to previous years. Anoxia at pond bottom should continue to be monitored closely for signs of degradation (i.e., increase in the extent and duration of anoxia experienced in late summer).
- Average pH in 2016 (6.0) was the lowest (worst) annual average on record, was 0.5 lower (worse) than the all data average (6.5), and fell below the optimal aquatic life criteria range of 6.5 to 8.0. This may be tending toward a degrading trend since 2013; further monitoring will be needed.
- Average alkalinity in 2016 (3.0 ppm) was lower (worse) than the all data average (3.7 ppm) and the lowest (worst) of the other ponds. Annual average alkalinity has been significantly decreasing (worsening) by nearly 2.5 ppm since sampling began in 1997.
- Average color in 2016 (9.0 PCU) was the lowest (best) annual average since 2011 and was 1.3 PCU lower (better) than the all data average (10.3 PCU). This was likely attributed to the extremely dry summer weather conditions that limited material runoff to the pond.

Trout Pond

- Historically, Trout Pond has experienced the best water quality of the other ponds, with the deepest water clarity, lowest total phosphorus, lowest chlorophyll-a, and lowest color. It is also the deepest (20+ meters) and least developed pond. Development around Trout Pond includes only a single large summer camp on the north end of the lake, known as Camp Susan Curtis.
- Average water clarity in 2016 (7.0 meters) was the third shallowest (worst) annual average behind 2012 (6.3 meters) and 2008 (6.8 meters) and was 0.8 meters shallower (worse) than the all data average (7.8 meters). This was despite the extremely dry summer experienced throughout most of the region, which contributed to generally better water clarity in most waterbodies. Water clarity may be tending toward a degrading trend; further monitoring will be needed.

- Average total phosphorus in 2016 (9.0 ppb) was the highest (worst) annual average on record and was 4.1 ppb higher (worse) than the all data average (4.9 ppb). Total phosphorus measured in June 2016 (47 ppb) was flagged as an outlier and removed from the historical and recent averages. The sample was most likely contaminated; however, total phosphorus measured in August 2016 (9.0 ppb) was elevated compared to the all data average and should be monitored closely in the upcoming field seasons.
- Average chlorophyll-a in 2016 (0.9 ppb) was the lowest (best) annual average on record and was 1.2 ppb lower (better) than the all data average (2.1 ppb). Algal growth may have been limited by some other factor aside from phosphorus.
- DO concentrations dropped below the aquatic life criterion of 5 ppm beginning at 19 and 13 meters depth in June and August 2016, respectively. This was expected and in line with historical measurements since Trout Pond's deeper waters are subject to thermal stratification that prevents oxygenated surface waters from reaching bottom waters. Anoxia at pond bottom should continue to be monitored closely for signs of degradation (i.e., increase in the extent and duration of anoxia experienced in late summer).
- Average pH in 2016 (6.1) was the lowest (worst) annual average on record, was 0.4 lower (worse) than the all data average (6.5), and fell below the optimal aquatic life criteria range of 6.5 to 8.0. This may be tending toward a degrading trend since 2013; further monitoring will be needed.
- Average alkalinity in 2016 (4.0 ppm) was slightly higher (better) than the all data average (3.6 ppm), which is the lowest (worst) of the other ponds.
- Average color in 2016 (7.0 PCU) was 2.2 PCU lower (better) than the all data average (9.2 PCU). This was likely attributed to the extremely dry summer weather conditions that limited material runoff to the pond. Trout Pond is the least colored waterbody of the other ponds.

KLWA volunteer helping to sample Bradley Pond in August of 2016. Photo Credit: FBE.

Annual variability in water quality is common for freshwater lakes, which is why collection of annual baseline data is important. This information will allow KLWA to assess long-term water quality trends in the Kezar Lake watershed.

TABLE 2. Historical and recent (2016) averages for water quality parameters for six ponds of the Kezar Lake watershed.

	Water Clarity (m)		**Total Phosphorus (ppb)**		**Chlorophyll-a (ppb)**		**pH**		**Alkalinity (ppm)**		**Color (PCU)**	
Pond	Historical[b]	Recent 2016[c]	Historical[b]	Recent 2016[c]	Historical[b]	Recent 2016[c]	Historical[b]	Recent 2016[c]	Historical[b]	Recent 2016[c]	Historical[b]	Recent 2016[c]
Bradley	5.3	4.7	9.4	10.5	3.5	3.4	6.3	5.9	3.9	4.0	21.2	18.5
Cushman	5.5	4.6	7.4	9.0	2.6	2.5	6.6	6.1	4.7	5.0	11.8	9.5
Farrington*	4.4	4.2	15.3	15.0	7.5	5.2	6.5	6.0	4.3	5.0	16.1	16.5
Heald*	4.6	4.6	9.6	8.8	4.1	3.7	6.6	6.2	5.5	6.0	24.0	22.5
Horseshoe	6.9	7.3	6.6	8.0	3.5	2.4	6.5	6.0	3.7	3.0	10.3	9.0
Trout	7.8	7.0	4.9	9.0	2.1	0.9	6.5	6.1	3.6	4.0	9.2	7.0
Maine Lakes[a]	4.8		12.0		5.4		6.8		11.8		28.0	

* Water clarity limited by lake depth - Secchi disk hits bottom

[a] Mean values obtained from VLMP's 2013 Maine Lakes Report

[b] Mean historical values calculated by FBE from all raw data sent by the MEDEP; duplicate values/days were averaged; only epicore samples were used in the analyses; includes FBE-collected-only data for 2015 and 2016

[c] Mean values calculated by FBE from 2016 data

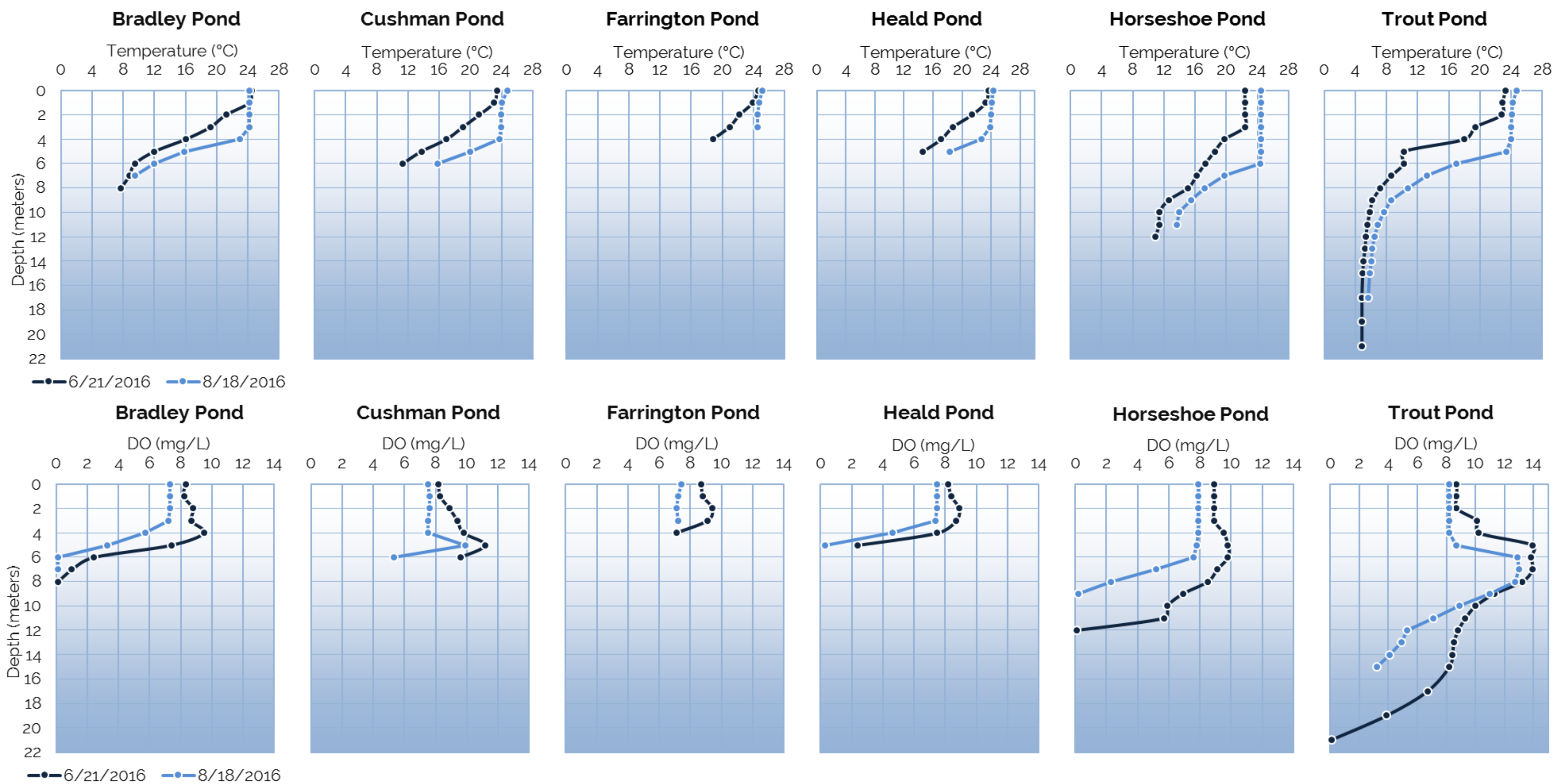


FIGURE 6. Temperature (top panel) and dissolved oxygen (bottom panel) profiles for six ponds of the Kezar Lake watershed.

TRIBUTARIES

Grab Samples

Boulder Brook was sampled at the outlet to Kezar Lake on the Boulder Brook Club property (BB-1) as well as upstream (BB-4) and downstream (BB-3) of the Route 5 crossing. Great Brook was sampled upstream of the Adams Road crossing adjacent to Hut Road (GB-1). Temperature, dissolved oxygen, pH, *E. coli*, and total phosphorus were measured on 6/21/16 and 9/15/16 at the four stream sites; though some temperature and dissolved oxygen readings were missed in 2016 (Table 3). At the request of KLWA, *E. coli* samples were also collected on 6/21/16 and 8/18/16 at Pleasant Point Beach and Lovell Town Beach. Counts were low and of no concern for primary contact recreation; though post-storm sampling should be conducted to ensure low counts are consistent (Table 3).

The two dissolved oxygen readings in both streams for 2016 averaged above 7 ppm, which is the Maine DEP criterion for Class A streams and the minimum concentration required by most aquatic species for survival and growth (Great Brook averaged 8.0 ppm and Boulder Brook averaged 7.9 ppm; Table 3). Water temperature was below 24°C, which is excellent for cold-water fish.

pH in the tributaries ranged from 5.6 to 6.1 with an average of 5.8 for both Great and Boulder Brooks in 2016 (Table 3). pH may be tending toward a degrading trend for both streams; further monitoring is needed.

Total phosphorus ranged from 5.0 to 40.0 ppb with an average of 5.5 ppb for Great Brook and 26.5 ppb for Boulder Brook in 2016 (Table 3). While total phosphorus in Great Brook has remained relatively stable, total phosphorus in Boulder Brook may be tending toward a degrading trend since 2012.

E. coli were well below the Maine DEP instantaneous criterion of 194 col/100mL for both Great and Boulder Brooks in 2016, though geometric means for both streams bracketed the Maine DEP geometric mean criterion of 29 col/100mL. In 2012, elevated *E. coli* measured at BB-3 (461 col/100mL) and BB-4 (548 col/100mL) prompted continued monitoring at Boulder Brook. Elevated *E. coli* under low flow conditions may indicate fecal contamination from groundwater sources (e.g., septic systems or wildlife). Further sampling and reconnaissance would be needed under wet weather conditions, as well as during peak summer months (July-August), to refine potential sources to Boulder Brook.

TABLE 3. 2016 water quality monitoring results for Kezar Lake tributaries (Great Brook and Boulder Brook) and two public beaches (Pleasant Point Beach and Lovell Town Beach).

Date	Site Code	Temp (°C)	DO (mg/L)	pH	*E. coli* (col/100mL)	TP (ppb)
Great Brook						
6/21/2016	GB-1	--	--	5.8	23	6
7/26/2016	GB-1	20.1	8.1	--	--	--
9/15/2016	GB-1	15.9	7.9	5.8	30	5
2016 Average	**GB-1**	**18.0**	**8.0**	**5.8**	**26**	**5.5**
Boulder Brook						
6/21/2016	BB-1	21.2	7.5	5.9	105	31
6/21/2016	BB-3	--	--	5.8	61	25
6/21/2016	BB-4	--	--	5.6	48	24
9/15/2016 (DUP)	*BB-1*	--	--	*5.9*	*10*	*8*
9/15/2016	BB-1	20.7	8.2	6.1	20	6
9/15/2016	BB-3	--	--	5.9	12	40
9/15/2016	BB-4	--	--	5.8	14	32
2016 Average		**21.0**	**7.9**	**5.8**	**30**	**26.5**
Pleasant Point Beach						
6/21/2016	PPB-1	--	--	--	3	--
8/18/2016	PPB-1	--	--	--	8	--
2016 Average	**PPB-1**				**5**	
Lovell Town Beach						
6/21/2016	LTB-1	--	--	--	11	--
8/18/2016	LTB-1	--	--	--	9	--
2016 Average	**LTB-1**				**10**	

Note: DEP instantaneous criterion of 194 col/100mL

Duplicates were averaged before taking the total average

Boulder Brook in August of 2016. Photo Credit: FBE.

Continuous Loggers

Funded by the Sally Mead Hands Foundation, the Climate Change Observatory (CCO) was established for the Kezar Lake watershed with the mission to evaluate potential impacts of climate change on watershed resources and identify actions to mitigate climate change in the watershed. As part of this mission, the CCO purchased and deployed five HOBO temperature loggers in Coffin, Boulder, Bradley, Sucker, and Long Meadow Brooks and two HOBO water level/temperature loggers in Beaver and Great Brooks in 2014. Two water level/temperature sites were added at the lower basin and outlet stream of Kezar Lake in 2015 (Figure 1). Loggers were deployed again at all nine sites in 2016. These data will serve as a baseline for future comparisons of water quality to assess long-term temperature and flow trends in the Kezar Lake watershed.

The water temperature loggers were deployed on 4/6/16 at five sites (Coffin, Boulder, Bradley, Sucker, and Long Meadow Brooks) and retrieved on 12/14/15 for a total deployment period of 252 days. These sites were checked on 6/21/16, 7/26/16, 8/18/16, 9/15/16, and 11/4/16. In most cases, loggers were submerged and in good condition. If a deeper spot was nearby, loggers were repositioned. The logger at Coffin Brook was found out of water on 6/21/16 and 7/26/16 and encased in ice upon retrieval on 12/14/16. The logger at Sucker Brook was found stolen or lost on 7/26/16; a replacement logger was deployed on 8/1/16.

The water level/temperature loggers were deployed on 4/6/16 at Beaver Brook and the Kezar outlet stream and on 4/13/16 at Great Brook and the lower basin (Heinrich Wurm's property) and retrieved on 12/14/16 for a total deployment period of 245-252 days. The stilling wells at Beaver Brook and the Kezar outlet stream were found in excellent condition on 4/6/16. The stilling well at Great Brook was relocated to the Adams Road bridge and attached to the culvert apron (downstream of the 2014-15 site). The stilling well at the lower basin was found on 4/6/16 to be in good condition, but angled from winter ice impact, and the staff gauge was completely dislodged. FBE returned on 4/13/16 to secure the stilling well and staff gauge and lower the logger position within the stilling well to ensure submergence throughout the season. Water level/temperature loggers at these four sites were checked on 6/21/16, 7/26/16, 8/18/16, 9/15/16, 10/21/16, and 11/4/16. Water level at the lower basin was extremely low in late summer, and the logger was out of water from 8/29-11/5/16. Water level was also low at Great Brook in August, and the logger was likely out of water from 8/4-8/10/16.

Water level data were corrected for atmospheric pressure, temperature, and reference field measurements using the Onset HOBO® Barometric Compensation Assistant. Measurement error (i.e., sensor drift) was accounted for by comparing the difference between the logger endpoint and the reference water level measurement at the time of collection; differences greater than or equal to

0.004 m were corrected for, assuming a constant rate of drift for the calibration period (Wagner et al., 2006). Any data flagged as suspect for being out of water or interfered in some way as to not reflect true stream conditions were deleted from the record. Only one stage-discharge measurement was collected at Great and Beaver Brooks on 7/26/16 during baseflow conditions. Three of the four water level sites were visited during the 10/21/16 storm event, but the streams were un-wadeable (too deep) and/or exhibited negative flow due to debris clogging the stream and causing a back-up in flow. A more robust stage-discharge relationship for each site will be needed to convert water level to flow.

Water level logger locations from left to right: Great Brook, Beaver Brook, lower basin, and Kezar outlet stream. Photo Credit: FBE & KLWA.

The following presents the processed (QA/QC) data from 2016 logger monitoring in the Kezar Lake watershed. Until more data are collected over the next few years to begin to account for interannual variability, no major conclusions or analyses can be made on this limited dataset aside from general patterns. Daily precipitation data were obtained from Weather Underground Creeper Hill, NW Cove, Kezar Lake (KMEFRYEB2). Hourly air temperature data were obtained from NOAA NCDC QCLCD Fryeburg Eastern Slopes Regional Airport (54772/IZG).

Water level at the lower basin gradually declined from April-August (due to summer evaporation) and was out of water from September-November until a series of late October-November storms gradually increased lake level (Figure 7). Water level at the fish control structure on the Kezar outlet stream followed a similar manner throughout the deployment period, gradually declining from April-October until the 10/21/16 storm event; due to the larger volume of water flowing from the lake through the outlet stream, water level increased and decreased much more slowly in the lower basin and outlet stream compared to the smaller headwater streams: Great and Beaver Brooks. Water level in Great and Beaver Brooks responded quickly to precipitation. Both streams experienced the greatest flows during a spring storm event on 6/5/16.

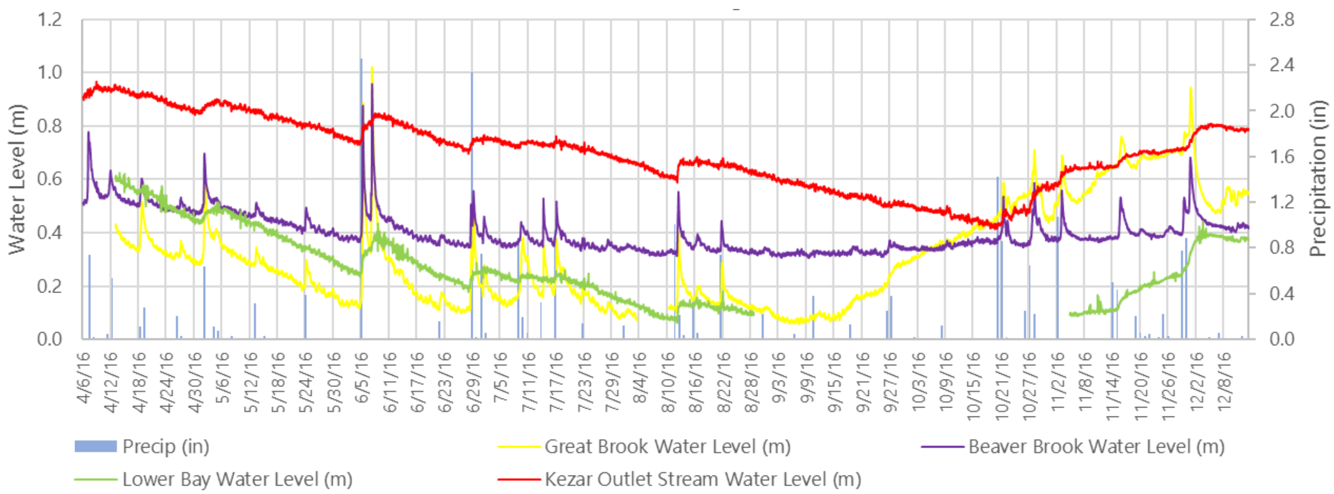


FIGURE 7. Water level data for Great Brook, Beaver Brook, the lower basin, and the Kezar outlet stream from 4/6/16 to 12/14/16. Daily precipitation data were obtained from Weather Underground Creeper Hill, NW Cove, Kezar Lake (KMEFRYEB2).

Water temperature increased at all sites from April to August and then steadily declined until retrieval in December, which followed closely with observed air temperature (Figure 8). Water temperatures at all sites converged from October to December. This likely represents leaf senescence in the fall after which all streams were exposed to similar light and air temperatures. Kezar outlet stream, the lower basin, Boulder Brook, and Long Meadow Brook experienced higher water temperatures than the other streams, likely due to having more open canopies or shallower water depths compared to the other sites. It would be interesting to conduct a brief survey of canopy cover in the summer at each of the sites to confirm this hypothesis.

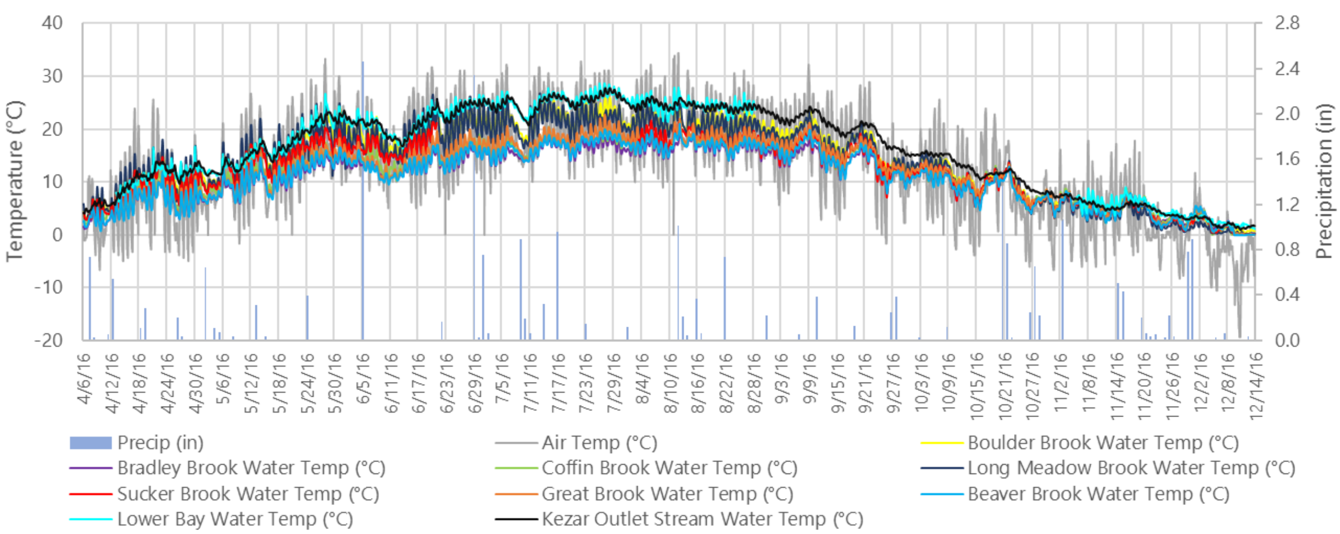


FIGURE 8. Water temperature data for all nine KLWA CCO sites from 4/6/16 to 12/14/16. Daily precipitation data were obtained from Weather Underground Creeper Hill, NW Cove, Kezar Lake (KMEFRYEB2). Hourly air temperature data were obtained from NOAA NCDC QCLCD Fryeburg Eastern Slopes Regional Airport (54772/IZG).

SUMMARY

Heinrich Wurm (KLWA, left) and Sabrina Vivian (FBE, right) on Kezar Lake in the summer of 2016. Photo Credit: FBE.

Kezar Lake remains one of Maine's cleanest and clearest lakes, with above average water quality and clarity. Historically and in the current monitoring year, Kezar Lake's trophic state indicators (water clarity, total phosphorus, and chlorophyll-a) have been better than Statewide averages. Chlorophyll-a in the upper and middle basins of Kezar Lake hit a record low in 2016, and the hypolimnion of all three basins of Kezar Lake were well-oxygenated, which helped cold-water fish species survive the warmest months of the year.

The extremely dry summer experienced throughout most of the region in 2016 contributed to generally better water quality in most monitored waterbodies, as seen with deeper water clarity, lower color, and lower chlorophyll-a in the lake and ponds. This pattern was especially apparent in the shallower ponds (Farrington and Heald Ponds), which also experienced lower total phosphorus. There were some interesting exceptions for the other four ponds (Bradley, Cushman, Horseshoe, and Trout Ponds), which experienced higher (worse) total phosphorus and shallower (worse) water clarity, despite weather conditions in 2016 and despite generally lower (better) chlorophyll-a, which may have been limited by some other environmental factor. These results are confounding and at times contradictory, making 2016 a unique study year when other non-measured factors were likely at play. Of mention for 2016 was the record low pH observed in all monitored waterbodies, which appears to be a consistent trend developing over the last 3-5 years. Most waterbodies with sufficient data are also experiencing a decreasing (degrading) trend in total alkalinity, which would otherwise help to buffer against dramatic changes in pH.

FUTURE MONITORING RECOMMENDATIONS

While the water quality of Kezar Lake and its tributaries and ponds is generally excellent, these waterbodies are sensitive to change. Continuing to monitor Kezar Lake, eight streams, and six ponds will help KLWA better understand long and short-term trends in water quality and maintain the high quality of the water in the Kezar Lake watershed for future generations. The recent establishment of the Climate Change Observatory (CCO) can help guide future water quality monitoring efforts that support ongoing collection of long-term baseline data in the watershed.

The following provides additional recommendations for future monitoring of Kezar Lake, ponds, and streams that expand the baseline monitoring program:

- Analyze results from the current, ongoing (2016-17) pH-alkalinity tributary study that includes samples for aluminum and calcium, and determine the potential impact of these parameters on aquatic organisms.
- Deploy a string of continuous dissolved oxygen loggers on a buoy line at the upper and lower basins of Kezar Lake (currently funded for 2017-18).
- Expand in-lake monitoring to include spring and fall profiles during turnover when these systems are most vulnerable to external and internal material loading.
- Collect bottom grab samples of phosphorus in August and September to monitor and quantify the impact of internal phosphorus loading because of low oxygen conditions.
- Collect winter DO-temperature profiles and epicore sampling of key parameters in February (it has been shown that biological and chemical processes that occur over winter dictate the productivity of lakes in summer).
- Develop a watershed management plan for the lake that summarizes water quality conditions, sets a water quality goal, and details next steps for improvements.
- Ensure a sustainable funding program is in place to continue water level and temperature monitoring at existing stream sites.
- Consider upgrading all existing stream sites to water level and temperature monitoring (pending a sustainable funding source).
- Consider deploying other continuous loggers (e.g., specific conductivity, turbidity, etc.) at existing stream sites (pending a sustainable funding source).
- Conduct stream macroinvertebrate analysis to determine macroinvertebrate richness and abundance during stream baseflow periods (late August - late September). This monitoring will provide baseline data for these streams, and can be replicated on a five-year (or more) cycle.
- Supplement monitoring efforts by adding a July sampling event for Kezar Lake and ponds to better assess seasonal (summer) water quality during the most productive time of the year.

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