Lake Almanor Water Quality Report, 2018

Prepared for

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

By

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Introduction and Project Overview

A water quality monitoring program for Lake Almanor was conducted during 2018, 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), the County of Plumas 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 2018 study are shown in Figure 1.

Figure 2. displays Almanor Basin land ownership parcels 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.).

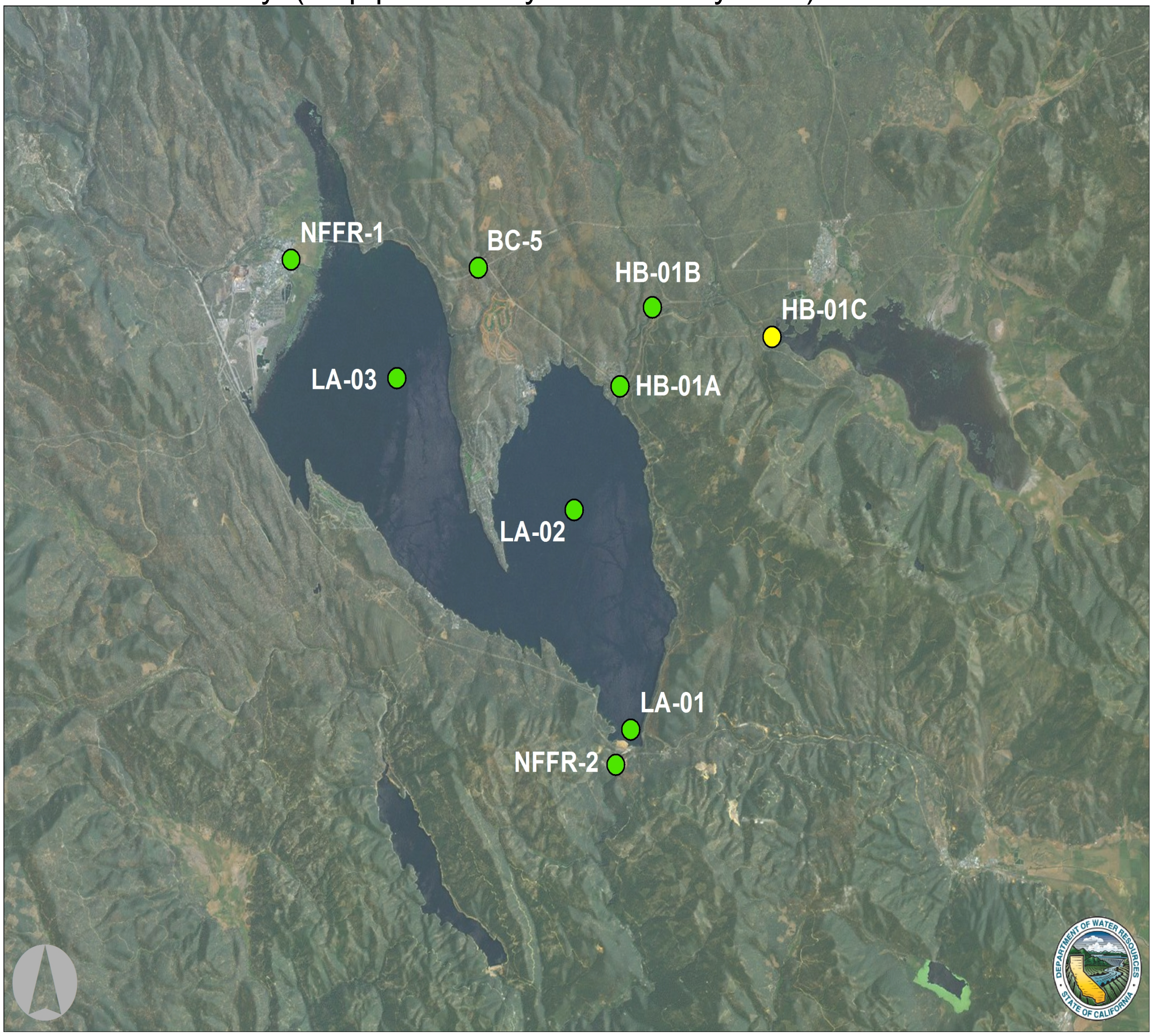
Parameters that were monitored in 2018 included:

1. Physical: temperature, dissolved oxygen, Secchi depth (where applicable), electrical conductivity, pH and turbidity.
2. Chemical: an analysis of many inorganic and organic elements and compounds, including nutrients.
3. Biological: phytoplankton and zooplankton at LA-02 and LA-03.

Methods Used for Sampling and Analysis

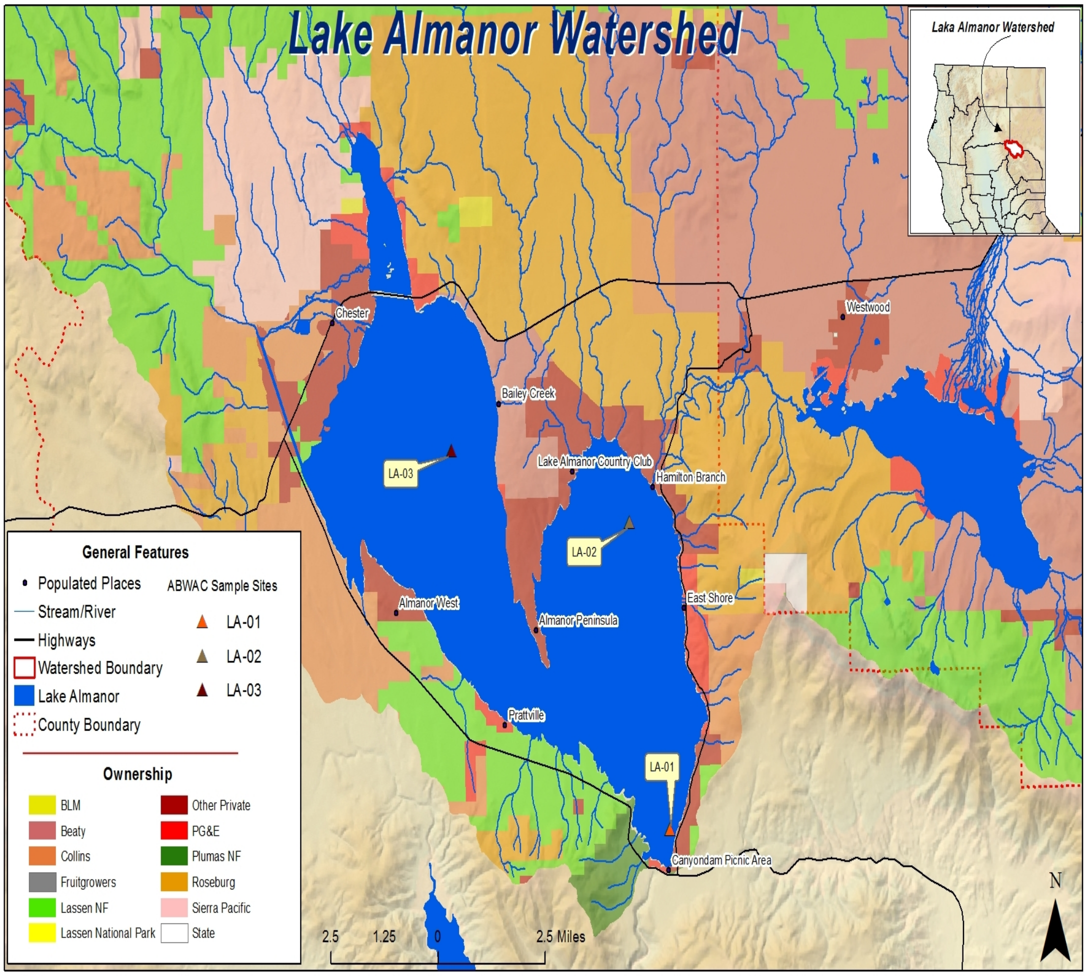
Field Parameters— **Stream-** Basic water quality parameters, including dissolved oxygen, conductivity, pH, and turbidity, were measured with properly calibrated field instrumentation at each visit to every monitoring station. Stream samples or measurements were collected about one foot below the surface 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 2018 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, 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 was 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).

Inorganic Chemistry—Water inorganic chemistry was assessed since these parameters influence beneficial uses of water and may become elevated due to contamination, which often results in deleterious effects to aquatic life and other beneficial uses. Limnological processes in lakes may alter the chemical state of some parameters, and include potential release of soluble metals from bottom sediments and methylation of mercury due to warmer water and organic content in Lake Almanor. Inorganic chemistry samples were collected approximately 0.5 meters below the surface and approximately 0.5 meters above the bottom with a Van Dorn water bottle and appropriate volumes dispensed into the sample containers.

Inorganic chemical analyses include minerals (calcium, sodium, potassium, magnesium, sulfate, chloride, boron, and alkalinity), nutrients (nitrate plus nitrite, ammonia, dissolved orthophosphate, total and dissolved organic carbon, and total phosphorus), and metals (aluminum, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, and zinc). For all metals except mercury, samples were collected for both total recoverable and dissolved metals. Mercury samples include total recoverable fractions. Total and suspended solids and hardness were also analyzed from samples collected at each site.

Samples for chemical analyses of streams were collected by wading into the channels and dipping sample containers to a depth of approximately one foot into the well-mixed channel flow. Mineral and nutrient samples were collected into clean polyethylene containers. Samples for trace metals analyses at water quality criteria levels were collected into polyethylene or glass (mercury only) bottles according to U.S. EPA Method 1669 (two-person, gloved, “clean hands/dirty hands” method). Surface samples for mineral, nutrient, and metal analyses from Lake Almanor were collected from the surface by dipping an inverted container to approximately 0.5 meters below the surface. Water samples at greater depths were collected with a Van Dorn water bottle for minerals and nutrients, and pre-cleaned, Teflon Kemmerer style bottles for trace metals. Chemical analyses of minerals, nutrients, and metals were performed at the DWR Bryte Chemical Laboratory in West Sacramento using U.S. EPA approved techniques, equipment, and methods.

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 2018 LA-01 and LA-02 and LA-03 were well mixed with a few degrees temperature difference between surface and bottom. At LA-01 temperature at the surface was about 12°C (54 °F), and at the bottom it was around 7 °C (45 °F). LA-02 was the same at the surface and the bottom was at 7 °C. LA-03 was around 12 °C (54 °F) at the surface and 9 °C at the bottom. Both LA-01 and LA-02 were about 2 °C cooler at the surface and about 2 °C cooler at the bottom than in 2015, similar to what was observed in 2016 and in 2017.

By mid July 2018 stations LA-01 and LA-02 were thermally stratified. The epilimnion was about 20-24 °C (68-75 °F). The metalimnion was between 11 and 14 meters. At LA-03 the temperature from top to bottom was about 21-24 °C. The surface temperature at all three stations was 24 °C. The bottom temperature was 10 °C at LA-01 and LA-02, which was similar to 2017.

The next sampling date was September 17, after Labor Day, and LA-01 was still strongly stratified. The epilimnion extended down to 10 meters depth. At LA-02 stratification was beginning to break up and the water column was well mixed to a depth of 12 meters with a temperature of 19 °C. the temperature then dropped off rapidly to 11 °C at the bottom (16 meters). LA-03 was well mixed, with a temperature of 19 °C (66°F) throughout.

By late November 2018 the lake was no longer thermally stratified at any station. Water temperature at LA-01 and LA-02 was about 9 °C (48 °F) throughout. LA - 03 was 7.5 °C.

Water temperatures were generally higher than in 2017. This was probably due to the decrease in spring precipitation and decreased inflow from tributaries.

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.

Data for Hamilton Branch at Lake Almanor are shown in Figure 7. The highest temperature was in September at about 11.1°C (52 °F), making it 3 °C (5 °F) cooler than the NFFR and about the same as the hypolimnion of Lake Almanor. Physical data for other tributaries are in the Appendix , Table 1. Of particular interest is the difference between Hamilton Branch at Mountain Meadows and where it enters Lake Almanor. There was about 12 °C (22 °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.

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.

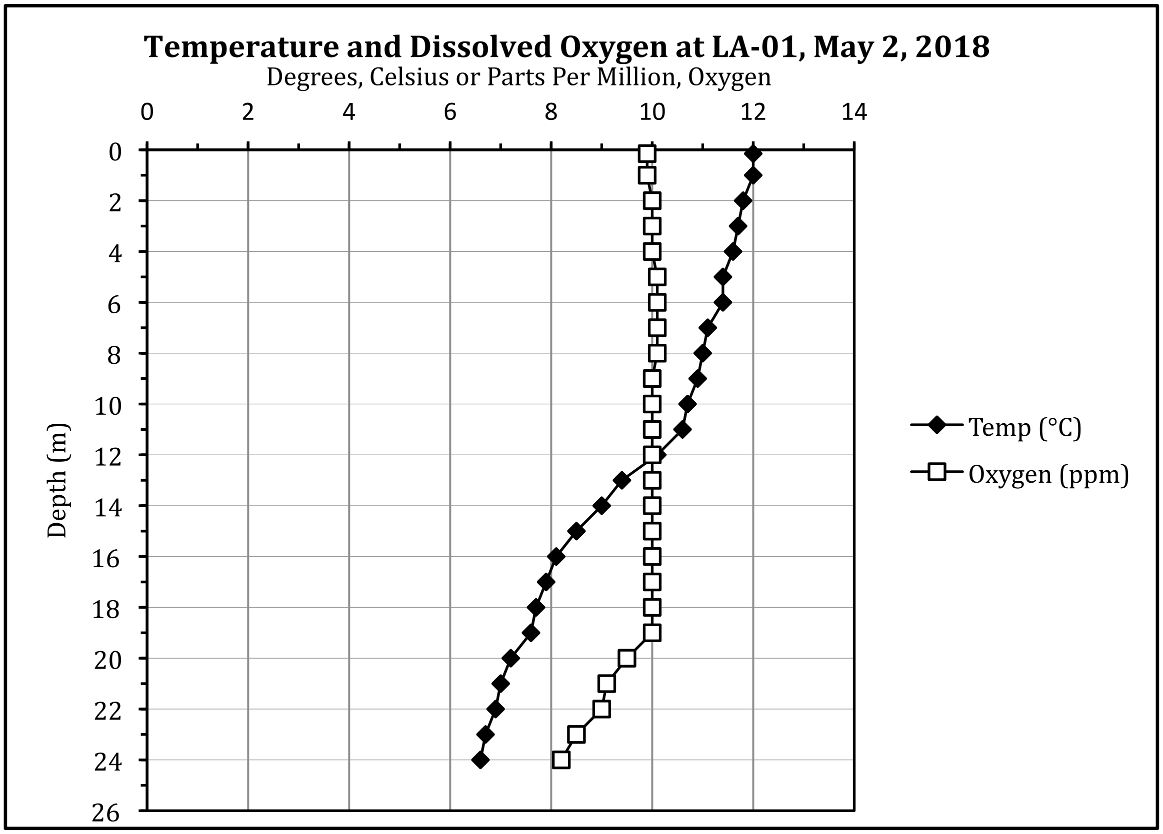
In May 2018 the oxygen concentration at all three lake stations was about 10 parts per million (ppm) throughout the water column. This was approximately the maximum that could be dissolved at that water temperature (12 ºC) and the existing atmospheric pressure and wind conditions.

In July 2018 oxygen concentration in the epilimnion at LA-01 and LA-02 was 8 ppm, and the epilimnion water temperature was 24 ºC (75 °F). Due to the shallow conditions at LA-03, oxygen was 8 ppm throughout. . In the hypolimnion at LA-01 and LA-02, the oxygen level dropped, but was still above 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-01 it dropped below 4ppm at 24 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.

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 increased in the thermocline and then dropped to 4 ppm at 14 meters. At LA-02, oxygen levels also increased in the thermocline and then dropped off to zero below 12 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.

Figure 3. Temperature and Dissolved Oxygen at Lake Almanor Station LA-01, 2018



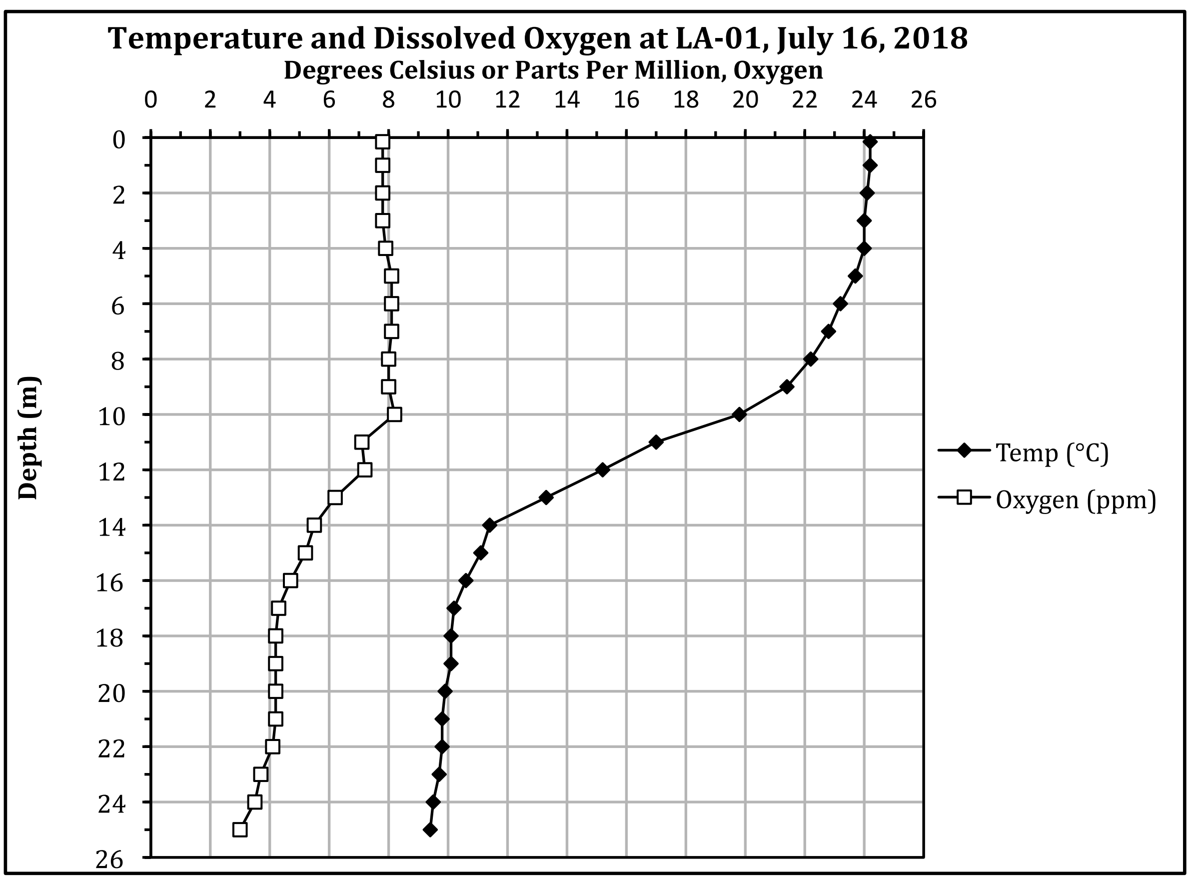
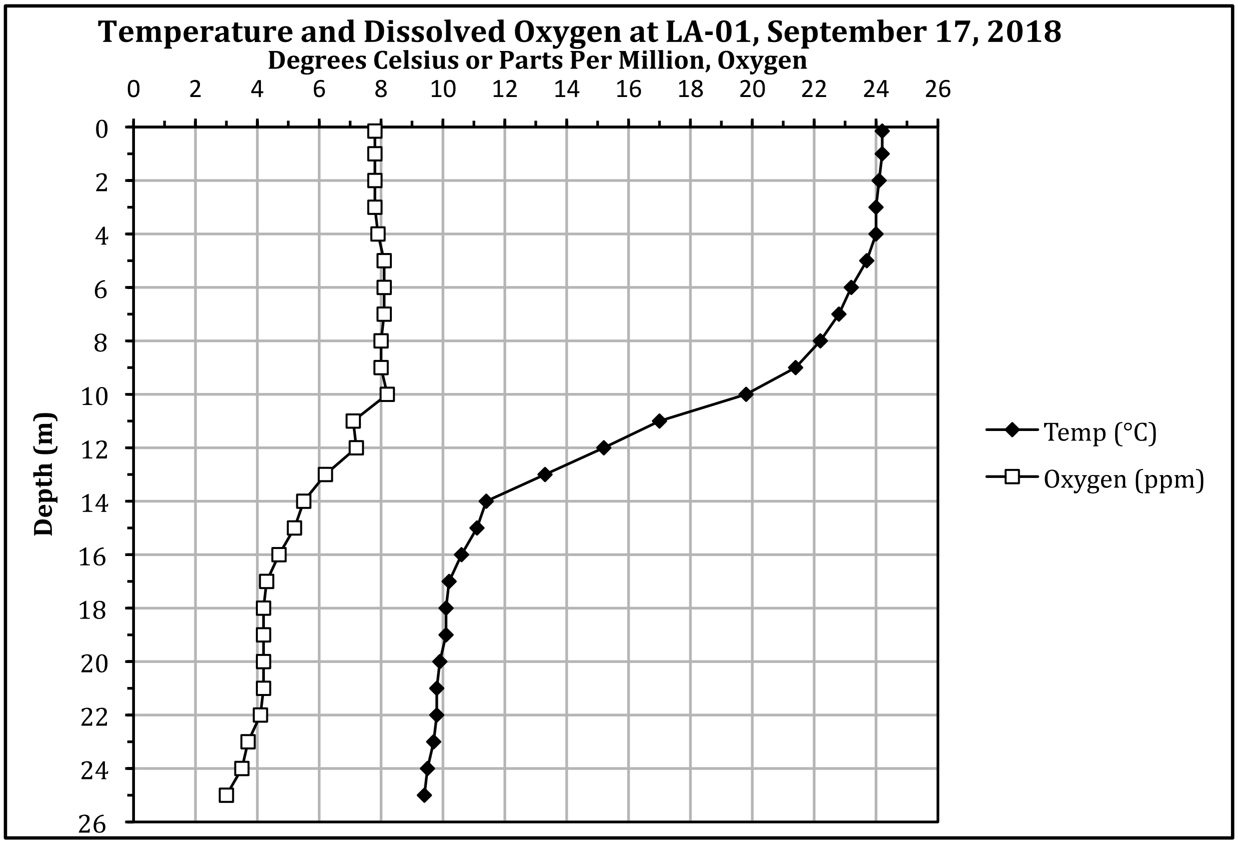


Figure 3 (cont.). Temperature and Dissolved Oxygen at Lake Almanor Station LA-01, 2018



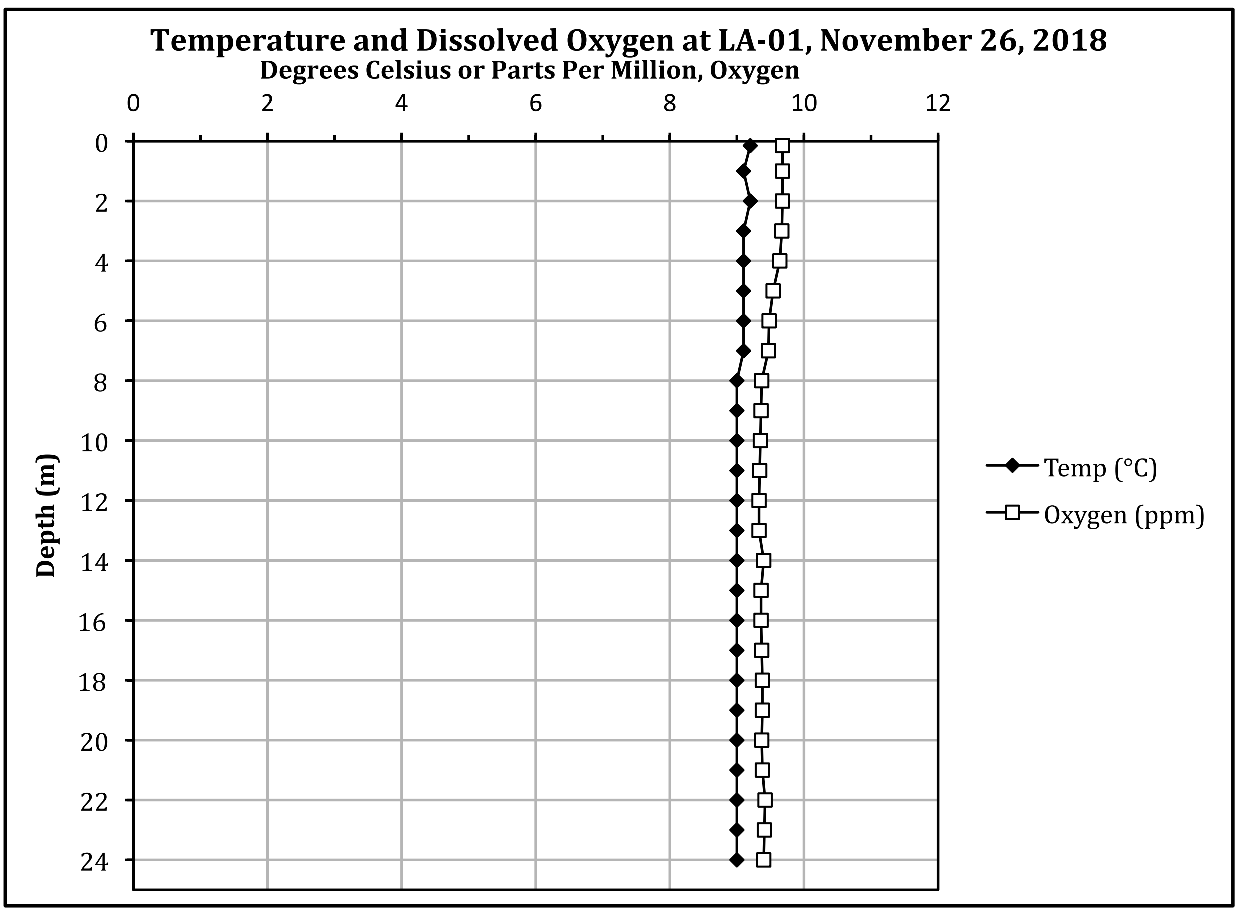
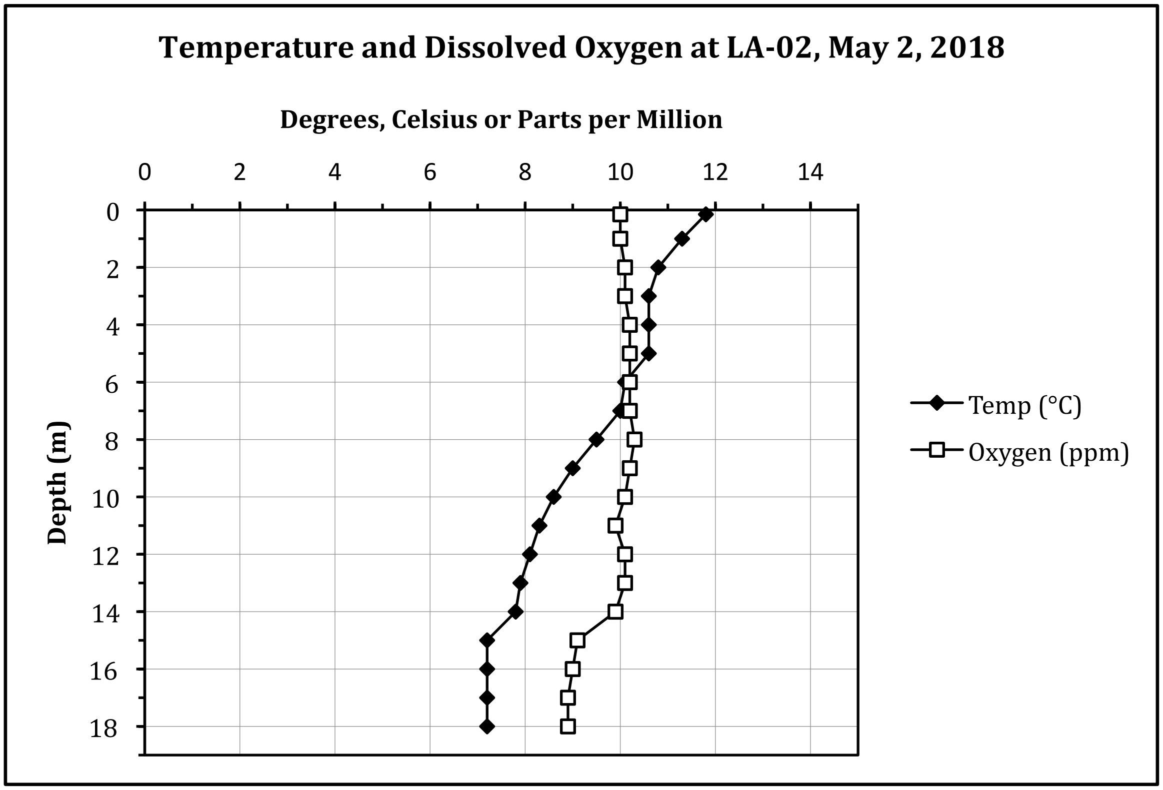


Figure 4. Temperature and Dissolved Oxygen at Lake Almanor Station LA-02, 2018



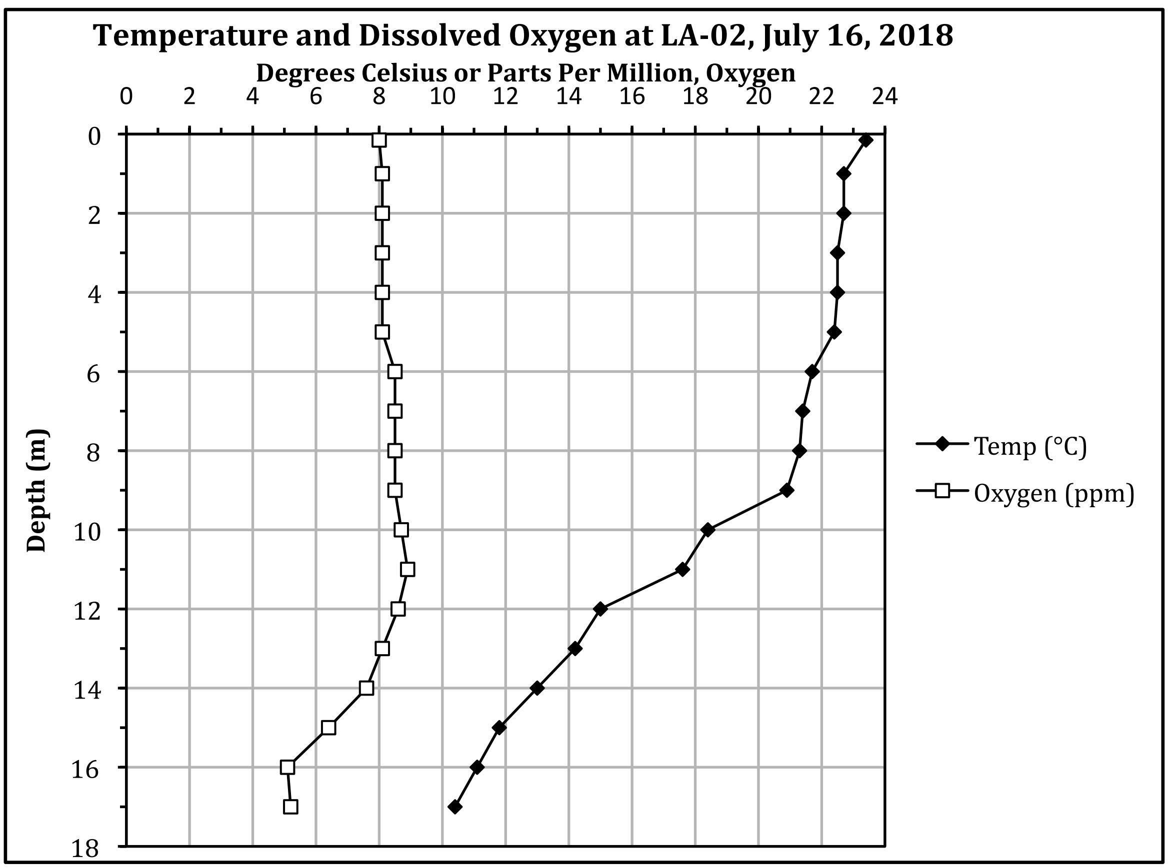
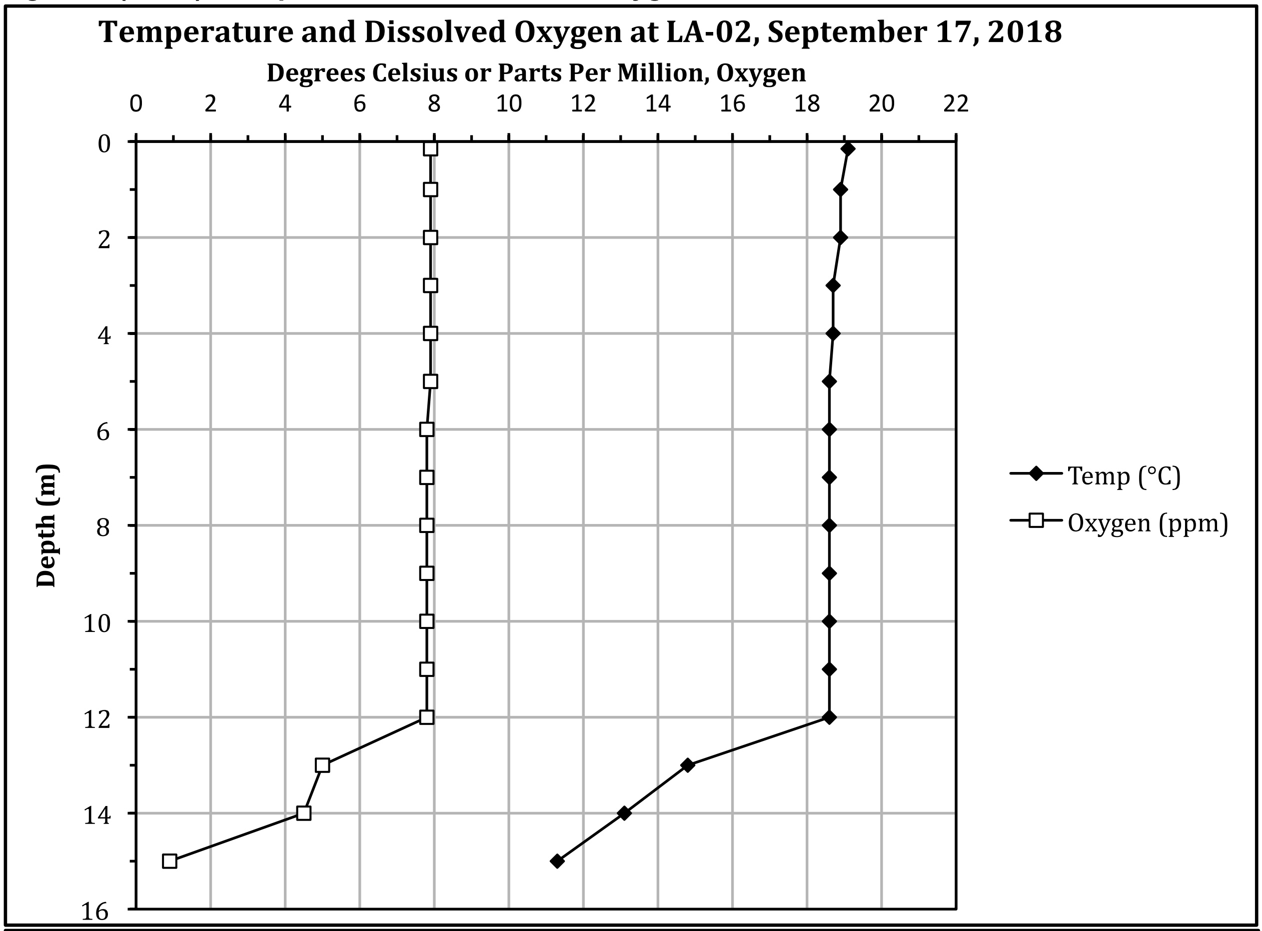


Figure 4 (cont.). Temperature and Dissolved Oxygen at Lake Almanor Station LA-02, 2018



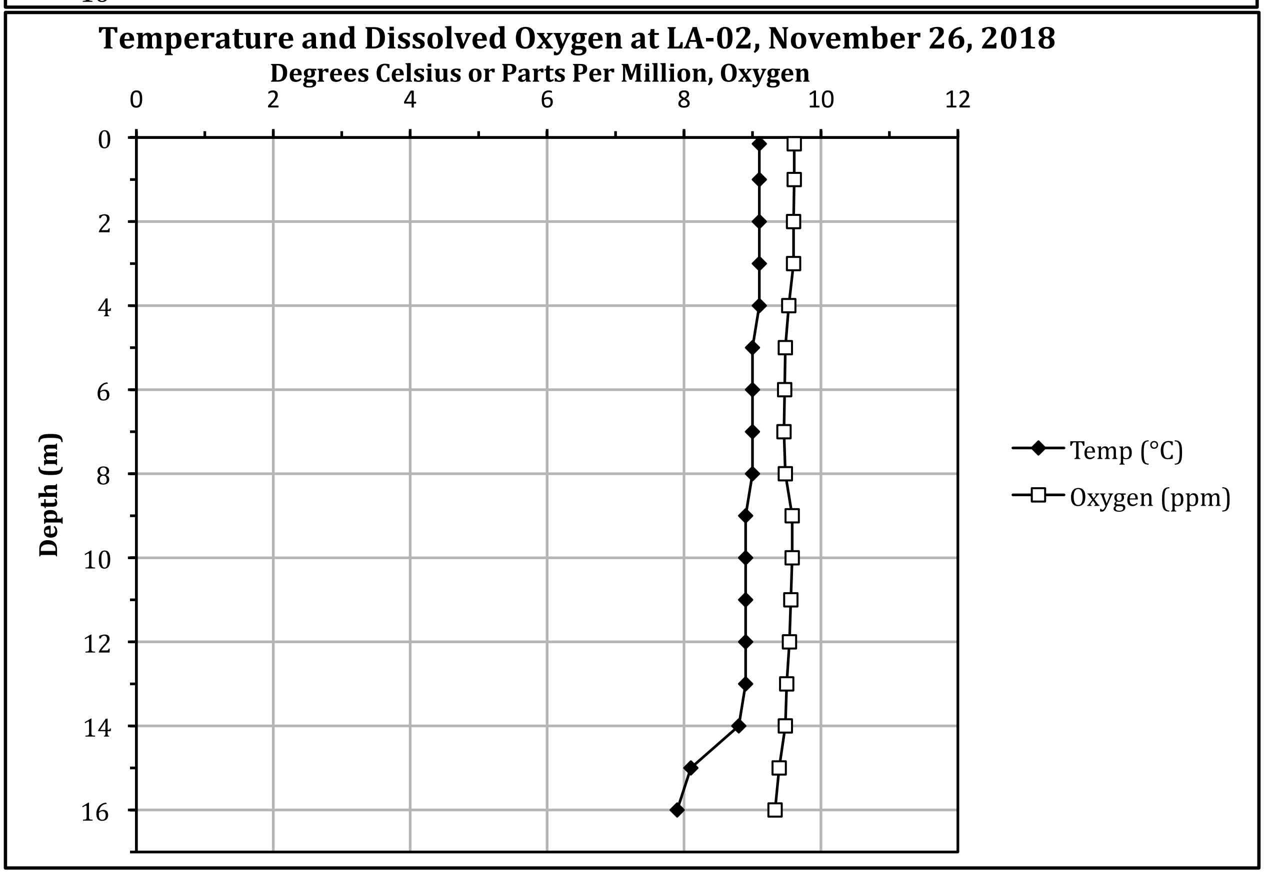
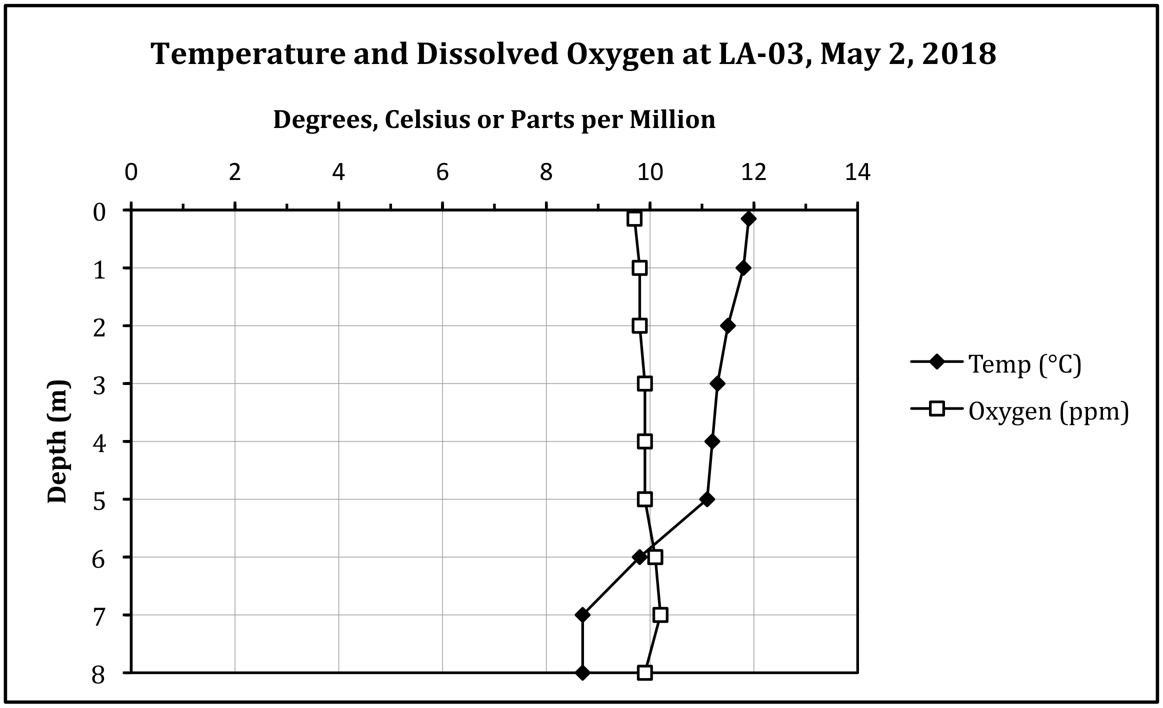


Figure 5. Temperature and Dissolved Oxygen at Lake Almanor, Station LA-03, 2018



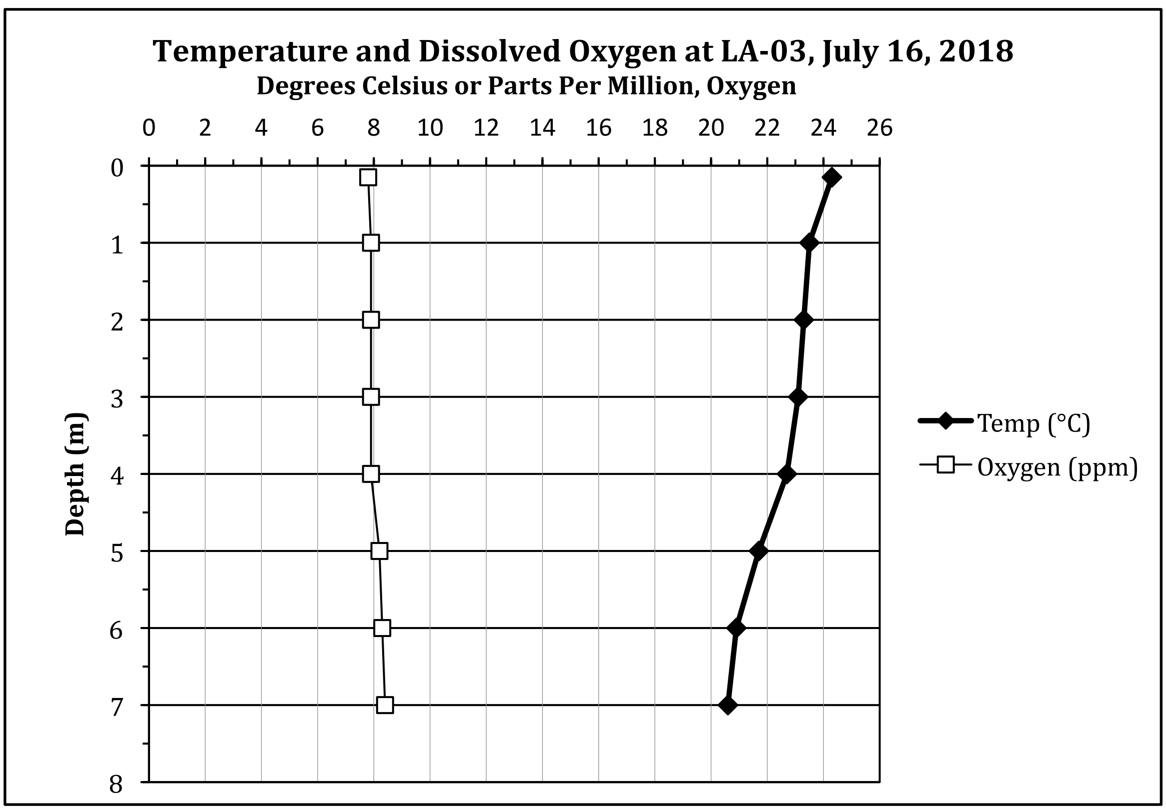
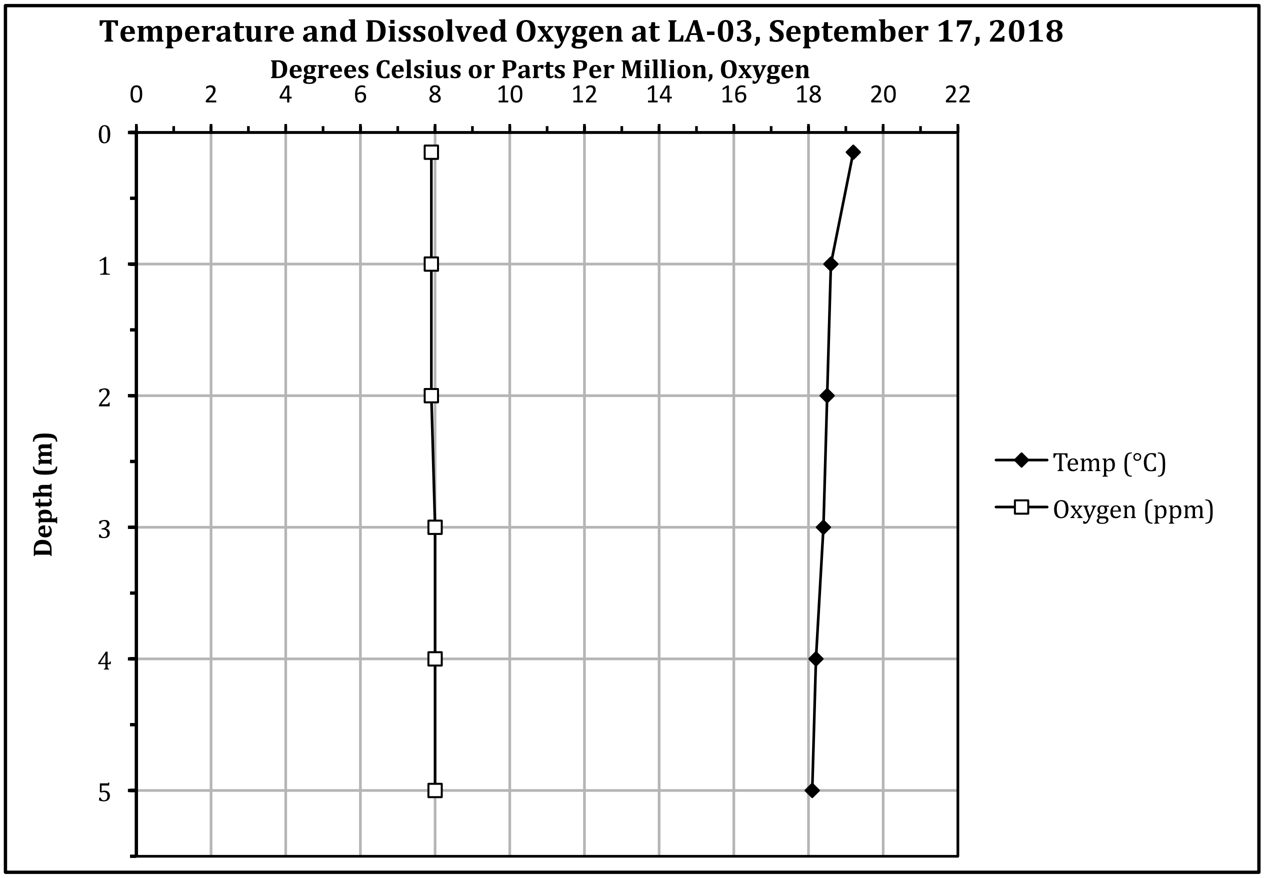


Figure 5 (cont.). Temperature and Dissolved Oxygen at Lake Almanor, Station LA-03, 2018



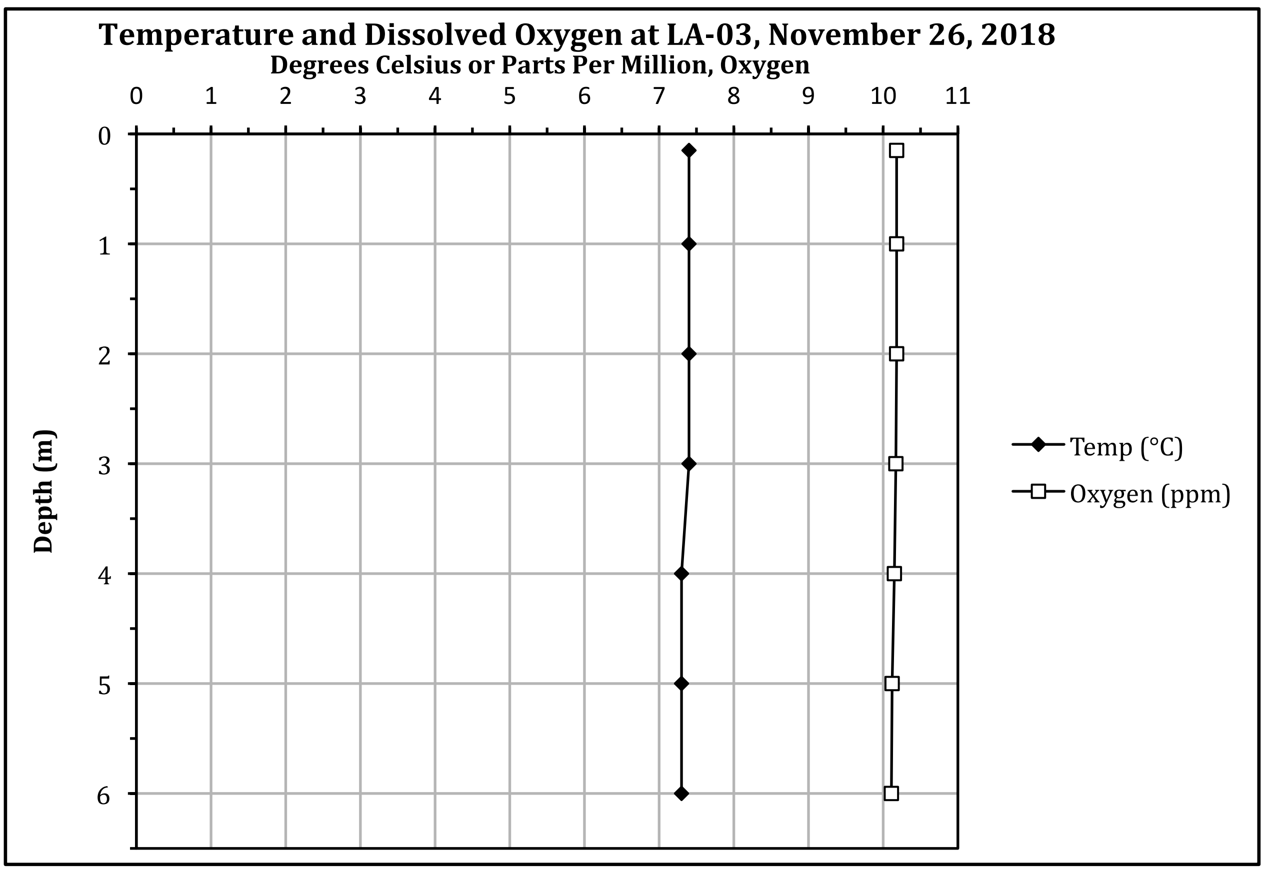


Figure 6. Temperature and Dissolved Oxygen at Station NFFR-1, Chester, During 2018

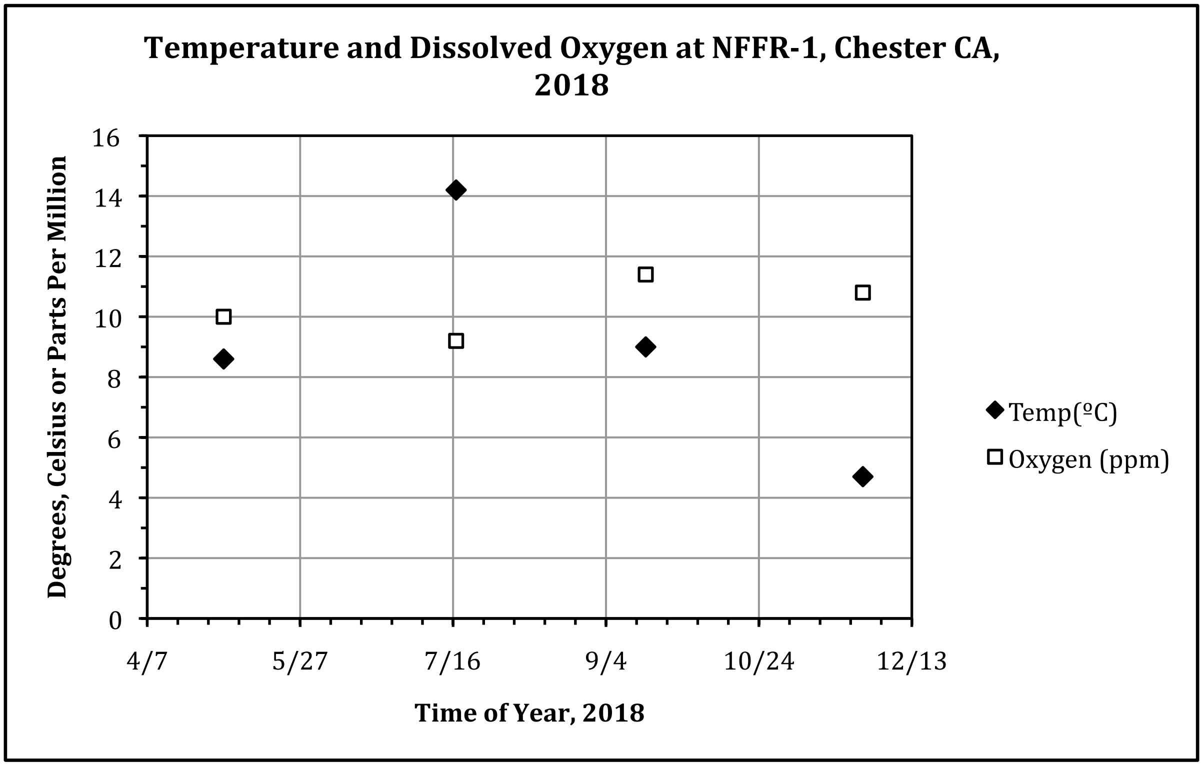
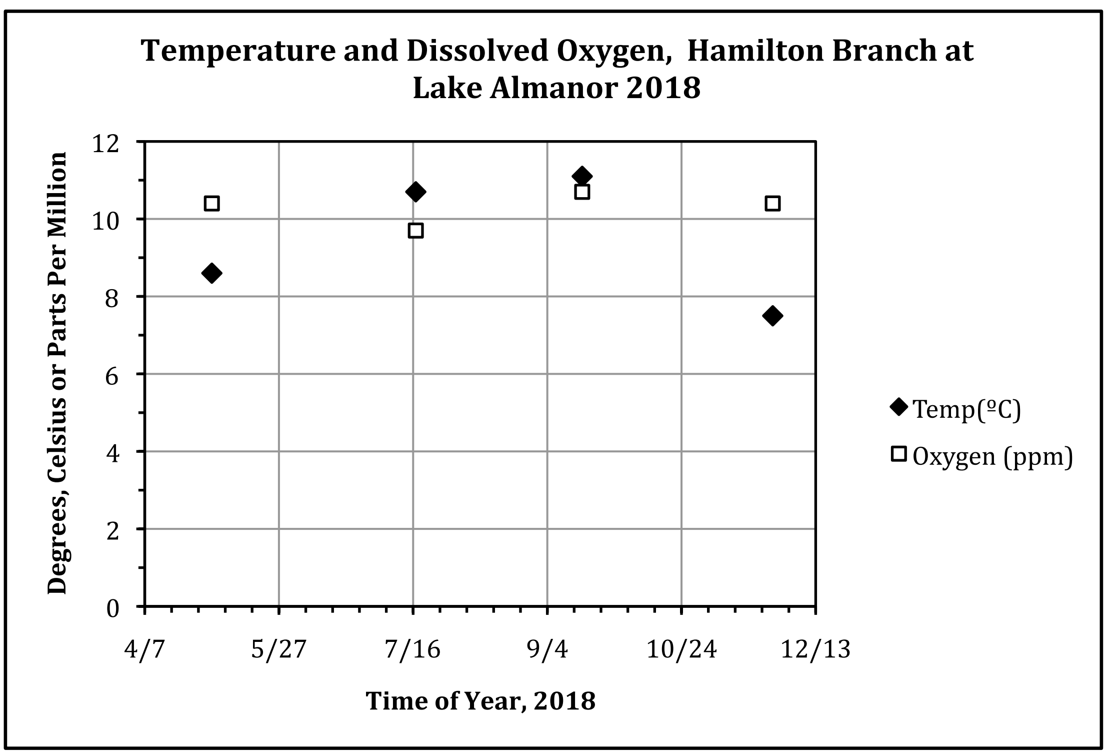


Figure 7. Temperature and Dissolved Oxygen, Hamilton Branch at Lake Almanor (HB-01A) During 2018



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 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 2018 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 9 °C in July and oxygen content was always near 10 ppm.

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 92-105 micro-mhos/cm at the lake stations and from 64-112 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.

Bailey Creek had the lowest conductivity (27 μmhos/cm), although it stopped flowing after the May sampling. Hamilton Branch downstream of the Mountain Meadows Dam generally had the highest value (90-189 μmhos/cm), higher than in 2017. The value of 189 in November was unusually high.
Electrical conductivity was higher than in 2017 at all stations due to less winter and 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 4.5-4.8 meters in May 2018. It increased to 9-9.5 meters at LA-01 and LA-02 in July, but was slightly less at LA-03 (7.7 meters). In September it was 9-9.6 meters at LA-01 and LA-02 and 5.0 at LA-03. In November it was 4-4.6 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 - 2017 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 (6.6 ntu)

2. Chemical Parameters: Nutrients

The results of all chemical analyses are presented in the Appendix, Table 4. Only the nutrient data for certain stations are shown and discussed below in Table 1. Nitrate plus nitrite nitrogen and total phosphorus are summarized for NFFR-1 at Chester, Hamilton Branch downstream of Mountain Meadows Dam (HB-01C), Hamilton Branch at Lake Almanor (HB-01A), and near the bottom at LA-01, LA-02 and LA-03 for the four dates in 2018.

The data show that the lake stations are generally low in nutrients. Hamilton Branch is usually higher in nutrients than the lake stations, especially just below Mountain Meadows Dam. However, this year Hamilton Branch at Lake Almanor was higher in nitrates and nitrites than Hamilton Branch below Mountain Meadows Reservoir. This was true in 2017, also. This suggests that the springs may be contributing nitrogen to the reservoir along Hamilton Branch. The emptying of Mountain Meadows Reservoir in late 2015 and increased precipitation in 2016 and 2017 may be responsible for decreased nutrients in upper Hamilton Branch.

Nitrate/nitrite values were high in Spring 2018, coinciding with high runoff, but then dropped to low values for the rest of the year. Total phosphorus values were never very high in the reservoir.

All nutrient values were well below limits for drinking water, but were typical of those found in mesotrophic lakes.

Table 1. Nutrient Concentration (mg/L) for Selected Stations At Lake Almanor, 2018

Date: May 1, 2018		
Station	**Nitrate +Nitrite (mg/L as N)**	**Total Phosphorus (mg/L as P)**
NFFR at Chester CA	0.01	0.03
Ham Brnch DS Mountain Meadows Dam	0.06	0.02
Ham Brnch @ Lake Almanor	0.12	0.01
Lake Almanor @ IT Tower Dam (LA-01) 27 meters	0.10	0.01
Lake Almanor East Arm (LA-02) 18 meters	0.09	0.01
Lake Alman West Arm (LA-03) 8 meters	0.03	0.01

Date: July 16, 2018		
Station	**Nitrate +Nitrite (mg/L as N)**	**Total Phosphorus (mg/L as P)**
NFFR at Chester CA	0.03	0.04
Ham Brnch DS Mountain Meadows Dam	0.15	0.01
Ham Brnch @ Lake Almanor	0.12	0.01
Lake Almanor @ IT Tower Dam (LA-01) 27 meters	0.02	0.02
Lake Almanor East Arm (LA-02) 18 meters	0.06	0.01
Lake Almanor West Arm (LA-03) 8 meters	0.81	0.01

Table 1 (continued). Nutrient Concentration (mg/L) for Selected Stations At Lake Almanor, 2018

Date: September 18, 2018		
Station	**Nitrate +Nitrite (mg/L as N)**	**Total Phosphorus (mg/L as P)**
NFFR at Chester CA	<0.01	0.06
Ham Brnch DS Mountain Meadows Dam	<0.01	0.03
Ham Brnch @ Lake Almanor	0.10	0.02
Lake Almanor @ IT Tower Dam (LA-01) 27 meters	<0.01	0.01
Lake Alman East Arm (LA-02) 18 meters	<0.01	0.01
Lake Alman W Arm 8 meters	<0.01	0.01

Date: November 26, 2018		
Station	**Nitrate +Nitrite (mg/L as N)**	**Total Phosphorus (mg/L as P)**
NFFR at Chester CA	<0.01	0.02
Ham Brnch DS Mountain Meadows Dam	<0.01	0.03
Ham Brnch @ Lake Almanor	0.12	0.01
Lake Almanor @ IT Tower Dam (LA-01) 27 meters	<0.01	0.01
Lake Almanor East Arm (LA-02) 18 meters	<0.01	0.01
Lake Almanor West Arm (LA-03) 8 meters	<0.01	0.02

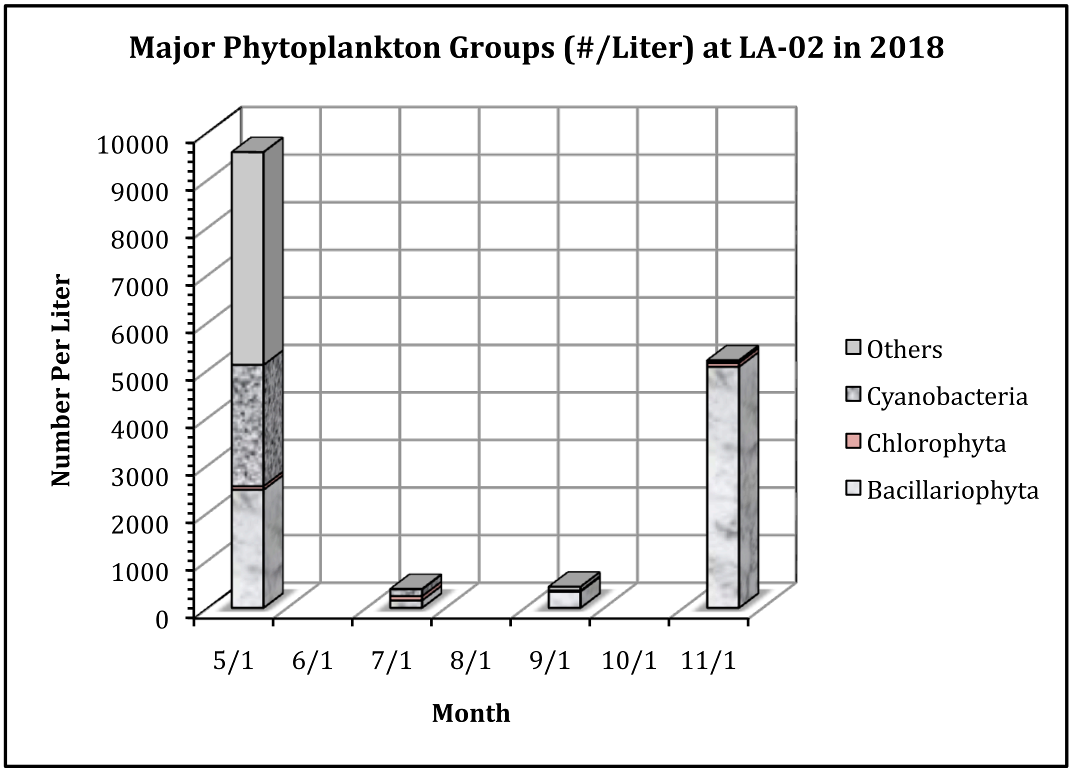
The general chemistry data from 2018 showed that metals, particularly iron and aluminum, but also manganese and lead, in Hamilton Branch below Mountain Meadows Dam had dropped back to normal levels. The concentrations of these metals were very high in October 2015, following the emptying of Mountain Meadows Reservoir. Higher amounts of these metals were also present in deep water samples from LA-01 and LA-02 in June and September 2016, as these substances were released from the sediments under anoxic conditions.
However, near normal precipitation in 2016 and above normal precipitation in 2017 resulted in bringing the concentrations of these metals down to very low levels in the lake. Normal precipitation in Spring 2018 continued to lower concentrations in Hamilton Branch and in the reservoir.

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 some bluegreen algae at LA-02, mostly *Aphanizomenon*. By mid- July the total volume of algae had dropped at both stations. Bluegreen algae, primarily the genus *Microcystis*, were present. (This genus forms colonies large enough to be seen with the naked eye and these may accumulate at the surface.) In mid September *the* algae at LA-02 were still mostly diatoms and populations were still low. By November, diatoms (Bacillariophyta) were the dominant group at both stations. LA-02 had its greatest volume of phytoplankton in November, following turnover, and coinciding with the high electrical conductivity inflow from Hamilton Branch.

Figure 8. Major Phytoplankton Groups at Lake Almanor, By Number/Liter and By Volume (cubic microns/milliliter), Station LA-02 in 2018



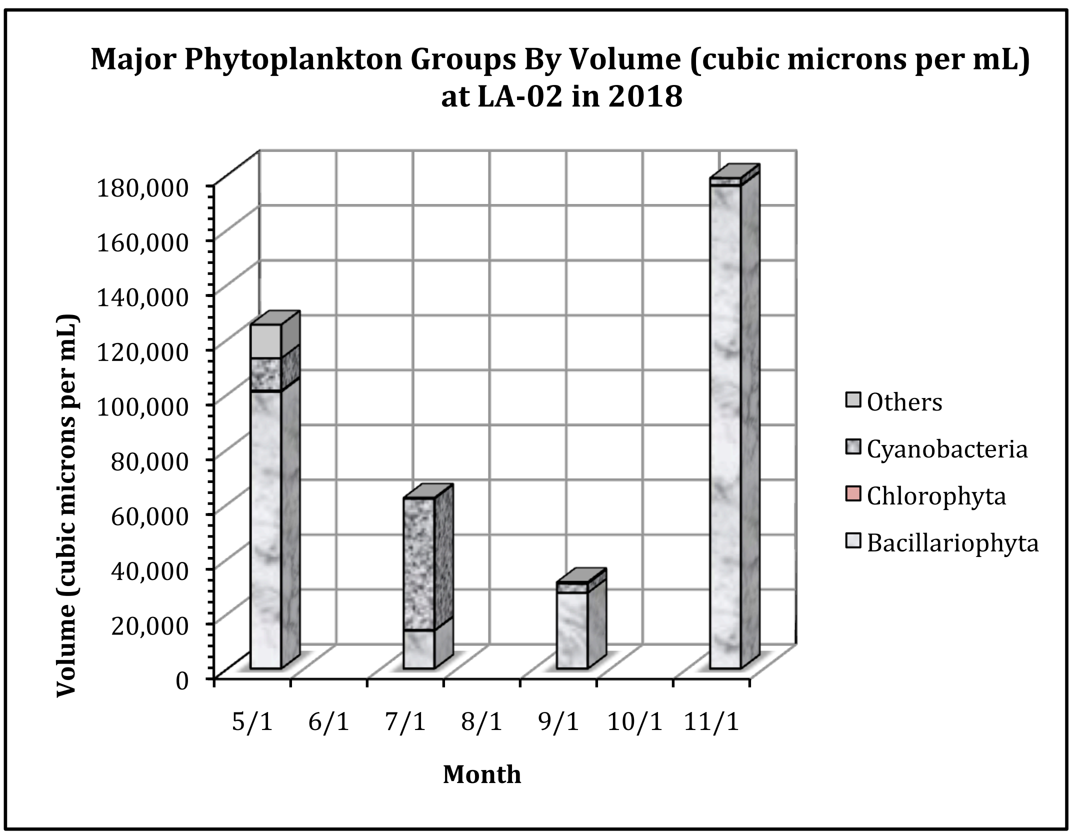
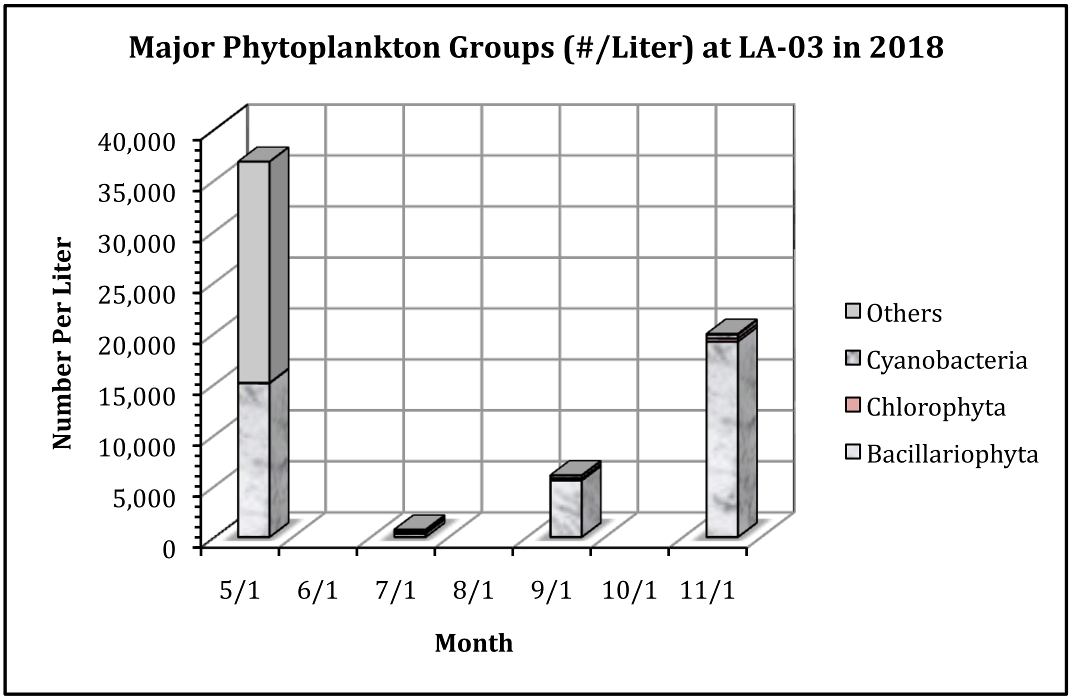
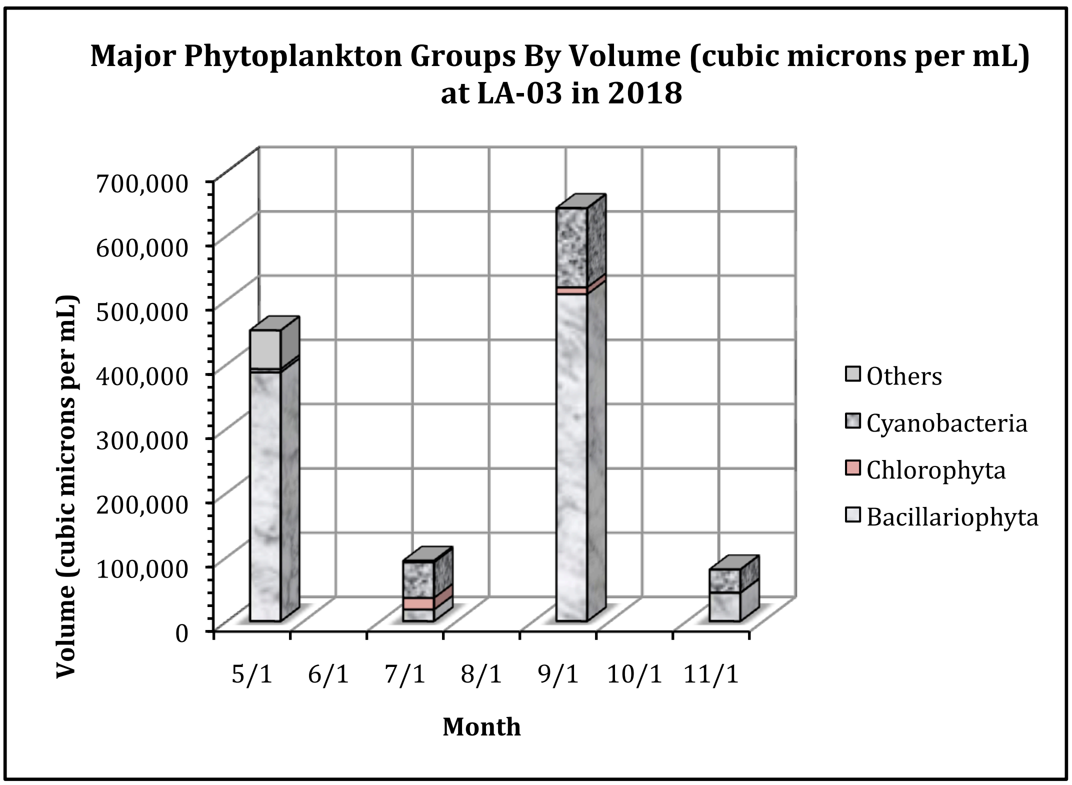


Figure 9. Major Phytoplankton Groups at Lake Almanor, By Number/Liter and By Volume (cubic microns/milliliter), Station LA-03 in 2018



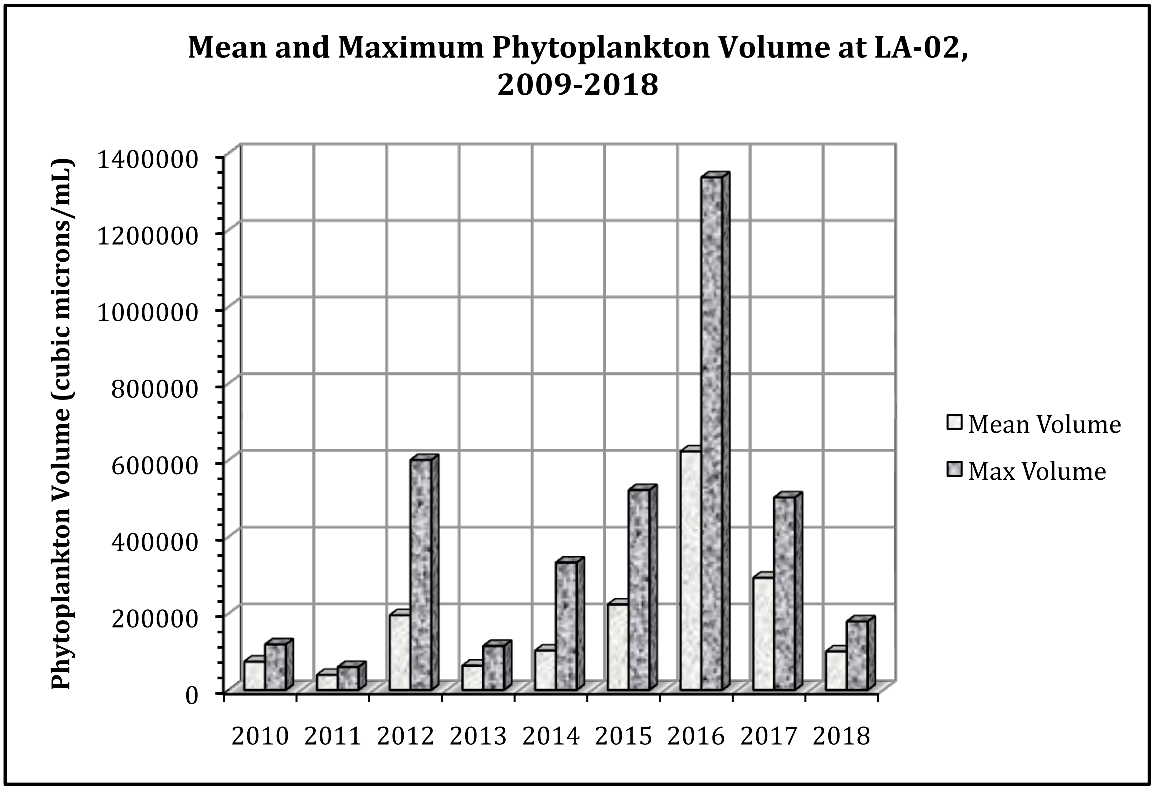


LA-03 had its maximum population in September, with diatoms (mostly *Aulocoseira*) and bluegreen algae (mostly *Lyngbya*).
Figure 10 shows the maximum amount of phytoplankton by volume at LA-02 and LA-03 from 2009 to 2018.The maximum was generally in November, but at LA-02 the greatest amount was in 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. 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.

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. While Rotifera continued to be very abundant, this was the second year that Copepoda and Cladocera were also numerous. This was probably due to fewer bluegreen algae and greater numbers of diatoms, which are very edible. The greatest abundance of zooplankton was in May at LA-02 and at LA-03. Cladocera were very numerous at LA-03 in November, which corresponded with a high population of a small diatom, *Cymbella*, which had not been present in large numbers before.

Figure 10. Mean and Maximum Phytoplankton Volume at LA-02 and LA-03, 2009 -2018



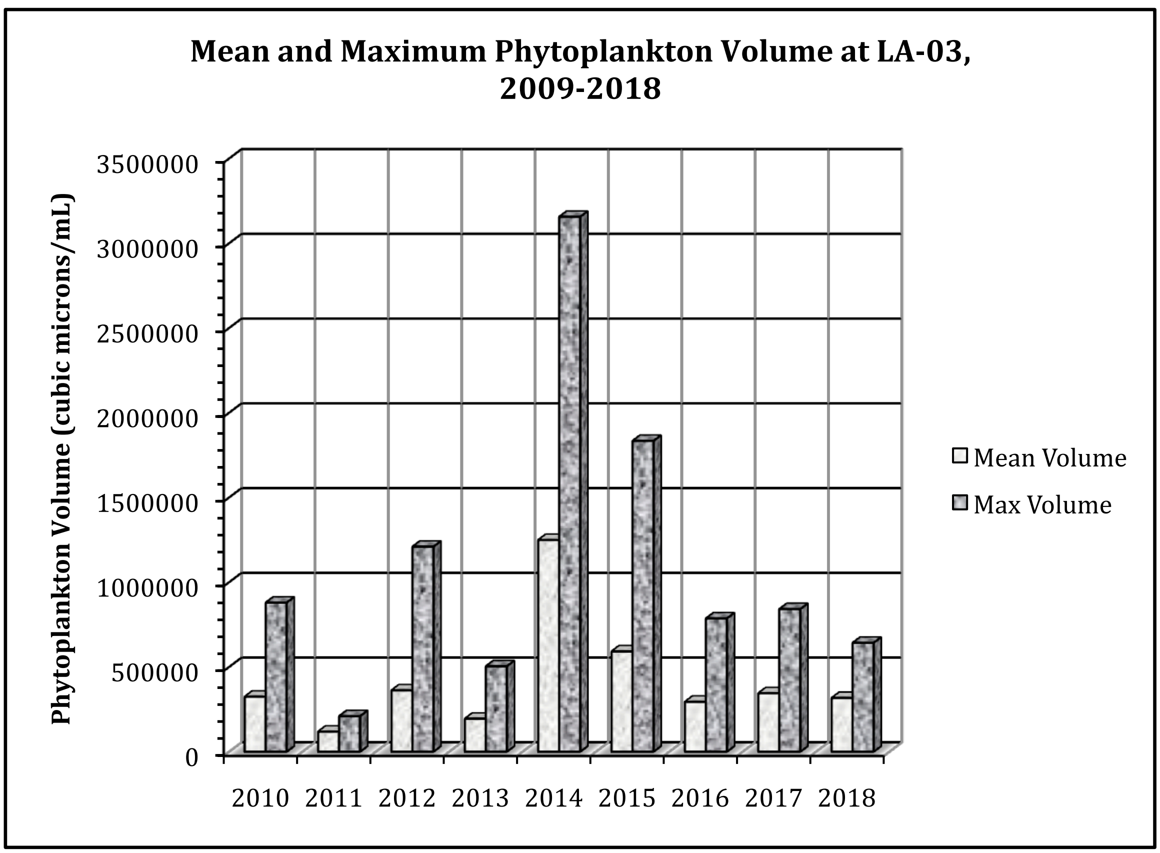


Figure 11. Major Zooplankton Groups (#/Liter) at Lake Almanor, Station LA- 02, 2018

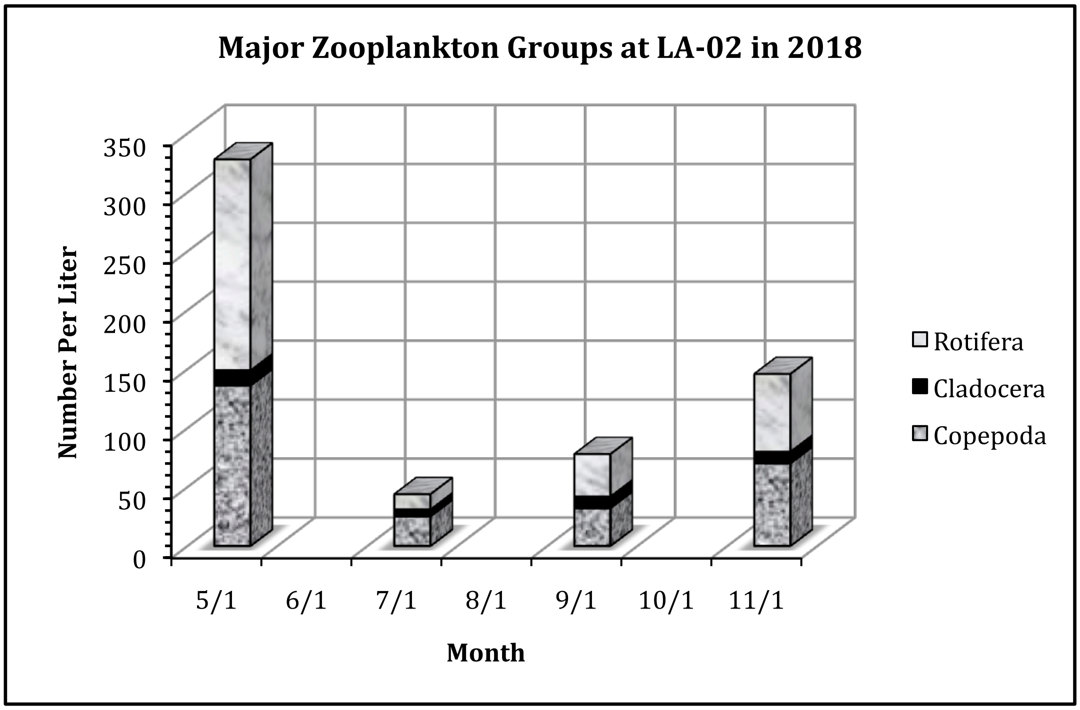
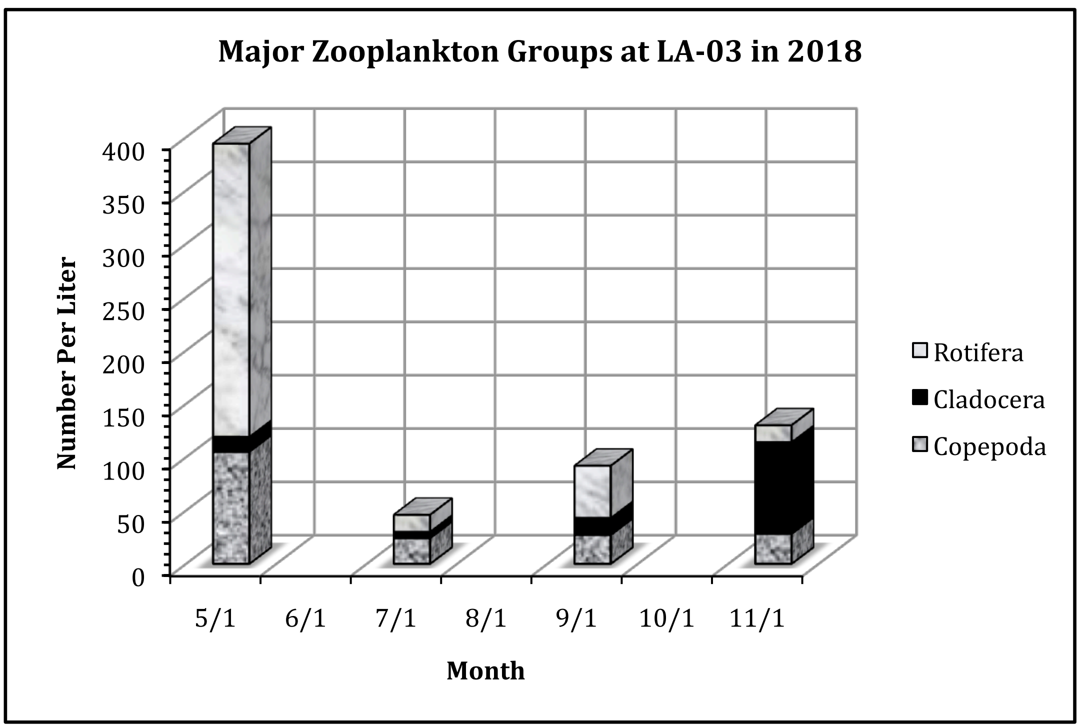


Figure 12. Major Zooplankton Groups (#/Liter) at Lake Almanor, Station LA-03, in 2018



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 would have been at a minimum or non-existent by August 2017, but the period was of shorter duration.

Spring 2018 was almost normal in terms of precipitation, with 17.8 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 2018. There was also more dissolved oxygen, which persisted through the summer at LA-01, so that the hypolimnion did not become anoxic. The hypolimnion at LA-02 was anoxic just near the bottom 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 previous years.

Cooler inflows, decreased nutrient inputs and dilution have decreased algal abundance at LA-02 and LA-03 to the lowest levels since 2013. There has also been a shift to more diatoms and away from 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.

Chemical and nutrient analyses have shown that Mountain Meadows Reservoir is a significant source of metals and nutrients to Lake Almanor, but in normal rainfall years, its effect is diluted. These are flushed out of the reservoir and do not accumulate in the sediments.

Additional sampling is needed to document ongoing water quality changes. As precipitation and water needs change, reservoir levels and water temperature change. These create a new set of conditions. Hopefully, a similar program of monitoring can be continued in 2019. We have a much better understanding of the reservoir ecosystem and its fragility than when we began collecting data in 2009. The data that we have collected will allow us to have an informed voice in the development of future monitoring programs by the state or PG&E.

General Conclusion: What Have We Accomplished In Ten Years of Monitoring?

With this report, LAWG (formerly ABWAC) has directed ten years of study of Lake Almanor.
From 2009-2013, Gina Johnston and John McMurtry contracted with ABWAC and Plumas County to perform investigations of reservoir water quality. These were generally limited to three in-lake stations and one NFFR station at Chester. No other tributaries were sampled. These data provided a clear picture of the thermal stratification that occurred every summer in the eastern basin and the loss of oxygen in the hypolimnion at stations LA-01 and LA-02. The anoxic conditions persisted until the lake mixed in the fall. Summer water temperatures in the western basin were generally too high for coldwater fish species. In 2010 a deep station off the Prattville intake was added to the study, but it also was low in dissolved oxygen during the summer. In certain years there was no suitable habitat in terms of both temperature and oxygen for coldwater fish species.

Chemical studies included total petroleum hydrocarbons (TPH) and benzene/toluene/ethylbenzene/xylene (BTEX), calcium, nitrogen and phosphorus in 2009. No TPH was detected and only very low levels of toluene and xylene were found at one station. The amount of calcium was sufficient to support Quagga mussels (9 ppm). Nutrients were very low in Spring 2009.
Nutrients were sampled in subsequent years and tended to be higher in April, low or not detectable in July and September, and then increase with the turnover in the fall. Phosphorus values have always been very low.

In April 2012, inorganic silver was sampled at several lake stations, as well as at the mouth of North Fork Feather River, Hamilton Branch and Bailey Creek. This sampling was performed because of public concern about the effects of cloud seeding and the potential for accumulation of silver in the Lake Almanor watershed. All samples were at or below the minimum detection level for this test.

Phytoplankton analyses showed that diatoms were the dominant group. However, during the summer months, bluegreen algal species often became numerous. Typically, the largest populations were in the spring and in the fall, coinciding with turnover and the fall precipitation.

Beginning in 2014, Scott McReynolds and his staff from California Department of Water Resources began a sampling program with LAWG that included the physical data in the reservoir, as well as in the tributaries. They also collected water samples for chemical analyses at all of these stations. They collected the plankton samples for Gina Johnston, who then performed the analyses and compiled all of the collected data into an annual report.

In 2015 Gina Johnston was able to use the data from 2009- 2015 to develop a response for Plumas County to the Draft Environmental Impact Report released by the California Water Resources Control Board. She argued that in drought years, such as 2012-2015, there was no excess cool water that could be withdrawn from Lake Almanor and used downstream to mitigate warming temperatures in the Feather River. During drought years the zone of cool water in the hypolimnion was shrinking and devoid of oxygen.

Without this data, Plumas County could not have made such a strong argument against the alternatives proposed by the Draft EIR.

The addition of the physical data from Hamilton Branch was extremely important for documenting its role in providing a source of cold water to the lake during the summer. The springs along Hamilton Branch drop the summer water temperature by as much as 10 °C from Mountain Meadows Reservoir to Lake Almanor. That is so important to the survival of coldwater fish species.

The chemical data collected by DWR provided documentation of the role of Mountain Meadows Reservoir as a source of nutrients (nitrogen and phosphorus) and metals (iron, manganese, aluminum, lead and nickel, as well as others). In 2015, following the draining of Mountain Meadows Reservoir, high concentrations of some metals were found in the sediments at LA-01 and LA-02 in Lake Almanor.

In 2015 data loggers were installed at LA-01, which gave continuous readings of temperature and oxygen. This provided a more precise look at the development of thermal stratification and loss of oxygen over the summer months. This was the fourth dry year in a row, with very warm water temperatures and large phytoplankton populations.

In 2016 spring precipitation approached normal values and phytoplankton populations were very high. Metal concentrations at LA-01 and LA-02 still showed the effect of the draining of Mountain Meadows Reservoir. With more runoff and a cooler spring, water temperatures were not as high.

Precipitation in 2017 exceeded the average value and this resulted in cooler lake water temperatures and greater flushing of the reservoir. Metal concentrations returned to normal values and the period of oxygen depletion in the hypolimnion at LA-01 and LA-02 was of shorter duration.

While 2018 was not as wet, it continued the pattern of near normal precipitation in the spring. This resulted in low nutrient levels, low phytoplankton populations and shortened periods of oxygen depletion.

After 10 years of monitoring we have seen that precipitation is a very important driver of reservoir health. During a series of drought years, the habitat for coldwater fish species quickly drops to zero in Lake Almanor. During wet years, bluegreen algae decline and healthier food webs become established. Each year’s data set has added to our understanding of how this ecosystem functions. As climate change influences the precipitation patterns and the proportion of rain to snow, the lake ecosystem will respond. We need an annual monitoring program that informs us of the overall health of this system so that we can use it wisely. Continued monitoring is critical to the effective management of Lake Almanor.