Lake Almanor Water Quality Report, 2019

Prepared for

Lake Almanor Watershed Group
Sierra Institute for Community and Environment
Plumas County Board of Supervisors

By

K.R. Gina Johnston, California State University, Chico
and
Scott McReynolds, California Department of Water Resources

Table of Contents

Introduction and Project Overview

A water quality monitoring program for Lake Almanor was conducted during 2019, combining the protocol used by California Department of Water Resources in previous years and that used by Dr. Gina Johnston in 2009-2013. The Sierra Institute for Community and Environment and the Lake Almanor Watershed Group (LAWG) provided oversight for the contract. Due to the limited funds available for this project, LAWG selected some of the important parameters that had been monitored in the past by California Department of Water Resources (DWR), Plumas County and Pacific Gas & Electric Company. Four sampling windows were chosen to provide a look at lake health: during spring turnover (May), the period of heavy recreational use (July and September) and fall turnover (November). Three stations in the lake were selected: LA-01 near the Intake Tower, LA-02 in the east arm, and LA-03 in the west arm. A station in Chester (NFFR-1) was selected for monitoring the North Fork of the Feather River just prior to discharge into the reservoir. Additional stations around the reservoir perimeter were also monitored: North Fork Feather River near Canyon Dam (NFFR-2), Bailey Creek at Highway 36 (BC-5), Hamilton Branch downstream of Mountain Meadows Dam (HB-01C), Hamilton Branch upstream of Lake Almanor (HB-01B) and Hamilton Branch at Lake Almanor (HB-01A).

Lake and tributary sampling stations for the 2019 study are shown in Figure 1.

Figure 2. shows land ownership parcels in the Almanor Basin, indicating general land uses in the various regions within the watershed. It is included to assist in understanding potential connections to sources of contaminants (nutrient loading), or physical water quality impairments (water temperature, sediment loads, etc.).

Parameters that were monitored in 2019 included:

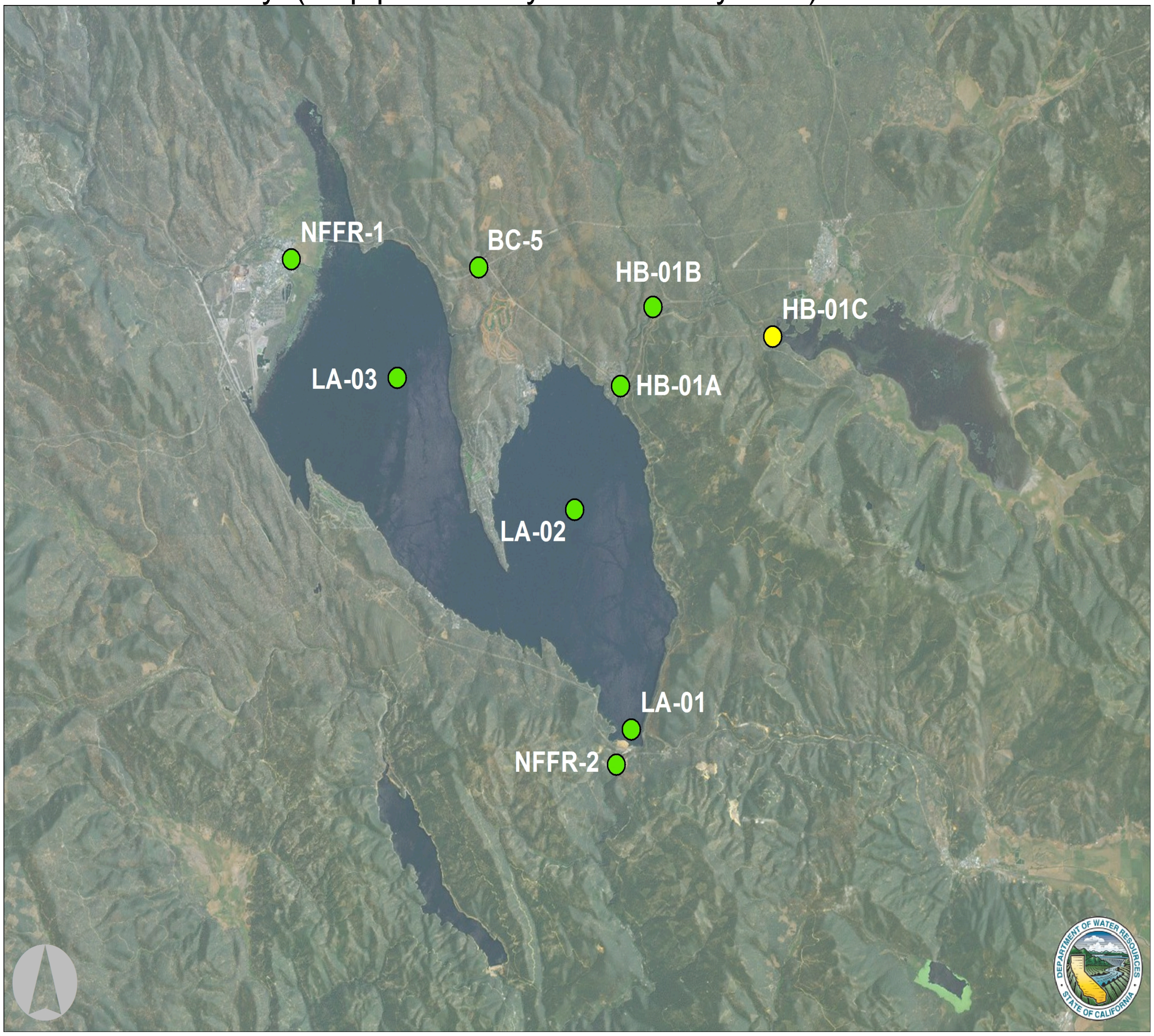
1. Physical: temperature, dissolved oxygen, Secchi depth (where applicable), electrical conductivity, pH and turbidity.
2. Biological: phytoplankton and zooplankton at LA-02 and LA-03.

   (Chemical analyses of inorganic and organic elements and compounds were not included in the 2019 study, as they have been in 2014-2018.)

Methods Used for Sampling and Analysis

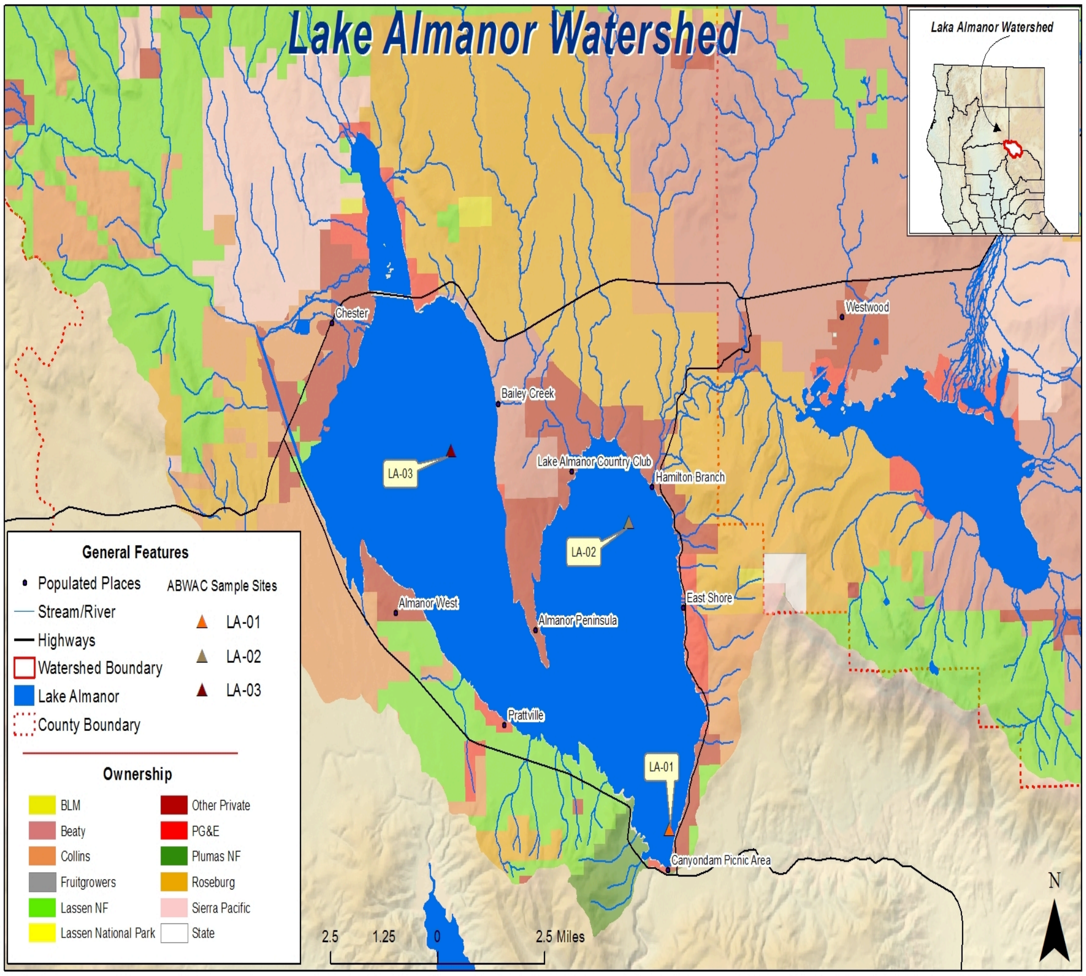
Field Parameters— Stream- Basic water quality parameters, including dissolved oxygen, conductivity, pH, and turbidity, were measured with properly calibrated field instrumentation at each visit to every monitoring station. Stream samples or measurements were collected about one foot below the surface in flowing, well-mixed riffle or run areas. Water temperature, conductivity, dissolved oxygen, and pH was measured in streams with a YSI Pro handheld multi-parameter meter with a 3-meter cable. The meter was calibrated within 3 days prior to sampling following the instrument manual. Turbidity was measured with a nephelometer (Hach P2100 Turbidimeter) from the bulk sample used to filter dissolved chemistry samples.

Figure 1. Lake and Tributary Sampling Station Locations in Lake Almanor Watershed Used in 2019 Study. (Map provided by Scott McReynolds)



Continuous stream water temperatures were recorded at 15-minute intervals at each stream station using Onset Hobo Pro V2 data loggers. These loggers were deployed at the sampling locations housed in a 6 in length of 2 inch diameter galvanized fence pipe, and attached to an onshore anchor site with an appropriate length of coated, stainless steel cable and a padlock to discourage theft of the equipment. The Bailey Creek data logger was removed when the stream went dry between the May and July sampling event.

Figure 2. Lake Almanor Watershed Land Ownership (Emily,Creely, formerly with Sierra Institute)



Field Parameters— **Lake-** Water temperature, conductivity, dissolved oxygen, and pH in the lake was measured at one meter intervals from the surface to the bottom using the same, calibrated YSI Pro meter and 30 meter cable assembly to access any potential depth in Lake Almanor. Turbidity was measured with a Hach P2100 Turbidimeter from samples collected using the Van Dorn water bottle.

Continuous lake water temperature and oxygen were recorded at 15-minute intervals using data loggers at station LA-01 near the Canyon Dam Intake Tower on a buoy deployed by PG&E with funds from LAWG. Two loggers were deployed from this buoy at ten and fifteen meters below the water surface on segmented lengths of stainless steel cable and a padlock to discourage theft of the equipment. All data were reported relative to the surface, (i.e. depth from surface remained constant, but distance from bottom changed as the lake level fluctuated up and down through the year).

Biological Parameters -Phytoplankton samples were collected with a Wisconsin type conical net (80 micron mesh) that was pulled from the bottom to the surface to produce an integrated sample. They were preserved with Lugol's solution.

Phytoplankton were counted and were identified to division (Chlorophyta, Chrysophyta, etc.) and to genus when this would allow for comparison with previous data and when the genus would be indicative of water quality.

Zooplankton samples were collected with a net towed from the bottom to the lake surface to produce an integrated sample and preserved with Lugol's Solution. Zooplankton were enumerated and identified to order (Cladocera, Copepoda, etc.) and to suborder or genus when this would allow for comparison with previous data or where the identity had water quality significance. (Again, certain genera are indicators of lake health and it is important to know their abundance.)

Results and Discussion

1. Physical Parameters

    a. Temperature

The temperature data are shown in graphic form for each lake station (See figures 3, 4, and 5, as well as Table 1 in Appendix). In May 2019 LA-01 and LA-02 were beginning to stratify. At LA-01 temperature at the surface was about 17°C (63 °F), and at the bottom it was around 7 °C (45 °F). LA-02 was about 16 °C at the surface and the bottom was at 7 °C. LA-03 was around 15 °C (59 °F) at the surface and 10 °C at the bottom. Both LA-01 and LA-02 were about 5 °C warmer at the surface than they have been the previous three years.

By mid July 2019 stations LA-01 and LA-02 were thermally stratified. The epilimnion was about 20-22 °C (68-72 °F). The metalimnion was between 11 and 14 meters at LA-01, but 7-12 meters at LA-02. At LA-03 the temperature from top to bottom was about 18-22°C. The surface temperature at all three stations was close to 24 °C. The bottom temperature was 10 °C at LA-01 and LA-02, which was similar to 2017 and 2018.

The next sampling date was September 19, after Labor Day, and LA-01 was still strongly stratified. The epilimnion extended down to 12 meters depth. At LA-02 stratification was breaking up and the water column was well mixed to a depth of 14 meters with a temperature of 18 °C. The temperature then dropped off rapidly to 13 °C at the bottom (16 meters). LA-03 was well mixed, with a temperature of 18 °C (64°F) throughout.

By mid November 2019 the lake was no longer thermally stratified at any station. Water temperature at LA-01 and LA-02 was about 10 °C (50 °F) throughout. LA - 03 was 9 °C.

Water temperatures were generally higher than in 2017 and 2018. This may have been due to less snow in spring precipitation and decreased inflow from tributaries in late spring.

In summary, the lake warms up over the summer as it absorbs solar radiation and the heat energy gets distributed through the water column primarily by wind mixing. The wind is not strong enough to mix deeper than about 10 meters, as marked by the depth of the top of the metalimnion. Below the metalimnion, the hypolimnion is stable and cool. LA-03 is only 7-9 meters deep, so water can be fully mixed by wind action. By late summer most of the lake volume is 15 °C (59 °F) or warmer and only the deeper parts of the eastern basin have water temperatures cooler than 12 °C (50 °F). By July only LA-01 has appreciable water with a temperature below 12 °C and that is in the deepest region of the lake (below 14 meters depth). This has been the case for several years.

Temperature in the North Fork of the Feather River at Chester, CA (Station NFFR-1) followed a similar seasonal pattern to the lake, although it was generally cooler than the lake temperature. The highest temperature was in July at 14.2 °C (57 °F), whereas the highest temperature in 2017 was in September. (See Figure 6, as well as Table 1 and Figure 2 in the Appendix.) The river temperature was showing the effect of increased snowmelt and runoff during Spring 2017, but started off warmer in Spring 2018, probably due to less snow. In Spring 2019 it was almost 2 °C warmer than in 2018. However, it didn't get as warm in July 2019, with its highest temperature reaching only 11 °C, as opposed to 14 °C in 2018.

Data for Hamilton Branch at Lake Almanor are shown in Figure 7. The highest temperature was in September at about 15°C (59 °F), making it 6 °C (11 °F) warmer than the NFFR and warmer than the hypolimnion of Lake Almanor. These warmer temperatures suggest less spring inflow this year compared to 2017 and 2018. Physical data for other tributaries are in the Appendix , Table 1. There was still a considerable temperature difference between Hamilton Branch at Mountain Meadows and where it enters Lake Almanor. There was about 9 °C (16 °F) drop in temperature along this creek in July, mostly due to spring inflow. This again shows the importance of the lower portion of Hamilton Branch as a coldwater refuge. (I believe the September temperature reading for Hamilton Branch at Lake Almanor was recorded incorrectly because it is 3 °C warmer than the Upper Hamilton Branch temperature on the same day 25 minutes earlier. Historically it has been cooler, indicating additional spring flow between the two sites.)

b. Oxygen

The oxygen data are shown in graphic form (Figures 3, 4, and 5) along with the temperature for each station for each date, as well as in Table 1 in the Appendix. The amount of oxygen that can be dissolved in freshwater is primarily a function of temperature and atmospheric pressure. Temperature is very important, since the higher the temperature the less oxygen can be dissolved. The higher the elevation, the lower the atmospheric pressure, and the lower the pressure, the less oxygen can be dissolved. Thus, alpine lakes and streams have less dissolved oxygen than their counterparts at sea level (where the atmosphere pressure is higher) when they are at the same temperature. Biological processes also affect the oxygen concentration. Photosynthesis produces oxygen and respiration, including decomposition, consumes oxygen. . Near the surface of a lake, photosynthesis generally exceeds respiration and dissolved oxygen concentration is high. In the deeper part of a lake, respiration exceeds photosynthesis and dissolved oxygen decreases. The amount of mixing with the atmosphere (usually due to wind action in a lake or turbulence in a stream) can affect oxygen concentration. All of these factors must be considered when trying to interpret the change in oxygen concentration from the surface of a lake to the bottom or the change from season to season.

In May 2019 the oxygen concentration at all three lake stations was about 9 parts per million (ppm) in the upper 10 meters of the water column. This was approximately the maximum that could be dissolved at that water temperature (16 ºC) and the existing atmospheric pressure and wind conditions. It increased to 10-11 ppm with depth as temperature decreased.

In July 2019 oxygen concentration in the epilimnion at LA-01 and LA-02 was 8 ppm, and the epilimnion water temperature was 22 ºC (72 °F). Due to the shallow conditions at LA-03, oxygen was 8 ppm throughout. . In the hypolimnion at LA-01, the oxygen level dropped, but was still about 4 ppm near the bottom. Once the lake was stratified, the deeper portion of the lake (hypolimnion) was isolated from the effects of wind mixing. Also, oxygen was consumed by decomposition at a faster rate than photosynthesis could produce it, so the oxygen level dropped. At LA-02 oxygen was above 6 ppm to a depth of 15 meters.

In 2015 there was no oxygen below 12 meters at LA-01 and LA-02. In 2016, there was some oxygen present at this depth. Conditions in 2017 were the best in several years in terms of cooler temperature and higher oxygen levels. 2018 was almost as good as 2017, with some oxygen available in the hypolimnion at LA-01 and LA-02. Conditions in 2019 were similar to 2018 except for warmer water temperature in the epilimnion.

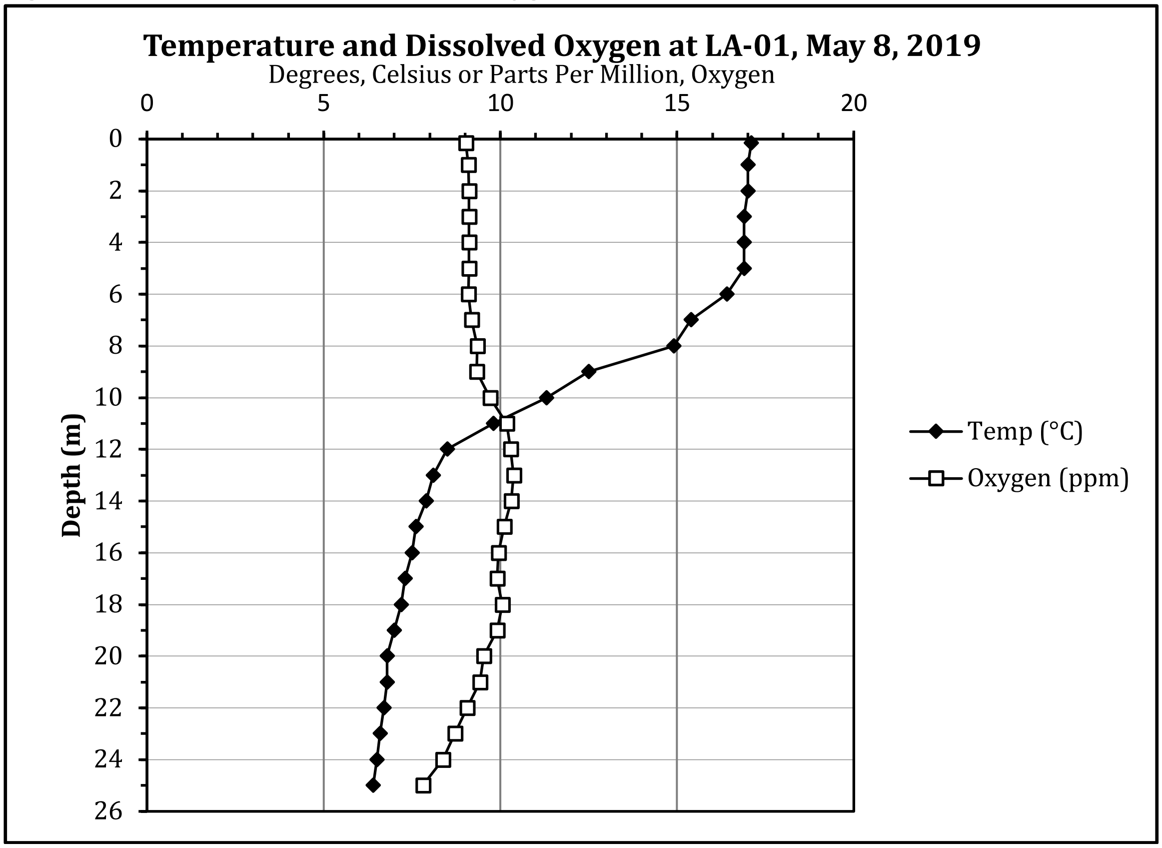
By mid September, thermal stratification was very strong and oxygen was still near 8 ppm in the epilimnion of LA-01. Mixing by the wind resulted in the epilimnion extending down to a depth of 10 meters. Below this depth at LA-01 oxygen decreased in the thermocline and then dropped to zero at 16 meters. At LA-02, oxygen levels were at 8 ppm to a depth of 14 meters and then dropped off to 2 ppm at the bottom (16 meters). Oxygen was 8 ppm throughout the water column at LA-03.
As the lake cooled in the autumn, the thermal stratification disappeared. By November, all stations were again well mixed and oxygen levels were above 7 ppm throughout.

An examination of the DWR data base (1989-2004) for Lake Almanor shows that the annual pattern for temperature and oxygen has been about the same since their records began. Low levels of oxygen in the hypolimnion are the “norm” for most of summer. However, during drought years, thermal stratification is established earlier and the temperature of the water in the deeper parts of the lake is warmer than in years with more normal precipitation. This is probably due to lack of snowmelt entering from streams or runoff in the spring. The result is very low or zero oxygen concentration in the hypolimnion from July through September. In years with more normal precipitation, such as 2016, or above average precipitation, such as 2017, thermal stratification is established later and the temperature of the hypolimnion is cooler. Oxygen persists longer in the hypolimnion during the summer.

As discussed in earlier reports, the low levels of oxygen stress the cold-water fish species in the lake, since the regions where both temperature and oxygen preferences are met become scarce. In dry years such as 2012-2015, the region of suitable temperature and oxygen may not be present at all from late July to late September. In 2016 suitable habitat was still present in the east arm in late June. It had disappeared by September. In 2017 there may have been some suitable habitat in the east arm in August. In 2018 and 2019 oxygen depletion was not as severe as in previous years and cool water with oxygen levels around 4 ppm was available throughout most of the summer in the eastern arm.

Oxygen levels in the Feather River are always higher than in the lake, primarily because of the colder water temperature and the turbulence of the water (See Figure 6). In 2019 the oxygen level stayed near 10 ppm all year. Even though Hamilton Branch was warmer in the late summer, it was still cooler than the lake surface water by 8 °C in July and oxygen content was always near 9 ppm.

Figure 3. Temperature and Dissolved Oxygen at Lake Almanor Station LA-01, 2019



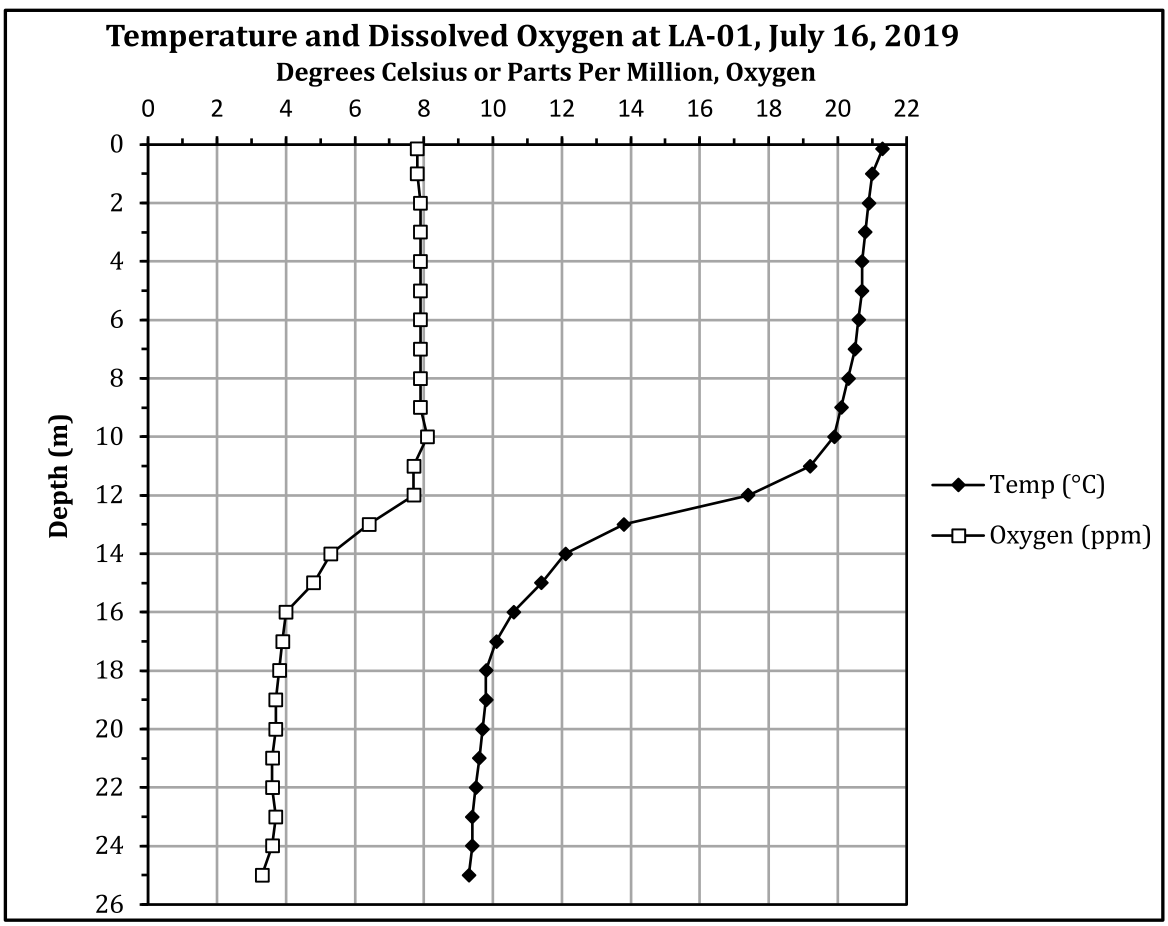
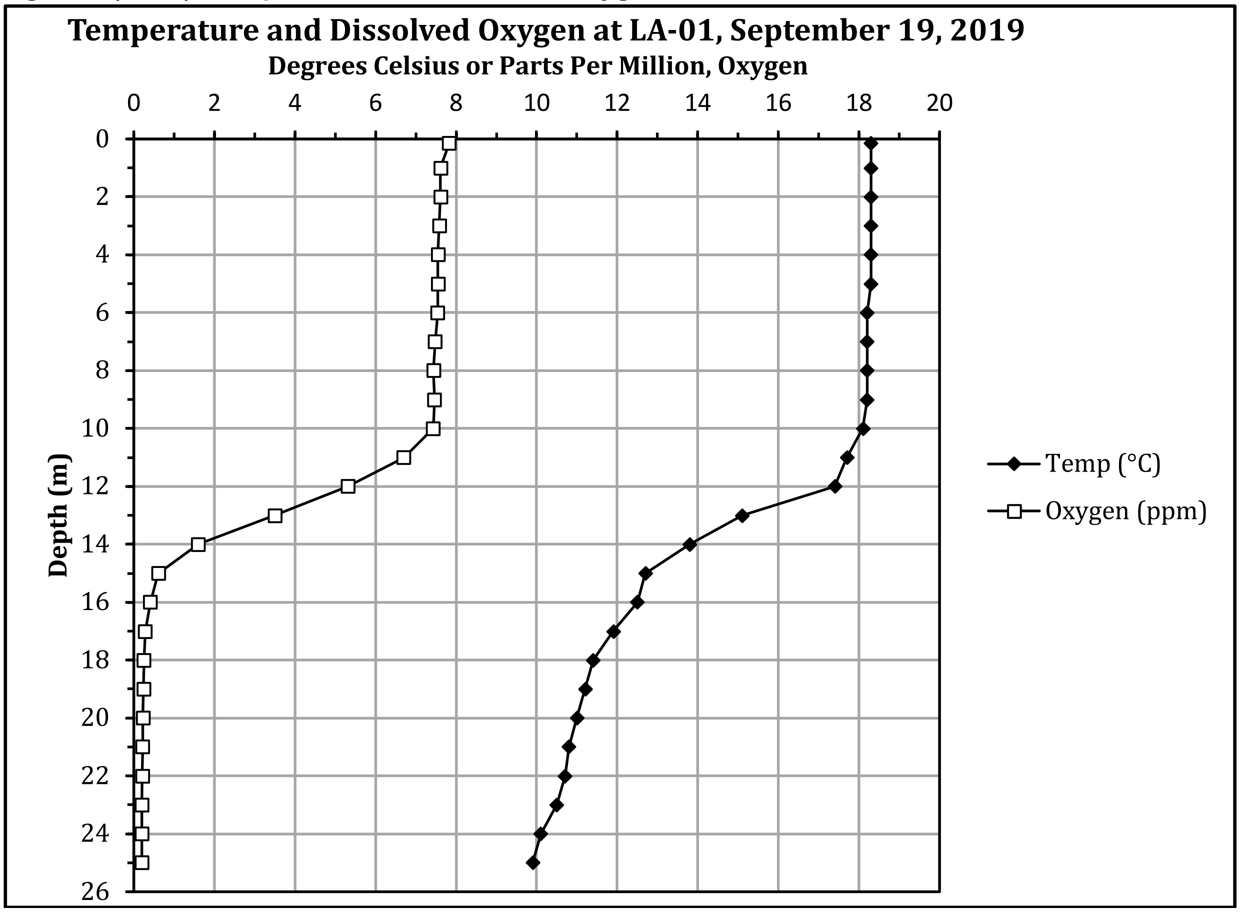


Figure 3 (cont.). Temperature and Dissolved Oxygen at Lake Almanor Station LA-01, 2019



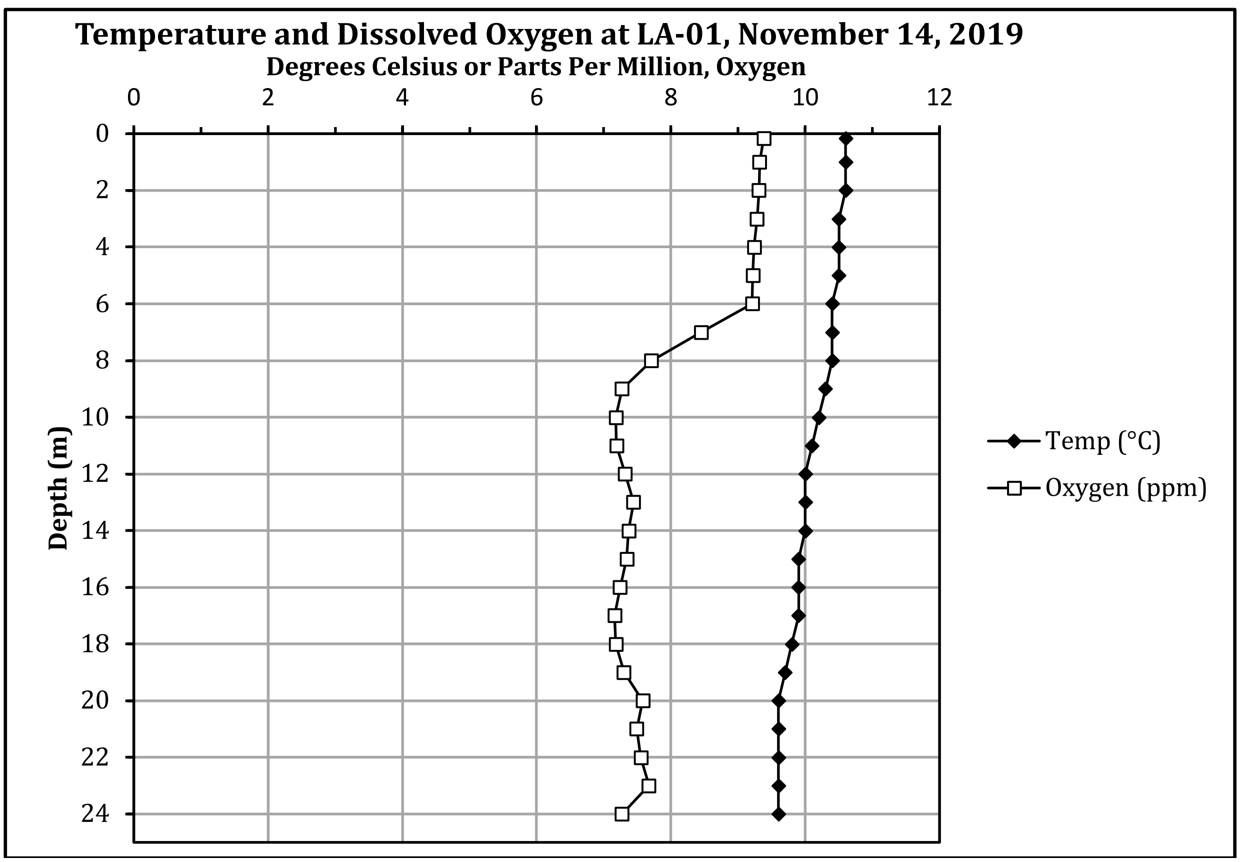
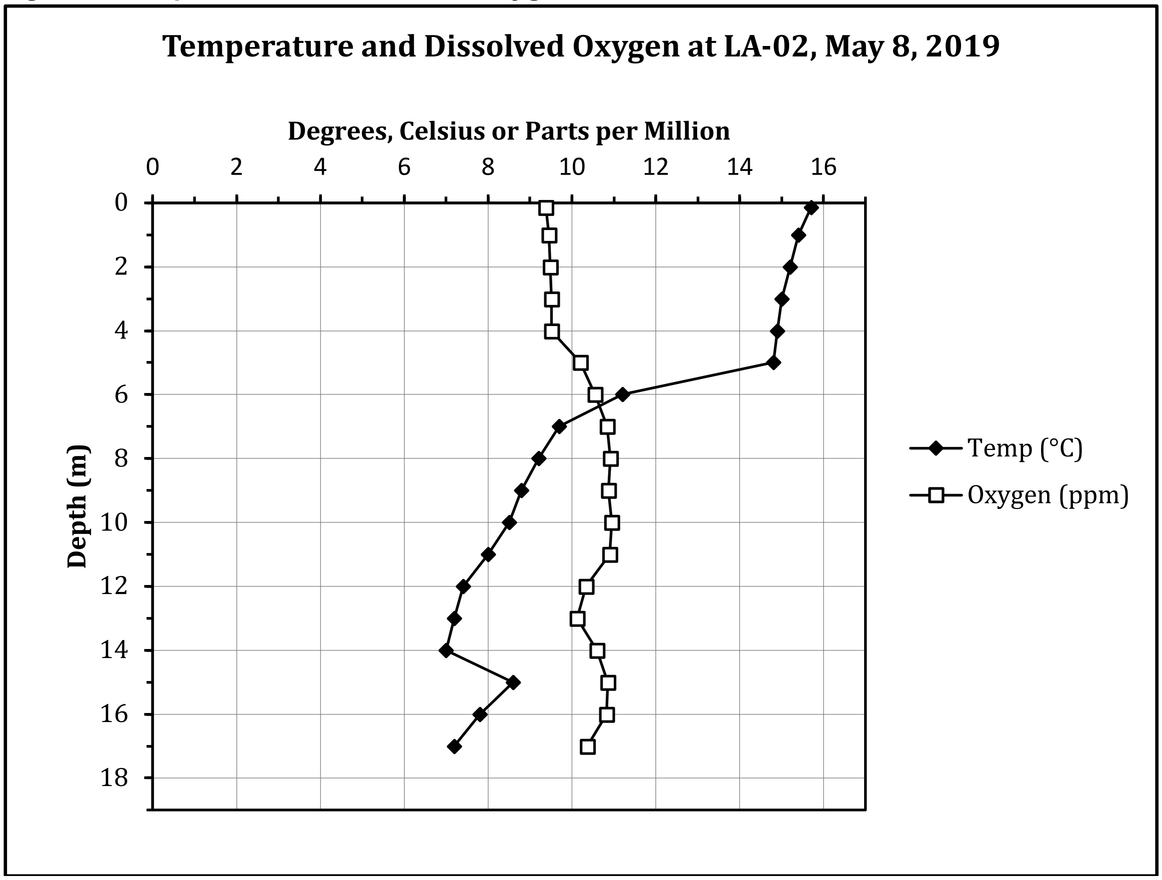


Figure 4. Temperature and Dissolved Oxygen at Lake Almanor Station LA-02, 2019



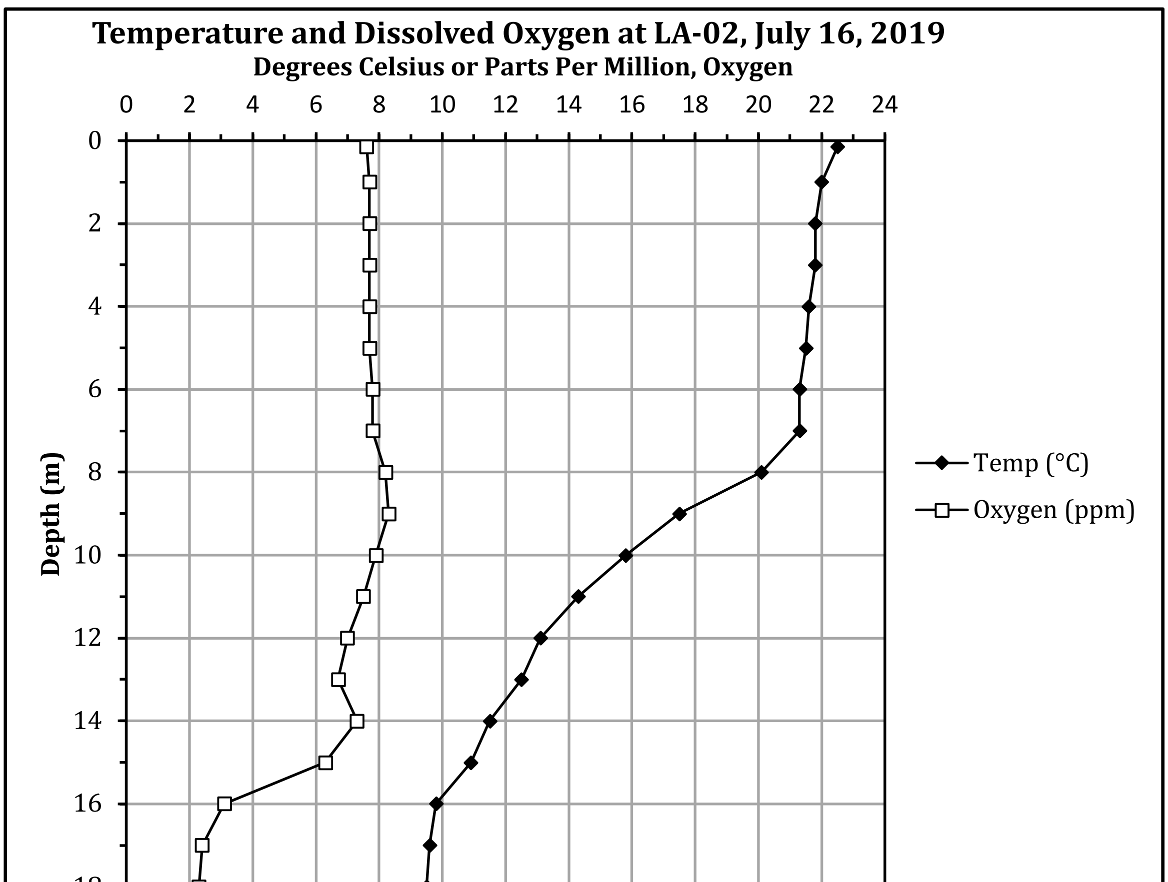
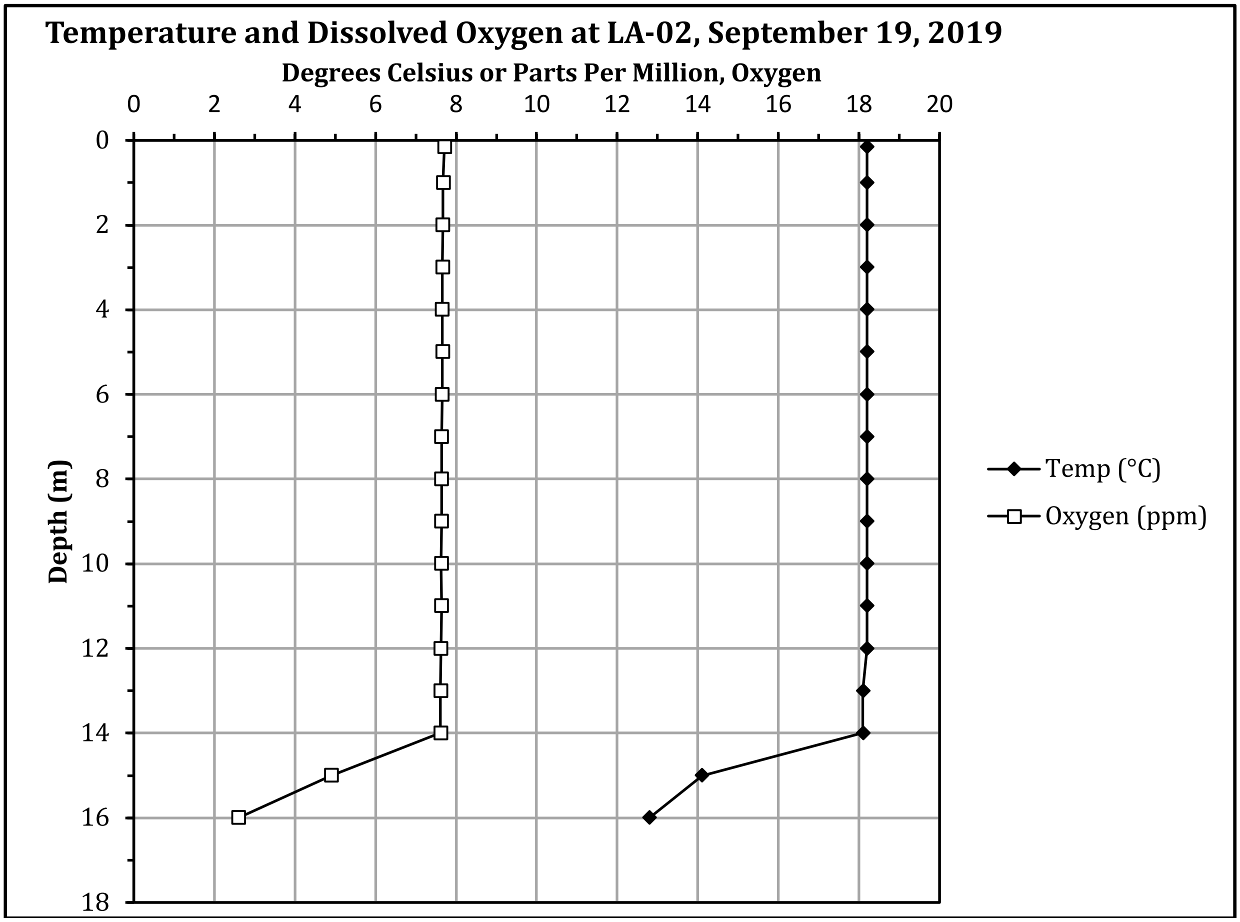


Figure 4 (cont.). Temperature and Dissolved Oxygen at Lake Almanor Station LA-02, 2019



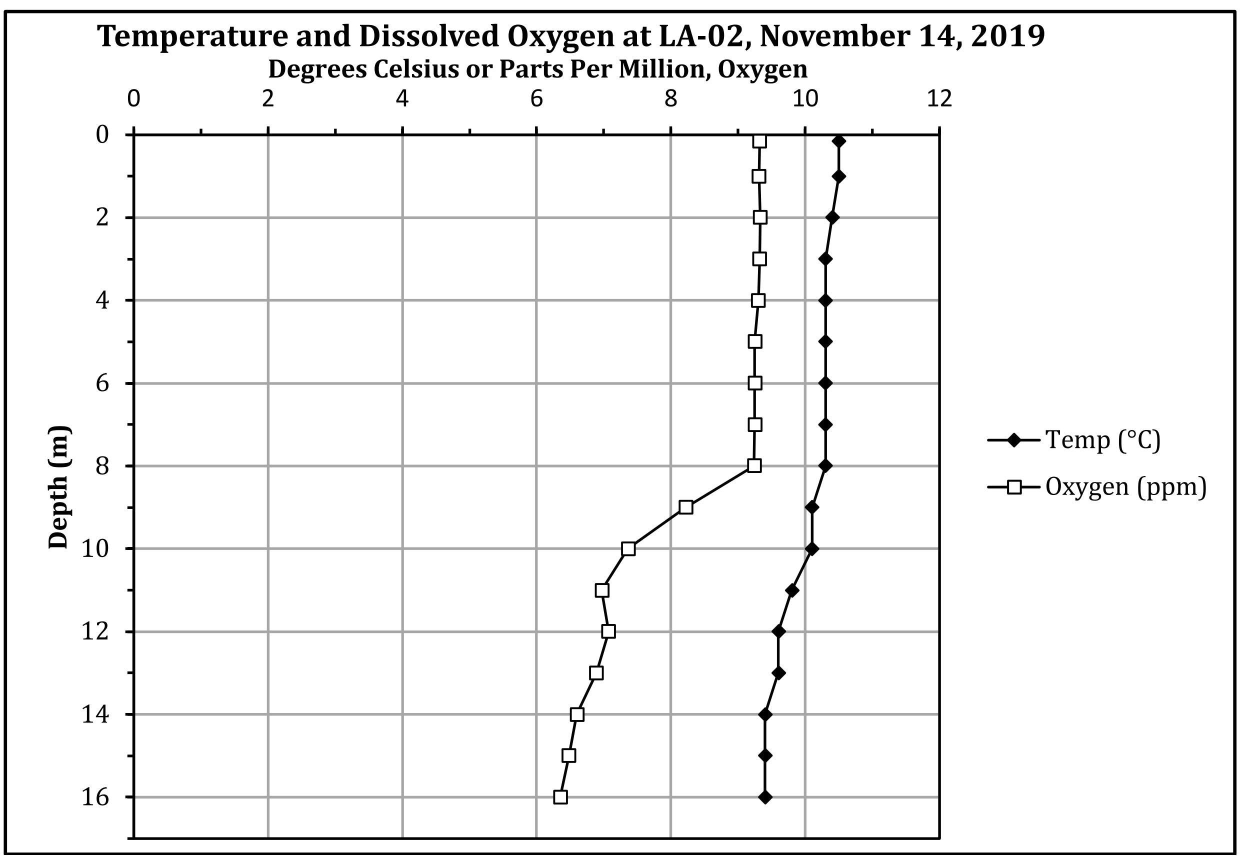
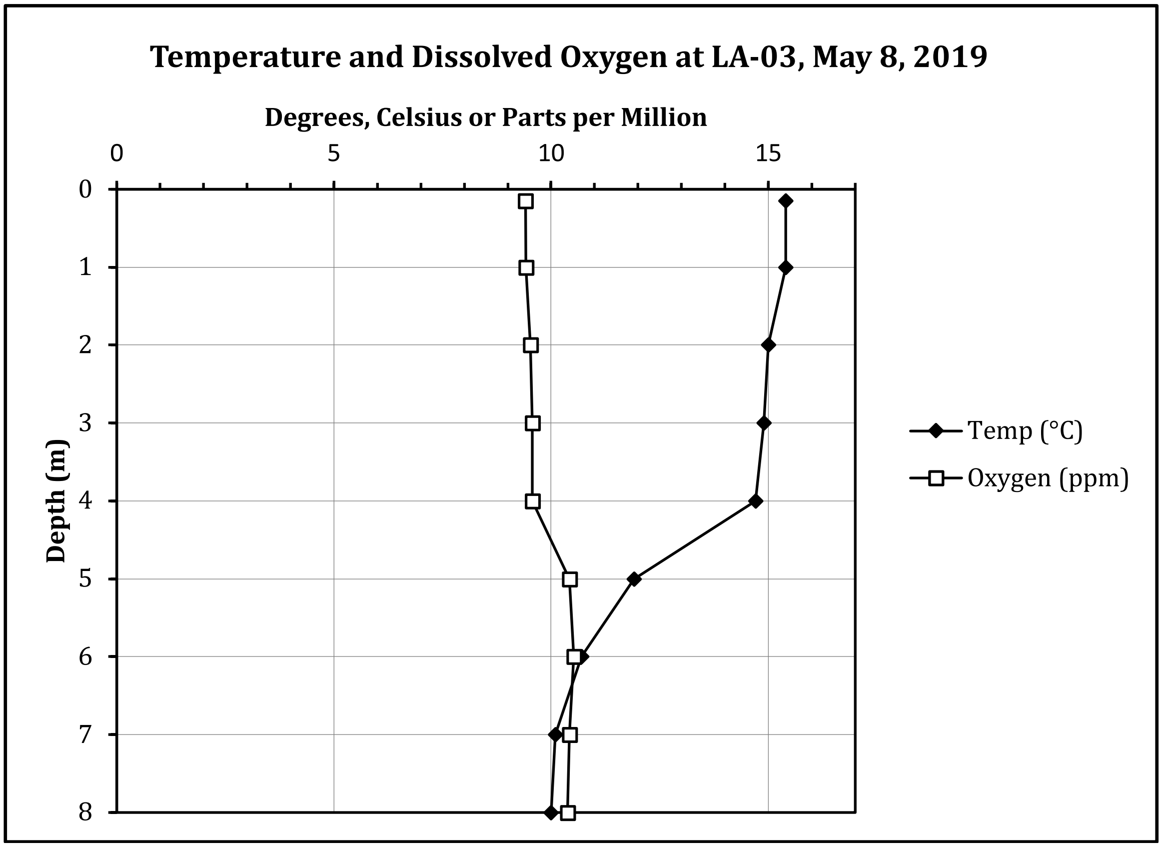


Figure 5. Temperature and Dissolved Oxygen at Lake Almanor, Station LA-03, 2019



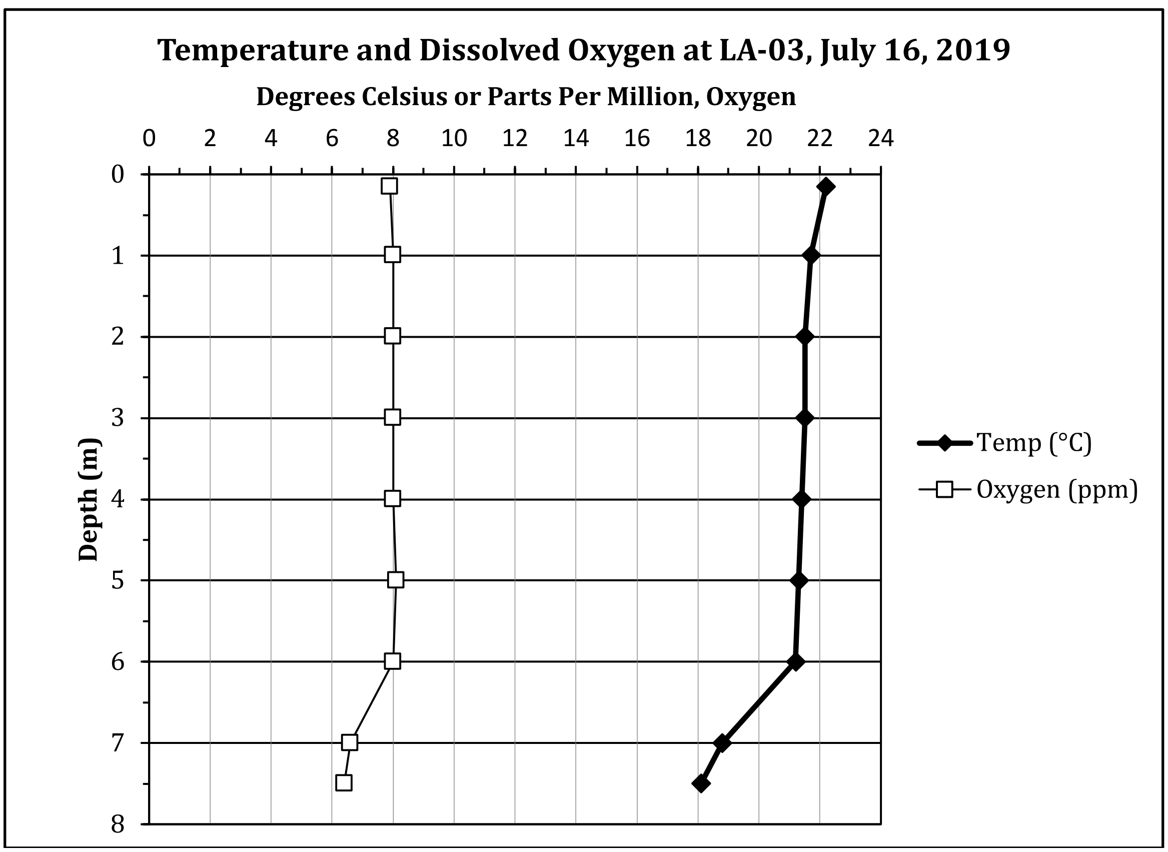
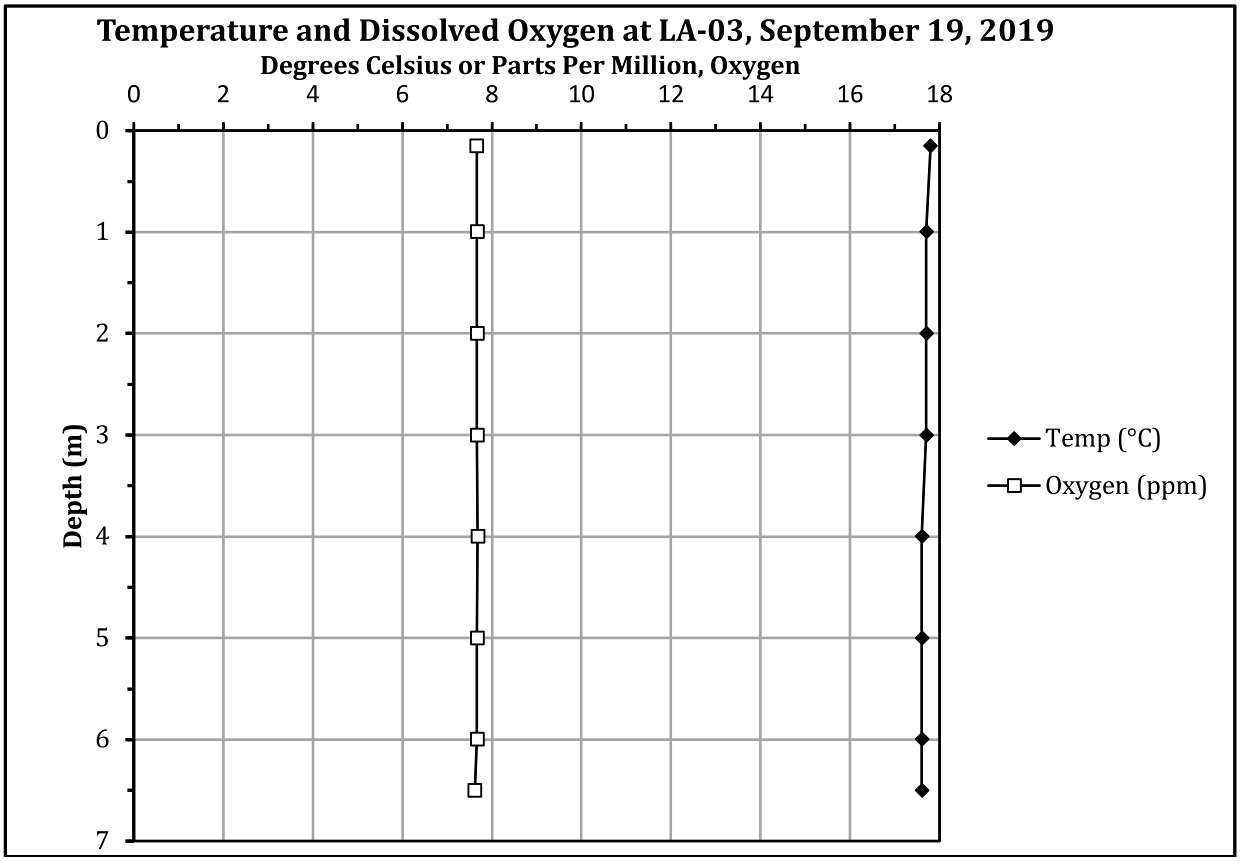


Figure 5 (cont.). Temperature and Dissolved Oxygen at Lake Almanor, Station LA-03, 2019



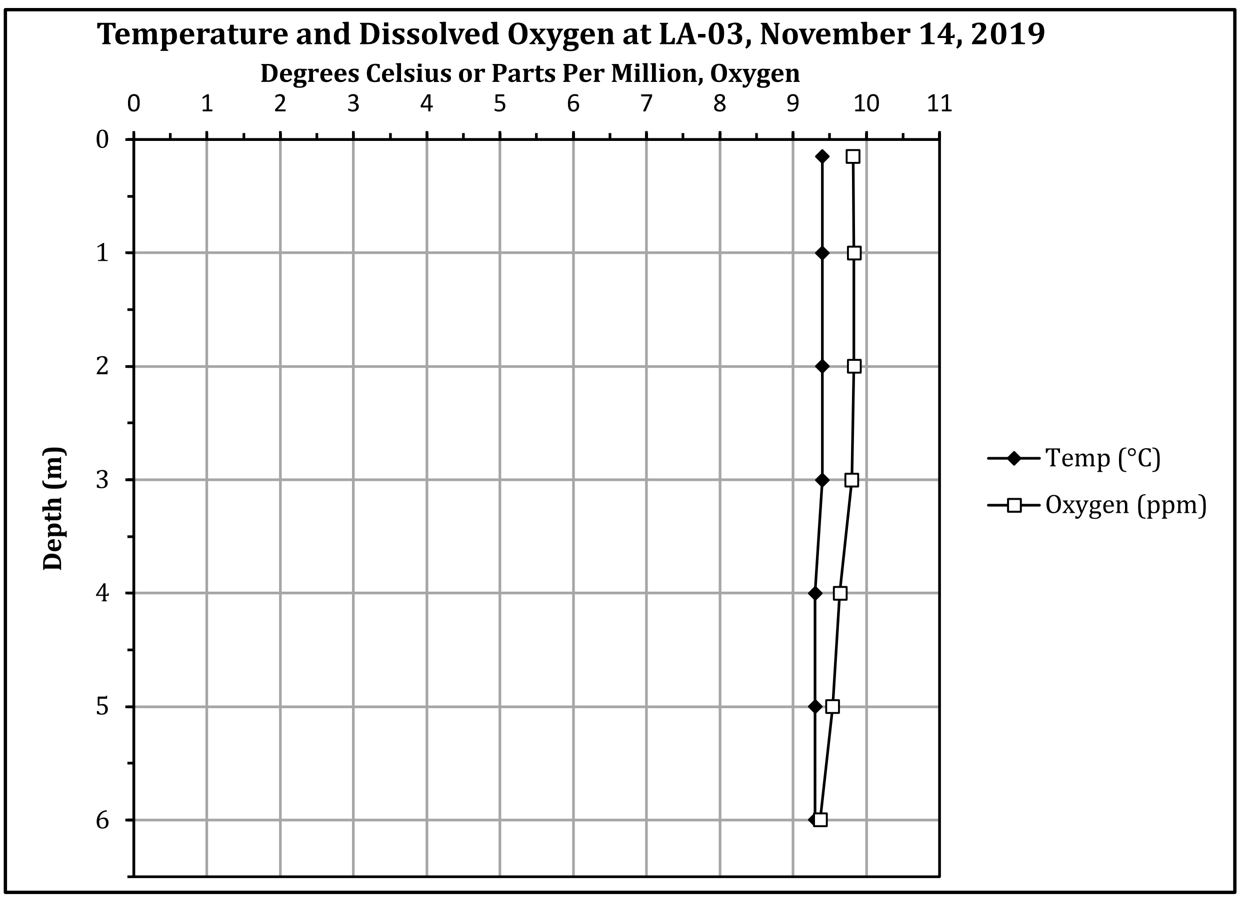


Figure 6. Temperature and Dissolved Oxygen at Station NFFR-1, Chester, During 2019

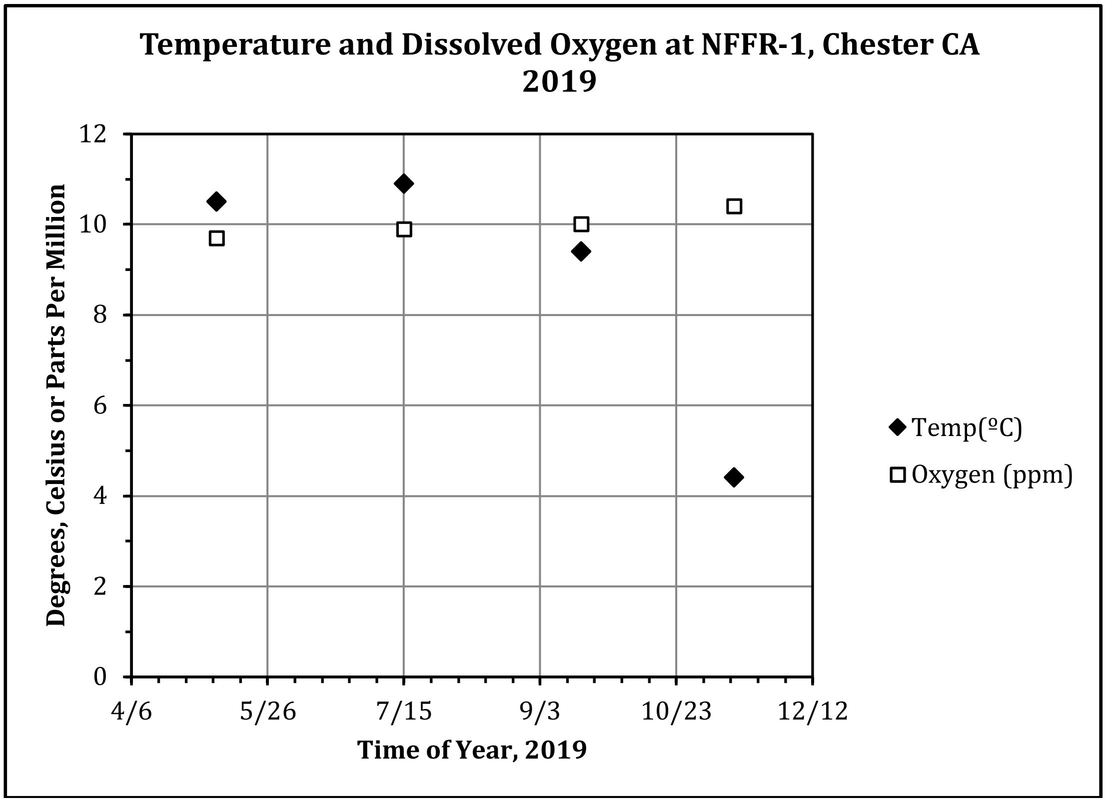
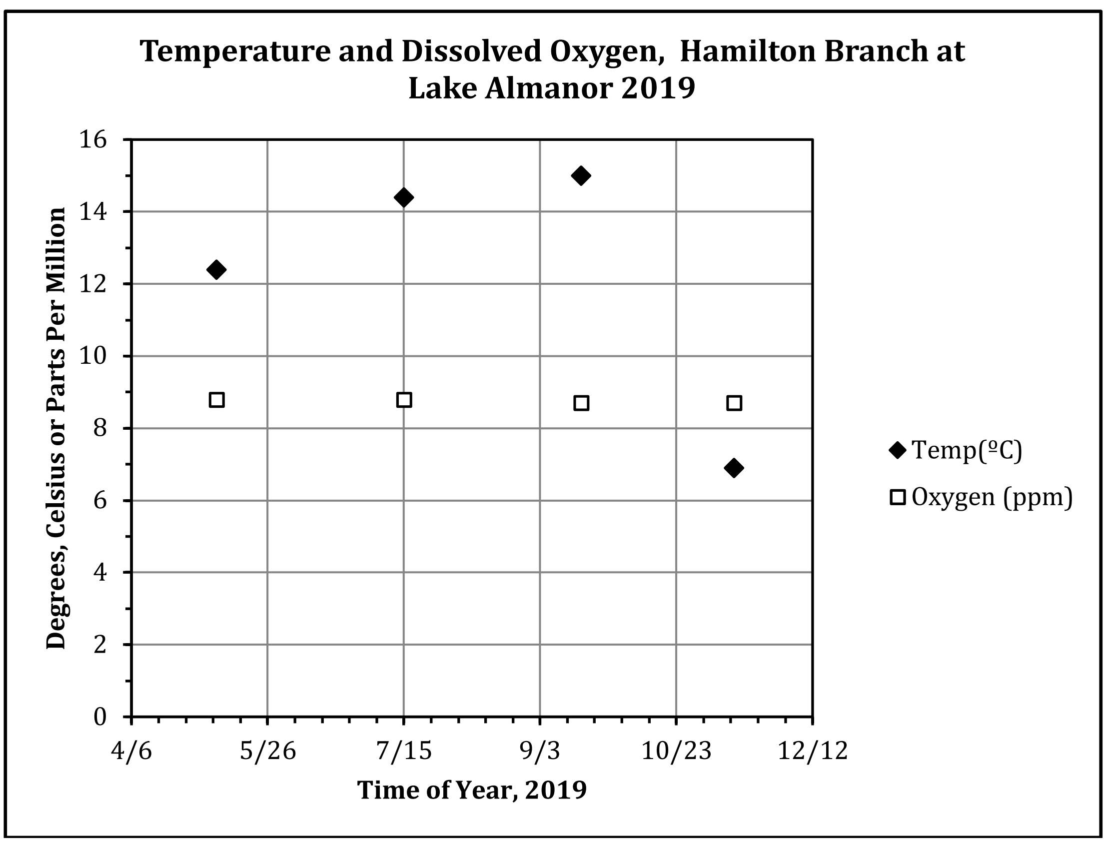


Figure 7. Temperature and Dissolved Oxygen, Hamilton Branch at Lake Almanor (HB-01A) During 2019



c. Electrical Conductivity

Electrical or specific conductivity is a measure of the dissolved salts in water. The data for all stations are presented in Table 1 in the Appendix. Values ranged from 91-111 micro-mhos/cm at the lake stations and from 47-87 micro- mhos/cm in the Feather River. There was little difference between lake stations, although LA-03 tended to be lower, due to the influence of the river. The range of data is similar to that in the DWR database for 1989-2004. The values were gradually increasing since 2011 due to the decreased precipitation in the watershed, but have decreased with increased precipitation in 2016 and 2017. In 2018 they increased again. The 2019 values were very similar to 2018 in May, but a little lower in July.

Bailey Creek had the lowest conductivity (28 μmhos/cm), although it stopped flowing after the May sampling. Hamilton Branch downstream of the Mountain Meadows Dam generally had the highest value (88-147 μmhos/cm), higher than in 2017, but lower than in 2018. Electrical conductivity has been increasing since 2017 at all stations due to less spring precipitation.

d. Secchi Depth and Turbidity

Secchi depth is an indication of suspended particles in the water column. Data for Secchi depth are presented in Table 1 in the Appendix. For all three stations Secchi depth was about 5.2-6.7 meters in May 2019. It increased to 7.7-8.2 meters at LA-01 and LA-02 in July, but was less at LA-03 (5.3 meters). In September it was 4 meters at LA-01 and LA-03 and 6.3 at LA-02. In November it was 4-4.8 meters at all three stations. Variation is probably related to sediment carried by inflowing streams, as well as the amount of phytoplankton (usually lower Secchi depths in spring and fall, which correspond to higher phytoplankton populations). Values were generally in agreement with those in the DWR database and with the 2009 - 2018 studies.

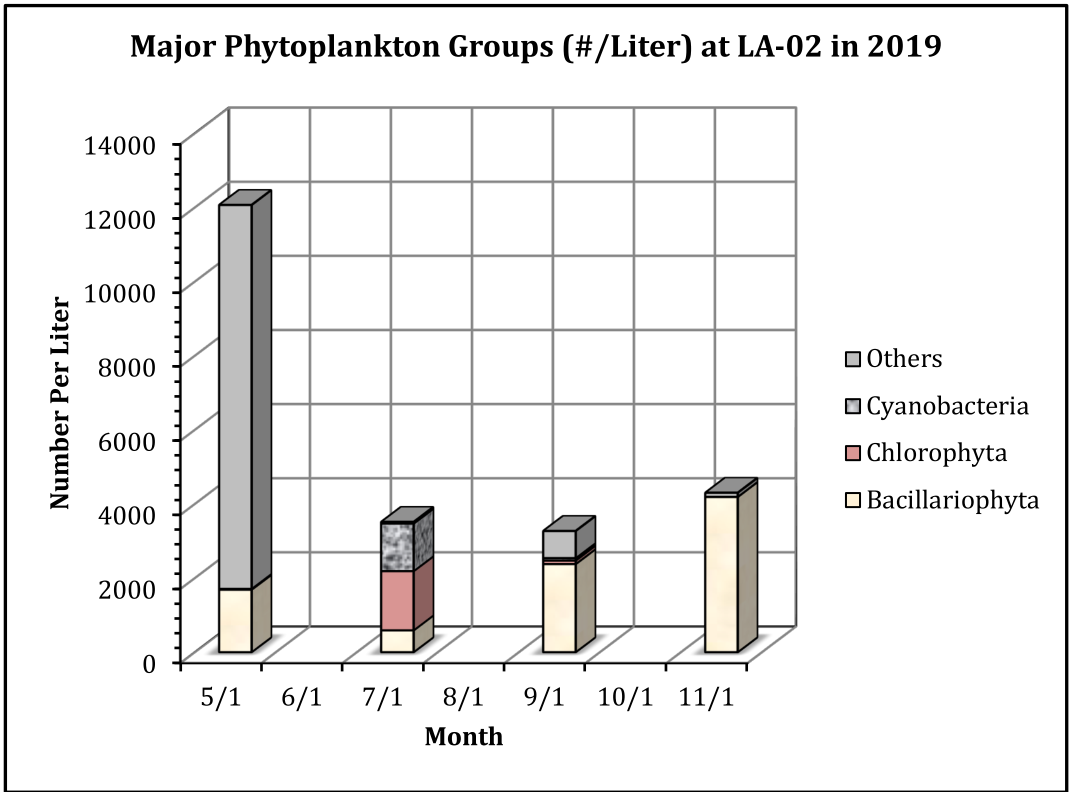
Turbidity was generally low in the tributaries and in the lake, with slightly higher values in spring and fall and lowest values in summer. The highest reading was in November in Hamilton Branch at Mountain Meadows (15 ntu)

3. Phytoplankton and Zooplankton

Phytoplankton samples were collected at LA-02 and LA-03 on all four sampling dates. Data for the major groups of phytoplankton are presented in graphic form in Figures 8 and 9. More detailed data are in the Appendix, Table 2. The data are presented in two different graphs for each station. The first graph shows the number of algal cells or colonies per liter of lake water. The second graph shows the volume of algal cells per milliliter of lake water (cubic microns per milliliter). This way of showing the data is more representative of the amount of algae present, since the size of individuals varies greatly. The number of cells per liter treats small and large cells equally. (Please note that the range for the vertical scale on the graph is not the same for LA-02 and LA-03.)

In May diatoms (Bacillariophyta) were the dominant forms at both LA-02 and LA-03, mostly *Fragilaria,* with *Asterionella* and *Aulocoseira* being numerous. There were a lot of *Dinobryon* – a yellow brown algal genus and *Lyngbya* – a bluegreen algal genus at LA-02. By mid- July the total volume of algae had dropped at both stations. Bluegreen algae, primarily the genus *Dolichospermum (*formerly *Anabaena)*, as well as *Lyngbya*, were present. (This genus forms filaments large enough to be seen with the naked eye and these may accumulate at the surface.) Green algae, primarily *Volvox*, were numerous at LA-03. In mid September *the* algae at LA-02 were mostly diatoms and populations were high. By November, diatoms (Bacillariophyta) were the dominant group at both stations. LA-02 had its greatest volume of phytoplankton in September, as thermal stratification was breaking down. LA-03 also had its greatest volume of phytoplankton in September. Usually the greatest volume is in November.

Figure 8. Major Phytoplankton Groups at Lake Almanor, By Number/Liter and By Volume (cubic microns/milliliter), Station LA-02 in 2019



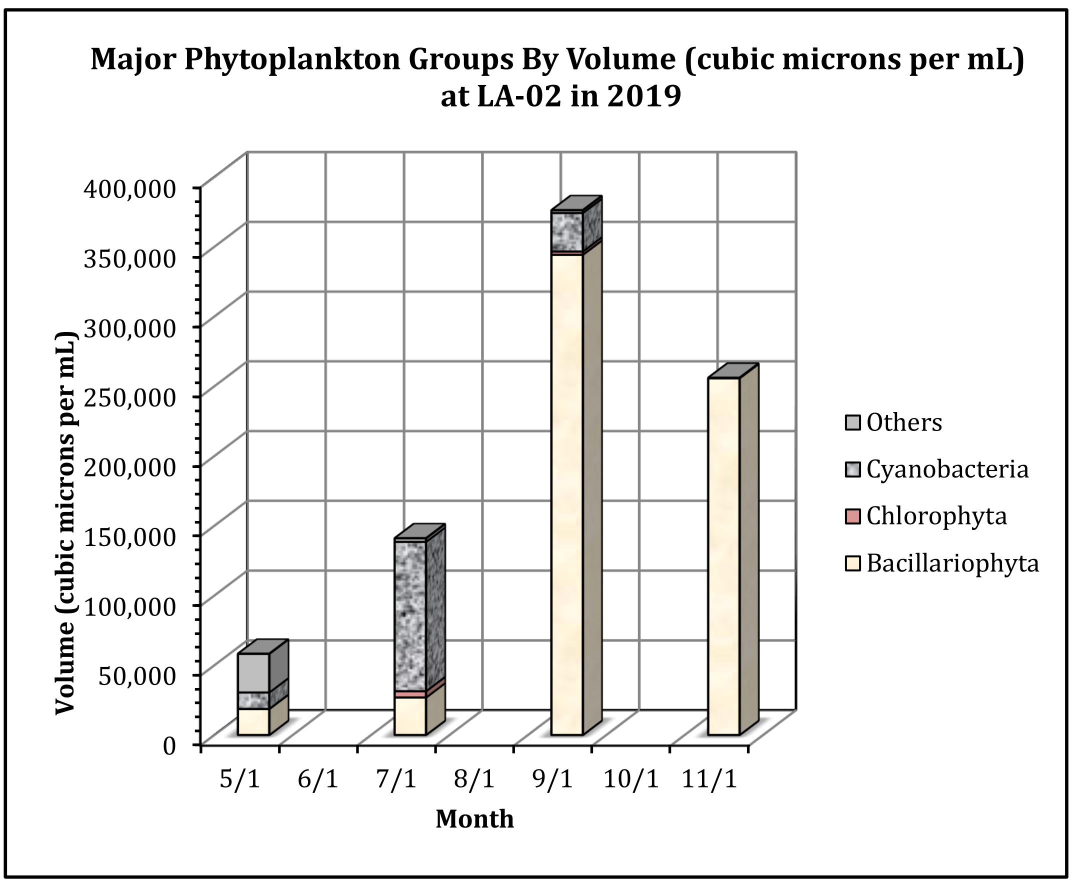
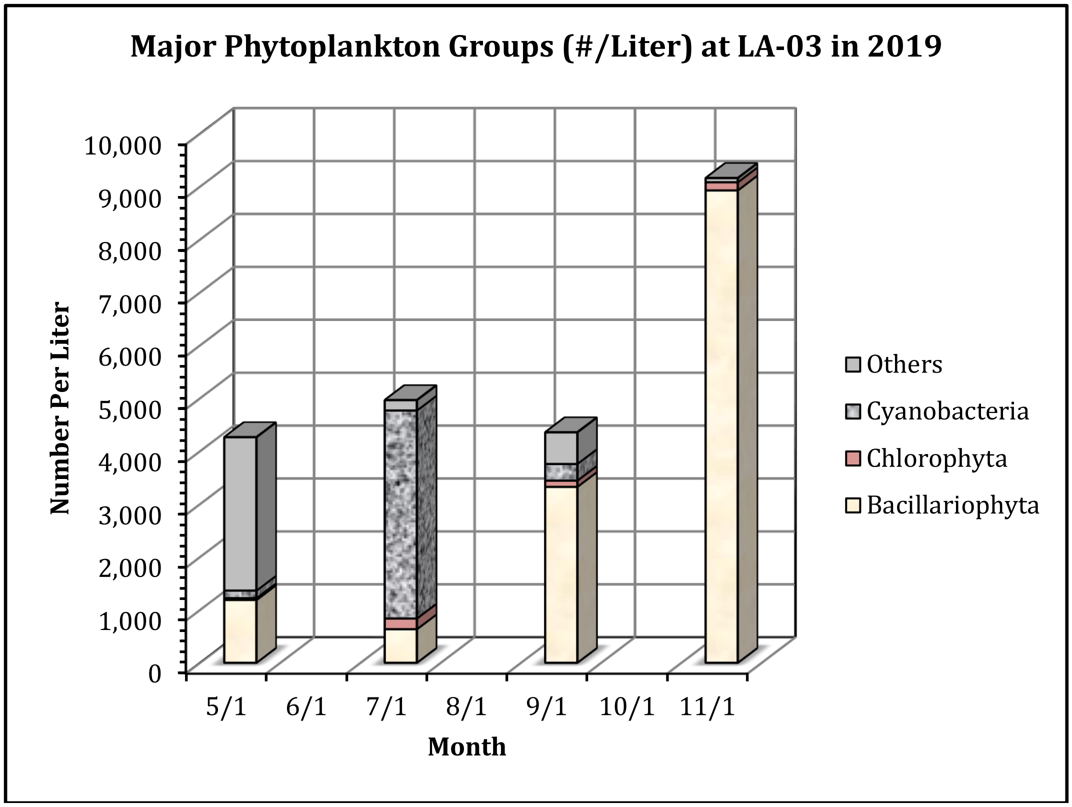


Figure 9. Major Phytoplankton Groups at Lake Almanor, By Number/Liter and By Volume (cubic microns/milliliter), Station LA-03 in 2019



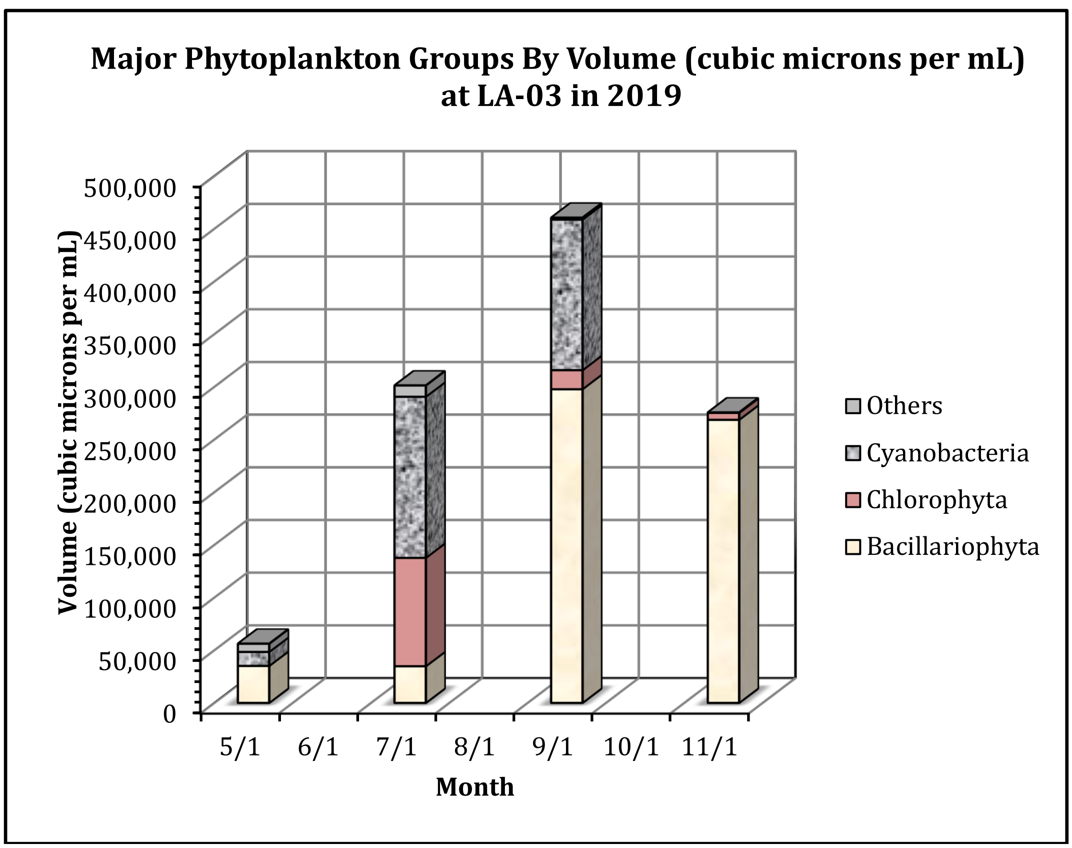
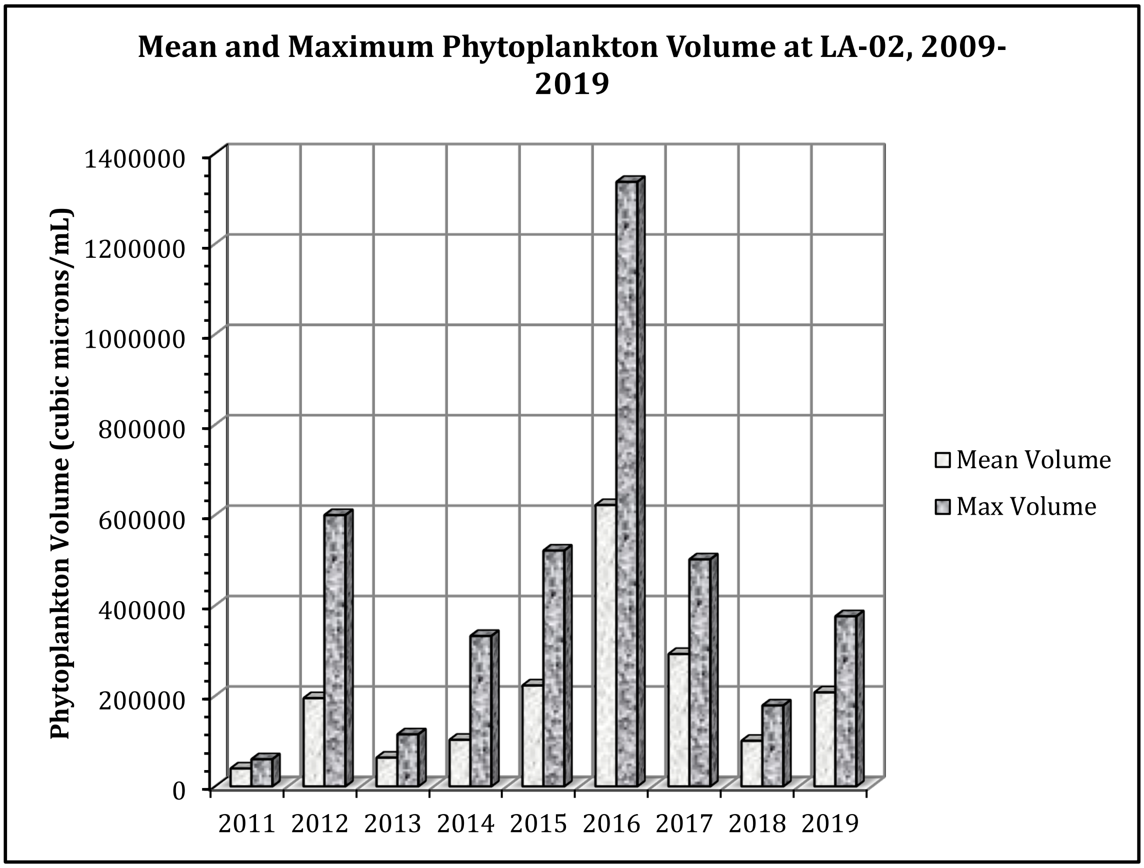


Figure 10 shows the maximum amount of phytoplankton by volume at LA-02 and LA-03 from 2009 to 2019.The maximum was generally in November, but at LA-02 the greatest amount was in April 2016, probably due to the emptying of Mountain Meadows Reservoir in Fall 2015. At LA-02 the volume of algae was increasing from 2013 to 2016, but had dropped back to less than its 2014 value. In 2019 it exceeded that value. At LA -03 the greatest volume in 2014 was six times the highest level in 2013 and was the highest in the previous five years. In 2015 values were only about 2/3 of those in 2014, and in 2016 the values were about half of 2015. The algal volume at LA-03 has been stable or decreasing slightly since 2015. Bluegreen algae continued to be numerous in the summer, but diatoms (Bacillariophyta) were the most numerous in spring and fall. The changing amount of algae overall was probably due to changes in nutrient input and water temperature, which were ultimately controlled by changes in precipitation. In recent years increased inflow from the North Fork Feather River has resulted in greater dilution at LA-03.

There are no recent data from DWR concerning the phytoplankton, but some tables from the 1970's show that many of the same species were present then.
The assemblage of genera is characteristic of meso-trophic lakes.

Zooplankton samples were collected along with the phytoplankton and results are presented in Figures 11 and 12. More detailed data are in the Appendix, Table 3. Rotifera continued to be very abundant, but Copepoda and Cladocera were not as numerous as in the previous two years. There were a third to half as many organisms present in May 2019 compared to May 2018. Summer populations were similar. The greatest abundance of zooplankton was in May at LA-02 and at LA-03.

Figure 10. Mean and Maximum Phytoplankton Volume at LA-02 and LA-03, 2009 -2019



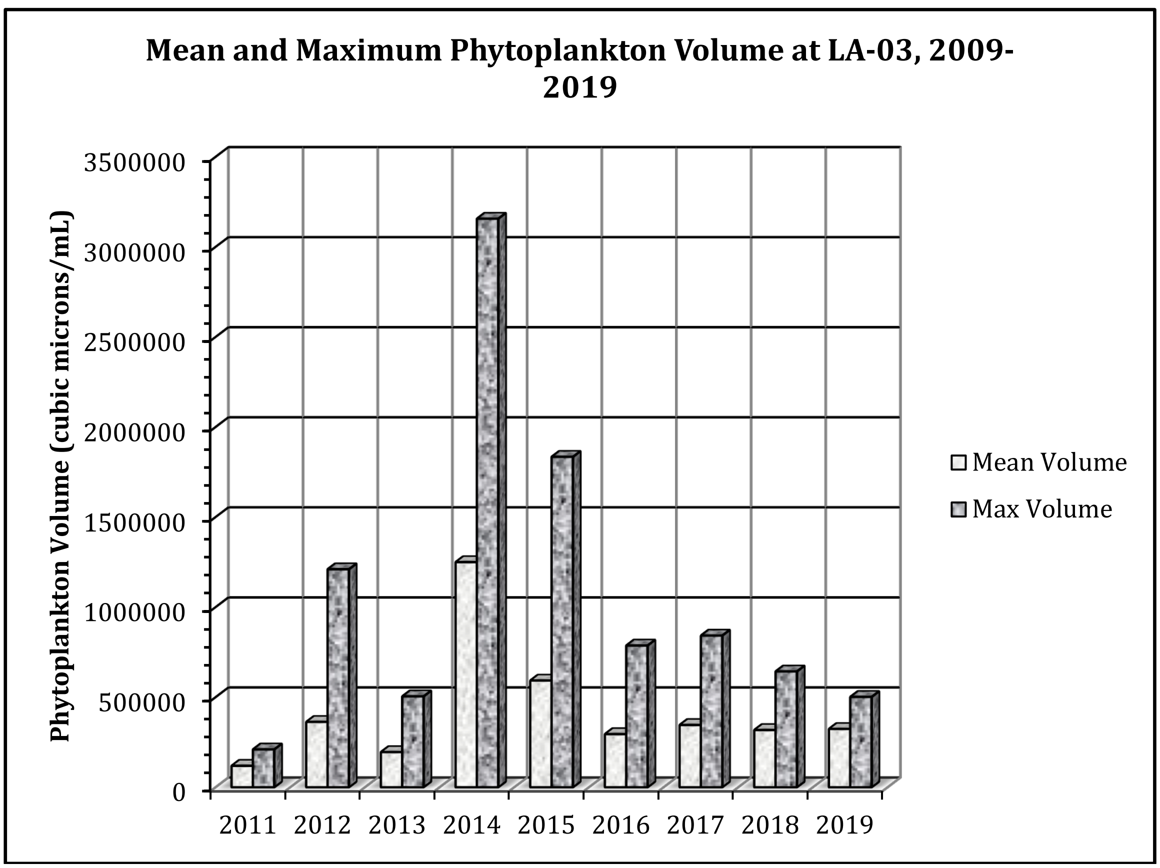


Figure 11. Major Zooplankton Groups (#/Liter) at Lake Almanor, Station LA- 02, 2019

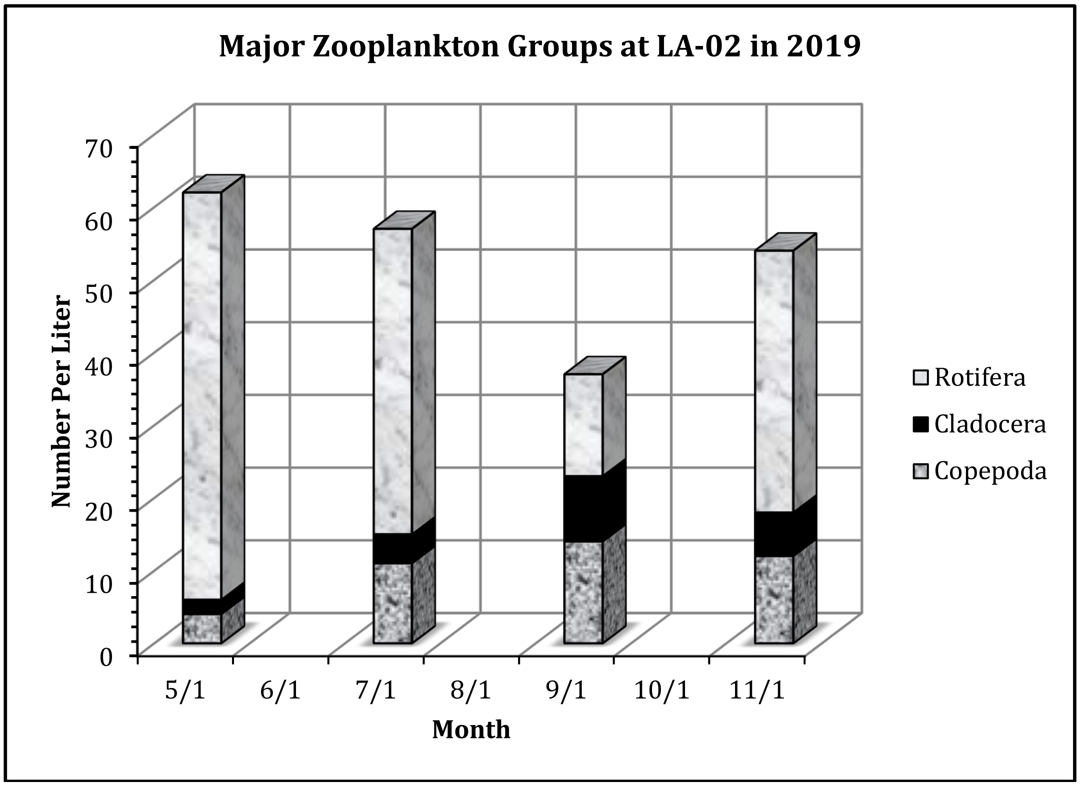
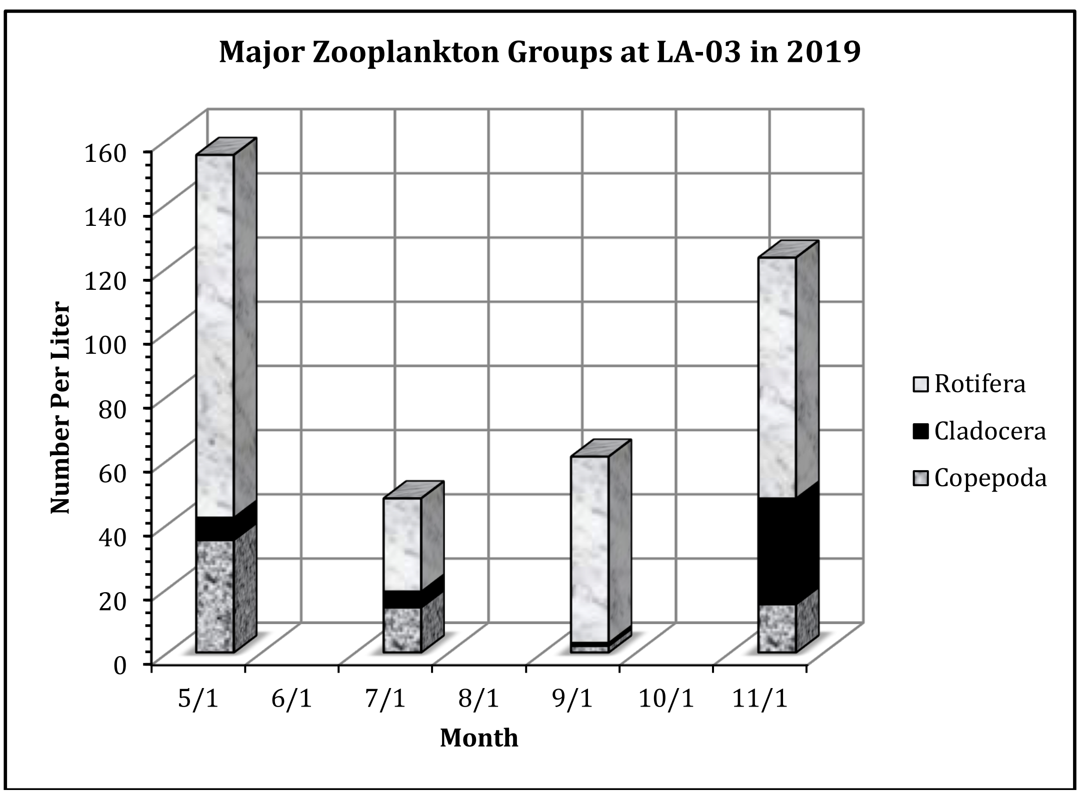


Figure 12. Major Zooplankton Groups (#/Liter) at Lake Almanor, Station LA-03, in 2019



Conclusion

Lake Almanor is a reservoir that is already undergoing many changes. Because of the lake's high elevation, the cooler water temperature and the short growing season limit some plant growth. However, the western basin is shallow and the water is warm in the summer. Phytoplankton and larger aquatic plants can become very numerous at this time of year. There are enough nutrients coming in from the river, streams or from human activities (septic tanks, golf courses, lawns) to support abundant plant growth. As more homes are built in the watershed, the nutrient input will increase.

An extensive sampling program undertaken by DWR beginning in 2014 has provided physical, chemical and biological data for three lake stations and major tributaries. Spring 2016 was the first year in the previous five where precipitation totals approached normal. 2017 did exceed average values. The lake was cooler in Spring 2016 and 2017 than in 2015 due to increased runoff. The physical data showed that there were lower water temperatures and more dissolved oxygen in the hypolimnion than in the previous five years. Dissolved oxygen in the hypolimnion still dropped to zero, but this occurred later than in 2015. Suitable coldwater fish habitat was at a minimum or non-existent by August 2017, but the period was of shorter duration.

Spring 2019 was above normal in terms of precipitation, with over 33 inches of rain from January – June, compared to the norm of 20.3 inches (not including snowfall)*. The pattern of cooler water temperatures in the reservoir continued through 2019. There was also more dissolved oxygen, which persisted through the summer at LA-02, so that the hypolimnion did not become anoxic. The hypolimnion at LA-01 was anoxic below 14 meters for only the latter part of the summer. While the water temperatures were warm for coldwater fish species, conditions were not as stressful as in years prior to 2017.

Cooler inflows, decreased nutrient inputs and dilution have decreased algal abundance at LA-02 and LA-03 to low levels. There has also been a shift to more diatoms and fewer bluegreen algae. This has resulted in more zooplankton, which is a major food source for small fish and aquatic insects. Ultimately, the overall food web has become healthier. Bluegreen algal species are still present in the summer months.

Continued sampling is needed to document ongoing water quality changes. As precipitation and water needs change, water temperature and reservoir levels change. These create a new set of conditions every year. Hopefully, a similar program of monitoring can be continued in 2020. We have a much better understanding of the reservoir ecosystem and its fragility than when we began the reservoir studies in 2009. The data that we have collected have given us a unique perspective of the reservoir and watershed dynamics and LAWG must be involved in the development of future monitoring programs by the county, state or PG&E.

*Source: www.usclimatedata.com/climate/chester/california/united-states/usca0209