# Lake Almanor Water Quality Report, 2021

Prepared for

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

**By**

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

## Summary of 2021 Water Quality Investigation at Lake Almanor

In 2021 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 and a group of volunteers (Phil Datner, Virginia Pritchard and Kevin Price) 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. They also collected plankton samples at two of the lake stations, LA-02 and LA-03. Dr. Gina Johnston, professor emerita of California State University, Chico, analyzed the data, as well as the plankton, and produced this report that shows all of the data and relates the results to previous studies. This was the thirteenth year that water quality analysis has been supported by LAWG.

2021 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 April at the first sampling date. By mid-July, the lake was thermally stratified, meaning that water near the surface had been 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 below 12 meters depth for most of the summer and fall. This created a situation where cold-water fish species could not find ideal habitat in much of the lake. The water was either too warm or lacked sufficient oxygen for these species.

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 2021, there was a bloom of blue-green algae (genus: *Dolichospermum*) in the western basin that persisted into January, 2022. This bloom followed the application of fire retardant along the west shore and eight inches of rain in late October. Because 2020 and 2021 were dry years, 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 has been decreasing since 2019, due to lack of precipitation.

**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 greater 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 12 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 are few 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)

## Introduction and Project Overview

A water quality monitoring program for Lake Almanor was conducted during 2021, 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 basin, and LA-03 in the west basin. 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 2021 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 2021 included:

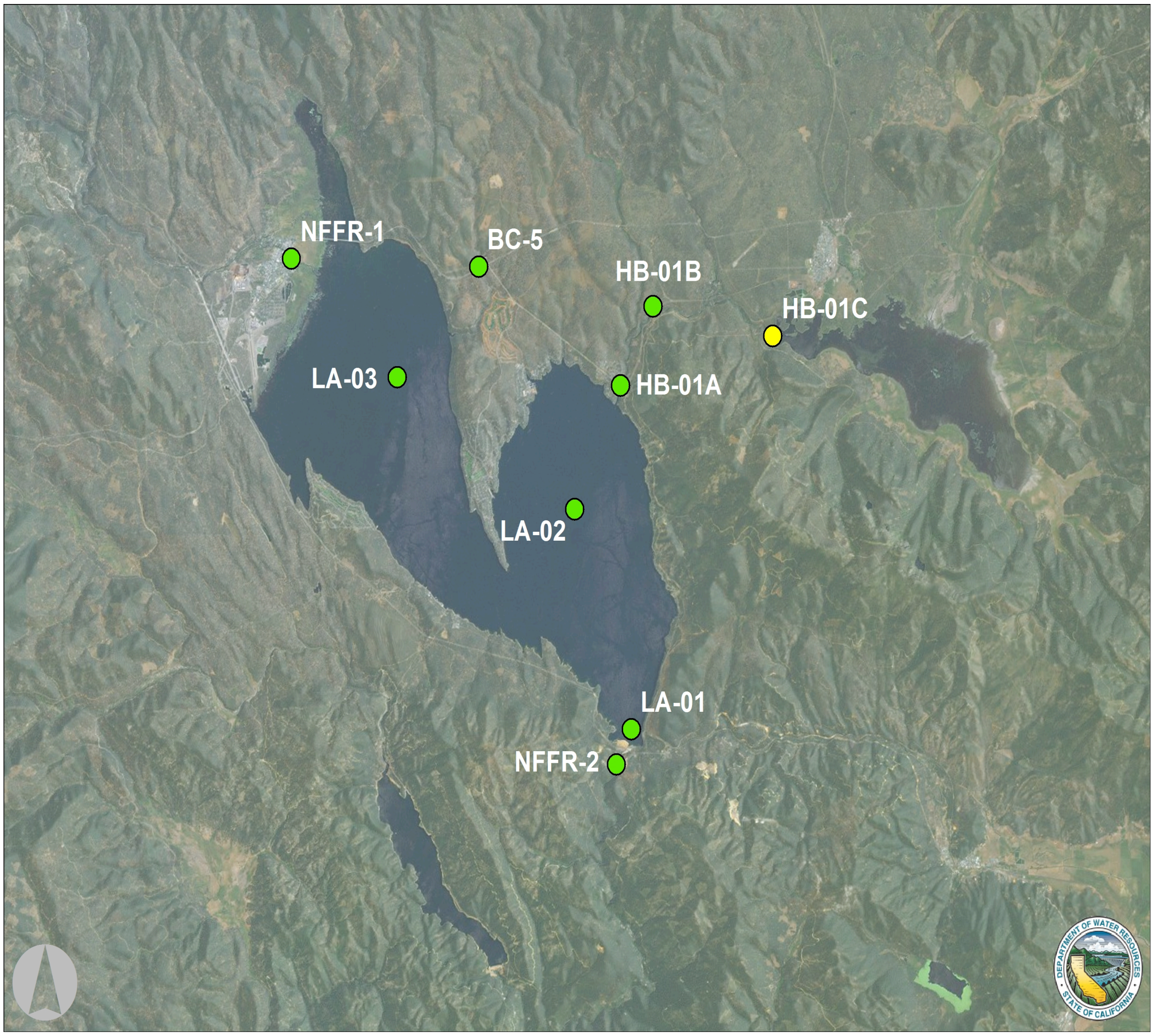
1. Physical: temperature, dissolved oxygen, Secchi depth (where applicable), electrical conductivity and pH at lake and tributary stations.
2. Biological: phytoplankton and zooplankton at LA-02 and LA-03.

   (Chemical analyses of inorganic and organic elements and compounds were not included in the 2021 study, as they were in 2014-2018. Turbidity was not included in 2021, although it had been in 2014-2020.)

## Methods Used for Sampling and Analysis

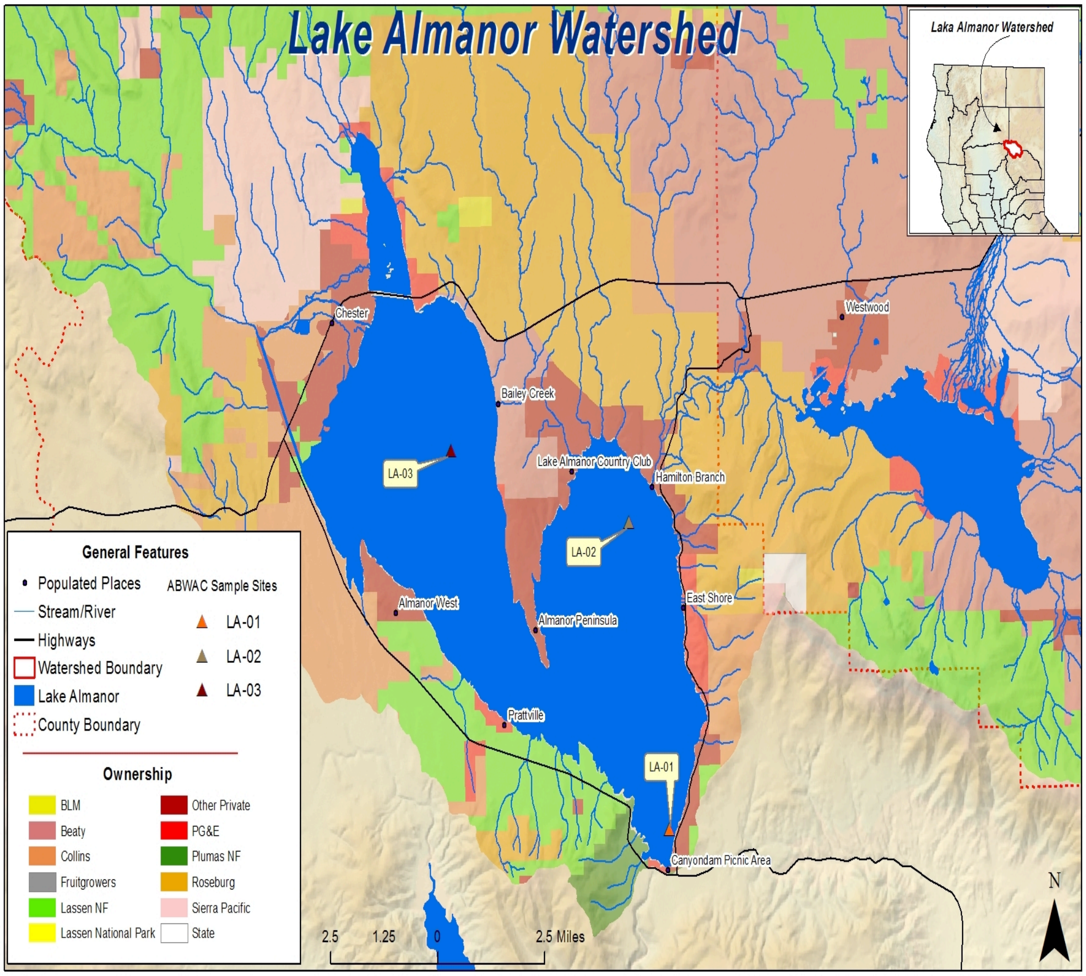
**Field Parameters— Stream-** Basic water quality parameters, including dissolved oxygen, electrical conductivity and pH, were measured with properly calibrated field instrumentation at each visit to every monitoring station. Stream samples or measurements were collected about one foot below the surface in flowing, well-mixed riffle or run areas. Water temperature, conductivity, dissolved oxygen, and pH was measured in streams with a YSI Professional Plus handheld multi-parameter meter with a 4-meter cable. The meter was calibrated the day prior to sampling following the instrument manual.

Figure 1. Lake and Tributary Sampling Station Locations in Lake Almanor Watershed Used in 2021 Study. (Map provided by Scott McReynolds)




Continuous stream water temperatures were recorded at 15-minute intervals at each stream station using Onset Hobo Pendant MX 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 Professional Plus meter and 30- meter cable assembly to access any potential depth in Lake Almanor.

Continuous lake water temperature and oxygen were recorded at 15-minute intervals using HOBO Pendant 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).

Secchi depth was measured at all three lake stations by lowering a disk attached to a tape measure until it was no longer visible and then raising the disk until it was just visible. The depth when it went out of view and the depth when it came into view were noted. These two depths were averaged and recorded as Secchi depth. This was done on the shady side of the boat to avoid reflection.

**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 formalin 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 formalin 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 April 2021 LA-01 and LA-02 were beginning to stratify. At LA-01 temperature at the surface was about 10°C (50°F), and at the bottom it was around 5°C (41°F). LA-02 was about 9°C at the surface and the bottom was at 5°C. LA-03 was around 9°C (48°F) throughout the water column. Both LA-01 and LA-02 surface temperatures were cooler than the values for 2020. This may have been due to the earlier sampling date.

By July 15, 2021, stations LA-01 and LA-02 were thermally stratified. The epilimnion was about 22°C (72°F). The metalimnion was between 8 and 13 meters at LA-01, but 7-15 meters at LA-02. At LA-03 the temperature from top to bottom was about 23°C. The surface temperature at all three stations was about the same. The bottom temperature was 8°C at LA-01 and 10°C at LA-02. These temperatures were slightly warmer than in 2020, which may be due to an later sampling date in July.

The next sampling date was September 22, and LA-01 was still strongly stratified, although the surface temperature had cooled to 16.5°C. The epilimnion extended down to 14 meters depth. At LA-02 stratification was still present and the epilimnion was well mixed to a depth of 10 meters with a temperature of 16.5°C. The temperature then dropped off to 11°C at the bottom (16 meters). LA-03 was well mixed, with a temperature of 16°C (61°F) throughout. Water temperatures were slightly cooler than in 2020 even though the sampling date in 2020 was later.

In November all three stations were isothermal with LA-01 and LA-02 at 9°C and LA-03 at 7.5°C.

Water temperatures were generally a little different than in 2020 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 12 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 15°C (59°F), which was 4°C higher than in 2019, but about the same as in 2020. (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 2021. It was also warmer in Spring 2018 than in Spring 2017, probably due to less snow in the watershed. By the middle of September 2021, it had cooled back to about 10°C (50°F) and then to 5°C by November.

Data for Hamilton Branch at Lake Almanor are shown in Figure 7. In mid-July it was 4°C cooler than the NFFR at Chester, CA. By mid-September it had cooled to below 10°C, while the lake epilimnion was 16°C. These cooler temperatures compared to 2020 suggest that more of the flow could be attributed to spring inflow this year. In 2020 it was still nearly 12°C.

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 8°C (14.4°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 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 April 2021 the oxygen concentration at all three lake stations was about 9-10 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 (8-10°C) and the existing atmospheric pressure and wind conditions. It decreased with increasing depth below 10-12 meters as temperature decreased at LA-01 and LA-02. This was unusual, because oxygen should increase as temperature decreases, suggesting that there was organic matter decomposing and using oxygen in the early spring.

In mid- July 2021, oxygen concentration in the epilimnion at LA-01 and LA-02 was 7 ppm, and the epilimnion water temperature was 22°C (72 °F). Due to the shallow conditions at LA-03, oxygen was 7 ppm throughout. In the hypolimnion at LA-01, the oxygen level dropped to about zero below 14 meters. 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 increased in the metalimnion between 6 and 10 meters and then dropped to zero.

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. In 2021 conditions at LA-01 were similar to 2015 with no suitable habitat for coldwater fish species. Conditions at LA-02 were better because of increased oxygen in the metalimnion.

By 22 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 below 16 meters. At LA-02, oxygen levels were at 8-10 ppm to a depth of 10 meters and then dropped off to 0 ppm below 12 meters. Oxygen was 7 ppm throughout the water column at LA-03.

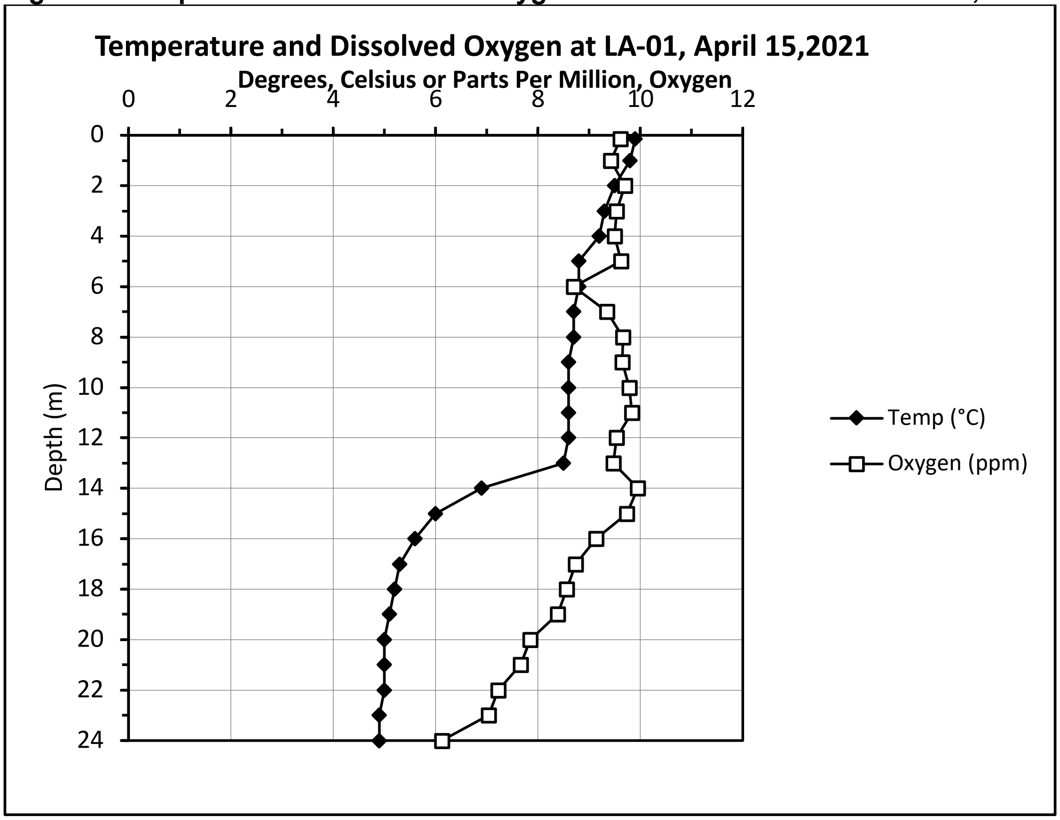
On the November sampling date, due to the breakup of thermal stratification, all three stations were at 9-10ppm oxygen throughout the water column.

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. The year 2021 was extremely dry and there was little to no spring runoff. By mid-July there was no oxygen below 14 meters at LA-01. This anoxia persisted until turnover in October. At LA-02 oxygen increased below the epilimnion between 6-12 meters as temperature decreased, creating a zone where fish could survive. Below 12 meters oxygen dropped and remained anoxic until turnover.

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 2021 the oxygen level stayed near 10 ppm all year, although the river got up to 15°C in July. Hamilton Branch did not get warmer in the late summer, and was cooler than the lake surface water by 11°C in July. Oxygen content was always near 10 ppm.

**Figure 3. Temperature and Dissolved Oxygen at Lake Almanor Station LA-01, 2021**



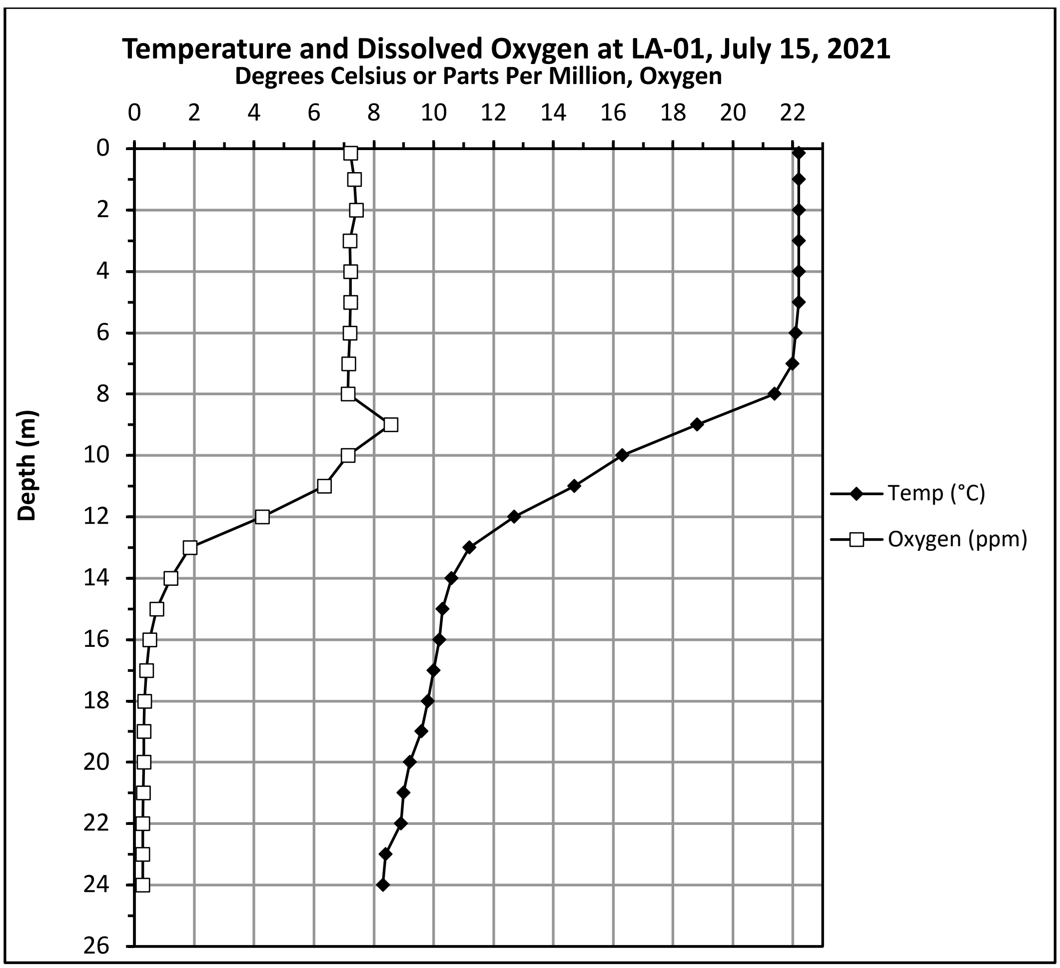
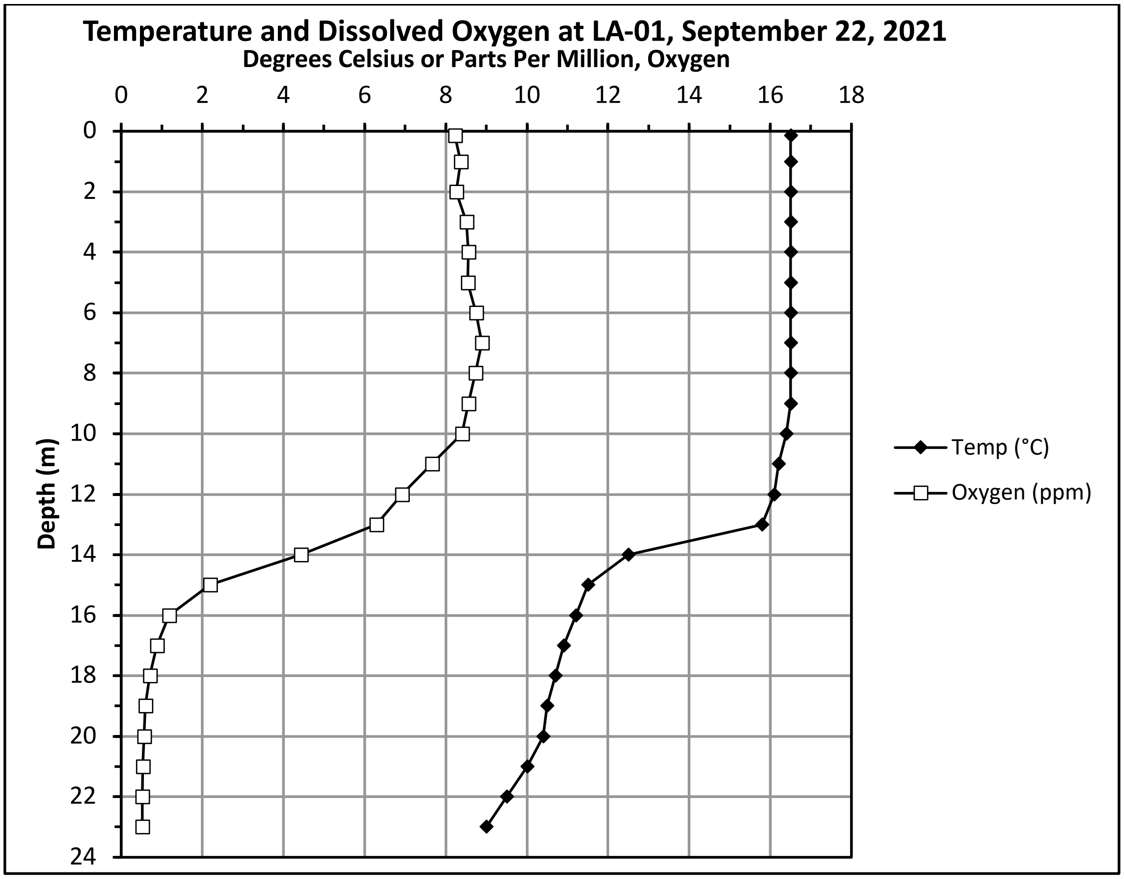



**Figure 3 (cont.). Temperature and Dissolved Oxygen at Lake Almanor Station LA-01, 2021**



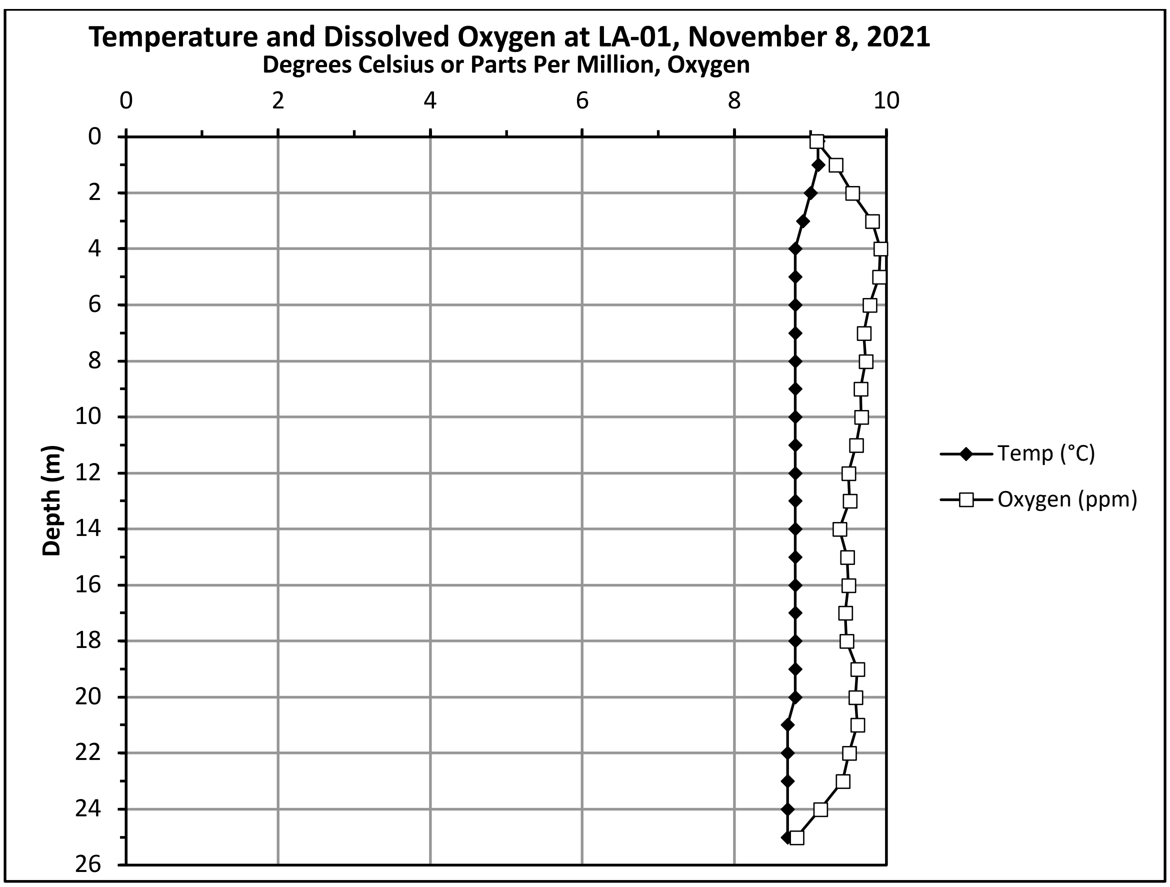
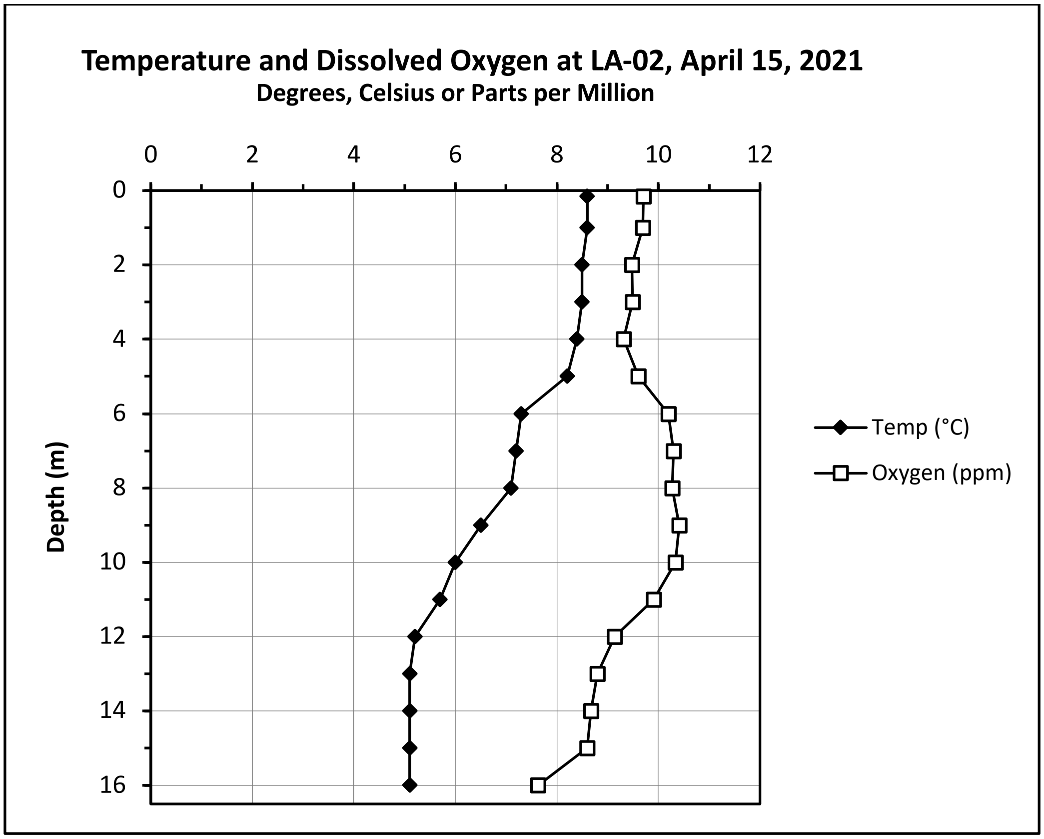



**Figure 4. Temperature and Dissolved Oxygen at Lake Almanor Station LA-02, 2021**



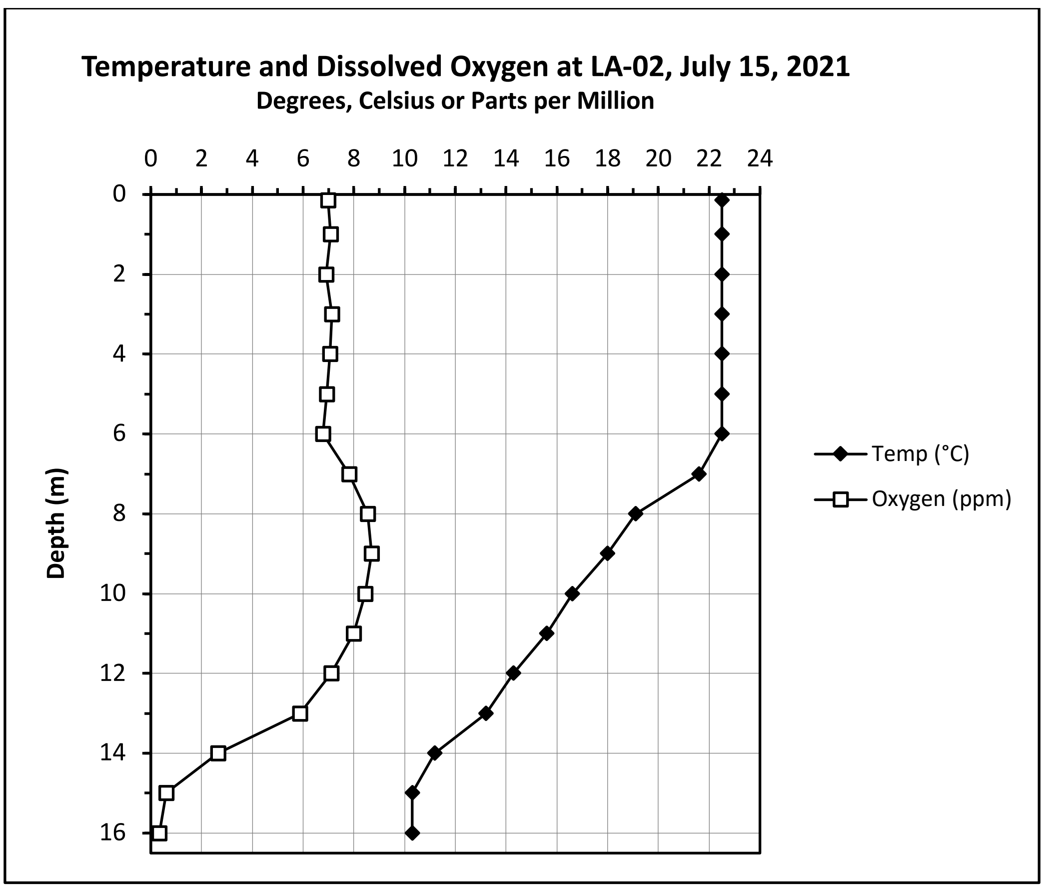
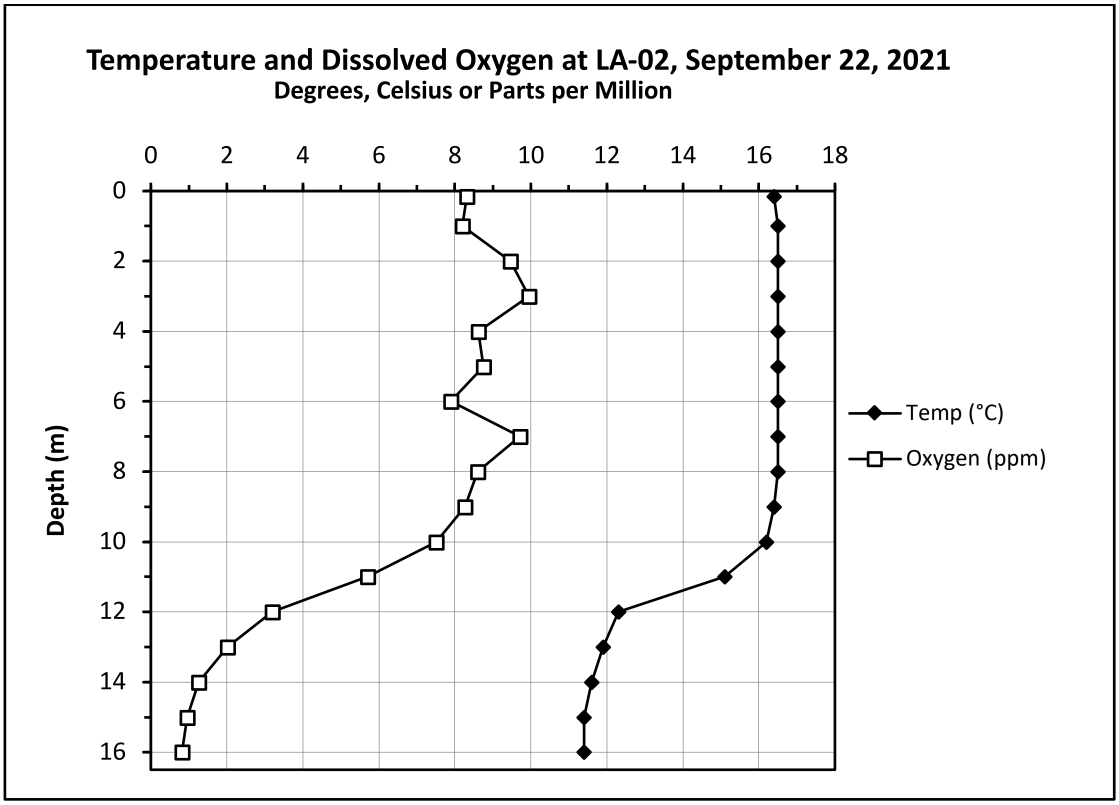



**Figure 4 (cont.). Temperature and Dissolved Oxygen at Lake Almanor Station LA-02, 2021**



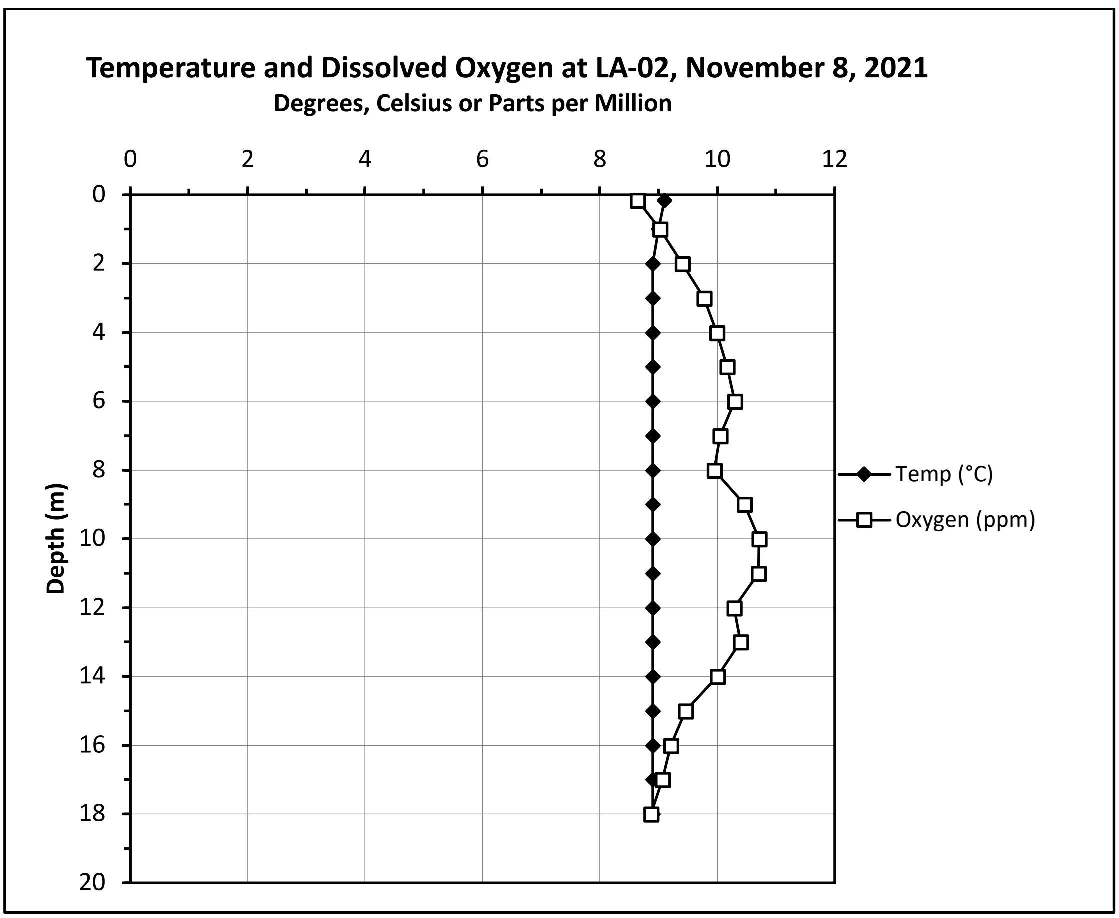
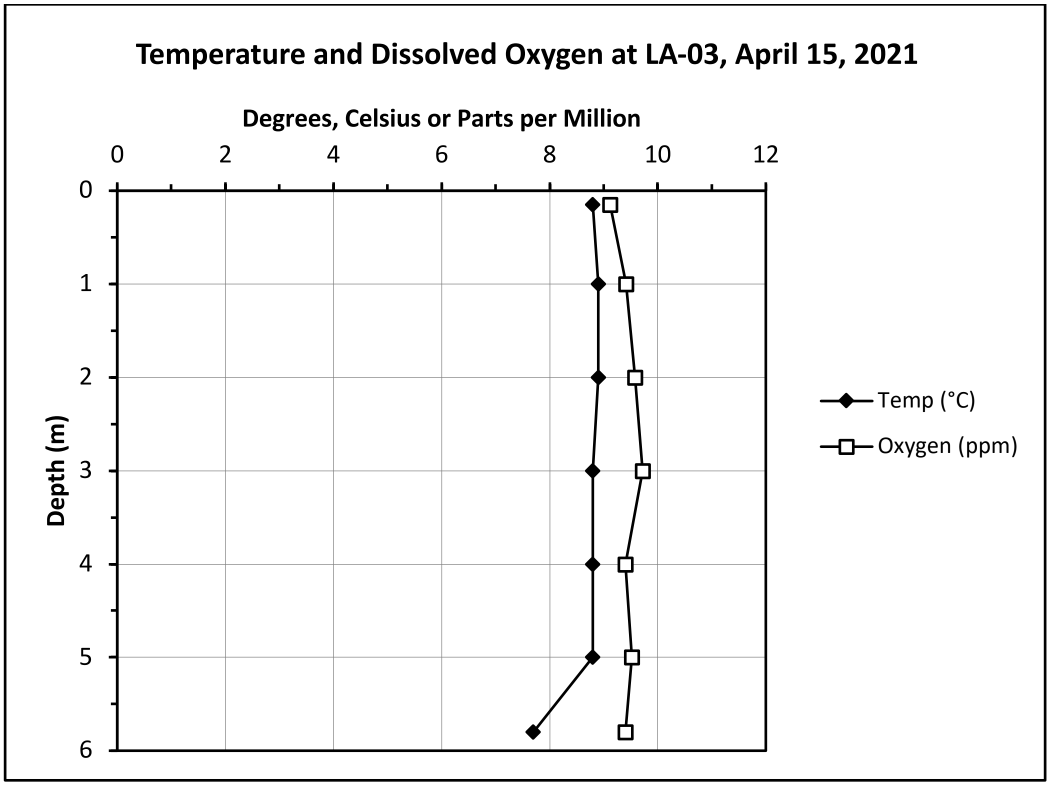



**Figure 5. Temperature and Dissolved Oxygen at Lake Almanor, Station LA-03, 2021**



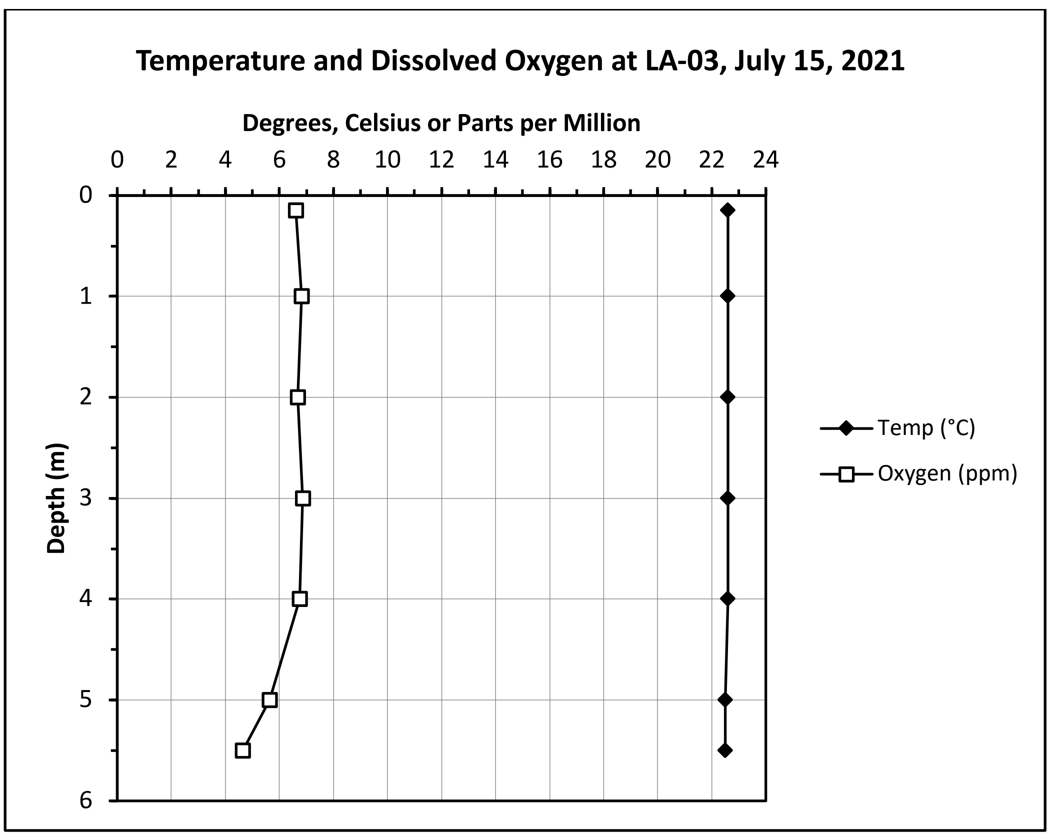
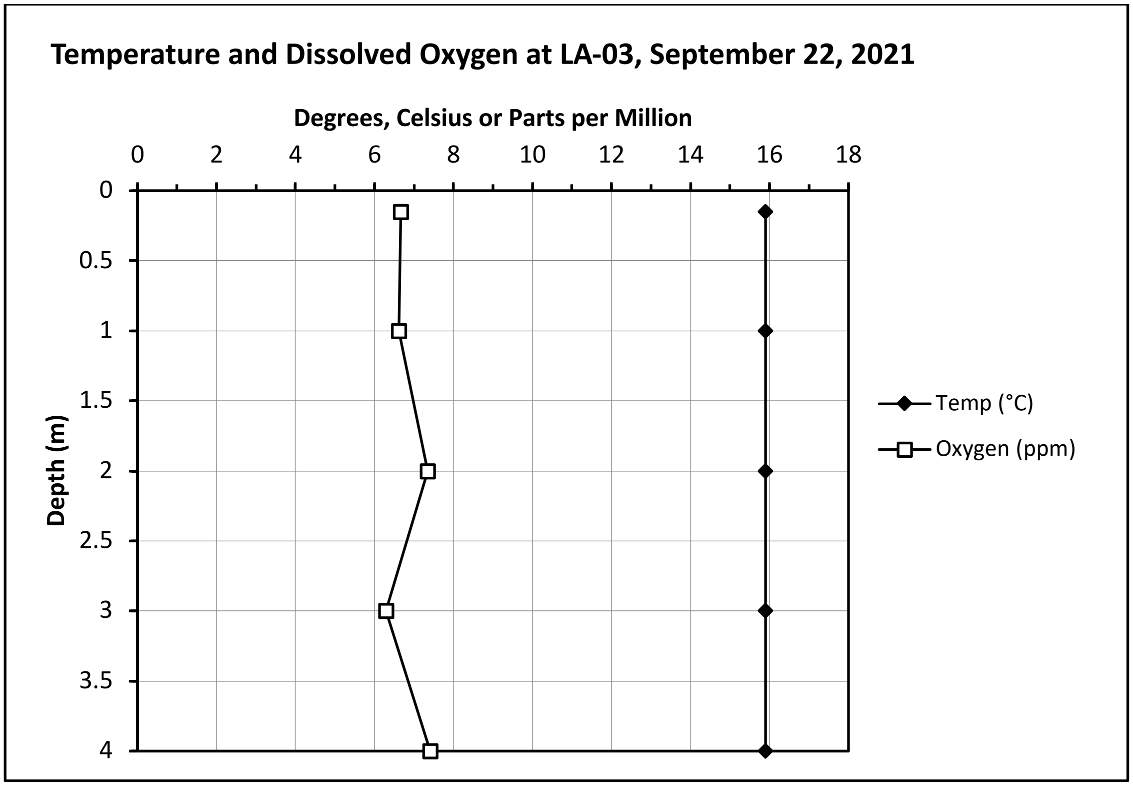



**Figure 5 (cont.). Temperature and Dissolved Oxygen at Lake Almanor, Station LA-03, 2021**



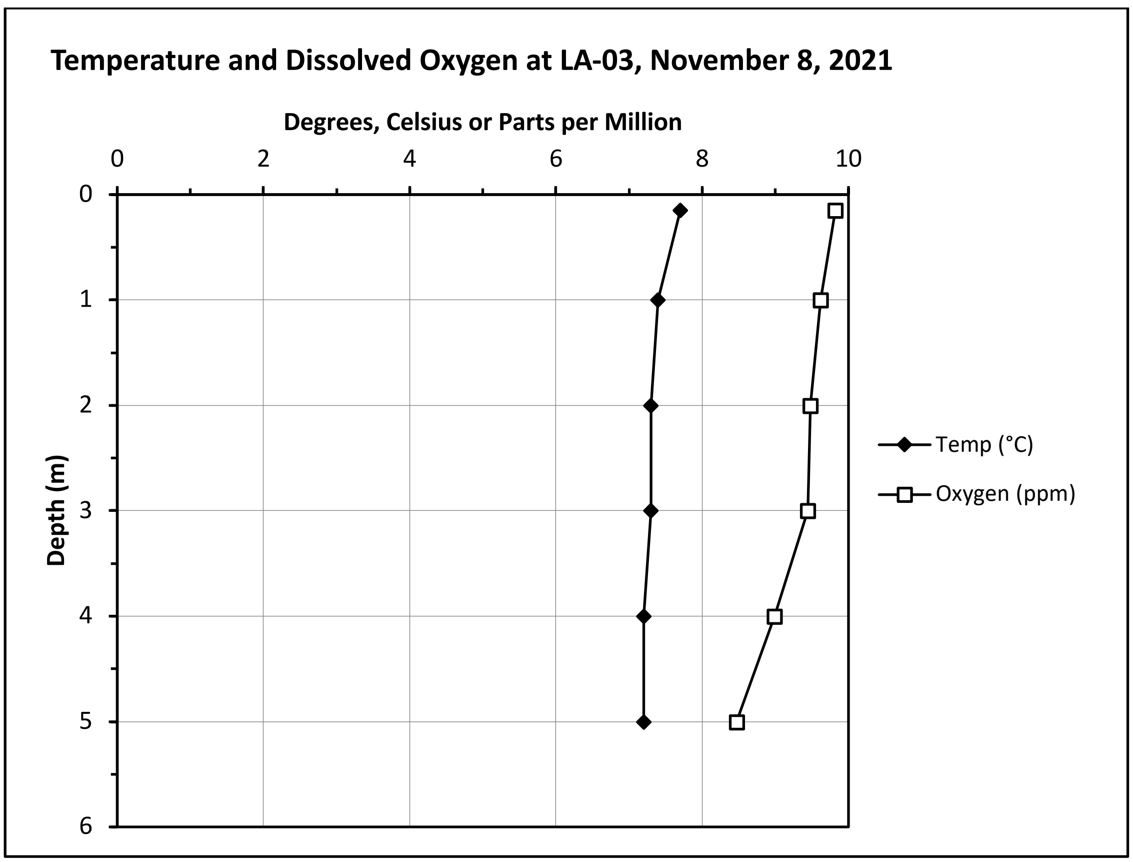



**Figure 6. Temperature and Dissolved Oxygen at Station NFFR-1, Chester, During 2021**

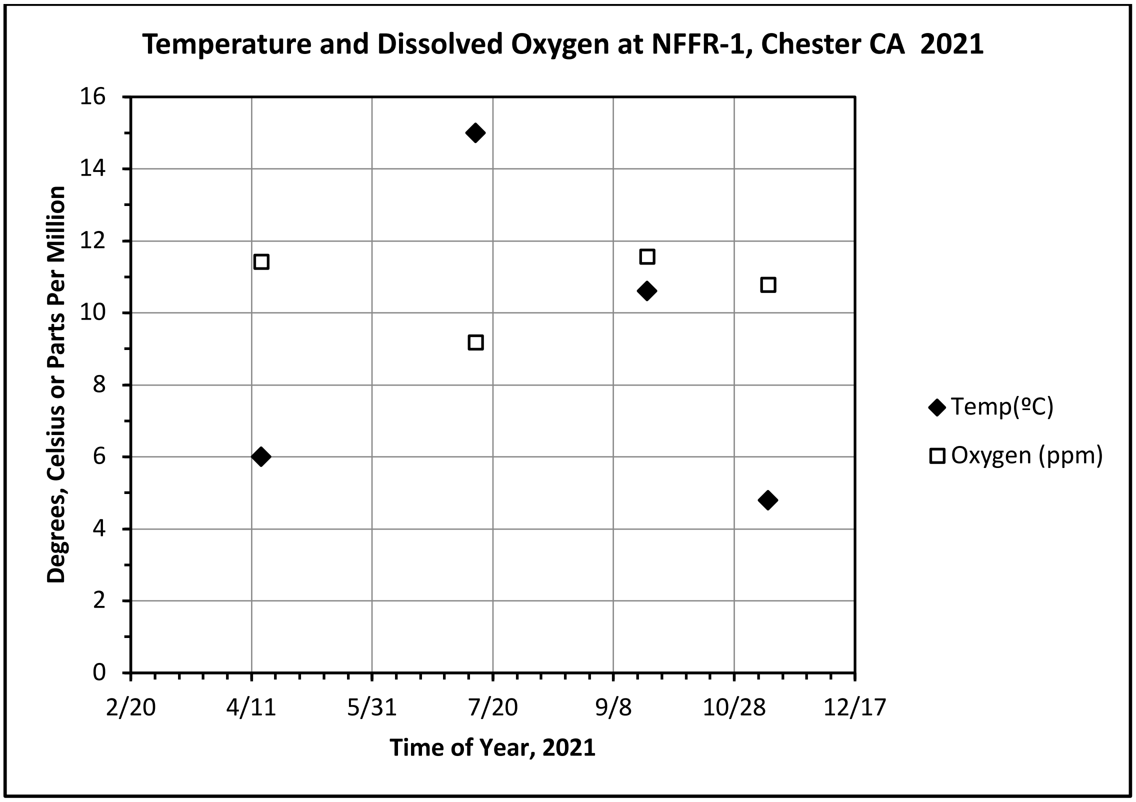
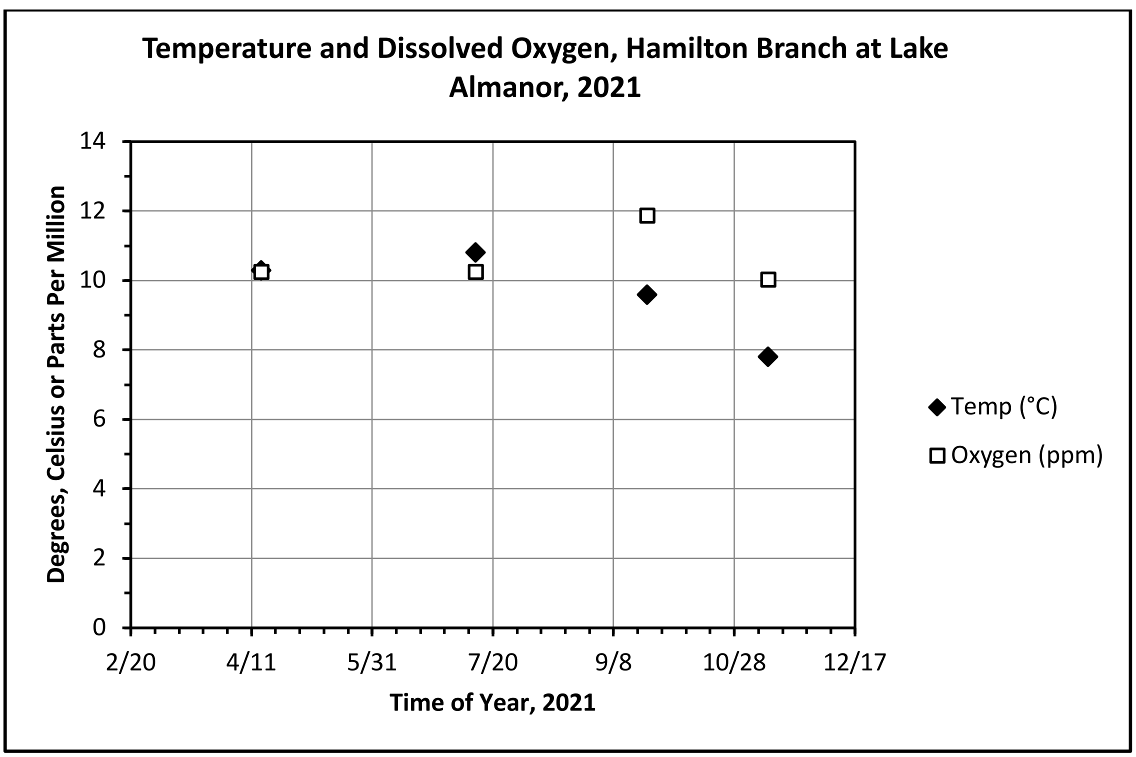



**Figure 7. Temperature and Dissolved Oxygen, Hamilton Branch at Lake Almanor (HB-01A) During 2021**



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 107-137 micro-mhos/cm at the lake stations and from 69-98 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 2021 values were a little higher than in 2020, due to the decreased precipitation. Bailey Creek (BC-5) had the lowest conductivity (33 μmhos/cm), although it stopped flowing after the Spring sampling. Hamilton Branch downstream of the Mountain Meadows Dam (HB-01C) generally had the highest value (112-210μmhos/cm), higher than in 2020. Electrical conductivity has been increasing since 2019 at all stations due to less spring precipitation.

d. Secchi Depth

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 5 meters in April 2021. It increased to 6-7 meters at LA-01 and about 11 meters at LA-02 in July, but only about 5 meters at LA-03. In September it was about 3 meters at all three stations. In November it was about 3 meters at LA-01 and LA-02, but down to 1 meter at LA-03, where there was a dense algal bloom. 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 low values in the Spring and Fall were definitely correlated with higher algal populations. Values were generally in agreement with those in the DWR database and with the 2009 – 2020 studies.

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.)

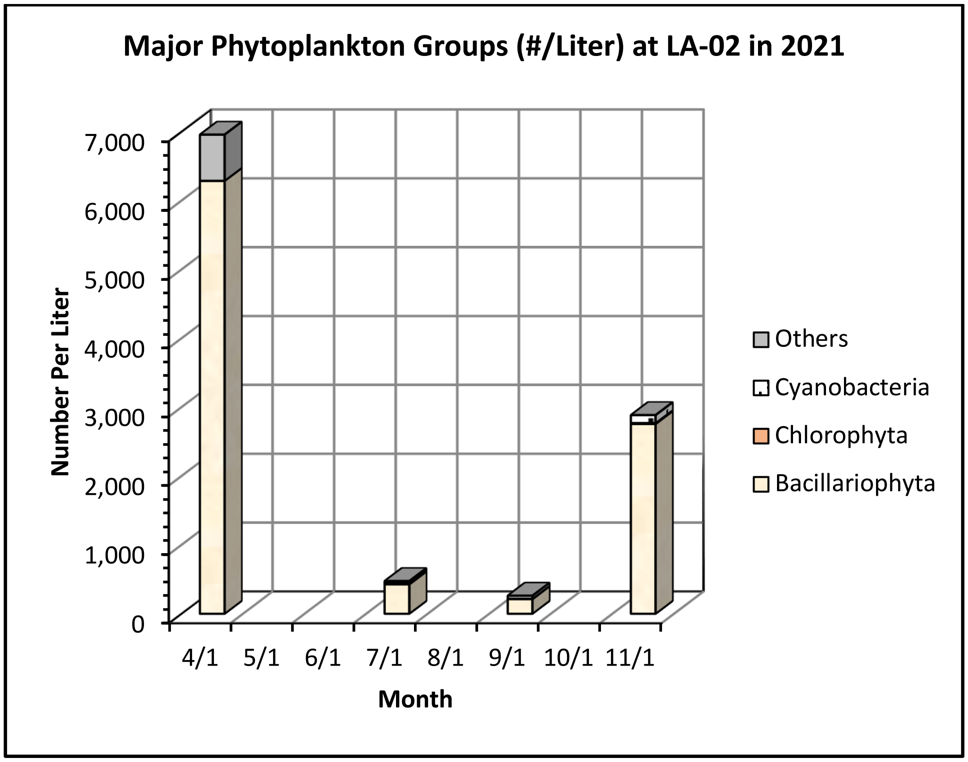
In April 2021 diatoms (Bacillariophyta) were the dominant forms at both LA-02 and LA-03, mostly *Fragilaria,* with *Stephanodiscus*` and *Aulacoseira* being numerous. There were also a lot of *Dinobryon* – a yellow brown algal genus at LA-02 and LA-03, similar to 2020. By mid- July the total number/liter and volume of algae had dropped at both stations. Bluegreen algae, primarily the genus *Lyngbya* as well as *some Dolichospermum*, were present. (The genus *Lyngbya* forms filaments large enough to be seen with the naked eye and these may accumulate at the surface.) By 22 September the algae at LA-02 were the same mix of diatoms, blue-green algae and some green algae, (*Volvox*) and populations were a little higher than summer. At LA-03, diatoms were very numerous, along with bluegreens (*Dolichospermum*) and some green algae ((*Volvox*).

By the last sampling in November, diatoms had increased in abundance at LA-02, but not to their high spring level. *Volvox* was still present. However, at LA-03 an increase of bluegreen algae, primarily *Dolichspermum*, as well as *Aphanizomenon*, reached bloom levels. This can be seen on Figure 9, with about 60,000 colonies per liter and 3,350,000 cubic microns per milliliter of lake water.

While LA-02 had its greatest volume of phytoplankton in April, prior to thermal stratification, LA-03 had its greatest volume of phytoplankton in November, following turnover. Often, the greatest volume is in November, corresponding to the mixing of the lake , but also to the beginning of the rainy season and the first inflows of the Fall. This seems to occur when blue-green algae are a large component of the population, since they thrive at warmer water temperatures.

LA-03 always has greater algal populations than LA-02, probably because of warmer water temperatures or greater penetration of sunlight.

**Figure 8. Major Phytoplankton Groups at Lake Almanor, By Number/Liter and By Volume (cubic microns/milliliter), Station LA-02 in 2021**



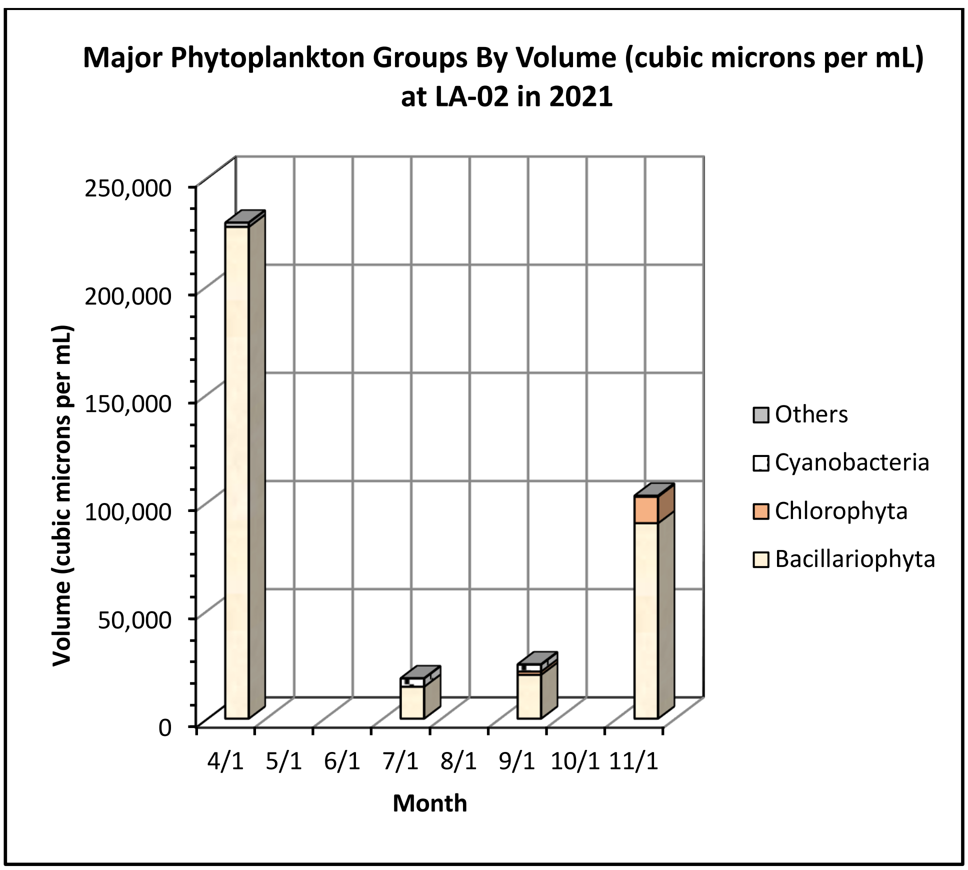
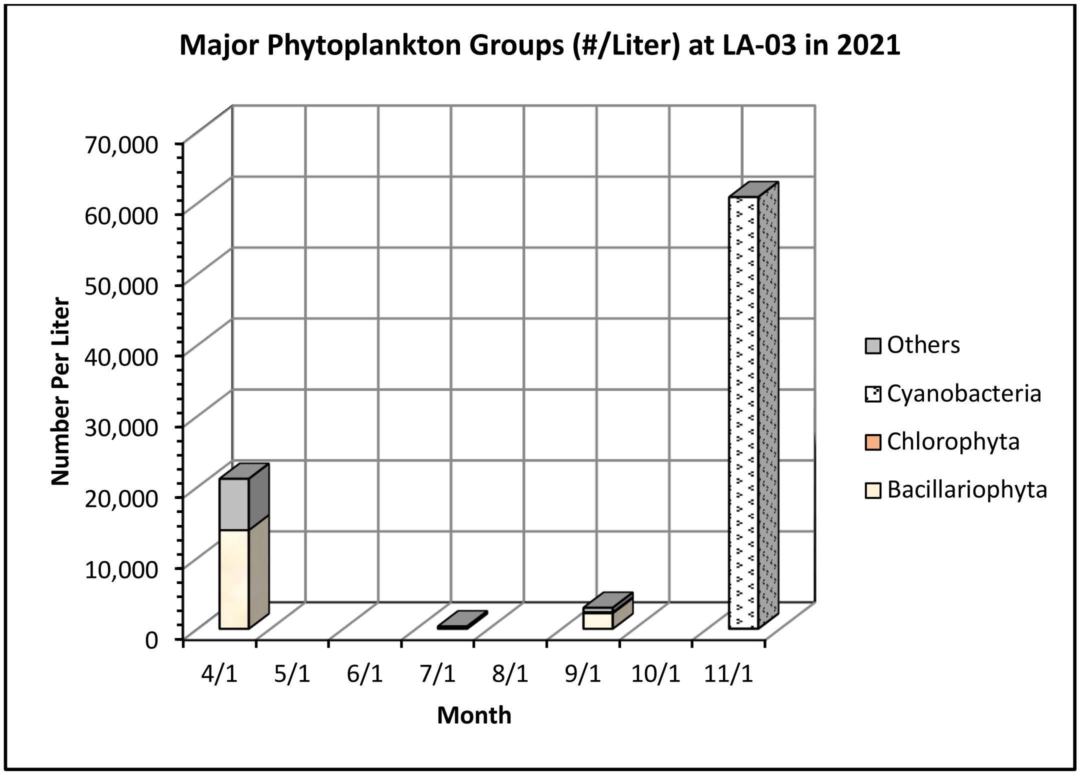
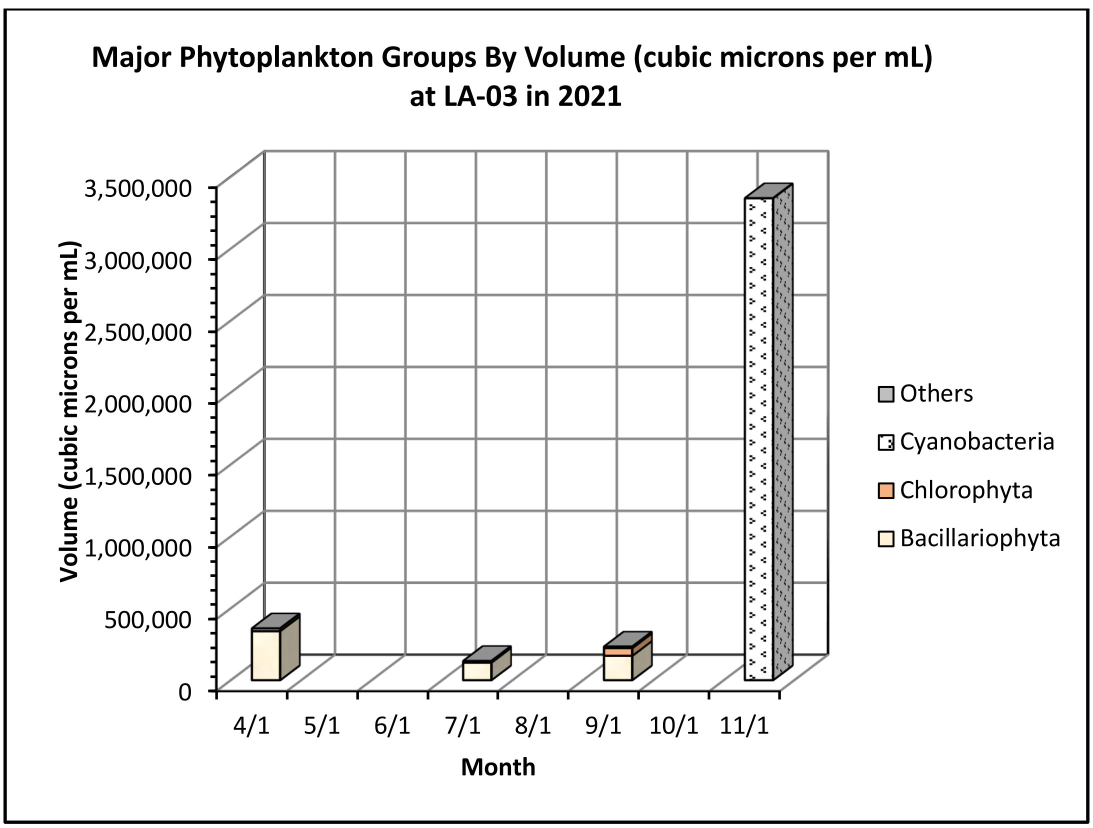



**Figure 9. Major Phytoplankton Groups at Lake Almanor, By Number/Liter and By Volume (cubic microns/milliliter), Station LA-03 in 2021**



Following the last sampling in November, Dr. Johnston was at REC. 2 area in Lake Almanor Country Club and noticed a large amount of algae around the boat ramp. She went home and analyzed the plankton samples and realized that a blue-green algal bloom was occurring in the lake. She registered the bloom on the California State Harmful Algal Blooms (HABs) website. Their satellite imagery showed a bloom spreading in the western basin (mywaterquality.ca.gov). Figure 10 below shows the approximate location of the bloom at three dates: October 31 (before our sample, but about a week after the rain event of 8 inches), November 8 (the day of our sample) and November 13 (about a week after our sample). The images are ten-day composites, so it is likely that our phytoplankton sample at LA-03 was still at the beginning of the bloom. Our sample had a an extremely large volume of Cyanobacteria, primarily *Dolichospermum sp. (*about 60,000 colonies per liter). This genus commonly occurs in Lake Almanor and often has large populations in the fall. The bloom continued through the month of December, 2021.

**Figure 10. Ten-Day Composite Satellite Images of HAB Bloom, Lake Almanor, October 31-November 13, 2021** (Redder pixels indicate a denser bloom at that location)

October 31, 2021

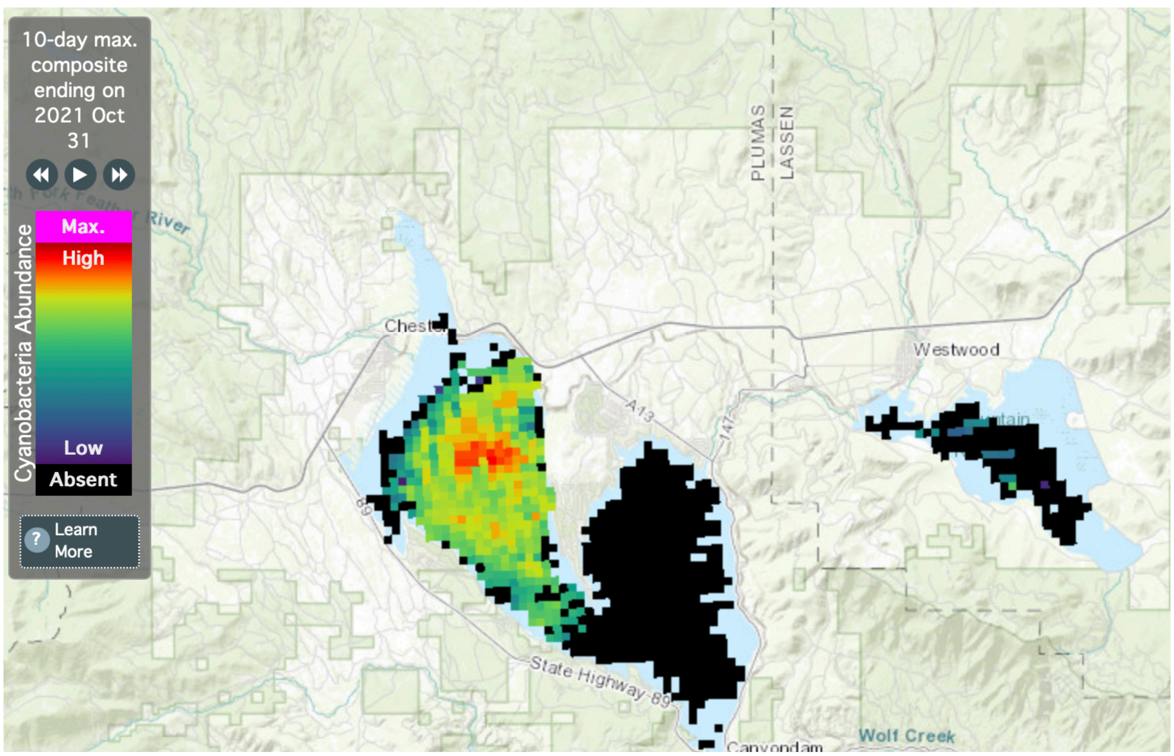
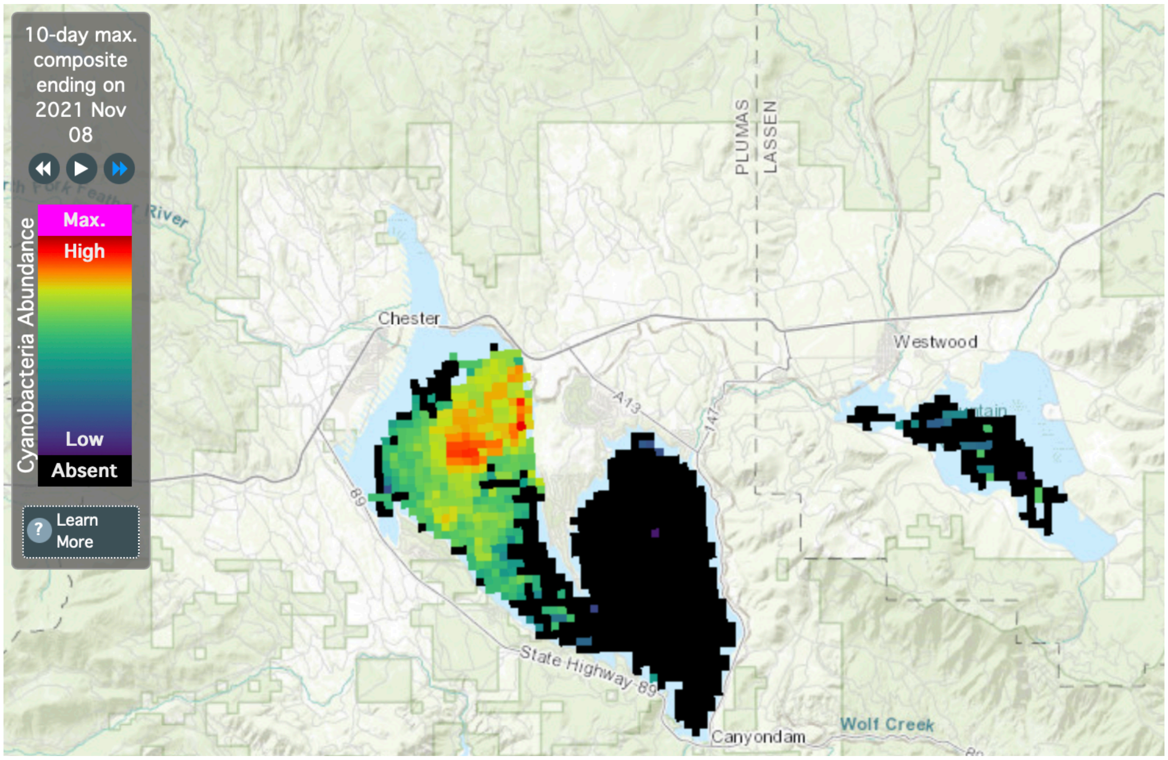


Figure 10 (cont.). **Ten-Day Composite Satellite Images of HAB Bloom, Lake Almanor, October 31-November 13, 2021** (Redder pixels indicate a denser bloom at that location)

November 8, 2021




November 13, 2021

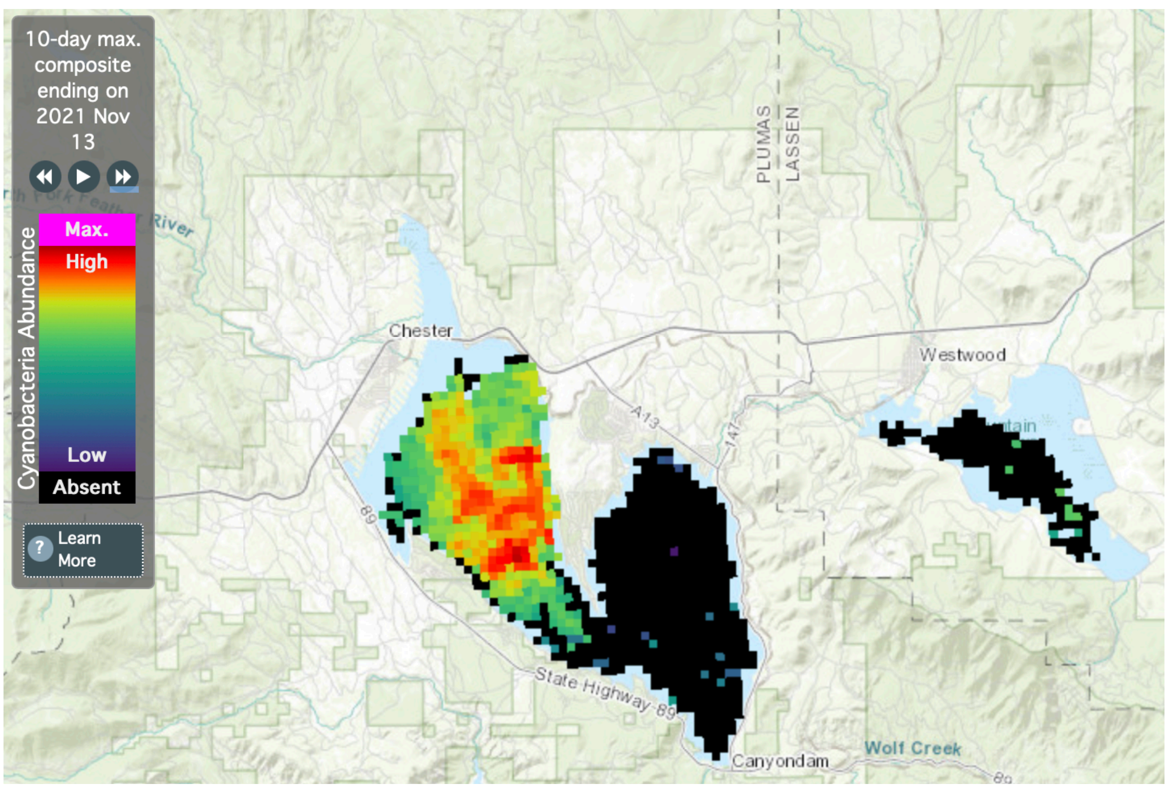


Figure 11 shows the mean and maximum amount of phytoplankton by volume at LA-02 and LA-03 from 2009 to 2021. (Please note that the vertical scale for the two stations is not the same.) The maximum has generally been in November, but we were not able to sample in November 2020. As a result, the amount for 2020 is not comparable to the other values. 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 and then increased considerably in 2021. 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 and 2021 that dilution did not occur.

With little to no spring runoff, LA-02 algal populations decreased in 2021, but LA-03 populations increased dramatically in November, 2021. It is possible that the fire retardant applied all along the western shoreline could have played a role in encouraging algal growth in the western basin. The fire retardant is Phos-Chek, which contains ammonium phosphate, a fertilizer. This is known to feed algal growth if applied on or near water bodies (See references in conclusion.) Along with the application of large amounts of fire retardant, there was a rain event in October that dropped eight inches of rain in a few days. This could have resulted in delivering fertilizer to the western basin and promoting the algal bloom. The fact that the 2021 bloom was considerably larger and longer lasting than the 2020 bloom supports this hypothesis.

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.

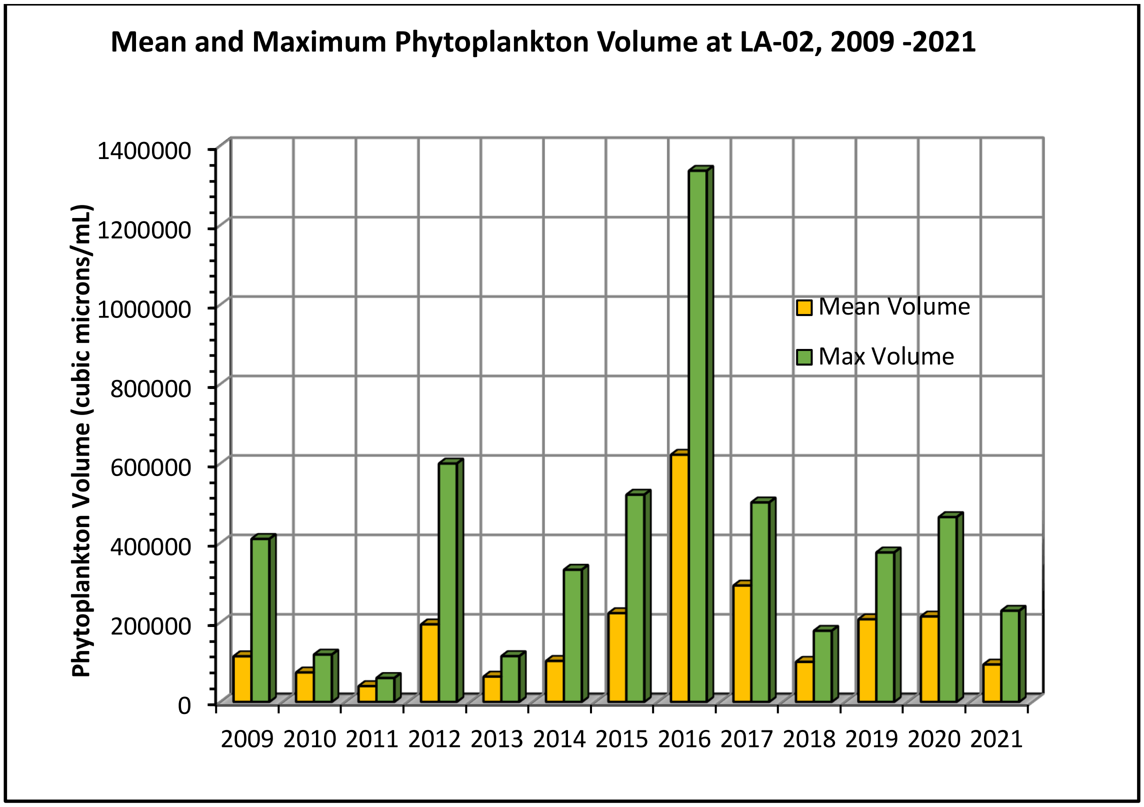
The assemblage of genera is characteristic of meso-trophic lakes.

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.

In 2021 populations were greatest in the spring at LA-02, dominated by rotifers. At LA-03 the greatest population was in the fall, with numerous rotifers and copepods. So, in both cases, they were correlated with the algal abundance.

In 2021 zooplankton were about half as numerous as in 2020, perhaps because the phytoplankton populations were also less abundant. Variation 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 -2021**



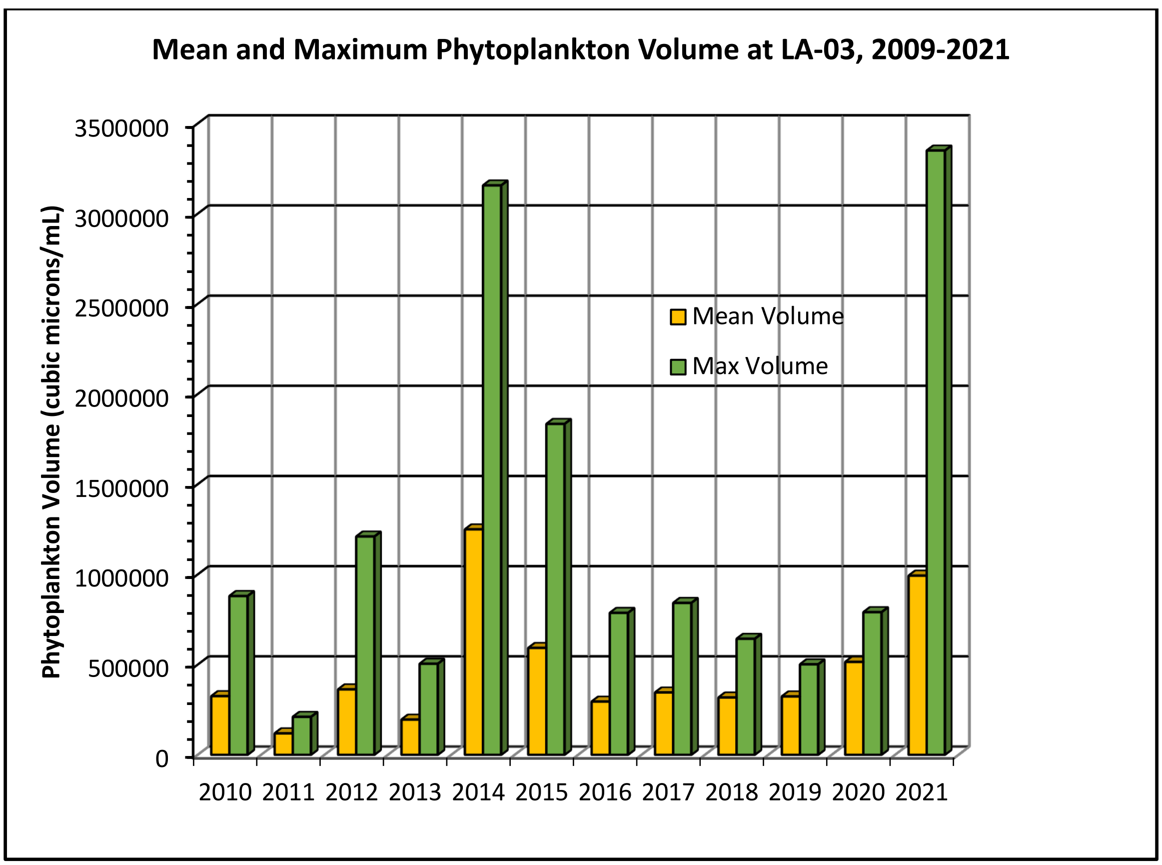



Figure 12. Major Zooplankton Groups (#/Liter) at Lake Almanor, Station LA- 02, 2021

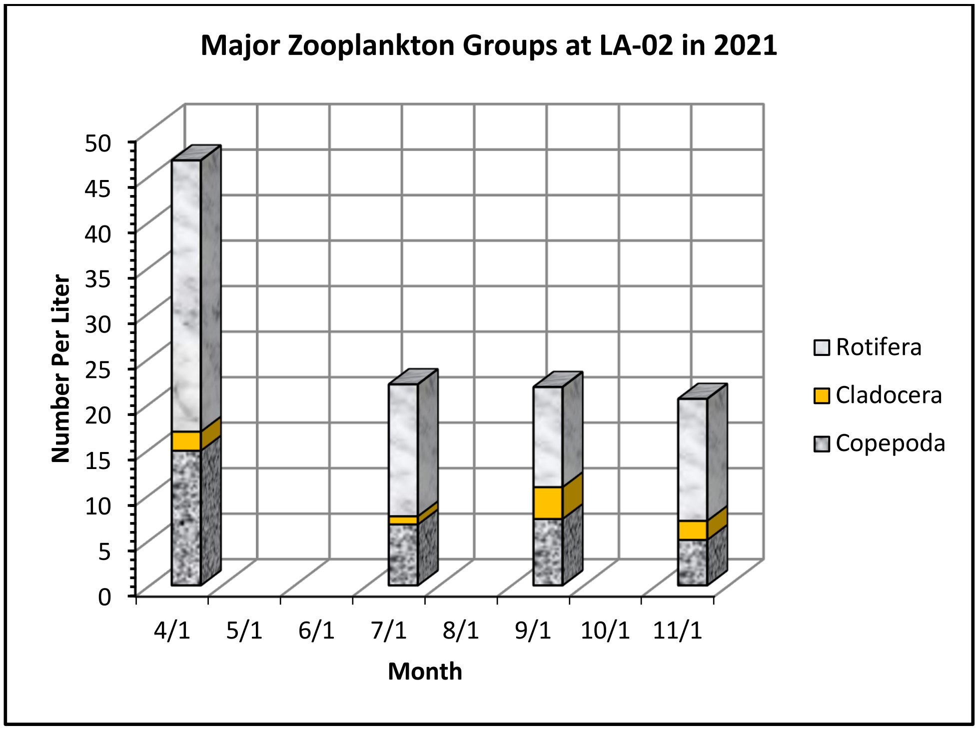
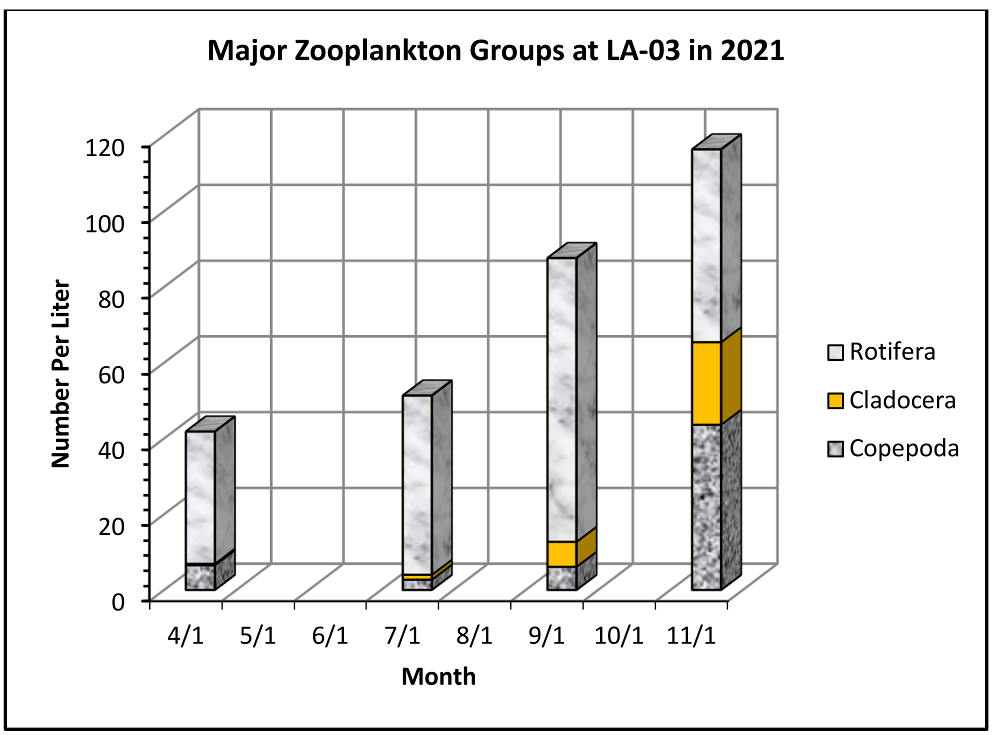



Figure 13. Major Zooplankton Groups (#/Liter) at Lake Almanor, Station LA-03, in 2021



## 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 begun in 2009 by Johnston and McMurtry and continued 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 snow. (Source: Western Regional Climate Center: wrcc.dri.edu)

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 and 2021 were very dry years. Precipitation as rain totaled only 10.75 inches from January to June in 2020 and 11 inches in 2021 compared to the mean of about 20 inches. This resulted in the establishment of thermal stratification early in the summer and its persistence through September. Oxygen was decreasing in the hypolimnion by the middle 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-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. Less inflow from tributaries into the eastern basin has resulted in lower algal abundance at LA-02.

There is a strong possibility that the blue-green algal bloom in the western basin was supported by runoff containing fire retardant along the western shore. Although a bloom did occur in 2020, this bloom was much larger and longer. It corresponded with the occurrence of a rain event of 8 inches in late October 2021. The effect of Phos-Chek (ammonium phosphate) as a fertilizer in aquatic ecosystems is well documented and is known to trigger algal blooms. (See "Fire

retardant use explodes as worries about water, wildlife risk grows." Weiser, Matt. The New Humanitarian, November 27, 2017. https://deeply.thenewhumanitarian>2017/11/27>
Also, "We're dumping loads of retardant chemicals to fight wildfires. What does it mean for wildlife?" Spanne, Autumn. Environmental Health News, September 27, 2021. https://www.ehn.org>fire-retardant-spray-wildfire-wild...

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. The Dixie Fire has added a new set of variables to the ecosystem and we anticipate that its impacts will be considerable in the watershed for many years. Hopefully, a similar program of monitoring can be continued in 2022. 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.