Lake Almanor Water Quality Report, 2020

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

Report Summary …………………………………………………………………..3
Introduction and Project Overview ………………………………………………4
Methods Used for Sampling and Analysis……………………………………….....4
Figure 1. Lake and Tributary Sampling Station Locations in Lake Almanor………………………………………………………………………..5
Figure 2. Lake Almanor Watershed Land Ownership……………………………..6
Results and Discussion, Physical Parameters: Temperature...…………………7
Results and Discussion, Physical Parameters: Oxygen ………………………....8
Figure 3. Temperature and Dissolved Oxygen at Lake Almanor Station LA-01 During 2020……………………………………………......11-12
Figure 4. Temperature and Dissolved Oxygen at Lake Almanor Station LA-02 During 2020……………………………………………...13-14
Figure 5. Temperature and Dissolved Oxygen at Lake Almanor Station LA-03 During 2020……………………………….………..…15-16
Figure 6. Temperature and Dissolved Oxygen at North Fork Feather River in Chester, Station NFFR-1, During 2020.…………………........17
Figure 7. Temperature and Dissolved Oxygen in Hamilton Branch At Lake Almanor (HB-01A) in 2020…………………………………..……17
Results and Discussion, Physical Parameters: Electrical Conductivity……..………………………………………………………...…..18
Results and Discussion, Physical Parameters: Secchi Depth and Turbidity…………..………………………………………………...…...18
Results and Discussion, Phytoplankton and Zooplankton……………….....…19
Figure 8. Major Phytoplankton Groups at Lake Almanor, Station LA-02 in 2020…………………………………………………….…20
Figure 9. Major Phytoplankton Groups at Lake Almanor, Station LA-03 in 2020……………………………………………...…...…21
Figure 10. Ten-Day Composite Satellite Image of HAB Bloom…………………22
Figure 11. Mean/Maximum Phytoplankton at LA-02 and LA-03, 2009-2020……………………………………………………..………………...24
Figure 12. Major Zooplankton Groups at Lake Almanor, Station LA-02 in 2020 …………………………………………………………25
Figure 13. Major Zooplankton Groups at Lake Almanor, Station LA-03 in 2020……………………………………………………….....25
Conclusion …………………………………………………………………...26
Glossary of Terms for Lake Almanor Reports…………………………………….27

Appendix (On Sierra Institute for Community and Environment website: www/Sierrainstitute.us)

Table 1. Physical Parameters at Lake Almanor, 2020
Table 2. Phytoplankton at Lake Almanor, 2020
Table 3. Zooplankton at Lake Almanor, 2020
Photos- Some Common Plankton of Lake Almanor

Summary of 2020 Water Quality Investigation at Lake Almanor

In 2020 the Lake Almanor Watershed Group (LAWG) authorized a water quality investigation of Lake Almanor and its main tributaries. Mr. Scott Mc Reynolds of California Department of Water Resources collected temperature, oxygen and electrical conductivity data at three stations in the lake, as well as stations on Bailey Creek, North Fork Feather River in Chester, North Fork Feather River at Canyon Dam and Hamilton Branch. He also collected plankton samples at two of the lake stations, LA-02 and LA-03. Collections were planned for four dates during the year, but due to COVID-19 concerns, the last sample date in November had to be canceled. Dr. Gina Johnston, professor emerita of California State University, Chico, analyzed the data, as well as the plankton, and produced a report that shows all of the data and relates the results to previous studies. This was the twelfth year that water quality analysis has been supported by LAWG.

2020 was a very dry year with precipitation about half the average. Lake Almanor was cool and had lots of oxygen dissolved in the water in May at the first sampling date. By July 1, the lake was thermally stratified, meaning that water near the surface was warmed by the sun and stayed on top of the cooler, denser water below. The effect of the thermal stratification was that oxygen could not be introduced to the deeper water and oxygen levels were at or near zero for most of the summer and fall. This created a situation where cold- water fish species could not find ideal habitat in Lake Almanor. Water quality is very closely tied to precipitation. With adequate precipitation and greater inflow to the lake, lake levels are high and water temperatures tend to stay cooler. During dry or drought years, water temperatures are warmer, the lake becomes thermally stratified sooner and is more likely to have low oxygen or no oxygen in the deeper regions of the lake. This increases stress on the fish populations. Also, blue-green algae (Cyanobacteria) increase in warm-water conditions. Some species of these algae have the ability to produce toxins that are harmful to children and pets. In Fall 2020, blue- algae were abundant, especially in the western basin.

Because 2020 was a dry year, oxygen levels dropped to low levels during the summer, similar to what happened during the drought years of 2014 -1016. Also, algal populations, especially the blue green algae, reached bloom proportions. In general, water quality was not as good as in 2019.

Introduction and Project Overview

A water quality monitoring program for Lake Almanor was conducted during 2020, 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). However, due to Covid-19 concerns, the November sampling had to be canceled. 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 2020 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 2020 included:

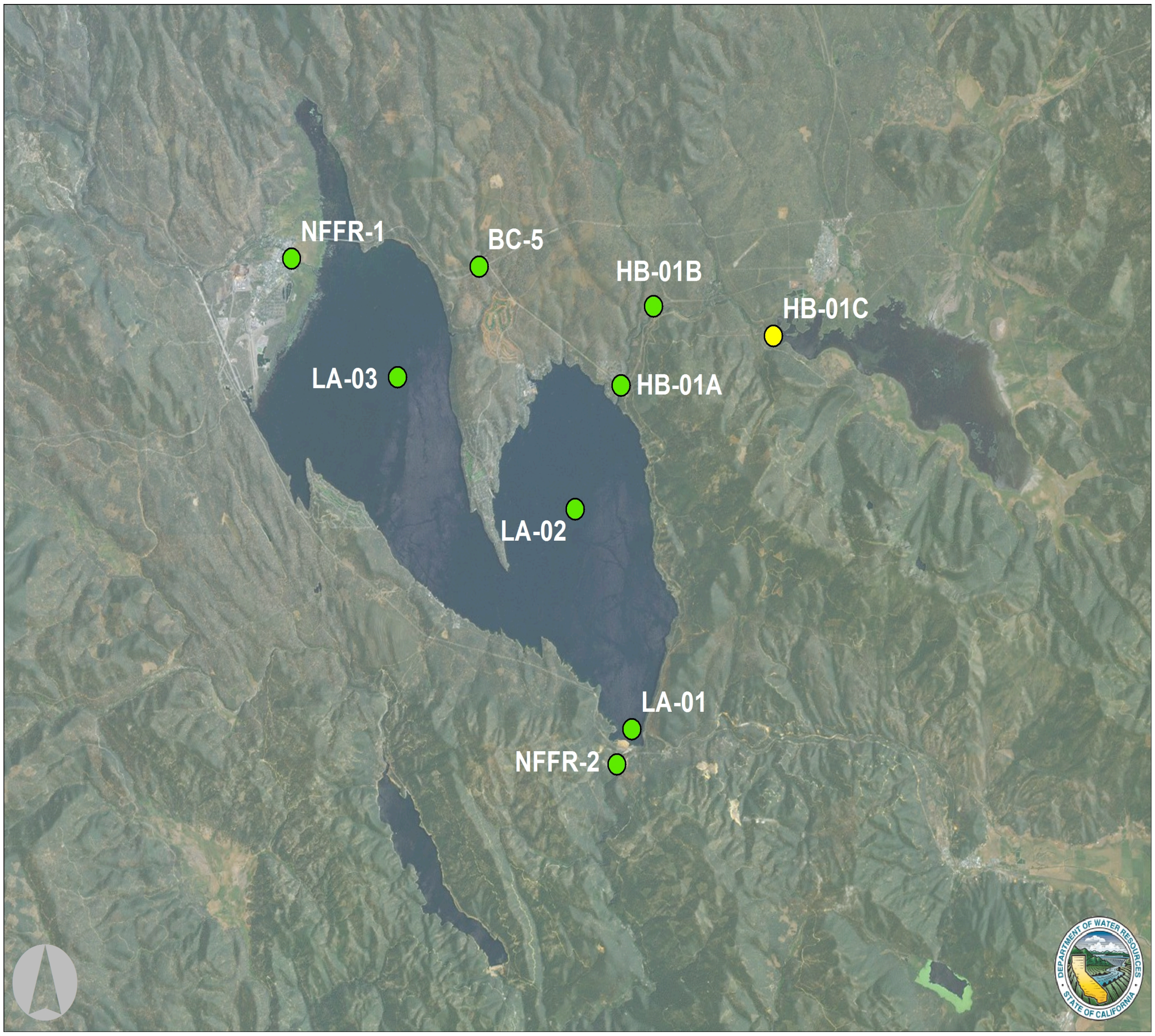
1. Physical: temperature, dissolved oxygen, Secchi depth (where applicable), electrical conductivity, pH and turbidity.
2. Biological: phytoplankton and zooplankton at LA-02 and LA-03.

   (Chemical analyses of inorganic and organic elements and compounds were not included in the 2020 study, as they were in 2014-2018.)

Methods Used for Sampling and Analysis

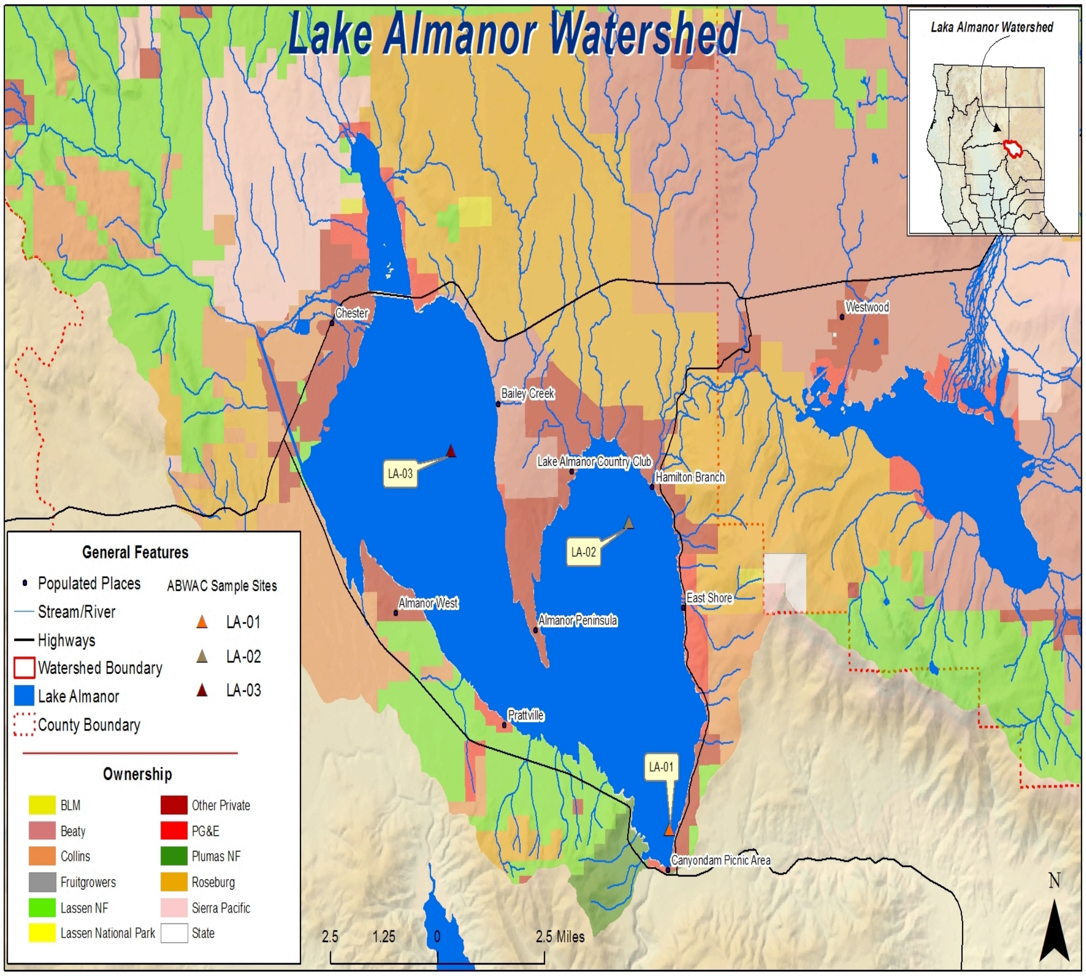
Field Parameters— Stream- Basic water quality parameters, including dissolved oxygen, electrical conductivity, pH, and turbidity, were measured with properly calibrated field instrumentation at each visit to every monitoring station. Stream samples or measurements were collected about one foot below 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 2020 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 inch 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, electrical 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 2020 LA-01 and LA-02 were beginning to stratify. At LA-01 temperature at the surface was about 15°C (59°F), and at the bottom it was around 7°C (45 °F). LA-02 was about 14°C at the surface and the bottom was at 8 °C. LA-03 was around 14°C (57°F) throughout the water column. Both LA-01 and LA-02 surface temperatures were cooler than the values for 2019. This may have been due to the earlier sampling date.

By July 1, 2020 stations LA-01 and LA-02 were thermally stratified. The epilimnion was about 20-21°C (68-70°F). The metalimnion was between 10 and 14 meters at LA-01, but 7-15 meters at LA-02. At LA-03 the temperature from top to bottom was about 18-20°C. The surface temperature at all three stations was close to 20°C. The bottom temperature was 9°C at LA-01 and 11°C at LA-02. These temperatures were slightly cooler than in 2019, which may be due to an earlier sampling date in July.

The next sampling date was September 30, and LA-01 was still strongly stratified. The epilimnion extended down to 14 meters depth. At LA-02 stratification was still present and the water column was well mixed to a depth of 9 meters with a temperature of 17°C. The temperature then dropped off to 13°C at the bottom (14 meters). LA-03 was well mixed, with a temperature of 17°C (63°F) throughout. Water temperatures were slightly cooler than in 2019 due to the later sampling date in 2020.

As mentioned previously, the November sampling run had to be canceled.

Water temperatures were generally a little lower than in 2019. This may have been due to differences in sampling dates.

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 16°C (61 °F), which was 5°C higher than in 2019. (See Figure 6, as well as Table 1 and Figure 2 in the Appendix.) The river temperature was showing the effect of decreased snowmelt and runoff during Spring 2020. It was also warmer in Spring 2018 than in Spring 2017, probably due to less snow in the watershed. By the end of September 2020, it had cooled back to about 10°C.

Data for Hamilton Branch at Lake Almanor are shown in Figure 7. In early July it was 5°C cooler than the NFFR at Chester, CA. The highest temperature was in September at about 12°C (54 °F), making it 2°C (11°F) warmer than the NFFR and about the same as the hypolimnion of Lake Almanor. These cooler temperatures compared to 2019 suggest that more of the flow could be attributed to spring inflow this year. 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 10°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 cold-water refuge. At the end of September there was still a 4.5°C drop in temperature in Hamilton Branch between Mountain Meadows and Lake Almanor.

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 water 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 2020 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 (14-15ºC) and the existing atmospheric pressure and wind conditions. It increased to 10 ppm with increasing depth as temperature decreased.

In early July 2020, oxygen concentration in the epilimnion at LA-01 and LA-02 was 8 ppm, and the epilimnion water temperature was 20-21ºC (70 °F). Due to the shallow conditions at LA-03, oxygen was 8 ppm throughout. In the hypolimnion at LA-01, the oxygen level dropped to about 2 ppm near the bottom. Because the lake was thermally 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 14 meters. It then dropped to 4 ppm.

In July 2015 there was no oxygen below 12 meters at LA-01 and LA-02. In 2016, conditions were slightly better, with 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. In 2020, conditions were similar to 2019, although the decrease in oxygen concentration in the LA-01 hypolimnion was more severe.

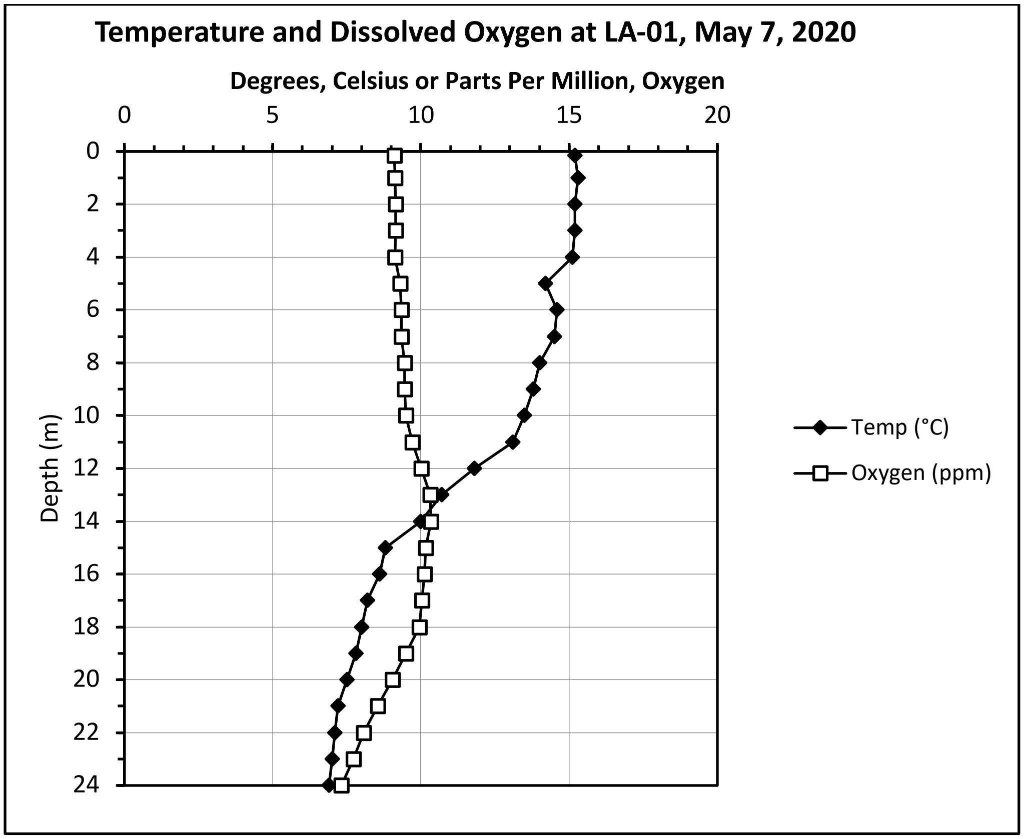
By late September, thermal stratification was still very strong and oxygen was still near 8 ppm in the epilimnion of LA-01. Mixing by the wind resulted in the epilimnion extending down to a depth of 14 meters. Below this depth at LA-01 oxygen decreased in the metalimnion and then dropped to zero at 16 meters. At LA-02, oxygen levels were at 8 ppm to a depth of 9 meters and then dropped off to 0 ppm below 11 meters. Oxygen was 8 ppm throughout the water column at LA-03.

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 and 2019, 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. Because 2020 was a dry year, it followed the pattern of drought years, with little to no oxygen available in the hypolimnion of LA-01 and LA-02 from July until turnover occurred. That was sometime after our last sampling date at the end of September. At our normal November sampling, the reservoir is no longer stratified.

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 2020 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.

Figure 3. Temperature and Dissolved Oxygen at Lake Almanor Station LA-01, 2020



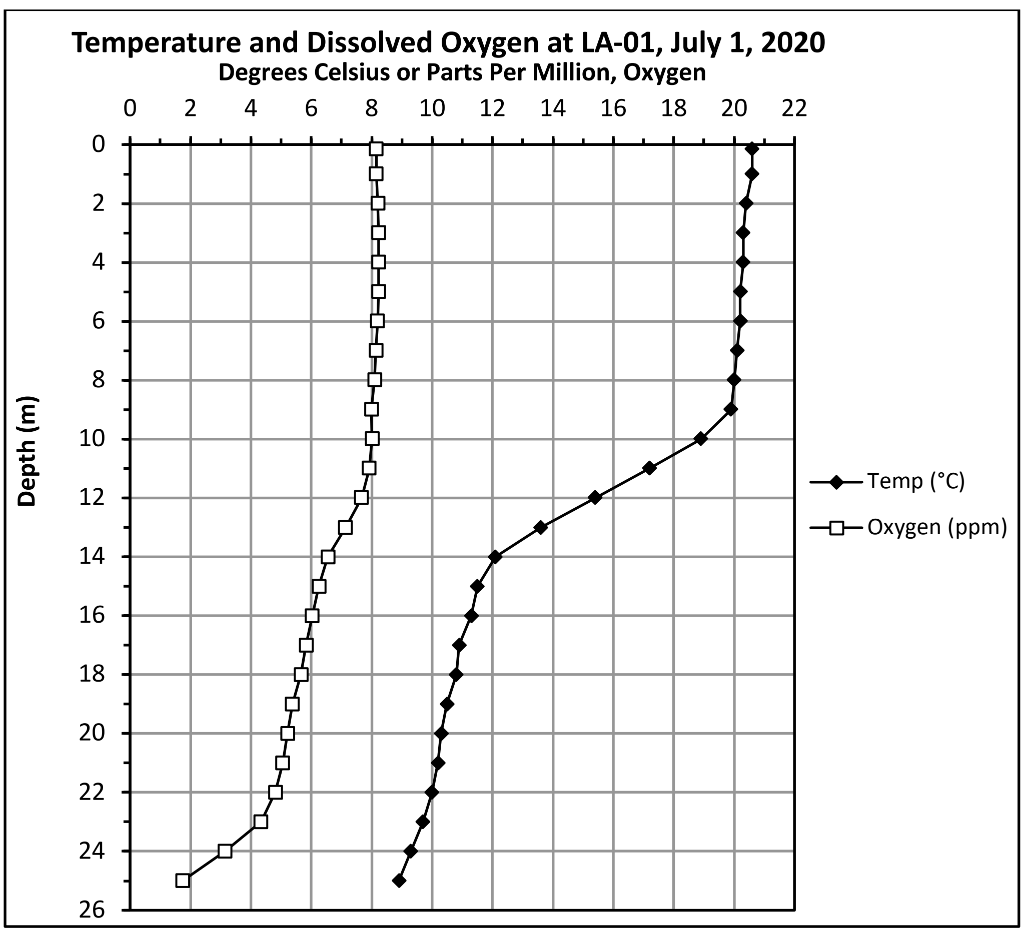


Figure 3 (cont.). Temperature and Dissolved Oxygen at Lake Almanor Station LA-01, 2020

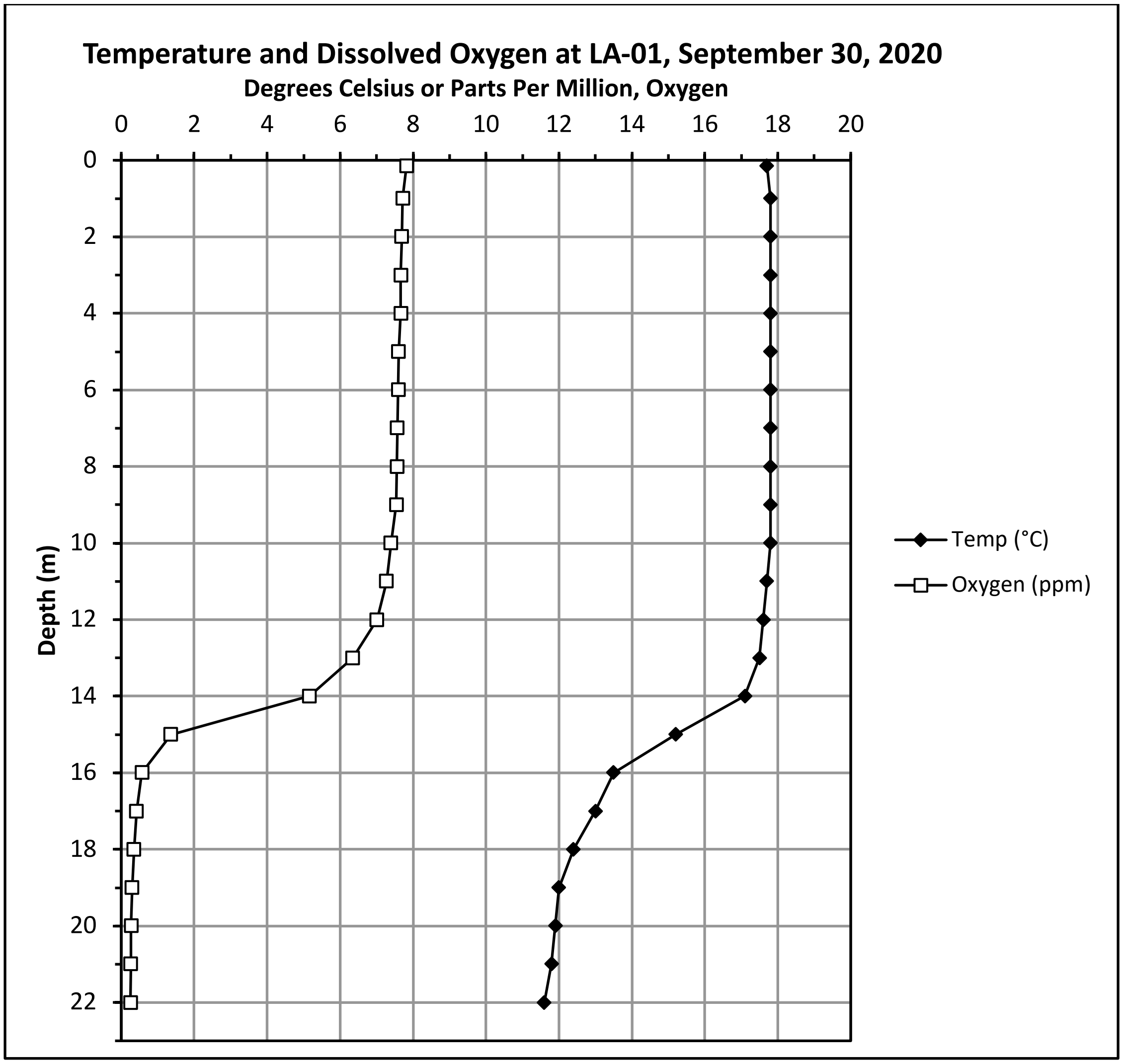
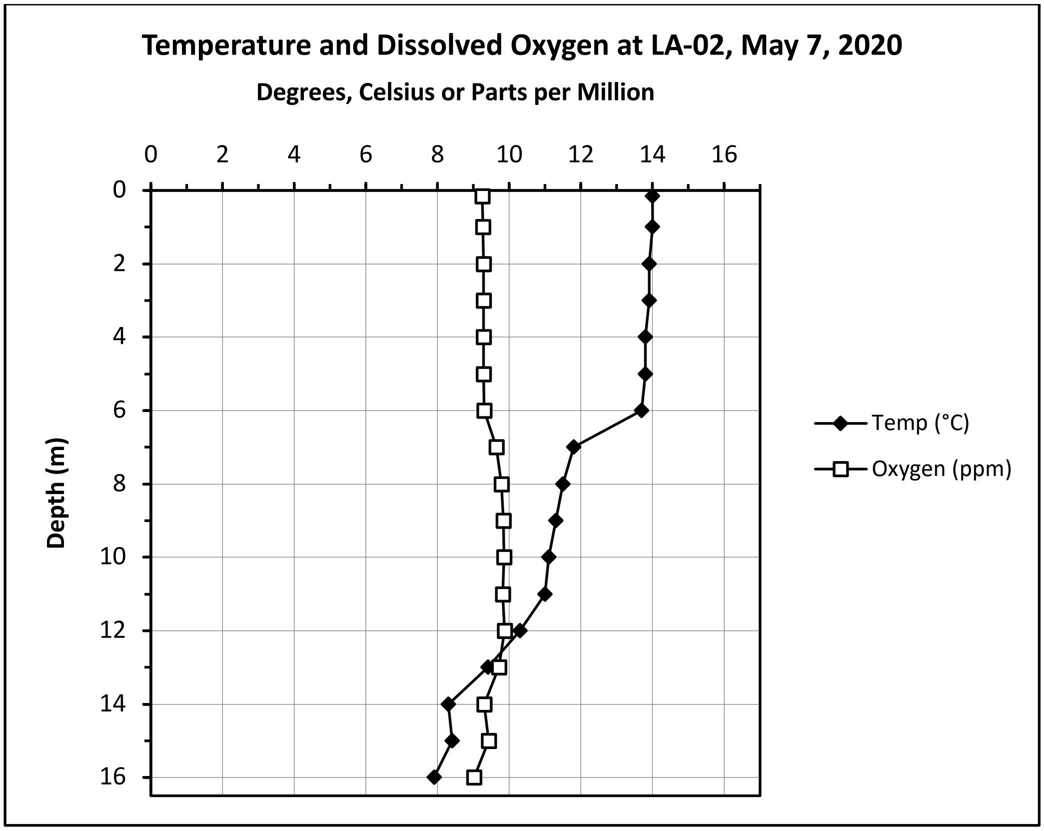


Figure 4. Temperature and Dissolved Oxygen at Lake Almanor Station LA-02, 2020



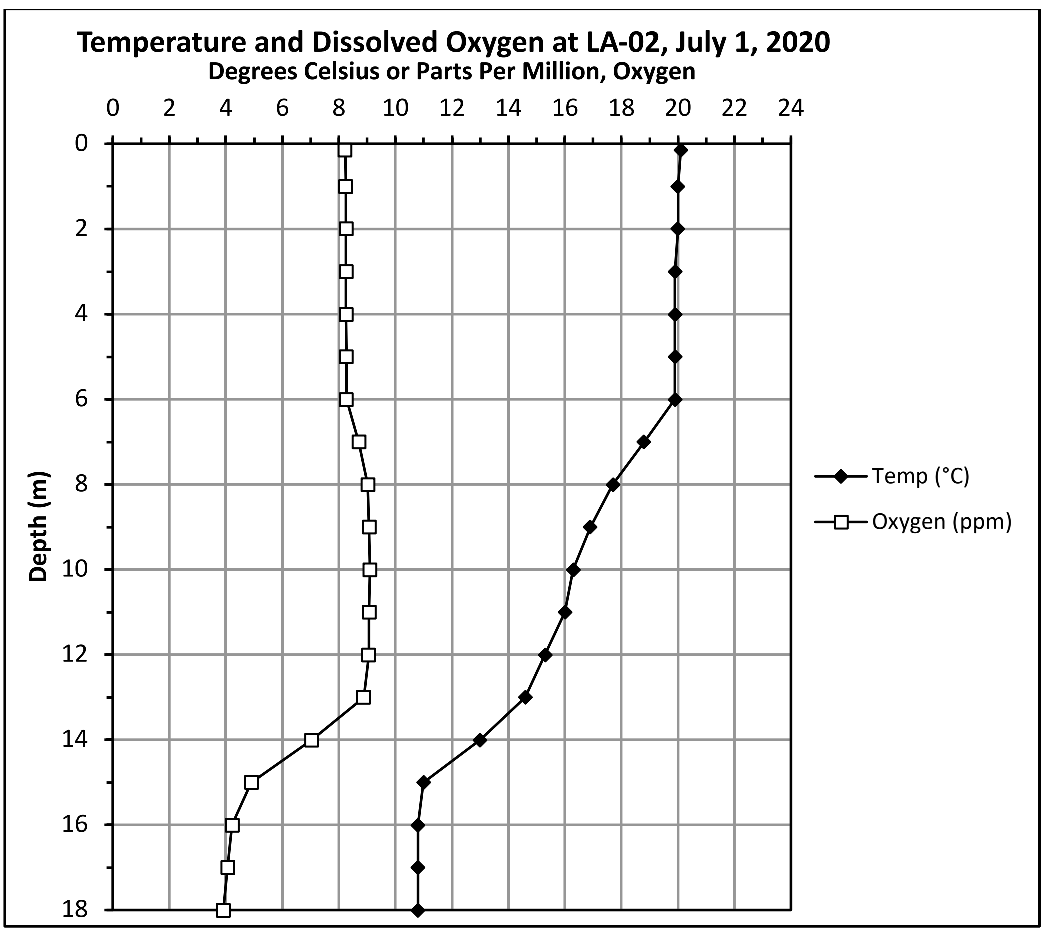


Figure 4 (cont.). Temperature and Dissolved Oxygen at Lake Almanor Station LA-02, 2020

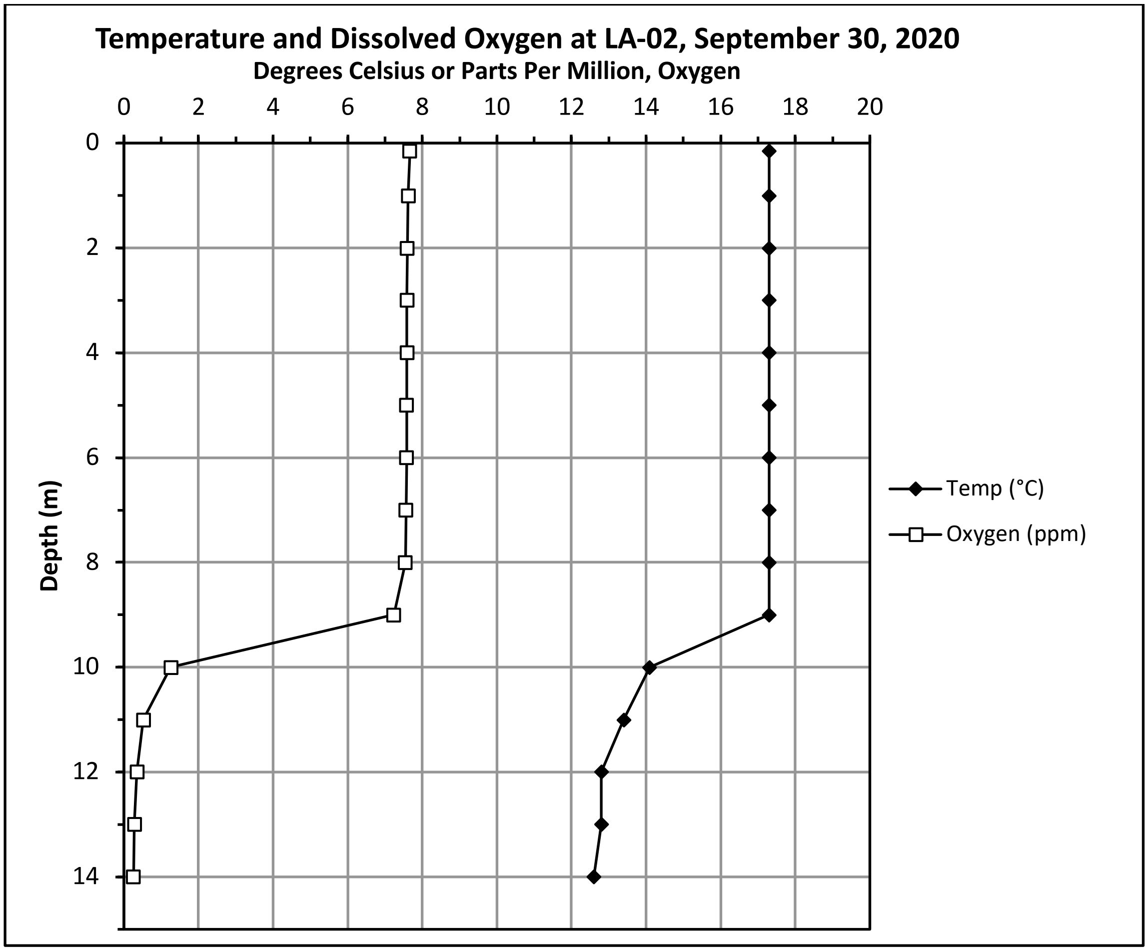
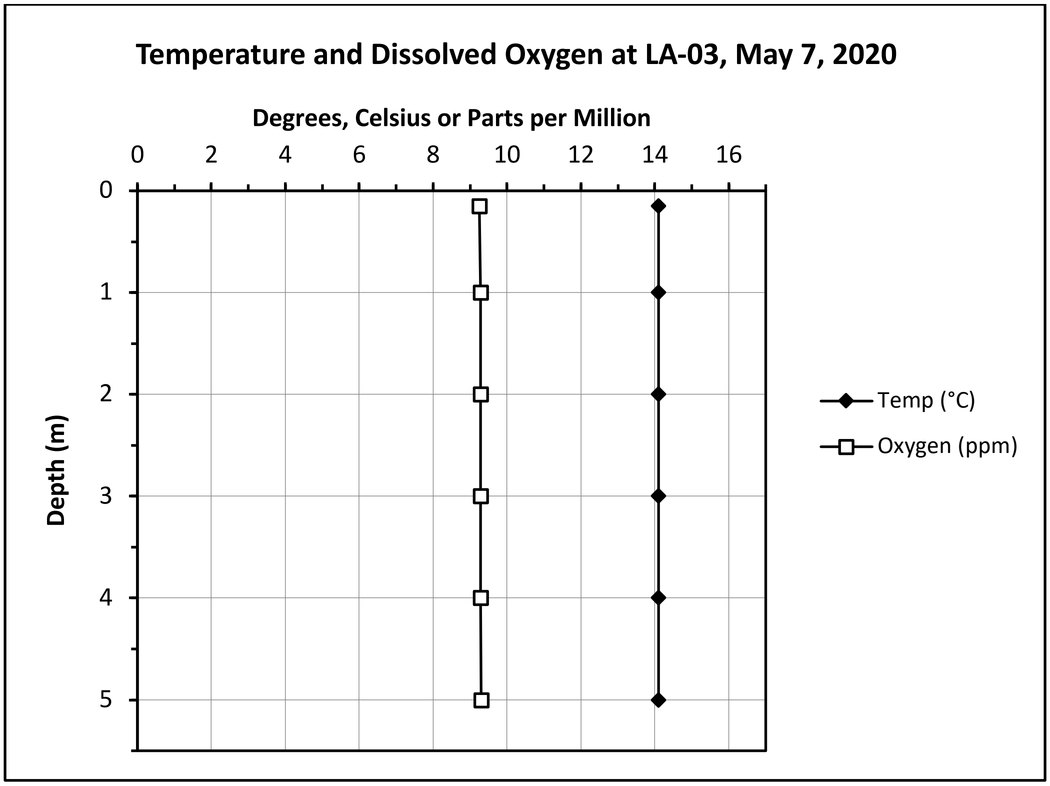


Figure 5. Temperature and Dissolved Oxygen at Lake Almanor, Station LA-03, 2020



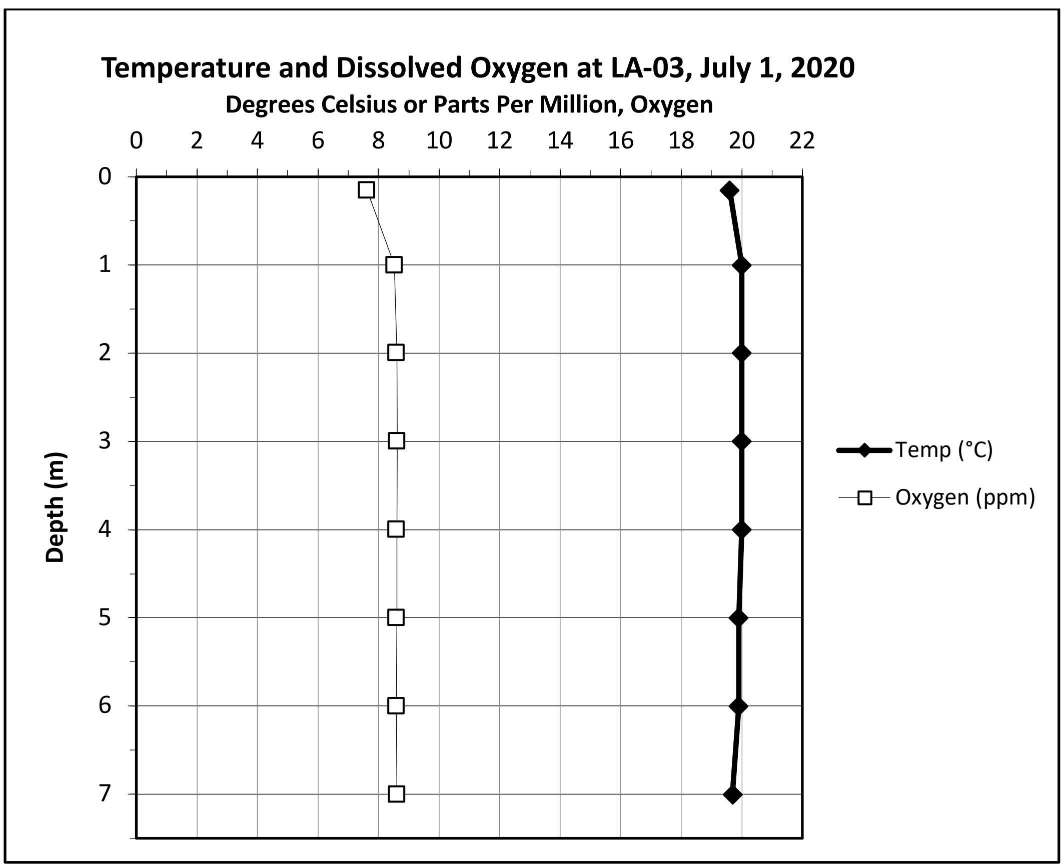


Figure 5 (cont.). Temperature and Dissolved Oxygen at Lake Almanor, Station LA-03, 2020

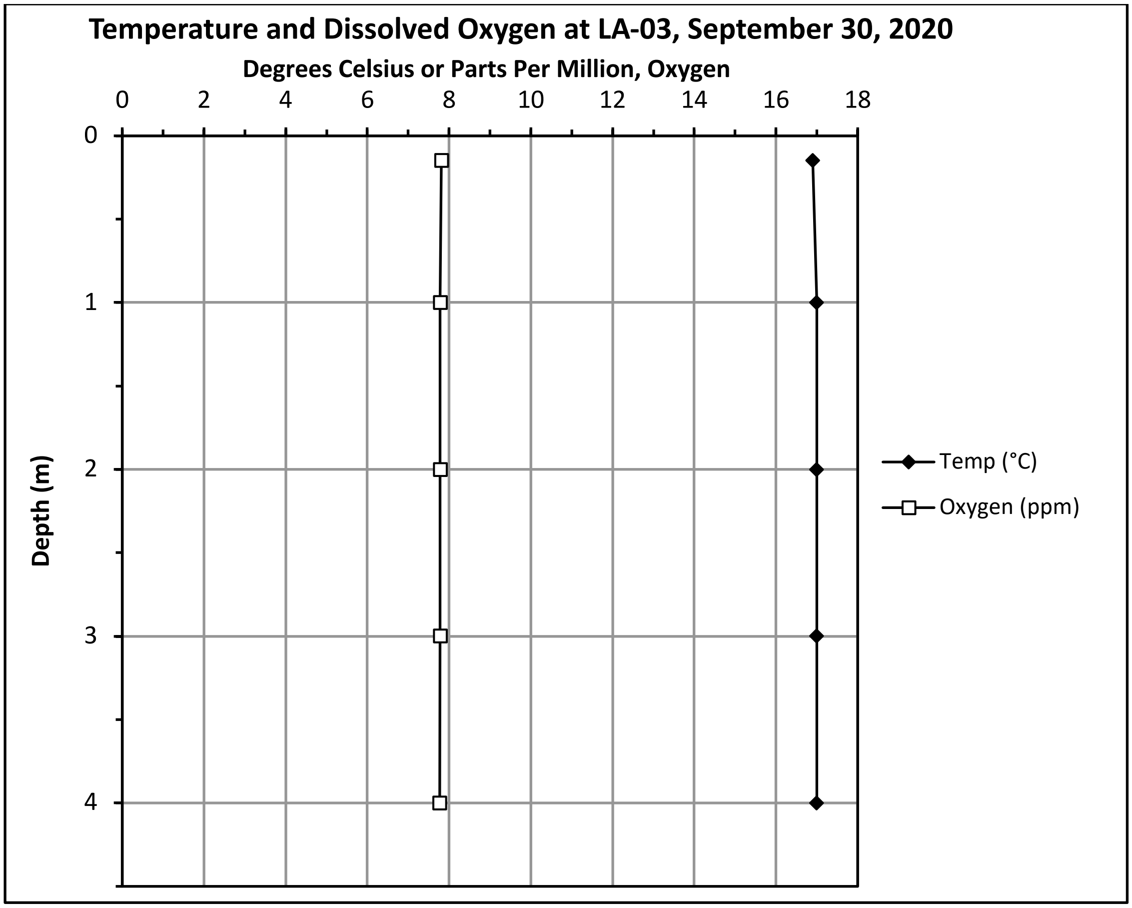


Figure 6. Temperature and Dissolved Oxygen at Station NFFR-1, Chester, During 2020

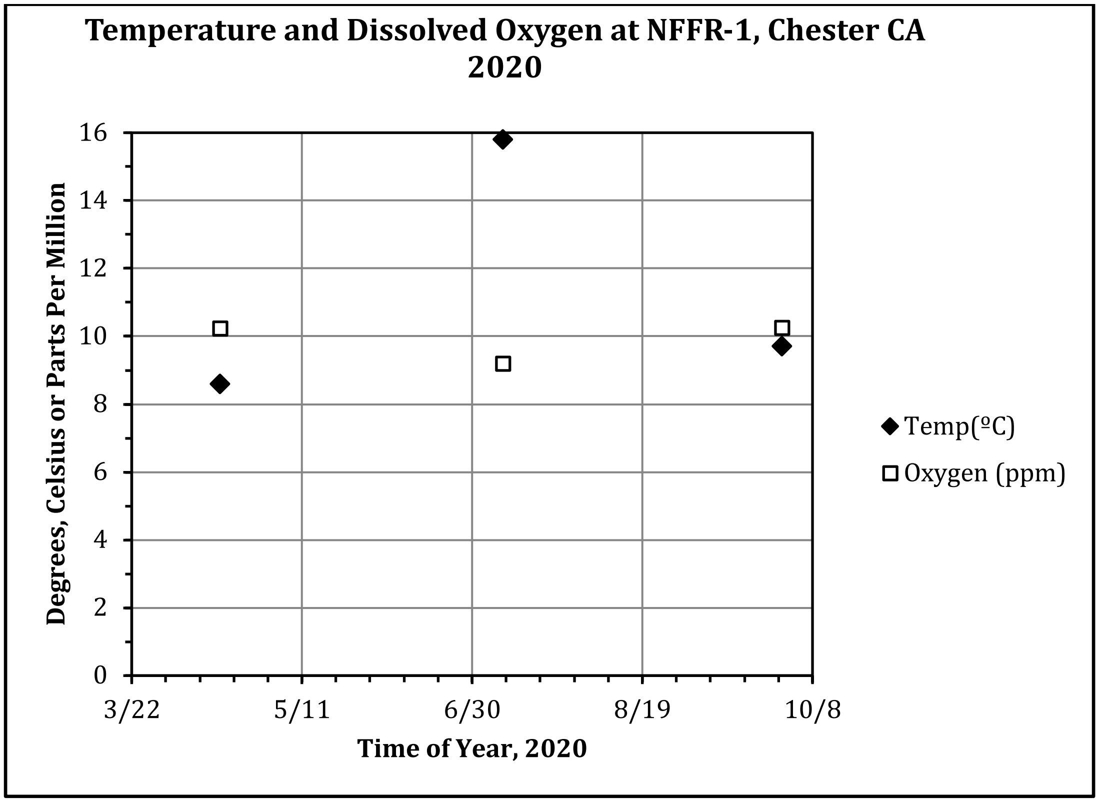
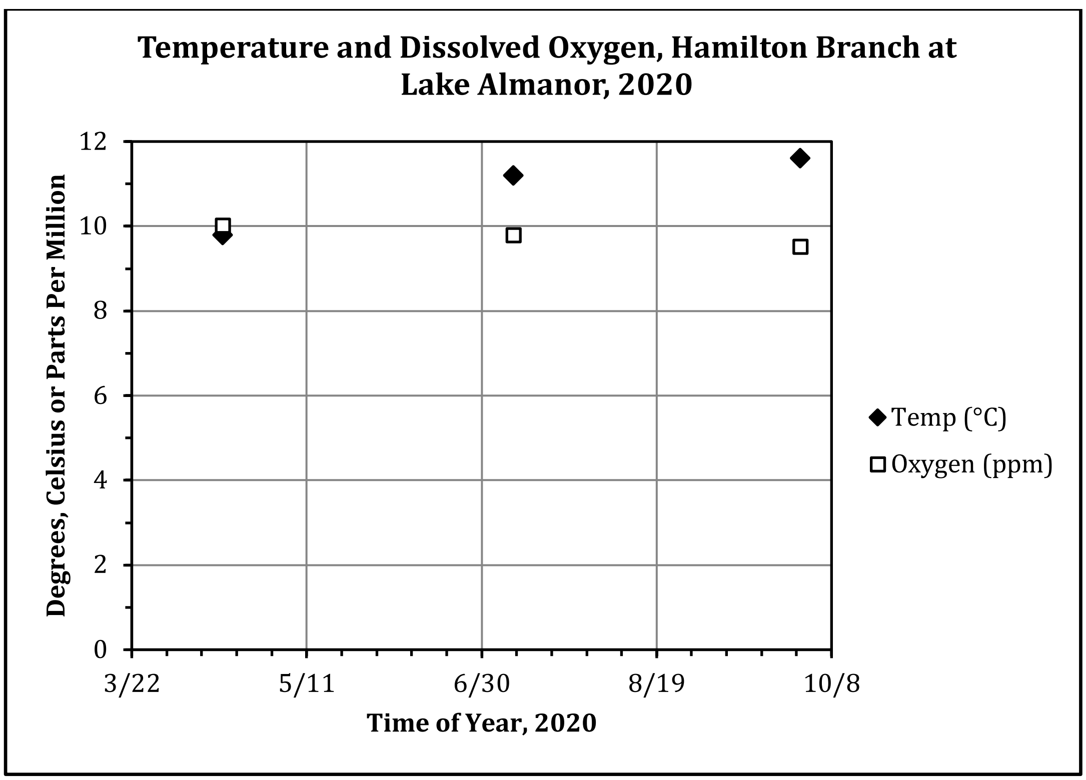


Figure 7. Temperature and Dissolved Oxygen, Hamilton Branch at Lake Almanor (HB-01A) During 2020



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 91-123 micro-mhos/cm at the lake stations and from 59-93 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 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. The 2020 values were a little higher than in 2019, due to the decreased precipitation and runoff.
Bailey Creek had the lowest conductivity (32 μmhos/cm), although it stopped flowing after the Spring sampling. Hamilton Branch downstream of the Mountain Meadows Dam generally had the highest value (114-135μmhos/cm), lower than in 2019. 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. At LA-01 and LA-02 Secchi depth was about 8-9 meters in May 2020. It decreased to 6-7 meters at LA-01 and LA-03 in July, but was high at LA-02 (9.4 meters). In September it was 4 meters at all three stations. Variation is probably related to sediment carried by inflowing streams, as well as the amount (biomass) of phytoplankton (usually lower Secchi depths in spring and fall, which correspond to higher phytoplankton populations). The high value in the Spring was probably due to low runoff and less sediment in the reservoir. Values were generally in agreement with those in the DWR database and with the 2009 - 2019 studies.

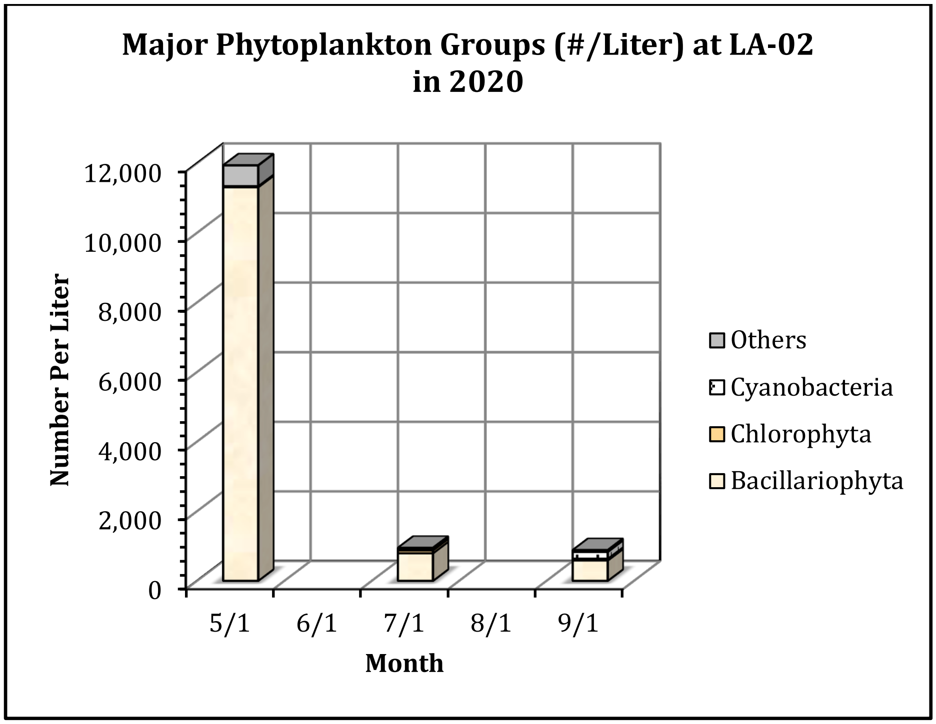
Turbidity was generally low in the tributaries and in the lake, with slightly higher values in Fall and lowest values in Spring. The highest reading was in September in Hamilton Branch at Mountain Meadows (19 ntu). The highest turbidity values in the reservoir were in September, corresponding with low Secchi depth, especially at LA-03 (7.1 ntu)

3. Phytoplankton and Zooplankton

Phytoplankton samples were collected at LA-02 and LA-03 on three 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 (biomass) 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 *Aulacoseira* being numerous*.* There were a lot of *Dinobryon* – a yellow brown algal genus and *Sphaerodinium* – a dinoflagellate at LA-02 and LA-03. By mid- July the total number/liter and 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.) In late September *the* algae at LA-02 were equally diatoms and blue-green algae and populations were a little higher than summer. LA-02 had its greatest volume of phytoplankton in May, prior to thermal stratification. LA-03 had its greatest volume of phytoplankton in September. Often, the greatest volume is in November, corresponding to the beginning of the rainy season and the first inflows of the Fall. However, in 2019 the greatest volume at LA-03 was also in September. This seems to occur when blue-green algae are a large component of the population, since they thrive at warmer water temperatures.

Figure 8. Major Phytoplankton Groups at Lake Almanor, By Number/Liter and By Volume (cubic microns/milliliter), Station LA-02 in 2020



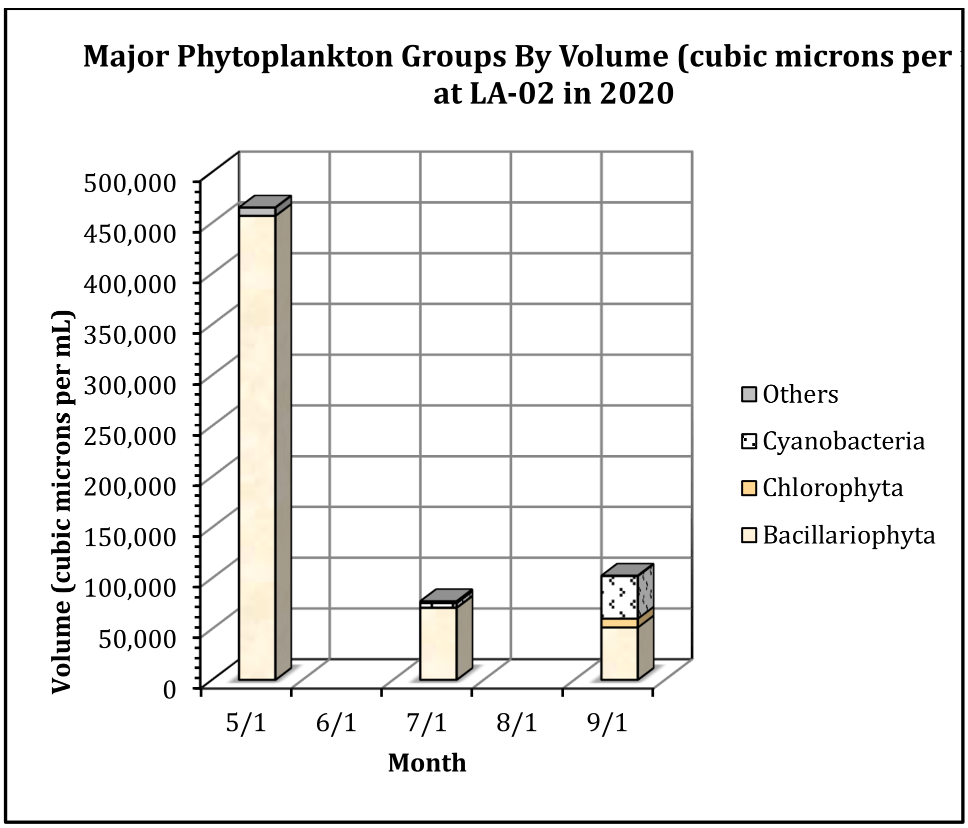
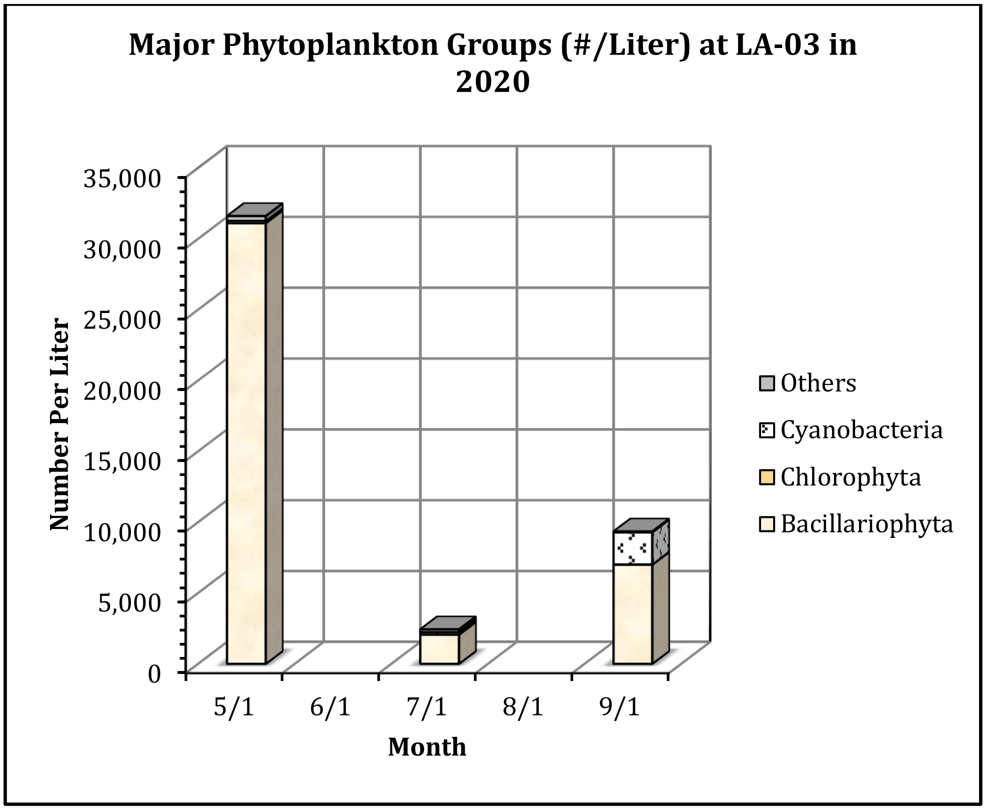
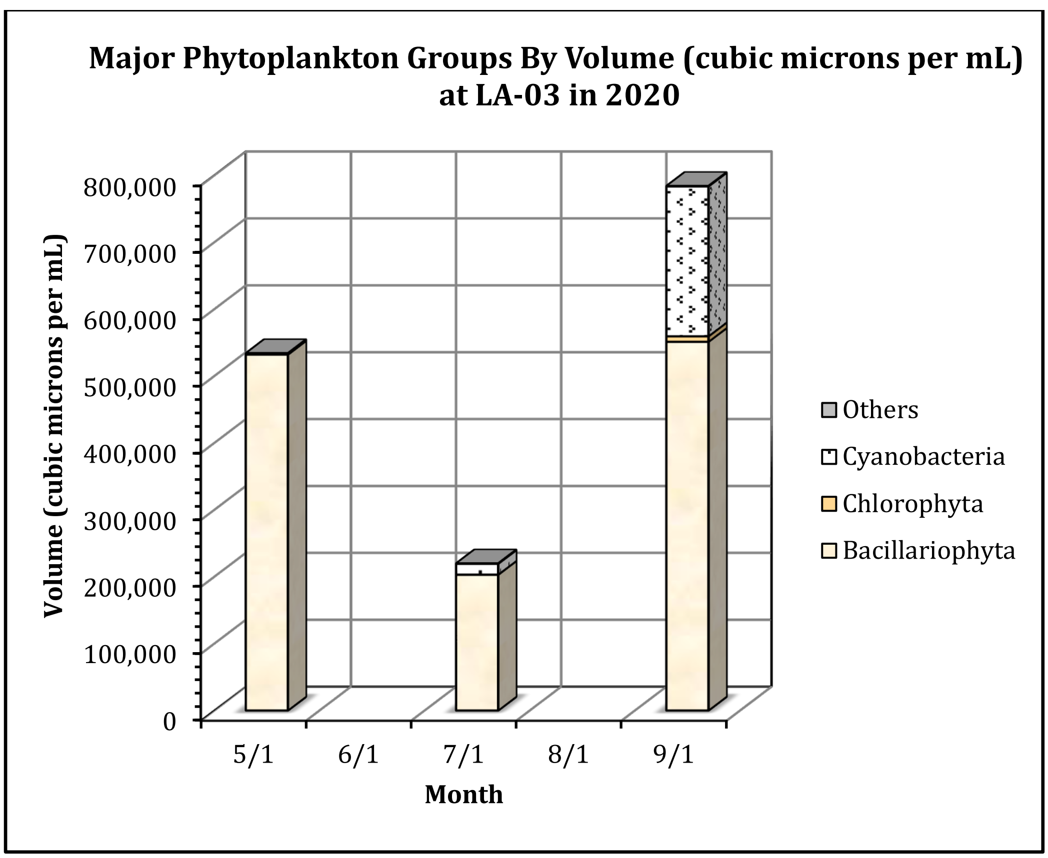


Figure 9. Major Phytoplankton Groups at Lake Almanor, By Number/Liter and By Volume (cubic microns/milliliter), Station LA-03 in 2020





Following the last sampling at the end of September 2020, a message was received from Keith Bouma-Gregson (California State Water Board) informing us of a potential Harmful Algal Bloom (HAB) in Lake Almanor. Satellite imagery showed a bloom throughout the western basin. Figure 10 below shows the approximate location of the bloom. The image is a ten-day composite, so it is likely that our phytoplankton sample at LA-03 captured the beginning of the bloom. Our sample had a large volume of Cyanobacteria, primarily *Dolichospermum sp.* This genus commonly occurs in Lake Almanor and often has large populations in the fall.

Figure 10. Ten-Day Composite Satellite Image of HAB Bloom, Lake Almanor, October 22, 2020 (Redder pixels indicate a denser bloom at that location)

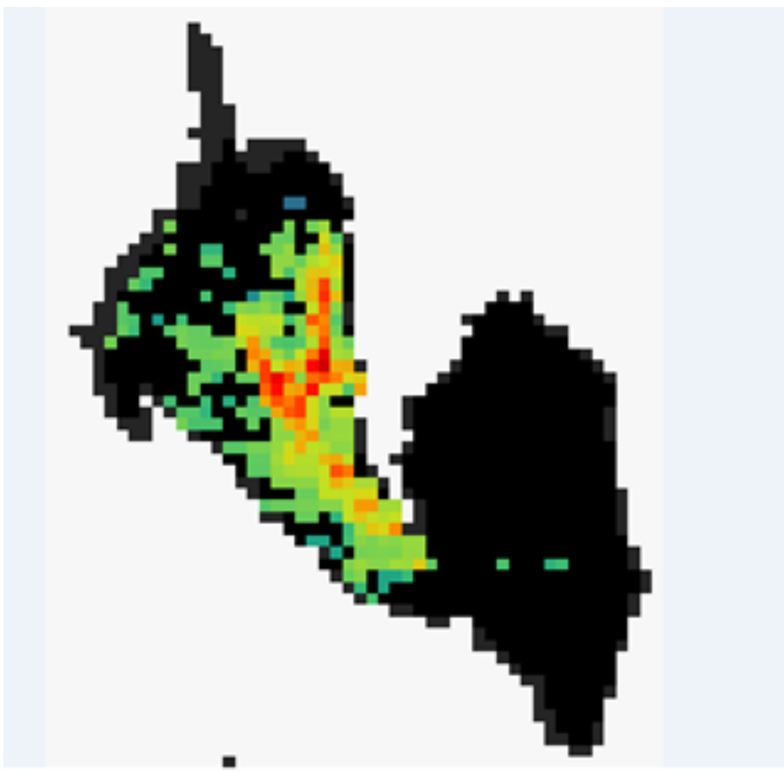


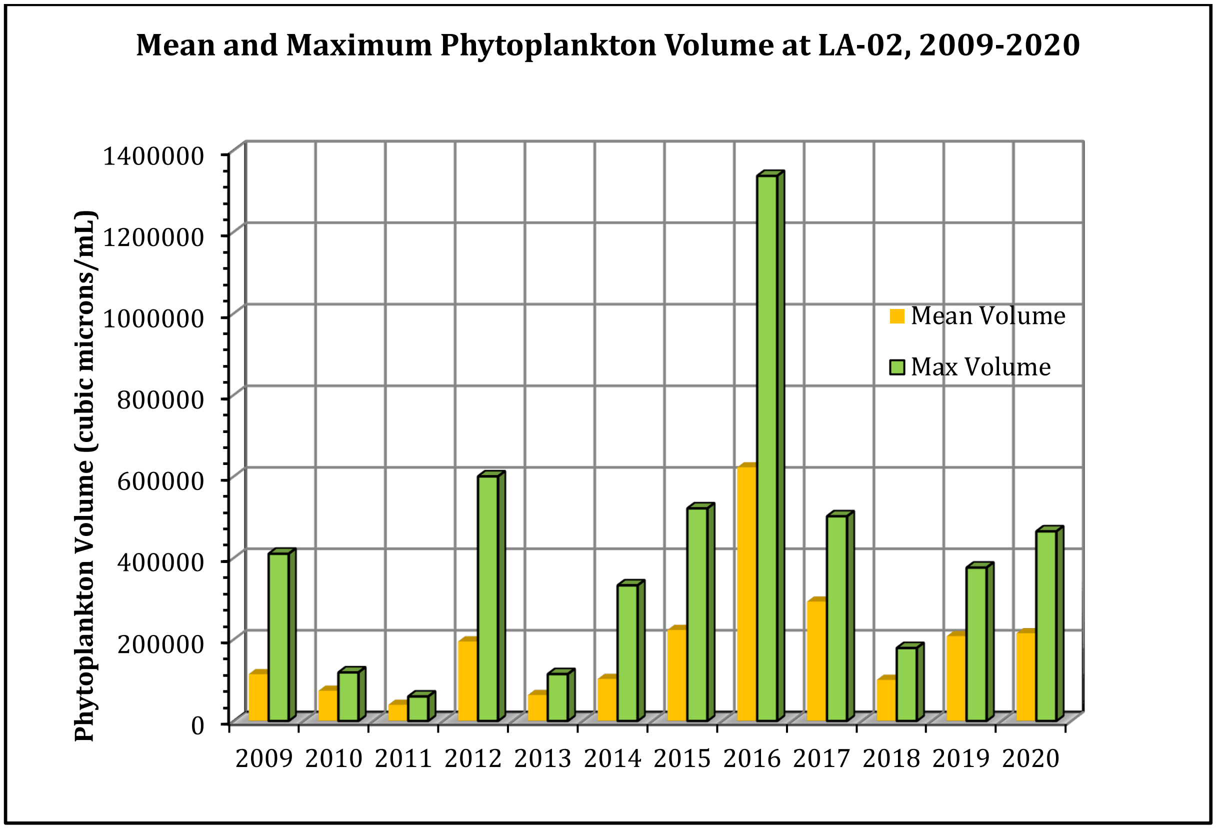
Figure 11 shows the mean and maximum amount of phytoplankton by volume at LA-02 and LA-03 from 2009 to 2020. (Please note that the vertical scale for the two stations is not the same.) The maximum has generally been in November, but we were not able to sample in November 2020. At LA-02 the greatest amount was in April 2016, probably due to the emptying of Mountain Meadows Reservoir in Fall 2015. The volume of algae was increasing from 2013 to 2016, but had dropped back to less than its 2014 value. In 2019 and 2020 it was increasing again. 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 had been stable or decreasing slightly from 2015 – 2019, but increased in 2020. Diatoms (Bacillariophyta) were the most numerous in spring and fall, but blue-green algae have continued to increase in the summer 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, but in 2020 that dilution did not occur.

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 12 and 13. More detailed data are in the Appendix, Table 3. Rotifera continued to be very abundant, but Copepoda and Cladocera were not as numerous in 2019. There were a third to half as many organisms present in May 2019 compared to May 2018. In 2020 there were more copepods and cladocerans in the spring and summer, but rotifers were dominant by September. Summer populations were similar. The greatest abundance of zooplankton was in September at LA-02 and at LA-03. Populations of rotifers were much greater at LA-03 than at LA-02, and also greater than they were in 2019.

Variations in zooplankton populations are largely a function of food supply – which algae are present, as well as temperature and predation by carnivores, such as young fish.

Figure 11. Mean and Maximum Phytoplankton Volume at LA-02 and LA-03, 2009 -2020



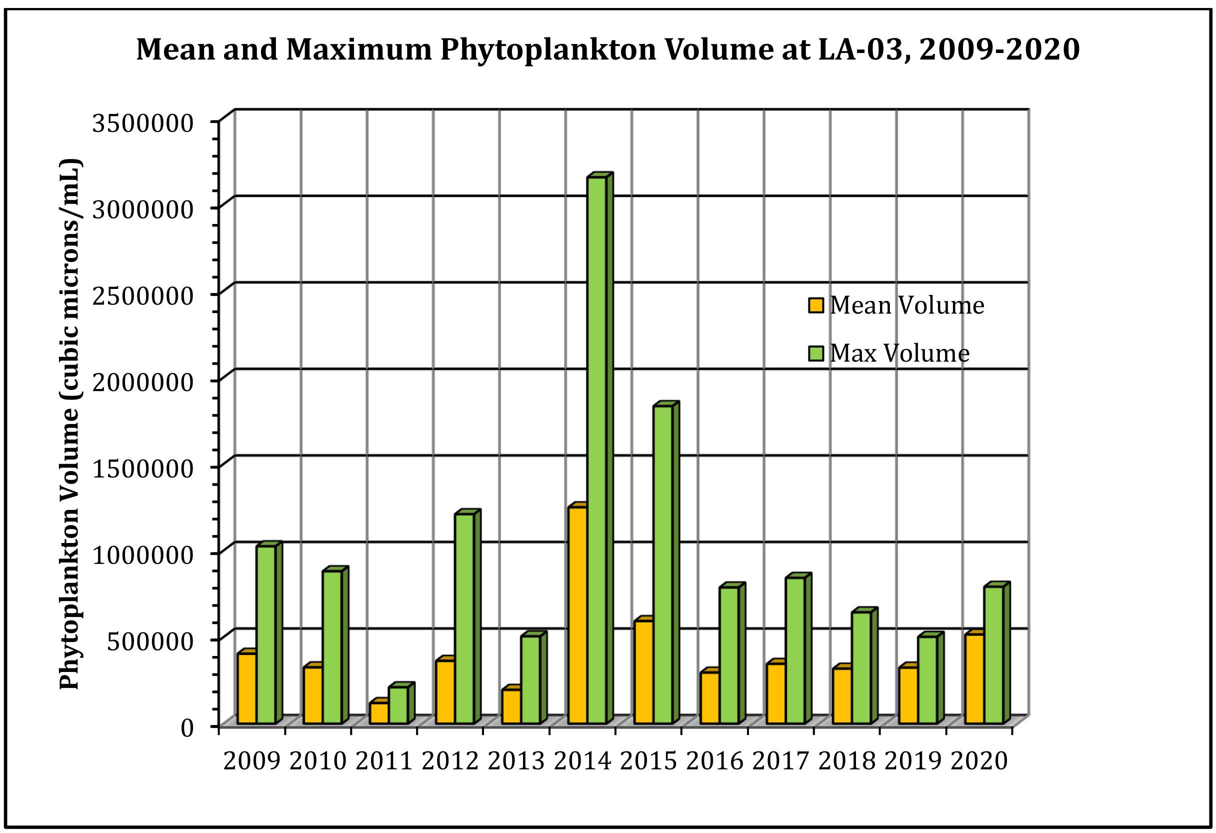


Figure 12. Major Zooplankton Groups (#/Liter) at Lake Almanor, Station LA- 02, 2020

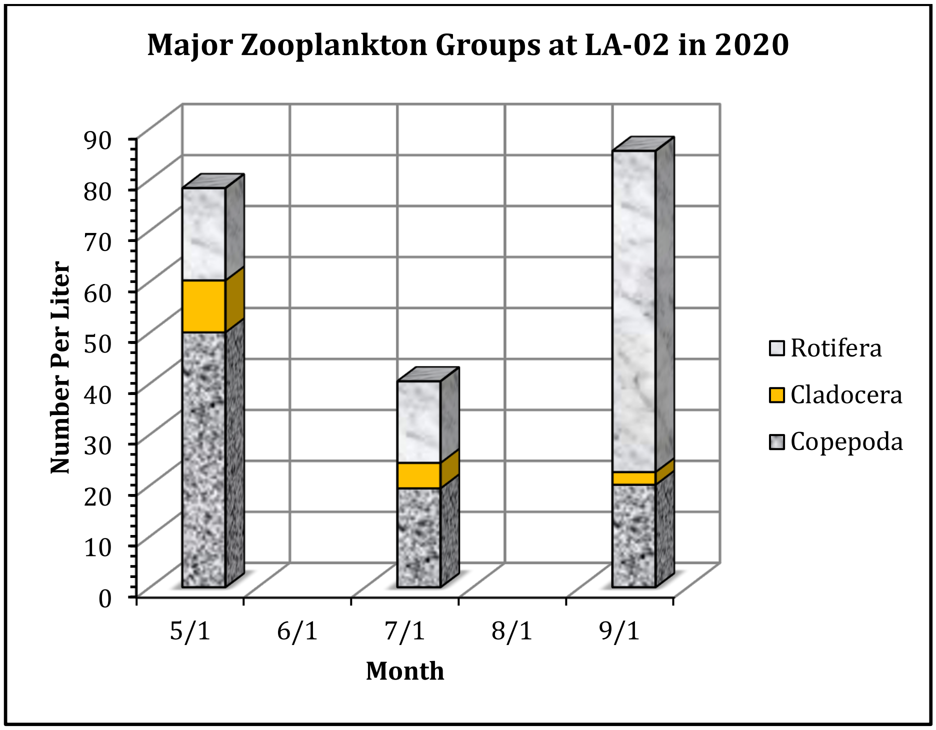
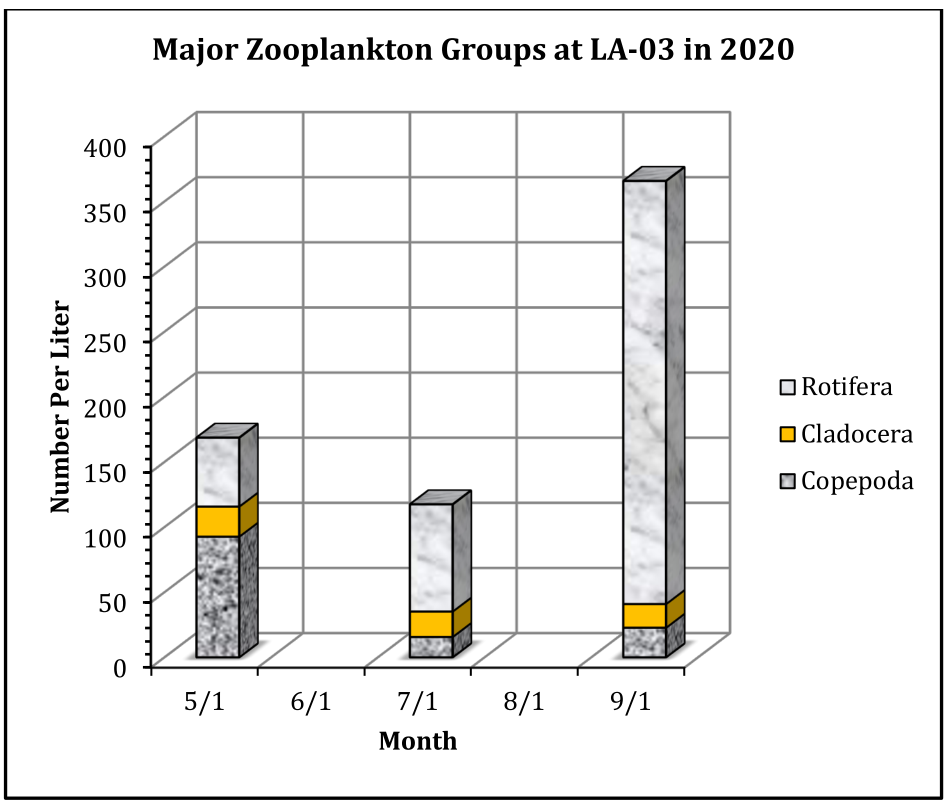


Figure 13. Major Zooplankton Groups (#/Liter) at Lake Almanor, Station LA-03, in 2020



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 since the study began 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 cold-water 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 about 20 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 cold-water fish species, conditions were not as stressful as in years prior to 2017.

However, 2020 was a very dry year. Precipitation as rain totaled only 10.75 inches. This resulted in the establishment of thermal stratification early in the summer and its persistence through September. Oxygen was decreasing in the hypolimnion at the beginning of July and was absent in the hypolimnion at both LA-01 and LA-02 until turnover. This probably occurred in October.

Warmer inflows and less dilution have increased algal abundance at LA-02 and LA-03 to higher levels than in 2019. There has also been a shift to more blue-green algae. Bluegreen algal species are common in the summer and fall 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 2021. 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: Western Regional Climate Center (wrcc.dri.edu)

Glossary of Terms Used in Lake Almanor Water Quality Reports

Algae. Algae (the plural form of alga) are one-celled plants that do not have a central vascular system for respiration and nutrient flow. Usually algae are very small, microscopic size. However, some are much larger, such a sea lettuce, but are still algae because each cell can survive on its own and there is no central vascular system. Various estimates indicate there are over 70,000 species of algae that inhabit fresh water.

"**Blue green algae**". These are more correctly Cyanobacteria, and not true algae. The chlorophyll in each cell is spread throughout the entire cell. This contrasts with a true algae cell which has a firmer wall, like a pea, and the chlorophyll is in sacks called chloroplasts. Most of the harmful algae bloom (HAB) problems in US lakes are caused by only about 30 species of cyanobacteria.
Cyanobacteria are found in many lakes and can destroy a lake's utility by producing potent toxins (cyanotoxins), taste, and odor in the lake water. The toxins can kill or harm humans that contact the lake water.

Anoxic. Anoxic water has little or no measurable dissolved oxygen.

Bloom. A "bloom" usually refers to excessive algal growth.
Cladocera. Relatively large members of the zooplankton, such as Daphnia (water fleas), that are primarily filter feeders that eat algae and other phytoplankton.

Coldwater Fishery. Waters in which the maximum mean monthly temperature generally does not exceed a certain value and, when other ecological factors are favorable, are capable of supporting year-round populations of cold- water aquatic life, such as trout.

Concentration. Concentrations of a substance in water are usually given as ppm in the English system or mg/l in the Metric system. Below is conversion information to go from the English to the Metric system:
1 part per thousand = 1 ppt is the same as 1 gram per liter = 1 g/l
1 part per million = 1 ppm is the same as 1 milligram per liter = 1 mg/l
1 part per billion = 1 ppb is the same as 1 microgram per liter = 1 ug/l
The above are weight ratios, not molar ratios. For example, 1 ppm means 1 pound of solute per 1,000,000 pounds of water.
Conductivity. A simple way to determine the salinity, or total dissolved solids (TDS), in water is to measure the electrical conductivity of the water using an electric meter compensated for water temperature. This works because water conductivity is affected by the amount of salts dissolved in water.

Copepods. Members of the zooplankton that can be predaceous on other organisms.

Cyanobacteria. See Blue-green algae.

Diatoms. Diatoms are beneficial microscopic cold -water algae with hard exoskeletons. These algae are typically brown, and impart a brown tint to lake water in the spring and fall.

Dissolved oxygen (DO). The amount of oxygen dissolved in water, and available for biological use and chemical reactions. Saturation refers to the maximum amount of DO

water can hold in solution. Both lower temperature and higher pressure result in higher DO saturation concentrations in water. Examples of the approximate saturation of DO in water at standard atmospheric conditions are: 50℉ (10℃) >> 11 mg/l of DO, 68℉ (20℃) >> 9.5 mg/l of DO, 86℉ (30℃) >> 8 mg/l of DO.
Epilimnion. The epilimnion is the upper portion of the lake above the metalimnion (See definition below.) In most US lakes and other fresh water bodies the epilimnion extends from the surface to 2-3 meters deep, but in some large lakes, such as Almanor, it can extend much deeper (down to 10 meters.in late summer). Usually the epilimnion is mixed well enough by wind so that the water temperature, dissolved oxygen (DO), pH, and conductivity, from the surface down to the metalimnion, are nearly the same at every test point in the lake.

Eutrophic. See trophic status.

Filter feeder. an animal that feeds by sieving or straining small food items from water.
Hypolimnion. The hypolimnion is the lower portion of the lake, from the metalimnion to the lake bottom. The temperature is constant and dissolved oxygen may be low or depleted.

Mesotrophic. See trophic status.

Metalimnion. The transitional layer in a thermally stratified lake between the upper warm epilimnion and the deep cold hypolimnion. Generally, temperature and dissolved oxygen decrease with depth. The thermocline is part of the metalimnion., where temperature declines at least 1 °C for every drop of 1 meter in depth.

Oligotrophic. See trophic status.

Photosynthesis. Photosynthesis involves the use of energy from sunlight, water and carbon dioxide to produce glucose and oxygen.

Phytoplankton. Microscopic algae or bacteria that live free floating in the water column.

Plankton. Organisms that live free-floating in the water column of a lake with little or no power of locomotion.

Respiration. Aerobic respiration breaks down organic molecules in the presence of oxygen to produce carbon dioxide and water.

Rotifers. Relatively small members of the zooplankton that can be filter feeders but some are also predaceous.

Secchi Depth. Secchi depth is a measurement of water clarity using a Secchi disc. The Secchi disc was invented by Pietro Angelo Secchi (science advisor to the Pope in the late 1800s). It is usually an 8-inch (20 cm) flat round plate, with alternating black and white quadrants, and a rope at the center to lower it into the water, usually from the shady side of a boat. The Secchi depth is the water depth at which the disc is no longer visible.

Thermal stratification: This usually refers to late spring and summer-time conditions when water near the surface is warmed up by the sun, and the wind can only mix the "less-dense" epilimnetic water that extends from the surface of the lake down to the metalimnion. The deeper regions of the reservoir are not circulating because they are denser than the warmer overlying epilimnion.

Thermocline. The traditional definition of a thermocline is the range of depths, in stratified summer conditions, where the water has a 1°C decline in temperature within a 1 meter change of depth.

Trophic Status. The trophic status usually refers to the level of algal nutrients, primarily nitrogen (N) and phosphorus (P), and organic production in an aquatic system. Lake water quality can be described by its trophic status:

Oligotrophic (low food availability) lakes are more often found in mountain areas or lakes with very little nutrient inputs. These lakes are clear and blue with low algal productivity, and with Secchi depth visibility > 8 m (25 ft). Since there is little algae, there is not much of a food chain and so fish need to be stocked in these lakes.

Mesotrophic (moderate food availability) lakes have sufficient algal productivity to support lake
fisheries, and have Secchi depths 2-4 m (6-12 ft)

Eutrophic (high food availability) lakes have large external nutrient inputs, and are characterized by excessive algae (primarily cyanobacteria) and aquatic weed growth. Fisheries are not as good, as cyanobacteria are not edible and their decomposition can deplete bottom waters of dissolved
oxygen. Secchi depths in eutrophic lakes range 1-2 m (3-6 ft) and less than 1 m (3 ft) in hypereutrophic lakes. These lakes often have noxious odors associated with the presence and decomposition of cyanobacteria blooms.

Turbidity. Cloudiness in water caused by particulate matter suspended in the water that decreases water clarity and can affect beneficial uses. Turbidity is either inorganic, such as clay particles, or organic, such as algal cells.

Warmwater Fishery. Warm-water fish streams and lakes support fish species such as smallmouth bass, largemouth bass, and other species with less stringent temperature requirements than trout. Warm-water streams and lakes can also contain stocked trout or salmon, but these fish may not survive year-round.

Water column. A conceptual column of water from the surface of a lake to the bottom sediment.
Watershed. An area of land that drains all the streams and rainfall to a common outlet such as the outflow of a reservoir, mouth of a bay, or any point along a stream channel.

Zooplankton. Tiny animals that have some motility, but are also carried passively in a body of water.

Some definitions modified from “Lakes A to Z Help Guide”, Medora Corporation (www.medoraco.com)