



SABBATHDAY LAKE

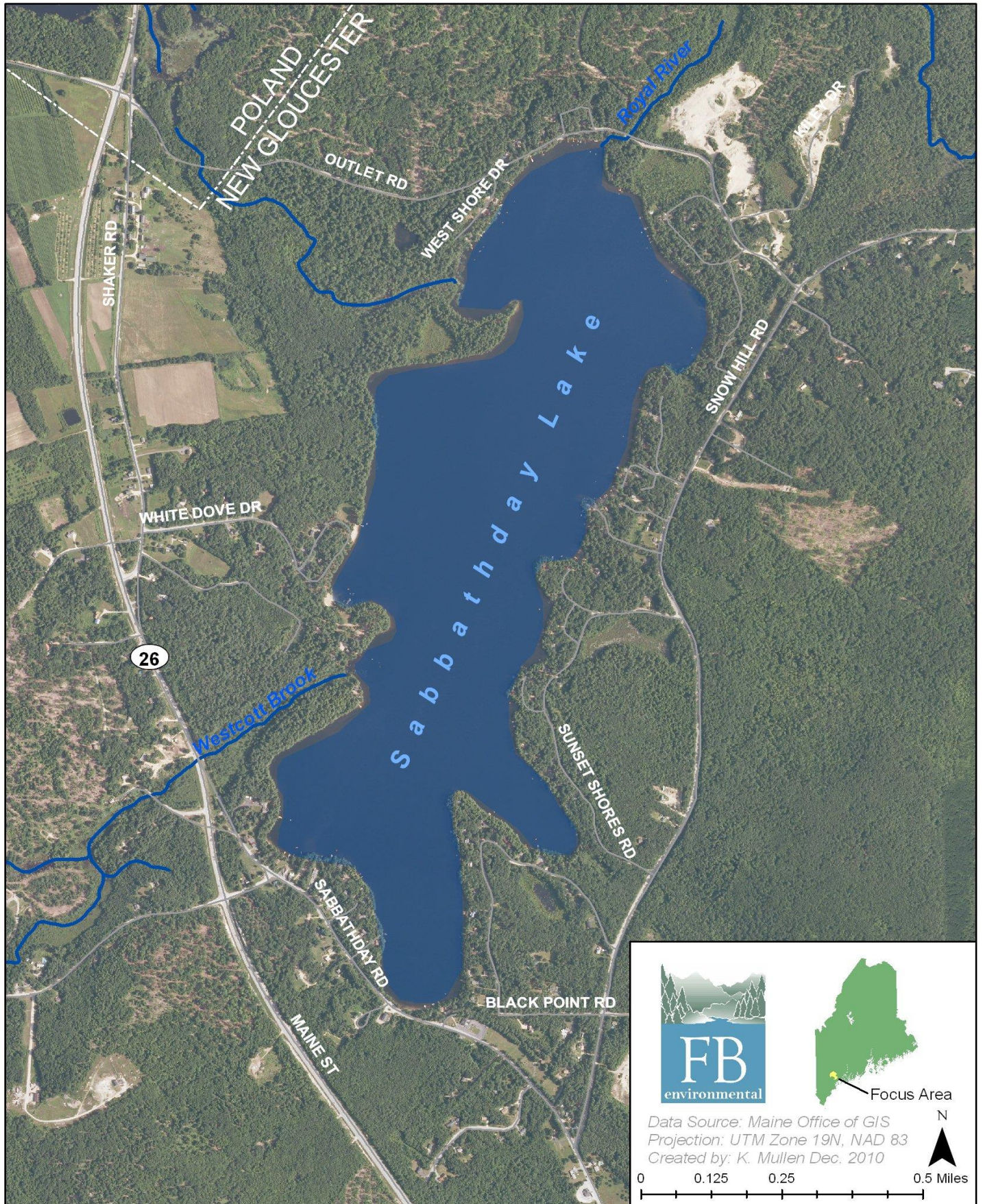
2018 WATER QUALITY REPORT



MARCH 2019



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Special thanks to Sabbathday Lake Association (SDLA) volunteers Rick and Cheryl Fortier for volunteering their time and boat over the course of the 2016 sampling season. Their ongoing support is greatly appreciated. Thanks to members of SDLA for supporting the long-term collection of water quality data.

Photo Credit: Jennifer Jespersen

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BACKGROUND

LAKE FACTS

Watershed: Royal River
Town: New Gloucester
Watershed Area: 5.33 sq. mi.
Mean Depth: 24 feet
Max Depth: 68 feet
Surface Area: 342 acres
Flushing Rate: 0.88 flushes/year



Sabbathday Lake is a 342-acre, non-colored waterbody located in the Town of New Gloucester, Cumberland County, Maine. The lake is part of the larger Royal River watershed and has a direct **watershed** area of 5.33 square miles, a maximum depth of 68 feet (20.7 meters), a mean depth of 24 feet (7.3 meters), and a flushing rate of 0.88 times per year (see DEP lake depth maps in Appendix A).

Historically, Sabbathday Lake has been an important natural resource for the local Shaker community and the Town of New Gloucester. Today, the lake provides recreational opportunities, such as swimming, boating, and fishing, as well as valuable habitat for fish, birds, and other wildlife.

Sabbathday Lake supports a cold- and warm-water fishery, which include largemouth bass, rainbow smelt, brown trout, brook trout, chain pickerel, and black crappie. Maine Inland Fisheries and Wildlife has stocked the lake with brown trout and brook trout since 1989. Cold-water fish, such as trout, need at least 5 parts per million (ppm) of **dissolved oxygen (DO)** in the water to survive and even higher levels to grow. Historically, Sabbathday Lake has experienced critically-low DO concentrations in the deepest areas of the lake in August and September. Low DO in Sabbathday Lake can release **phosphorus** from bottom sediments into the water column where it can fuel algal growth. Thus, DO monitoring is an important part of the annual water quality evaluation.

Based on historical measures of Secchi disk transparency (SDT) or **water clarity**, total phosphorus (TP), and **chlorophyll-a (Chl-a)**, the water quality of Sabbathday

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

Dissolved Oxygen (DO) is the concentration of oxygen dissolved in water. DO is critical to the healthy metabolism of many organisms that reside in the water. DO concentrations may change dramatically with lake depth due to the natural process of thermal stratification in summer. 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).

Phosphorus is one of the major nutrients needed for plant growth, and is naturally present in small amounts. Humans can add phosphorus to a lake through stormwater runoff, lawn or garden fertilizers, and leaky or poorly-maintained wastewater disposal systems. Excess phosphorus can lead to increased plant and algae growth in lakes.

Water clarity is a vertical measure of transparency or the ability of light to penetrate water, obtained by lowering a black and white disk into the water until it is no longer visible. Changes in transparency may be due to increased or decreased algal growth or the amount of dissolved or particulate suspended material in a lake, resulting from human disturbance or other impacts.

Lake is considered above average since monitoring began in 1975 (Lakes of Maine, 2015). However, Sabbathday Lake is sensitive to pollutants in stormwater runoff from the watershed. Significant amounts of stormwater runoff can temporarily reduce water clarity and, if erosion in the watershed increases, long-term degradation in water clarity can become extremely difficult to reverse.

METHODS

FB Environmental Associates, with assistance from Ecological Instincts and SDLA volunteers, collected water quality data at the deep spot (Station 1) of Sabbathday Lake on three sampling days in 2018 (July 17, August 21, and September 14). Sampling was conducted in accordance with standard methods and procedures for lake monitoring established by the Maine Department of Environmental Protection (Maine DEP), the U.S. Environmental Protection Agency (USEPA), and the Maine Volunteer Lake Monitoring Program (VLMP). All water samples were analyzed at the Health and Environmental Testing Lab (HETL) in Augusta.

An integrated epilimnetic core, or a core of water taken from the surface of the lake to the upper part of thermocline, was collected at the deep spot (Station 1) of Sabbathday Lake during each sampling event. Due to thermal stratification, the depth of the core sample (or upper part of the thermocline) varied throughout the season. Parameters measured included **Trophic State Indicators** (i.e., water clarity, TP, and Chl-a), DO and water temperature profiles, **true color**, **total alkalinity**, and **pH**.

Sabbathday Lake is a mesotrophic lake and has intermediate levels of phosphorus and chlorophyll-a and water clarity between 4 and 8 meters depth.

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.



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.

True Color measures 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.

Total Alkalinity: A measure of the capacity of water to neutralize acids (i.e., buffering capacity). Total alkalinity above 20 ppm buffers against drastic changes in pH that could impact aquatic plants and animals.

pH: a measure of the acidity of a solution on a scale of 0-14. Most aquatic species require a pH between 6.5 and 8.0.

RESULTS

WEATHER

Weather is one of the major factors influencing inter-annual variability in lake water quality. Abnormally dry summer conditions (as experienced in 2010 and 2016) reduce the amount of runoff, containing sediment and nutrients, to the lake, resulting in improved water quality (e.g., higher water clarity, lower phosphorus, and lower chlorophyll-a or algae). Conversely, wetter years transport more material from the landscape to the lake, resulting in degraded water quality. The region experienced the lowest total summer rainfall of the decade in 2016, with only 12 inches in New Gloucester, Maine (Figure 1). With a total of 17.6 inches, 2018 was an average year for the current decade.

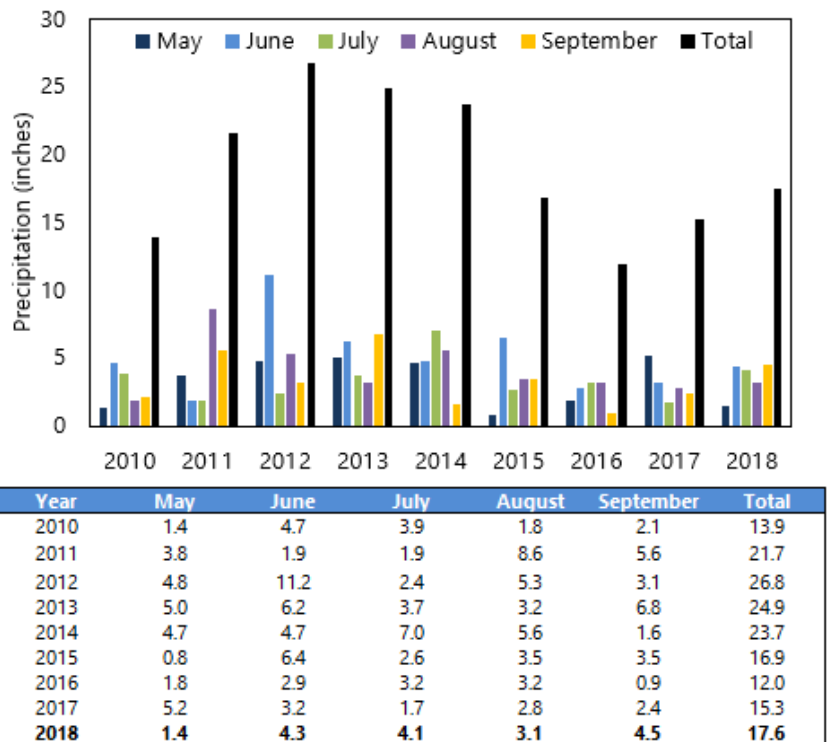


FIGURE 1. Monthly precipitation for Sabbathday Lake from May-September (2010-2018). All units are in inches of rainfall. Data are from NOAA NCDC for station GHCND: US1MECM0003 - New Gloucester 3.0, SE, ME, US.

TROPHIC STATE INDICATORS

Water Clarity

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 suspended 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 4.81 meters (VLMP, 2015). 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 1975, water clarity in Sabbathday Lake has ranged from 4.0 to 9.2 meters, with an all data average of 6.6 meters. Sabbathday Lake is generally clearer than the average water clarity of Maine lakes and has shown a relatively stable trend in water clarity over the sampling record (Figure 2). In 2018, water clarity in Sabbathday Lake ranged from 7.4 to 8.4 meters, with an average of 8.0 meters, which nearly ties the deepest annual average over the entire sampling record (8.1 m, set in 2016) and is 1.5 meters deeper than the all data average (Table 1). As previously discussed, 2018 was an average year for precipitation (see Weather), leaving the cause of the higher than normal clarity uncertain. May 2018 was relatively dry with 1.4 inches.

Total Phosphorus

Since 1982, total phosphorus in Sabbathday Lake has ranged from 3.0 to 15.0 ppb, with an all data average of 6.6 ppb. Sabbathday Lake has low phosphorus compared to average phosphorus levels in Maine Lakes and has shown a relatively stable trend in phosphorus over the sampling record (Figure 2). In 2018, total

phosphorus in Sabbathday Lake ranged from 3.0 to 5.0 ppb, with an average of 4.0 ppb, which is the lowest annual average on record and is 2.6 ppb better than the all data average (Table 1).

Maine DEP also collected bottom grab samples in summer (June-September) for total phosphorus at Sabbathday Lake from 1982 to 2011. Phosphorus at the bottom of the lake ranged from 6.0 to 22.0 ppb, with an all data average of 11.9 ppb (almost double the all data average for epilimnetic phosphorus). Higher phosphorus in bottom waters of the lake compared to surface waters indicates that internal phosphorus cycling is active during periods of low oxygen in summer. A profile sample collected shortly after both spring and fall turnover would provide more information about potential internal phosphorus cycling in Sabbathday Lake.

Chlorophyll-a

Since 1975, chlorophyll-a in Sabbathday Lake has ranged from 1.6 to 10.6 ppb, with an all data average of 3.8 ppb. Sabbathday Lake has low chlorophyll-a (algae) compared to average chlorophyll-a levels in Maine Lakes and has shown a relatively stable trend in chlorophyll-a over the sampling record (Figure 2). In 2018, chlorophyll-a in Sabbathday Lake averaged 2.0 ppb, which is tied with 2016 for the lowest annual average over the entire sampling record and is 1.9 ppb better than the all data average (Table 1). *Gloeotrichia* were noted in the water column on the August and September sampling dates, despite the very low phosphorus and chlorophyll-a values.

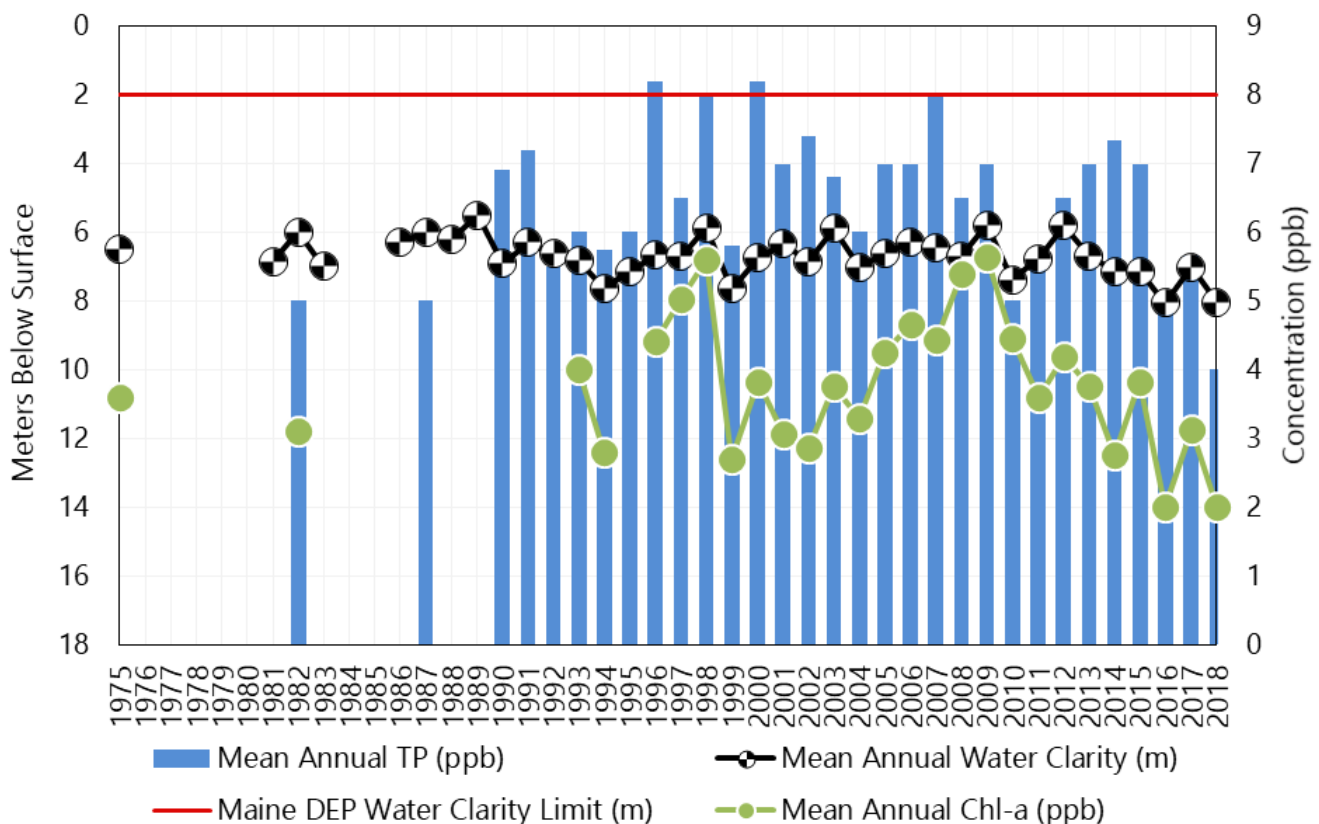


FIGURE 2. Average annual water quality data for trophic state indicators (water clarity, total phosphorus (TP), and chlorophyll-a (Chl-a)) for Sabbathday Lake. 2015-2018 annual averages include only data collected by FBE. Other data incorporation pending final QA/QC and acceptance by the Maine DEP and VLMP.

DISSOLVED OXYGEN & TEMPERATURE

Sabbathday Lake has a history of DO depletion in deep, cold areas of the lake (below 8 meters) in late summer. In 2018, DO levels dropped below 5 ppm at approximately 12 meters in July, 9 meters in August, and 9 meters in September (Figure 3). As in previous years, the most significant DO depletion occurred in September, when DO levels dropped below 2 ppm beginning at 10 meters.

A DO metalimnetic max (commonly referred to as an “oxygen bubble”) between 4 and 8 meters, accompanied by a marked decrease in water temperature, is indicative of the thermocline and persists all season. The upper part of the thermocline is where algae are most productive; below this, decreasing light penetration limits algal growth. In addition, cold-water fish prefer waters of 18°C and can tolerate waters up to 24°C. In summer, the upper 4-6 meters are too warm for cold-water fish, while deeper waters are oxygen-depleted, restricting the suitable habitat of cooler, oxygenated waters to between 6 and 9 meters depth.

Continued monitoring of DO is needed to characterize oxygen depletion over time in Sabbathday Lake. Collecting regular phosphorus samples near the bottom of the lake could also provide information on internal phosphorus cycling, a process triggered by low DO that releases phosphorus from bottom sediments to serve as fuel for algal growth.

CHEMICAL PARAMETERS

Color

Since 1982, color in Sabbathday Lake has ranged from 5 to 32 PCU, with an all data average of 13.2 PCU. Sabbathday Lake has low color compared to average color in Maine Lakes and has shown a relatively stable trend in color over the sampling record (Figure 4). In 2018, color in Sabbathday Lake consistently measured 9 PCU (for an average of 9 PCU) – just above the lowest annual average over the entire sampling record and 4.2 PCU better than the all data average (Table 1).

Alkalinity

Since 1982, total alkalinity in Sabbathday Lake has ranged from 7.1 to 17.5 ppm, with an all data average of 10.8 ppm. Sabbathday Lake has slightly lower alkalinity compared to average alkalinity in Maine Lakes and has shown stability over the sampling record (Figure 4). In 2018, total alkalinity in Sabbathday Lake ranged from 12.0 to 13.0 ppm for an average of 12.3 ppm, which was the highest since 2004 and 1.5 ppm

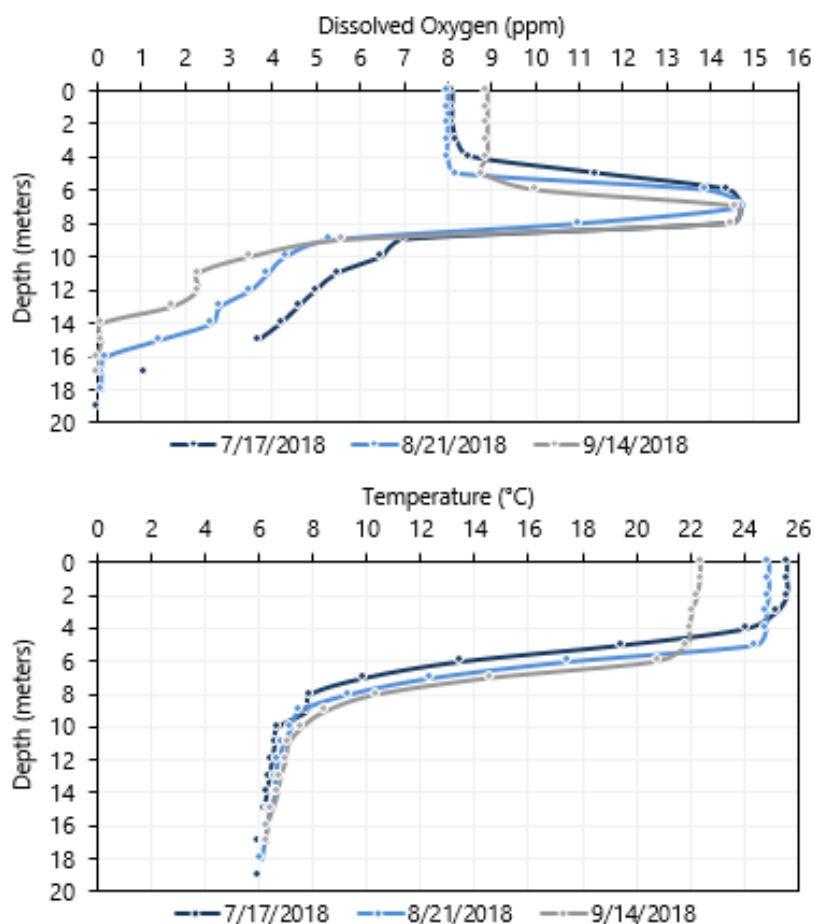


FIGURE 3. Dissolved oxygen (top) and temperature (bottom) profiles collected in 2018 at Sabbathday Lake.

higher than the all data average (Table 1). Per the USEPA, these average total alkalinity levels in Sabbathday Lake fall in the “sensitive” category of 10 ppm to less than 20 ppm. A lake is well-buffered against changes in pH if total alkalinity is greater than 20 ppm.

pH

Since 1982, pH in Sabbathday Lake has ranged from 6.6 to 7.5, with an all data average of 7.0 (Table 1). Sabbathday Lake has slightly higher pH compared to average pH in Maine Lakes and has shown a relatively stable trend in pH over the sampling record (Figure 4). In 2018, pH in Sabbathday Lake ranged from 7.0 to 7.2, with an average of 7.1, which is just above the all data average (Table 1).

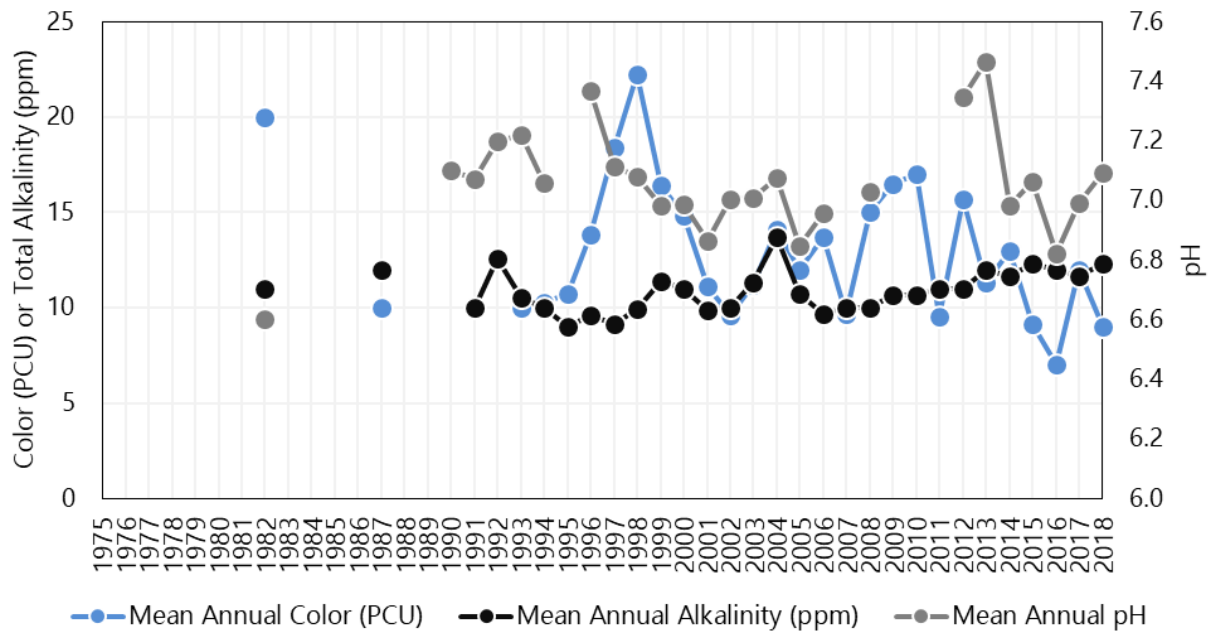


FIGURE 4. Average annual water quality data for chemical parameters (color, total alkalinity, and pH) for Sabbathday Lake. 2015-2018 annual averages include only data collected by FBE. Other data incorporation pending final QA/QC and acceptance by the Maine DEP and VLMP.

Date	Water Clarity (m)	TP (ppb)	Chl-a (ppb)	Color (PCU)	Alkalinity (ppm)	pH
7/17/2018	7.4	5.0	2.0	9.0	12.0	7.2
8/21/2018	8.3	4.0	2.0	9.0	13.0	7.0
9/14/2018	8.4	3.0	2.0	9.0	12.0	7.1
2018 Average (SDL)	8.0	4.0	2.0	9.0	12.3	7.1
Historical Avg. (SDL)	6.6	6.6	3.9	13.2	10.8	7.0
Average (Maine Lakes)	4.8	12.0	5.4	28.0	11.8	6.8

TABLE 1. Summary of 2018 data and historical averages for water clarity, total phosphorus (TP), chlorophyll-a (Chl-a), color, alkalinity, and pH at Sabbathday Lake. Average Maine lake values were obtained from VLMP (2013).

SUMMARY

Sabbathday Lake continues to have above-average water quality compared to the average for Maine lakes (Table 1).

All water quality parameters measured at Sabbathday Lake show no trends in annual averages over the entire sampling record.

Though 2018 was not an abnormally dry year, many water quality parameters resembled a those of a very dry year on Sabbathday lake, such as 2016. Phosphorus had the best annual average of the entire historical record.

- Water clarity, chlorophyll-a, and color annual averages were all close to the best values of the entire historical record.
- pH was in line with the historical average for Sabbathday Lake.
- Total alkalinity in 2018 was the highest since 2004.

It is possible that runoff was limited by the timing or the intensity of rainfall events, thereby producing water quality characteristic of a dryer year. Further study would be necessary to determine if these or other factors were at play.

DO depletion at the deep spot of Sabbathday Lake is a consistent issue, with less than 5 ppm as shallow as 9 meters in August September 2018. Desirable habitat of cool, oxygenated water for cold-water fish was restricted to between 6 and 9 meters below the water surface in 2018. This low DO may also be releasing biologically available phosphorus from bottom sediments, though phosphorus remains low overall in Sabbathday Lake.

RECOMMENDATIONS

- Continue the baseline annual water quality monitoring program at Sabbathday Lake.
- Consider adding hypolimnion (bottom) grab samples for phosphorus to the three sampling events.
- Consider collecting water quality data (especially DO and temperature profiles and epilimnion and/or hypolimnion grab samples for phosphorus and chlorophyll-a) immediately after spring and fall turnover to better characterize internal phosphorus cycling in Sabbathday Lake. Low oxygen in late summer when thermal stratification sets in (creating a barrier to lake mixing, so oxygen-rich surface waters cannot replenish bottom waters) causes a chemical reaction with iron-bound phosphorus in bottom sediments that can re-release phosphorus into the water column and fuel algal growth.
- Consider adding a water quality monitoring buoy that continuously measures DO and temperature throughout the ice-free season (can also measure temperature during the winter months). This will help pinpoint spring and fall turnover and the extent and duration of low DO in Sabbathday Lake.

WAYS TO PROTECT THE LAKE

There are many ways that individual landowners can help reduce sediment and nutrient input to Sabbathday Lake to protect and even improve water quality, including:



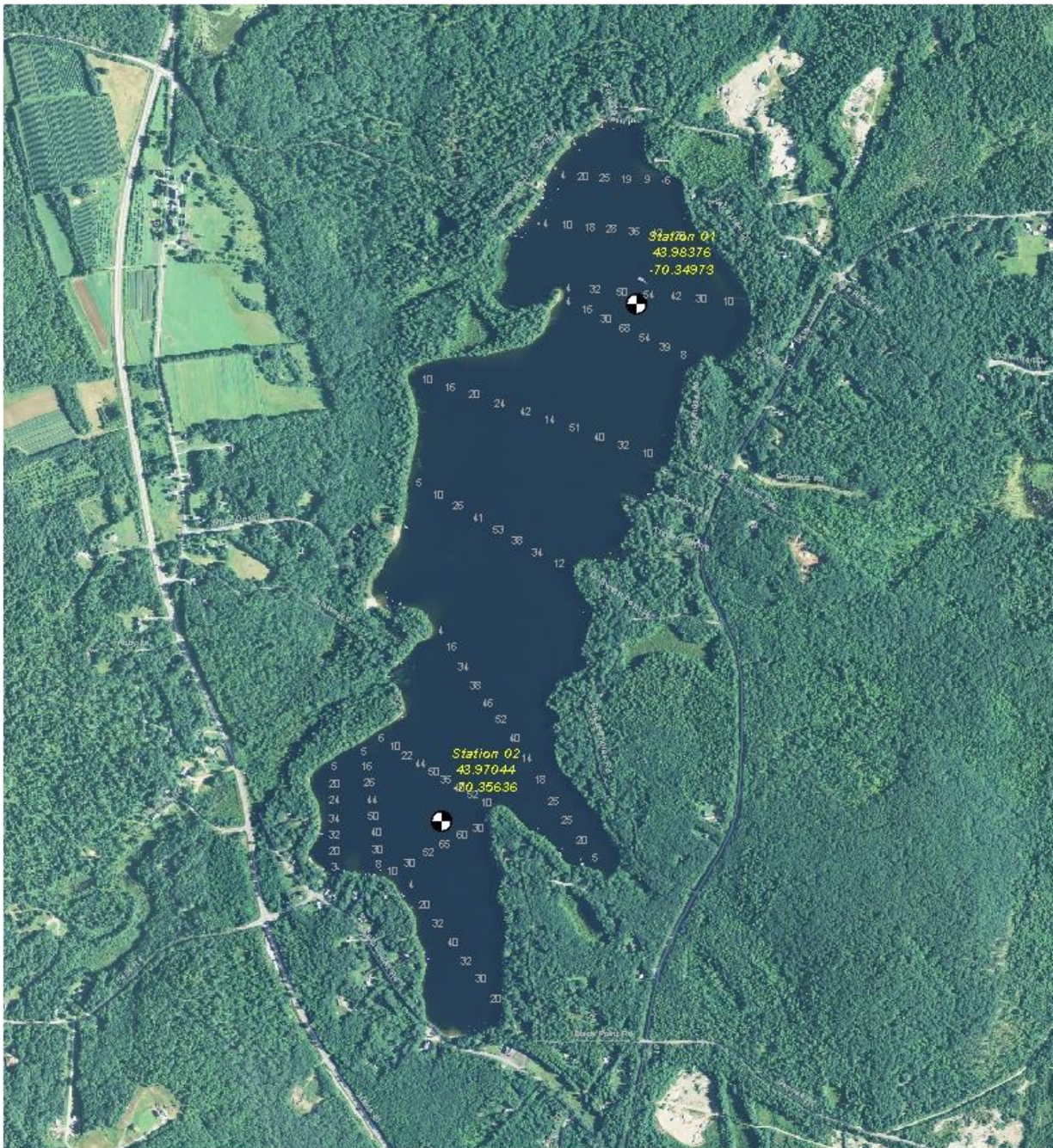
- Join the Sabbathday Lake Association (SDLA)
- Participate in a watershed survey every 10 years
- Pump your septic system every 2-3 years, participate in a septic survey, and inspect your septic system if older than 20 years
- Help form a road association
- Participate in volunteer surveys, including water quality and aquatic plants surveys
- Use phosphorus-free fertilizers and household products
- Plant a vegetated buffer (100-250 feet wide is ideal) along your shorefront area
- Vegetate and mulch bare soils using native materials
- Terrace and vegetate steep slopes
- Create meandering footpaths to slow storm flow to the lake
- Repair eroding driveways to prevent erosion
- Line eroding ditches with rock
- Educate neighbors about lake science
- Become LakeSmart by contacting SDLA and the Maine Lakes Society (207-495-2301 or email info@mainelakessociety.org) for a free LakeSmart evaluation; or become a certified LakeSmart evaluator



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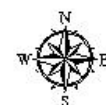
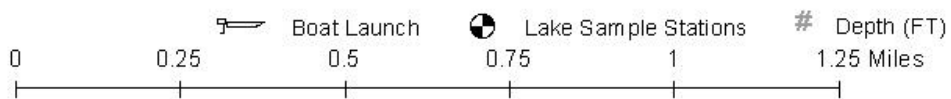
APPENDIX A | DEPTH MAPS



Sabbathday Lake

MIDAS # 3700

New Gloucester, Cumberland Co. - Delorme Page 5 - 342 acres



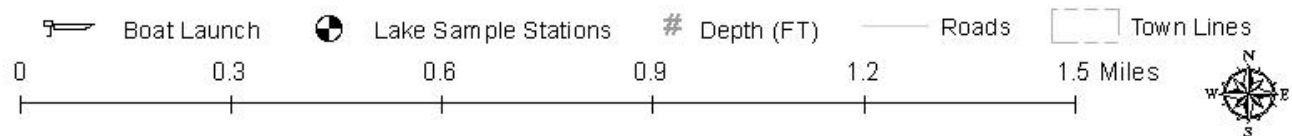
Source: Lakes of Maine, Online: <http://www.lakesofmaine.org/lake-overview.html?m=3700>



Sabbathday Lake

MIDAS # 3700

New Gloucester, Cumberland Co. - Delorme Page 5 - 342 acres



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