TAHOE: STATE OF THE LAKE REPORT 2018

UC DAVIS
Tahoe Environmental Research Center

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INTRODUCTION

The University of California, Davis has conducted continuous monitoring of Lake Tahoe since 1968, amassing a unique record of change for one of the world's most beautiful and vulnerable lakes.

In the UC Davis Tahoe: State of the Lake Report, we summarize how natural variability, long-term change, and human activity have affected the lake's clarity, physics, chemistry, and biology. We also present the data collected in 2017. While Lake Tahoe is unique, the forces and processes that shape it are the same as those acting in most natural ecosystems. As such, Lake Tahoe is an indicator for other systems both in the western United States and worldwide.

Our goal is to explore this complexity and to use the knowledge gained to provide the scientific underpinnings for ecosystem restoration and management actions. Choosing between management options and implementing them is the role of management agencies that need to take into account a host of other considerations. This annual report is intended to inform non-scientists about variables that affect lake health. Previously, only one indicator of Lake Tahoe's health status was widely reported: the annual clarity (often called the Secchi depth, after the instrument used to collect the clarity data). In this report we publish many other environmental and water quality factors that provide a more complete assessment of the lake's condition.

This report sets the context for understanding the changes that are seen from year to year and those that are observed over longer time scales. Is Lake Tahoe continuing to warm? Are the inputs of algal nutrients to the lake declining? How do extreme events play into the long-term trends? And, of course, how do all these changes affect the lake's famous clarity? We also present updates on some of our current research. New research results highlight some of the most exciting findings of work that is still in progress, and will be reported on fully in the months and years to come.

The data we present are the result of efforts by a great many scientists, engineers, students, and technicians who have worked at Lake Tahoe throughout the decades since sampling commenced. I would, however, like to acknowledge (in alphabetical order) the contributions of Brant Allen, Nancy Alvarez, Karen Atkins, Brandon Berry, Liz Bronson, Mike Bruno, Tom Burt, Luciana Cardoso, Sudeep Chandra, Bob Coats, Zack Coats, Richard Cobb, Kenneth Easter, Alex Forrest, Charles Goldman, Cordie Goodrich, Scott Hackley, Breanne Harris, Tina Hammell, Bruce Hargreaves, Alan Heyvaert, Simon Hook, Camille Jensen, Yufang Jin, Amelia Jones, Kyungwoo Lee, Jack Lewis, Christine Limon, Anne Liston, Patricia Maloney, Elisa Marini, Jasmin McInerney, John Reuter, Bob Richards, Gerardo Rivera, Derek Roberts, Steve Sadro, Goloka Sahoo, Heather Segale, Katie Senft, Steven Sesma, Sheri Smith, Lidia Tanaka, Raph Townsend, Alison Toy, Aaron Vanderpool, Shohei Watanabe, Sara Wilson, and Andy Wong to this year's report. In particular, Shohei Watanabe was responsible for the majority of the data analysis and Alison Toy led the compilation of the final report.

Funding for the actual data collection and analysis has come from many sources over the decades. While many additional water quality variables could be tracked, funding ultimately limits what we measure and report on. Current funding for the long-term monitoring and analysis is provided by the the California Tahoe Conservancy, Lahontan Regional Water Quality Control Board, Tahoe Regional Planning Agency, U.S. Geological Survey, and UC Davis.

Funders for current projects include the following: California Tahoe Conservancy, Institute for Museum and Library Services, Nevada Department of Tourism and Cultural Affairs, Nevada Division of Environmental Protection, Nevada Division of State Lands, Tahoe Fund, and Tahoe Truckee Community Foundation.

Our monitoring is frequently done in collaboration with other research institutions and agencies. In particular, we would like to acknowledge the Desert Research Institute (DRI), the National Aeronautics and Space Administration (NASA), the Tahoe Resource Conservation District (TRCD), the U.S. Forest Service (USFS), the U.S. Geological Survey (USGS), and the University of Nevada, Reno (UNR).

We are very proud to recognize the funding support for the actual production of this annual report from the following organizations: California Tahoe Conservancy, Incline Village Waste Not Program, Lahontan Regional Water Quality Control Board, Lake Tahoe Marina Association, League to Save Lake Tahoe, Nevada Division of Environmental Protection, Parasol, Tahoe Fund, Tahoe Lakefront Owners Association, Tahoe Regional Planning Agency, and Tahoe Water Suppliers Association. We sincerely thank these organizations for their dedication in supporting science to save the lake.

Sincerely,

Geoffrey Schladow, director
UC Davis Tahoe Environmental Research Center
291 Country Club Drive
Incline Village, NV 89451
gschladow@ucdavis.edu
(775) 881-7563

EXECUTIVE SUMMARY

The long-term data set collected on the Lake Tahoe ecosystem by the University of California, Davis and its research collaborators is an invaluable tool for understanding ecosystem function and change. It has become an important guide for responsible management by elected officials and public agencies tasked with restoring and managing the Tahoe ecosystem. This is, in large part, because it provides an independent basis for assessing the progress toward attainment of Tahoe's restoration goals and desired conditions; scientific assessment of how elements of the system are evolving in response to large-scale drivers; and builds our shared understanding of the natural processes that drive the ecosystem.

The UC Davis Tahoe Environmental Research Center (TERC) is constantly using new approaches to enrich the long-term data record for Lake Tahoe. These include real-time measurements at over 25 lake stations; long-term assessment of 84 forest plots at varying elevations; remote-sensing from autonomous underwater vehicles, satellites, helicopters, and aerial drones; and the deployment of a suite of numerical models. Chosen approaches focus on quantifying changes that are happening and understanding what actions and measures will be most effective for control, mitigation, and management.

This annual *Tahoe: State of the Lake Report* presents data from 2017 in the context of the long-term record. While we report on the data collected as part of our ongoing, decades-long measurement programs, we also include sections summarizing current research on important, emerging issues. These include: the dramatic change in Lake Tahoe's clarity that occurred in 2017; a new ecology-based approach to restoring lake clarity; an intensive study of the lake's nearshore region to characterize both the physical processes that take place there and their impacts on attached algae; the health of the basin's forests and actions to imbue resilience to forest restoration efforts; some initial indications of how climate change will impact air temperature, precipitation, and soil dryness; and a comparative study initiated between Lake Tahoe and Lake Geneva, two lakes that were at the forefront of launching the field of limnology in the 19th century.

The clarity of Lake Tahoe declined in 2017 to its lowest level since regular measurements commenced in 1968. The data suggest that this was due to the combined effects of the accumulation of sediment during a five-year drought that ended with a winter of record high precipitation levels that extended late into the spring. More sediment was washed into the lake in 2017 than the combined amounts from the previous five years. The clarity conditions were particularly poor in late summer and fall when the unusually warm lake conditions may have trapped sediment-reducing fine particles near the lake surface. Indications from clarity readings in the first half of 2018 are that the clarity is back in its normal range, and that the result for 2017 can be considered to be an outlier. However, 2017 highlighted the reality that extreme climatic and hydrologic events will become more common

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[1]"Previous year" for some parameters means data collated in terms of the water year, which runs from October 1 through September 30; for other parameters, it means data for the calendar year, January 1 through December 31. Therefore, for this 2018 report, water year data are from Oct. 1, 2016 through Sept. 30, 2017. Calendar year data are from Jan. 1, 2017 through Dec. 31, 2017.

EXECUTIVE SUMMARY

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in the future. The adequacy and the extent of present monitoring and predictive capabilities need to be reviewed and upgraded. It is these extreme years that can provide the information most needed to plan future restoration and infrastructure projects.

Efforts to restore Lake Tahoe's clarity have focused on land-use management. The improvements in winter clarity over the last 10 to 20 years are evidence that this approach has been working. However, recent research has shown that a parallel ecological approach may accelerate progress. Test data show that the removal of the invasive Mysis shrimp results in the return of the native zooplankton Daphnia, coinciding with many meters of clarity improvement in both summer and winter. A pilot project in Emerald Bay is testing whether Mysis numbers can be reduced sufficiently to sustain such a clarity improvement.

Project UPWELL was a unique, philanthropy-funded collaboration between researchers from UC Davis, Stanford University, and the University of British Columbia. By pooling equipment, it was possible to install a curtain of almost 100 instruments to measure the enormous internal waves that transport nutrients from the depths of Lake Tahoe to feed the attached algae (periphyton) that cover the shoreline rocks. Currents, temperature, oxygen, and nitrate were measured for over two months to supplement the data from TERC's Nearshore Water Quality Network. Periphyton growing on artificial substrates were also measured to determine what limits growth.

Lake Tahoe's forests were stressed during the drought, making trees more prone to insect and pathogen attacks. Forest surveys undertaken in 2009 and 2017 (before and after the drought) show increased mortality in all three elevation zones (lower montane, upper montane, and subalpine). Mountain pine beetle was a significant cause of mortality in large stands of sugar pine in lower montane forests, particularly on the north shore. TERC's forest and conservation biology lab collected seeds from diverse sugar pine trees within the Lake Tahoe Basin that survived drought and mountain pine beetle attacks and are therefore likely more resilient. By germinating those seeds and rearing them in a new lathe house, 10,000 trees will be available to revegetate impacted stands on public and private lands. In future years, these conservation collections will be expanded to include other species.

Surveys of the forest have also shown the value of active forest management. Stands that received no forest treatments (thinning, prescribed fire, etc.) had much higher populations of mountain pine beetle compared to stands that received treatments.

Our climate change researchers are currently applying downscaled future climate projections to the Tahoe Basin. Using an ensemble of four models that capture the range of uncertainty, and assuming that the atmospheric carbon dioxide does not decline until the end of the century (called the RCP 8.5 scenario) temperatures could rise from 7 to 9 °F across the basin by the end of the century. Soil dryness,

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EXECUTIVE SUMMARY

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expressed as “climatic water deficit,” may increase by over 100 percent on the north and east parts of the basin. The impact of these changes on the lake and the other aquatic resources are the subject of ongoing research.

Knowledge of the circulating currents (or gyres) in Lake Tahoe is important for understanding how contaminants are moved around the lake. A new turbulence probe on the UC Davis autonomous glider “Storm Petrel” is currently being tested in Lake Geneva, Switzerland. Tahoe measurements in 2019 will form the basis of a comparative study between these two famous lakes.

The long-term trend shows rising air temperatures and a reduction in the number of days with below-freezing temperature. In 2017, monthly air temperatures were generally cooler than recent years during winter, but warmer during summer. In 11 out of 12 months, the monthly air temperatures were higher than the 1910-2017 average. Water Year 2017 was the second highest precipitation year with 68.9 inches, compared to the long-term average of 31.6 inches. January and February were particularly wet. This resulted in the lake level rising 5.7 feet, between January 1 and July 7, to within an inch of the top.

The volume-averaged lake temperature continues to increase. In 2017, the lake was slightly warmer than the previous two years, making it the warmest ever. The absence of deep mixing for the sixth year in a row contributed to the storage of heat. The July surface water temperature was the warmest ever recorded at 68.4 °F, an astounding 6.1 °F above the 2016 value due largely to unusually low wind speeds. The length of the stratified season (the period of time when the lake exhibits summer-like water temperature conditions) also continues to increase. Since 1968, this period has increased by 26 days. In 2017, peak snowmelt occurred on April 25, over 5 weeks later than the previous year. This was due to the extremely large snowpack and an extended precipitation season.

The input of stream-borne nutrients (nitrogen and phosphorus) and suspended sediment were all at record levels in 2017 due to the high streamflow. The suspended sediment load from the Upper Truckee River exceeded the load for the previous five years. The levels of nutrients building up at the bottom of the lake continue to rise, in large part due to the absence of deep mixing. This internal cycling is an important source of nutrients for phytoplankton growth, particularly nitrate. Phosphorus, which was at its lowest level in 2009, has been increasing steadily over the last eight years. It is currently at levels not seen since the 1980s. However, as in the case of nitrate, a large factor in this increase is the absence of deep mixing.

Biologically, the primary productivity of the lake has increased dramatically since 1959. In 2017, there was an increase in primary productivity to 237.2 grams of carbon per square meter. By contrast, the biomass (concentration of algae in the lake) has remained remarkably steady over time. The annual average concentration for 2017 was 0.67 micrograms per liter. For the period of 1984-2017,

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EXECUTIVE SUMMARY

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the average annual chlorophyll-*a* concentration in Lake Tahoe was 0.70 micrograms per liter. From an abundance viewpoint, diatoms were the most common algal group (40 percent of the cells). Whereas the small *Cyclotella gordonensis* diatom, which has proliferated in recent years and previously contributed to low summer clarity, was present in extremely low concentrations for 2017.

The attached algae around the shoreline were also present in relatively low concentrations, particularly when measured at the standard height of 1.6 feet below the water surface. However, this is misleading as the rapid water level rise meant that the measurements were taken on rocks that had been out of the water weeks earlier. The measurements at 3.3 feet depth showed significantly heavier growth. Highest growth was generally at the more urbanized locations.

For the 12th straight year, TERC continued to expand its education and outreach offerings. During 2017, TERC recorded 14,204 individual visitor contacts. The majority represented student field trips and visitors to the Tahoe Science Center at Incline Village.

This report is available in its entirety on the UC Davis Tahoe Environmental Research Center website (http://tahoe.ucdavis.edu/stateofthelake/).

ABOUT LAKE TAHOE AND THE TAHOE BASIN

- Maximum depth: 1,645 feet (501 meters), making it one of the deepest lakes in the world and second deepest lake in the United States
- Average depth: 1,000 feet (305 meters)
- Lake surface area: 191 square miles (495 square kilometers)
- Watershed area: 312 square miles (800 square kilometers)
- Length: 22 miles (35 kilometers)
- Width: 12 miles (19 kilometers)
- Length of shoreline: approximately 75 miles (120 kilometers)
- Volume of water: 39 trillion gallons
- The daily evaporation from Lake Tahoe (half a billion gallons) would meet the daily water needs of 5 million Americans
- Number of Secchi depth measurements taken at Lake Tahoe since 1967 is 2,020.
- The number of individual data points recorded in Lake Tahoe each year is 11,000,000 more or less.
- Number of inflowing streams: 63, the largest being the Upper Truckee River
- Number of large lakes worldwide with annual clarity exceeding Tahoe's: 0
- Number of outflowing streams: one, the Truckee River, which leaves the lake at Tahoe City, California, flows through Truckee and Reno, and terminates in Pyramid Lake, Nevada.
- Length of time it would take to refill the lake: about 600 years
- Average elevation of lake surface: 6,225 feet (1,897 meters)
- Highest peak in basin: Freel Peak, 10,891 feet (3,320 meters)
- Latitude: 39 degrees North
- Longitude: 120 degrees West

ABOUT THE UC DAVIS TAHOE ENVIRONMENTAL RESEARCH CENTER (TERC)

The UC Davis Tahoe Environmental Research Center (TERC) is a world leader in research, education, and public outreach on lakes and watersheds, providing critical scientific information to help understand, restore, and sustain the Lake Tahoe Basin and other systems worldwide. Since 1968, UC Davis has maintained the continuous scientific monitoring of Lake Tahoe, creating the foundation on which to base restoration and stewardship efforts.

TERC's activities are based at permanent research facilities in the Tahoe Basin and at the University's main campus in Davis, California, about 90 miles west of the lake.

Our main laboratories and offices are in Incline Village, Nevada, on the third floor of the Tahoe Center for Environmental Sciences building.

On the first floor, we operate the public Tahoe Science Center, an educational resource for K-12 students and learners of all ages.

In Tahoe City, California, we operate a field station (housed in a fully renovated, former state fish hatchery) and the Eriksson Education Center. Tahoe City is also the mooring site for our research vessels, the John LeConte and the Bob Richards.

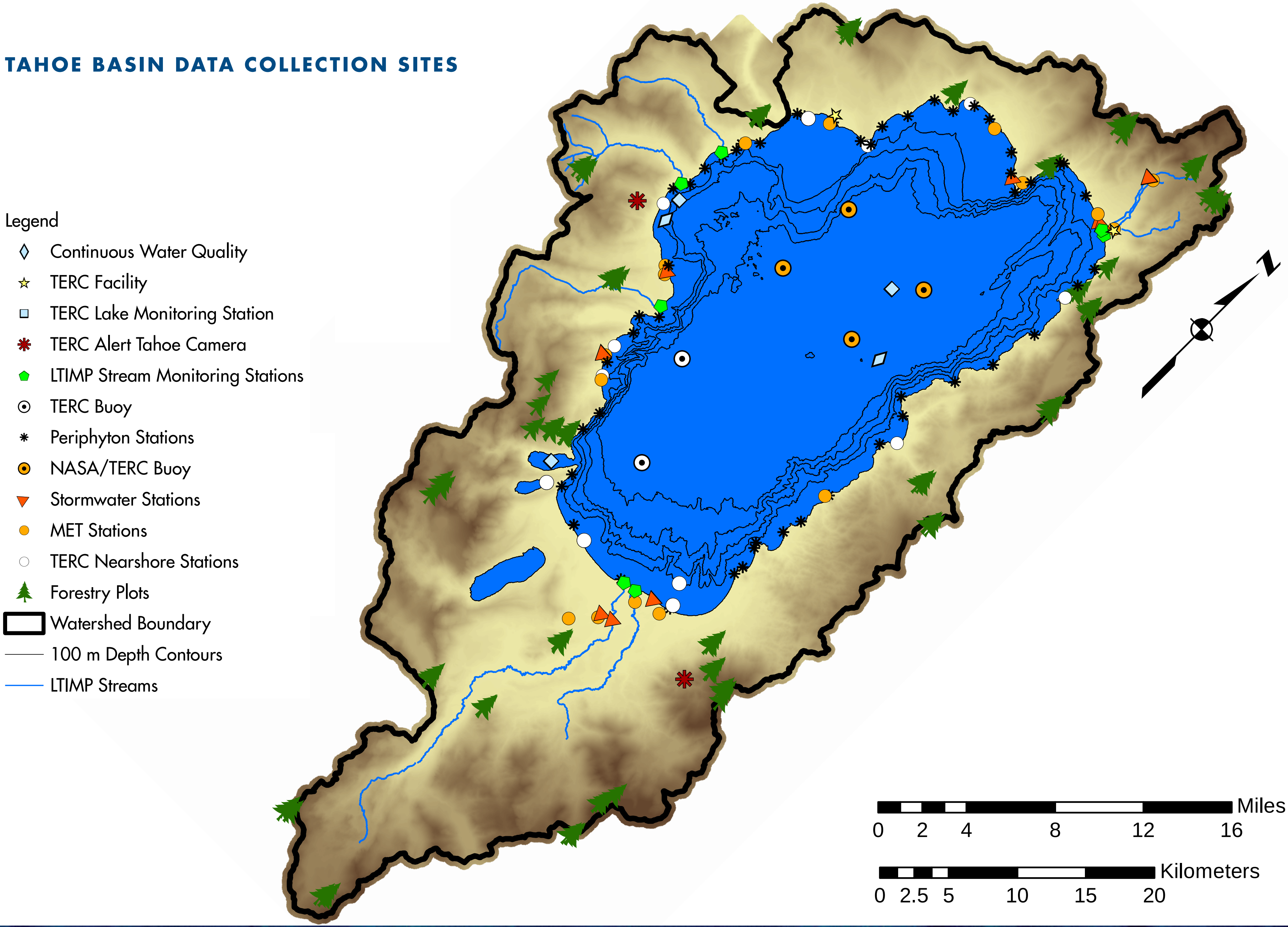
Our secondary laboratories and offices are located on the UC Davis campus at the Center for Watershed Sciences and in Wickson Hall.

At locations throughout the basin, we have sensors continuously reporting on the health and well-being of the lake and its environs, as well as long-term monitoring sites distributed throughout the forests, streams, urban areas, as well as the lake itself. These assets, when fully combined make Lake Tahoe the smartest lake in the world.

Our website (http://tahoe.ucdavis.edu) has more information about our facilities and programs, including:

- Information for potential students, staff, faculty, research collaborators and visitors;
- Access to near-real-time data gathered by our growing network of sensors;
- An extensive list of over 600 Tahoe research publications;
- Exhibits and events at the Education Centers; and
- Information about supporting our research and learning programs.

TAHOE BASIN DATA COLLECTION SITES



TAHOE: STATE OF THE LAKE REPORT 2018

CURRENT RESEARCH

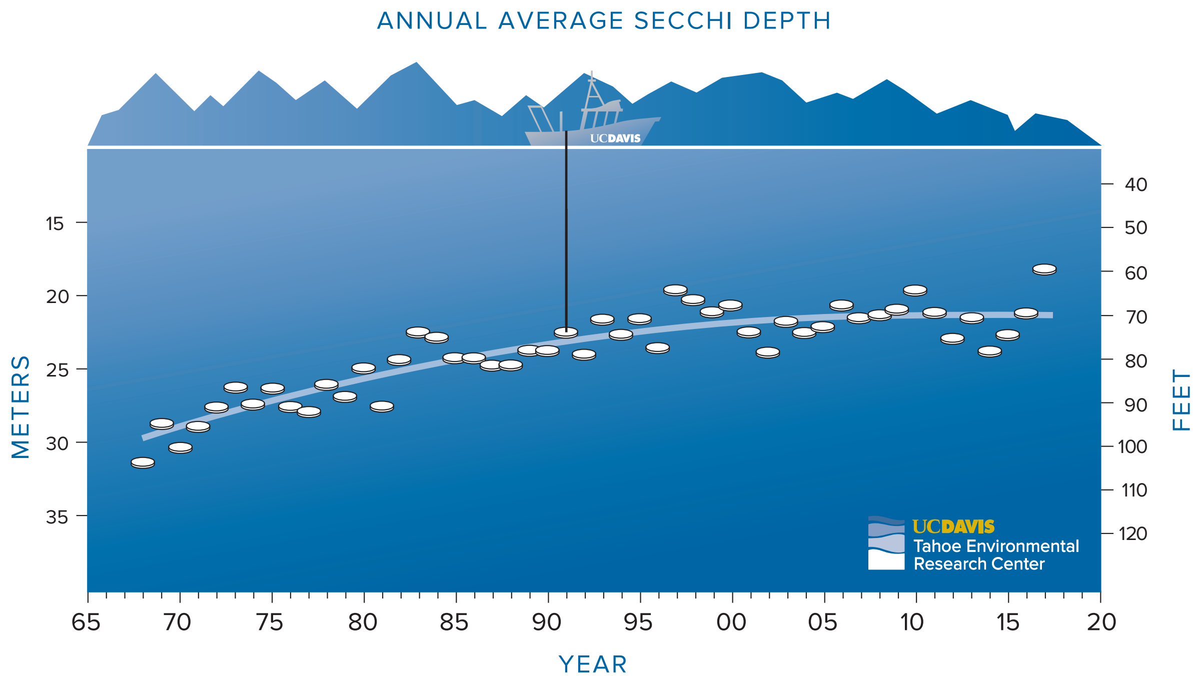
UC DAVIS
Tahoe Environmental
Research Center

CURRENT RESEARCH

Lake clarity in 2017

Annual average Secchi depth

In 2017, 26 individual clarity readings were taken from January through December 2017. The highest value recorded in 2017 was 90.2 feet on March 9, and the lowest was 47.6 feet on October 17 and December 19. The average clarity level for 2017 was 59.7 feet, a 9.5 foot decrease from the previous year, and the lowest level ever recorded. The long-term record of annual average clarity in Lake Tahoe is shown in the figure below.



Long-term annual average clarity in Lake Tahoe.

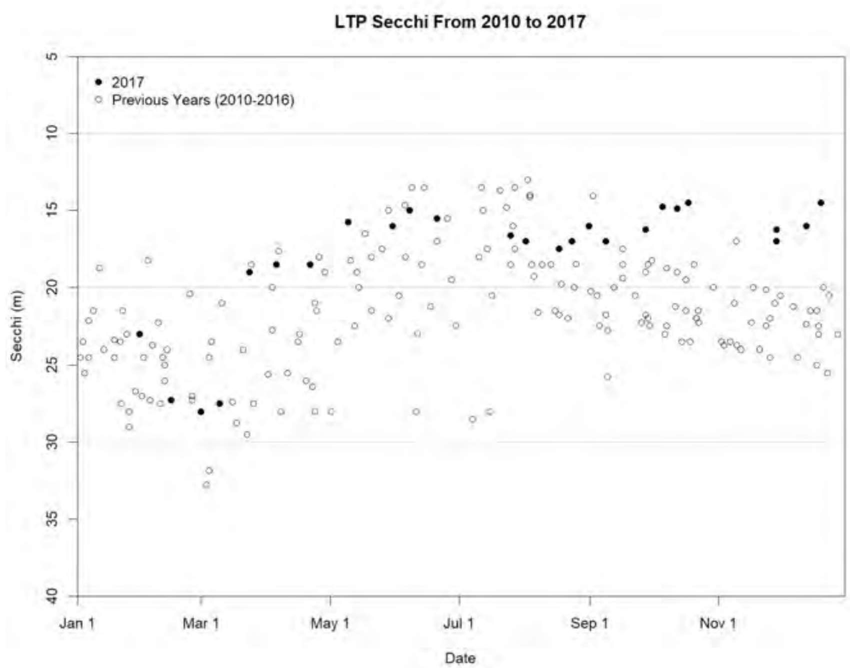
CURRENT RESEARCH

Lake clarity in 2017, continued

Individual Secchi depth measurements

Secchi depth measurements typically follow a seasonal pattern. In summer, clarity is usually at its lowest due to the impacts of spring runoff, warmer temperatures, and long hours of sunlight. As winter approaches, the surface layer of the lake mixes and deepens, diluting the upper layers with clearer, deep water. This clearing through the winter continues until the following spring when the pattern starts again. While no two years are identical, this pattern has long been established.

The year 2017 had a departure from this seasonal pattern. In the figure below, the individual values of Secchi depth are shown for the years 2010 through 2017. The 2010 to 2016 values are shown as hollow circles, while the 2017 values are filled circles. Until September 2017, values generally fell within the historical range. From September through the end of the year, the 2017 clarity values were 10 to 20 feet less than the historical range. It is the Secchi disk values in this four-month period of time that are responsible for the record low clarity of 2017. The usual winter clearing of the water column did not initiate before the end of December.



Individual Secchi depth measurements for 2010-2016 (hollow circles) and 2017 (filled circles).

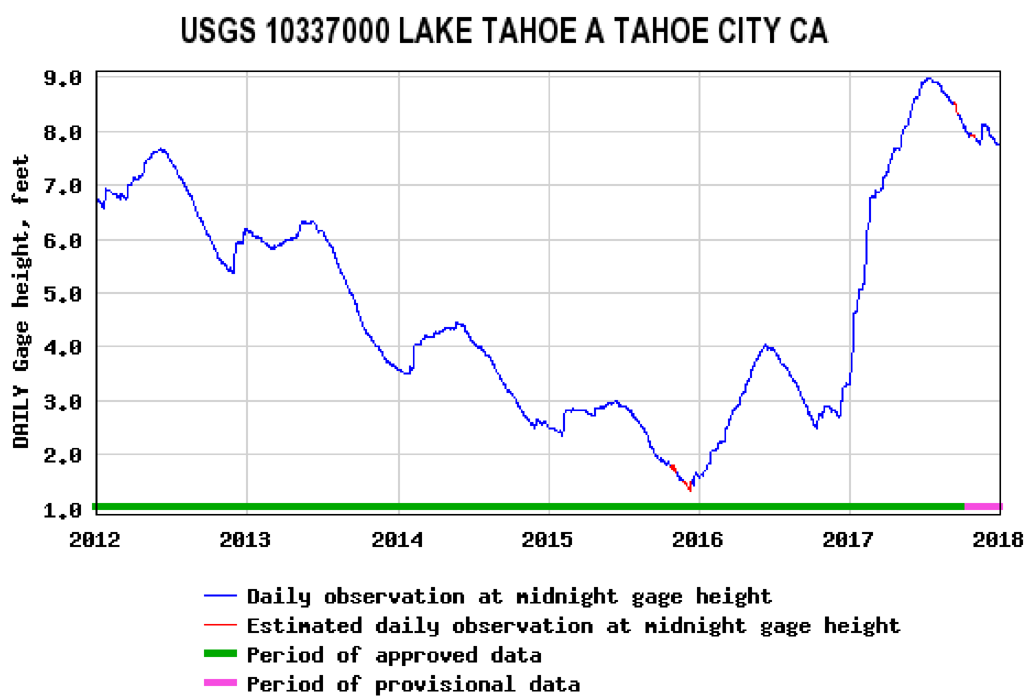
CURRENT RESEARCH

Lake clarity in 2017, continued

Lake level 2012-2018

Based on all the available data, a combination of two extreme climatic and hydrologic events was the primary cause of the unprecedented clarity conditions in 2017. The first key event was the record five-year drought that commenced in 2012. During this time, total precipitation, as well as the fraction of precipitation as snow, was particularly low in the northern Sierra Nevada.

The second key event was the record high precipitation that occurred in 2017 to officially end that drought. Water Year 2017 (Oct. 2016 - Sept. 2017) was California's second wettest and Nevada's seventh wettest in a 122-year record. A lake level rise of six feet in a six-month period in 2017 is shown below.



The overall drop in lake level during the drought years is evident, as is the rapid rise during 2017.

CURRENT RESEARCH

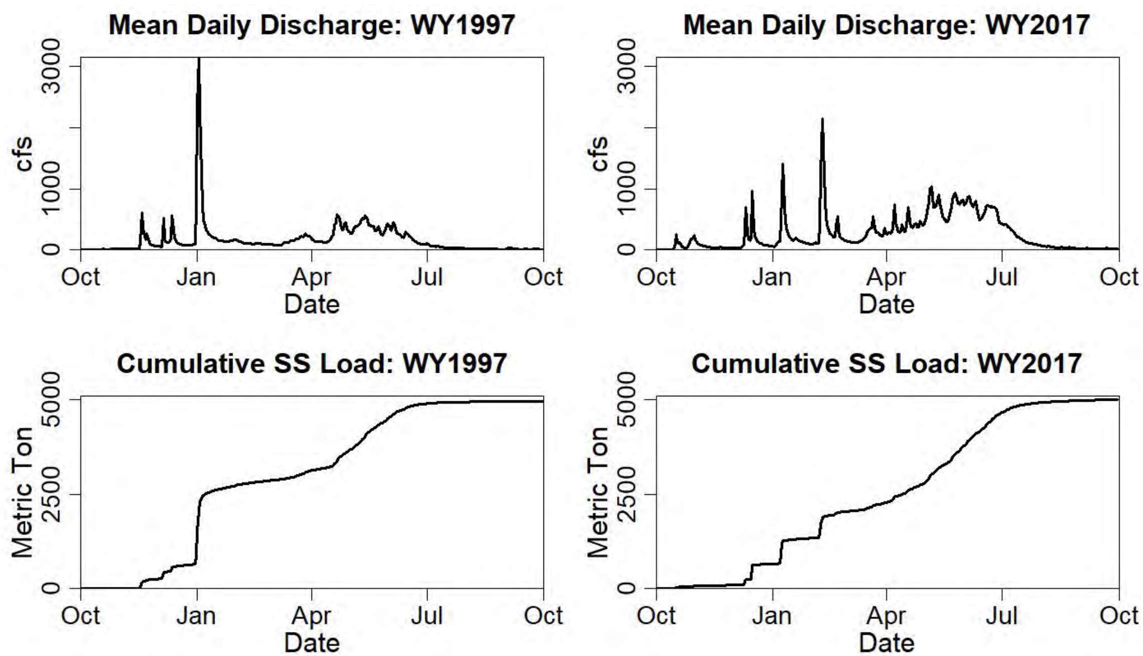
Lake clarity in 2017, continued

Comparing 1997 and 2017

A comparison of 1997, the previous lowest clarity year, and 2017 is illustrative. Upper panels of the figure below compare the flow of the Upper Truckee River for both these years. In 1997, major flooding downstream of Lake Tahoe occurred, as well as low clarity conditions. While 1997 had a larger peak flow, 2017 had more frequent peaks and a more sustained flow well into August.

The lower two panels show the cumulative sediment load and it is evident that 2017 and 1997 had similar loads. In 2017, the load came later in the year when surface warming had already commenced.

These plots are for the Water Year (October 1 – September 30), so 2017 does not include the sediment flux associated with the large rainfall and flow event in November 2017.



The Upper Truckee River in WY 1997 and WY 2017. Upper panels are discharge (cubic feet per second). Lower panels are the suspended sediment cumulative load from October 1st to September 30.

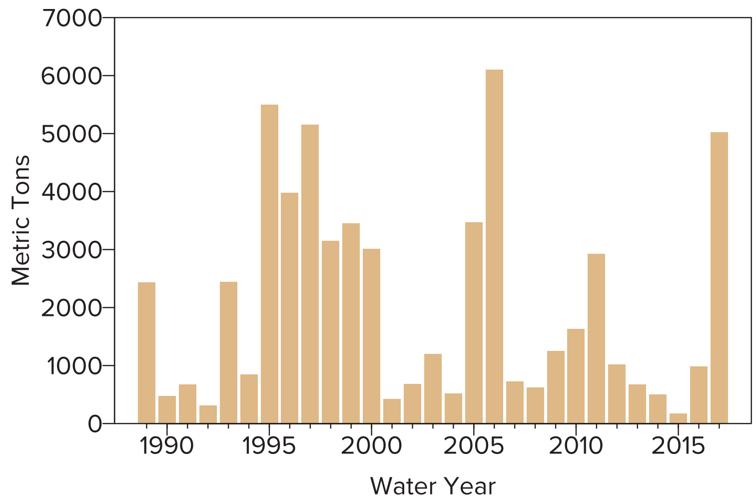
CURRENT RESEARCH

Lake clarity in 2017, continued

Suspended sediment load

The figure below indicates the annual suspended sediment load from the Upper Truckee River to the lake for each water year from 1989 through 2017. The 2017 sediment load in metric tons is larger than the sum of all of the sediment loads for the previous five years combined.

The loads were the direct result of the combination of the extreme drought (2012-2016) that was followed by an extreme wet year. The high and sustained flows in winter 2017 both mobilized accumulated sediment and caused additional erosion within the watershed (see picture below). High flows in 2017 extended into August. Additionally, there was also a late November storm (WY 2018) that added considerable sediment to the lake.



Annual suspended sediment load of Upper the Truckee River to the lake (metric tons).

Erosion gully on a fire road in the Tahoe watershed. Photo: H. Segale

CURRENT RESEARCH

Lake clarity in 2017, continued

Lake temperatures

The drop in the annual Secchi depth is the most obvious in-lake response to these climatic and hydrologic drivers. However, alterations to some of the physical processes in the lake due to a changing climate may have exacerbated the situation. The summer temperatures in 2017 were the warmest on record at Lake Tahoe, almost 4° F higher than the previous three years. As evident in the figure below, the elevated water temperatures extended into September 2017. This increase in the lake's thermal stratification would keep inflow waters and their sediment loads suspended in the upper part of the lake.

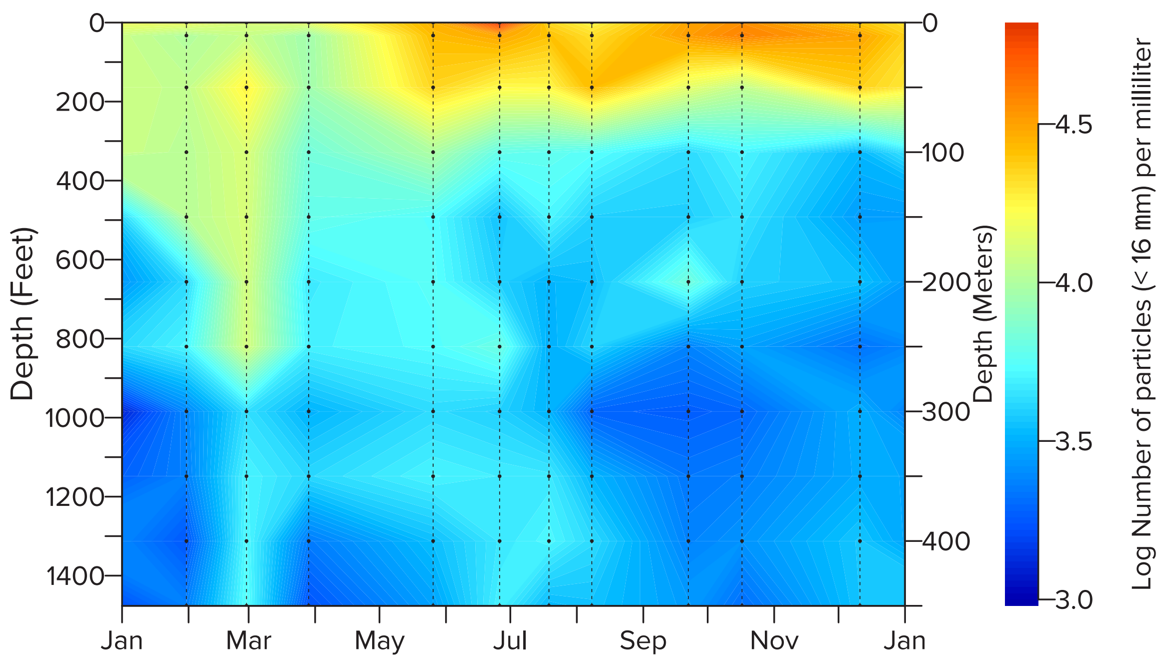
Surface water temperature in 2010 to 2016 (blue) and 2017 (red).

CURRENT RESEARCH

Lake clarity in 2017, continued

Fine sediment distribution

Fine sediment was kept in suspension in the upper part of the lake in the latter part of 2017 as shown in the figure below, where the concentration of fine particles (less than 16 micron diameter) are shown over the full lake depth for 2017. From May until the end of the year, a distinct, high concentration layer of fine particles, those causing the loss in clarity, is evident.



Fine sediment distribution in 2017.

CURRENT RESEARCH

Lake clarity in 2017, continued

Conclusion

In 2017, Lake Tahoe's low clarity was primarily the result of the coincidence of two extreme climatic and hydrologic events. There are likely other factors at play that are producing changes in the behavior and response of the lake, such as the warming of the lake and an alteration to the mixing regime due to the impacts of a changing climate. As such, the clarity value for 2017 may be seen as an anomalous value and should not be considered as representing the underlying long-term trend. Clarity data for the first six months of 2018 appear to confirm this, with the "regular" Lake Tahoe range of clarity readings returning.

Photo: N. McMahon

CURRENT RESEARCH

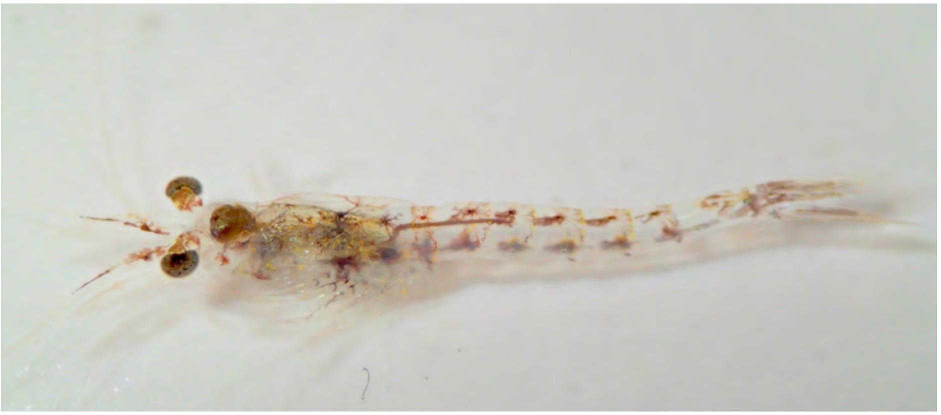
The nexus between invasive species and lake clarity

Pilot project in Emerald Bay

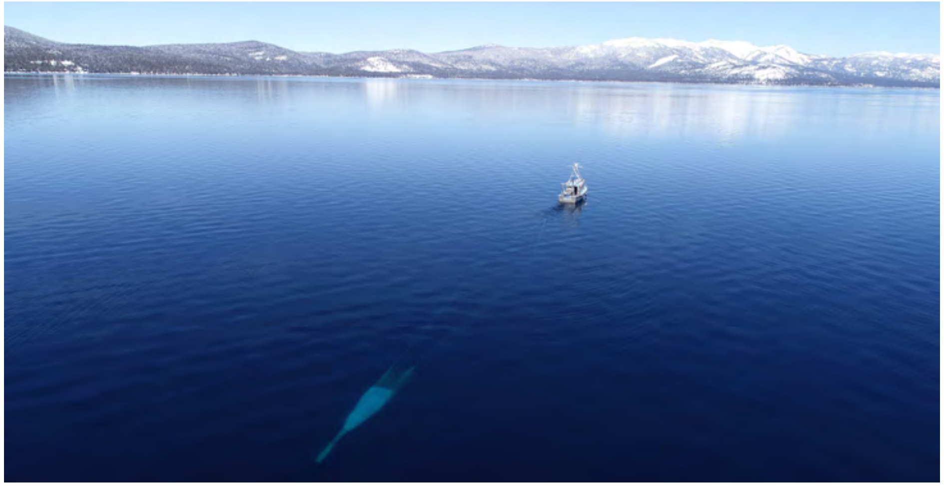
During a six-year study (2011-2016) funded by private donors, TERC researchers were able to chronicle a doubling of clarity in Emerald Bay. This clarity improvement was coincident with the disappearance of the introduced Mysis shrimp and the return of the native zooplankton, Daphnia.

This occurrence presented two intriguing questions. First, were Mysis shrimp having a large impact on clarity through their intense grazing of algae-eating Daphnia? The answer to that appears to be yes. Second, is it possible to harvest Mysis to the point where Daphnia can return throughout the lake and help with the restoration of lake clarity? These answers are being addressed in an ongoing pilot project.

The 2018-2020 pilot project is being funded by the California Tahoe Conservancy and the Nevada Division of Environmental Protection. It entails the location and quantification of the Mysis shrimp in Emerald Bay using echosounding technology, and then removal of Mysis using a custom-designed trawl net. Prior research has shown that the Mysis only have to be reduced by 50-70% for Daphnia to return.



A Mysis shrimp (actual length 1/2 inch).



A Mysis trawl net being tested in Lake Tahoe.

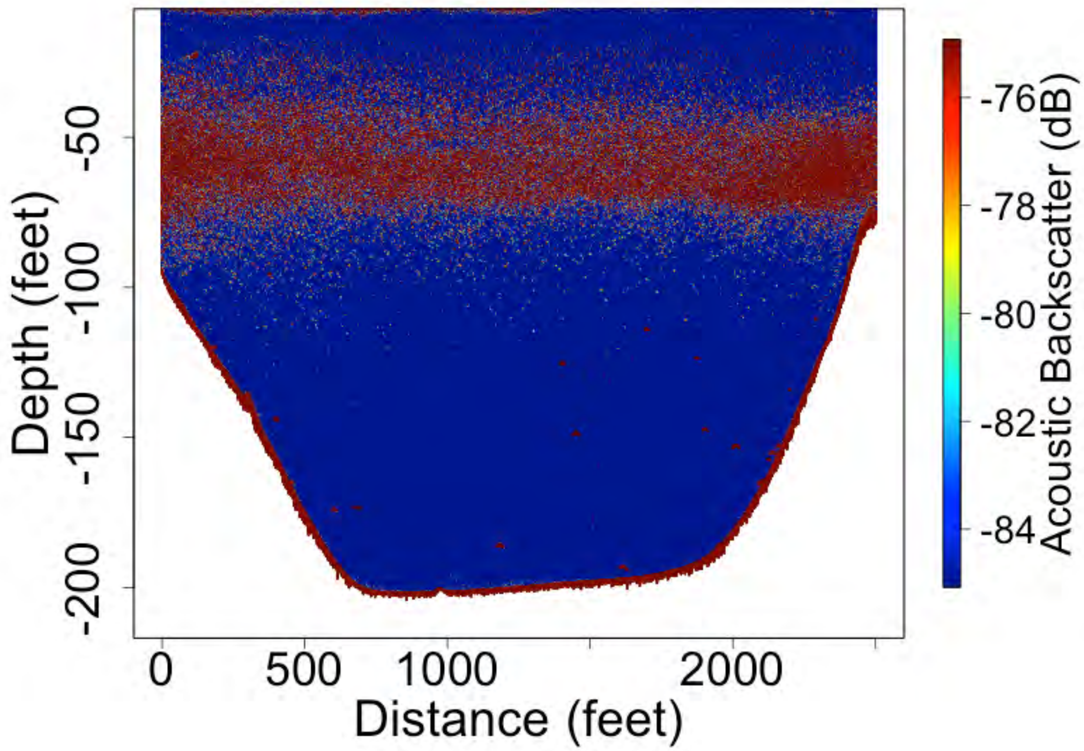
CURRENT RESEARCH

The nexus between invasive species and lake clarity, continued

Pilot project in Emerald Bay

While this sounds simple enough, the real challenge is presented by the daily, vertical migration that the Mysis shrimp undertake. To avoid predation, Mysis spend daylight hours on the lake bottom, and then swim toward the surface at night. The figure below produced by a Biosonics Echosounder shows the location of the discrete band of Mysis shrimp in Emerald Bay close to midnight. This image shows researchers precisely the depth at which the trawl net needs to be maintained in order to intercept the largest concentrations of Mysis shrimp during nighttime removal.

While undertaking this research is proving to be arduous, the potential it holds for restoring lake clarity is tremendous.



An echogram showing the location of a band of Mysis shrimp in Emerald Bay at midnight, The peak of their distribution is at a depth of 60 feet.

CURRENT RESEARCH

Project UPWELL

A collaboration on lake physics

In the spring of 2018, TERC graduate student Derek Roberts led a collaboration of researchers from UC Davis Civil and Environmental Engineering, Bodega Bay Marine Laboratory, Stanford University, and the University of British Columbia in a first-of-its-kind experiment in the nearshore region of a lake. The overarching goal of UPWELL (**U**pwelled **P**elagic **W**ater **E**xchange driving **L**ittoral **L**imnology) experiment, was to document the rising and falling of deep, nutrient-rich water on Lake Tahoe's west shore, and to ascertain its impact on the growth of algae on shoreline rocks (periphyton).

A 1.5 mile wide "measurement curtain" was installed in the lake from the shoreline toward the center of the lake. Pre-programmed instruments were deployed at seven moorings along the curtain, the shallowest near the shoreline at 7 feet and the farthest offshore at almost 900 feet depth. Temperature, current velocity, and dissolved oxygen measurements were taken every 30 seconds in order to resolve the upwellings that were driven by the strong spring winds. An autonomous, underwater glider was used to collect data along the shoreline to examine how variable the upwelling was along the west shore. Water samples were taken for nutrient concentrations before, during, and after upwelling events.

One of TERC's real-time Nearshore Water Quality Stations (right) with a newly installed Acoustic Doppler Anemometer (left) for turbulence measurements during UPWELL. The instruments were at 6.5 feet depth. Notice the heavy periphyton growth covering the rocks. Photo: B. Allen

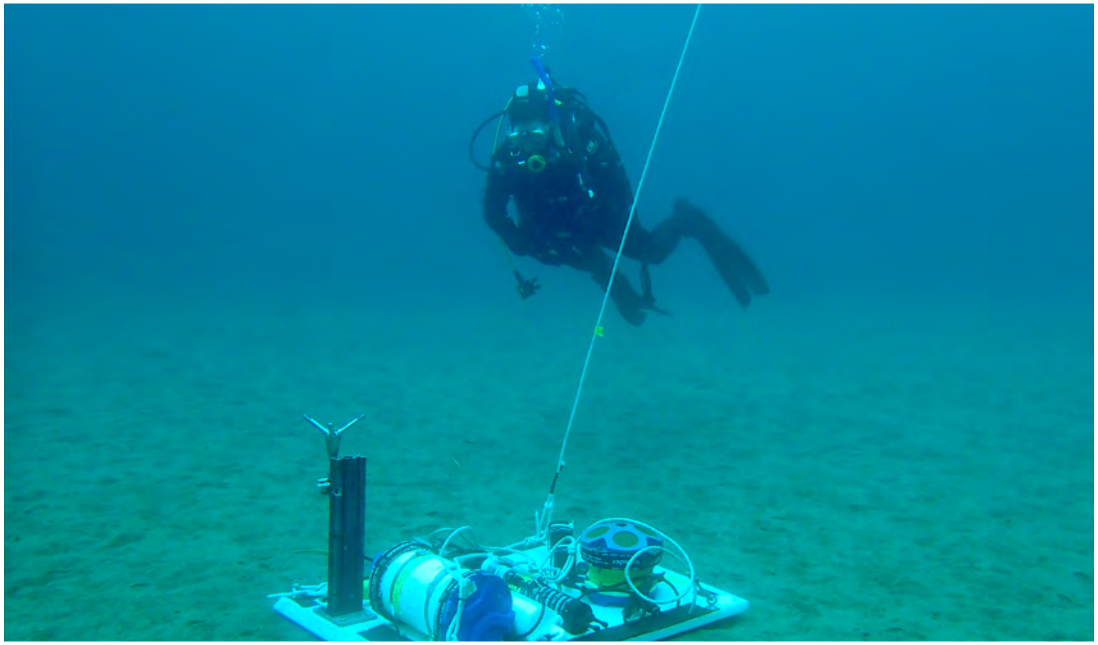
CURRENT RESEARCH

Project UPWELL, continued

A collaboration on lake physics

The experiment was motivated by data from the TERC Nearshore Network of water quality instruments. The network has shown that an upwelling event can bring water 1,000 feet deep, up to the surface of the lake, but how this process stimulates periphyton growth is not well understood.

The instruments were recovered and the data were downloaded in June 2018, and for the next six months these data will be analyzed in great detail. But even after an initial look, it is clear that our understanding of upwelling dynamics has been advanced. The experiment was able to document two major and two minor upwelling events. During the major events (May 31 and June 9), water from as deep as 500 feet rose to the surface along the west shore in a matter of several hours, dropping west shore temperatures to a frigid 40° F while the east shore remained a balmy 57° F. The upwelling ended with a rapid transition to a downwelling. After the wind died down, the cold water rushed back down the west slope of the lakebed and warm water from the east shore surged back across the lake surface. The speed of this water was in excess of 2 feet per second (1.5 mph).



A diver inspects UPWELL instruments at 33 feet depth. The Acoustic Doppler Current Profiler (right) measures currents between the bottom and the surface. The Acoustic Doppler Velocimeter (left) measures current turbulence near the bottom. Photo: B. Allen

CURRENT RESEARCH

Where does the nearshore end?

Periphyton diversity

Periphyton, or attached algae, can make lake rocks slippery and green. To help understand the distribution of conditions that favor growth, TERC graduate student Karen Atkins deployed growth surfaces for periphyton at different depths and distances from the shore. The periphyton colonized and grew on the surfaces during two months of spring, their peak growing season. At the end of the experiment, the taxonomy and quantity of algae was assessed from nearly 80 substrate surfaces.

An example of the diversity of the alga in a periphyton sample. Those shown here include *Golenkinia, Cyclotella*, *Gomphoneis*, and *Synedra*. The diameter of the view is approximately 0.6 mm. Photo: K. Atkins

CURRENT RESEARCH

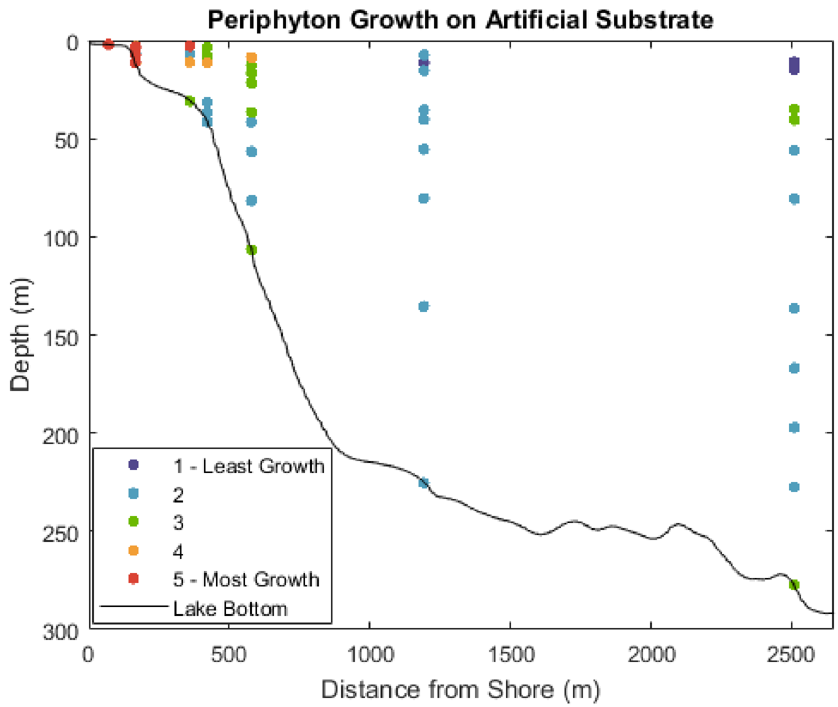
Where does the nearshore end?, continued

Periphyton growth

The outcome of a visual growth assessment is shown below. A rating of 5 indicates that the algae colonizing the substrate grew to a large mass that included filamentous strands. By contrast, surfaces exhibiting a rating of 1 had no visible algae and did not feel slick with a biofilm.

The results showed that periphyton growth is highest at the surface, toward the nearshore. The growth toward the surface was not unexpected, as the periphyton require light to photosynthesize. What was surprising was the Level 3 growth at depths down to 40 m (130 feet). Also surprising was the observation that conditions favoring high growth (Level 3 and 4) extend to over 500 m (1,650 feet) from the shore, corresponding to a depth at this west shore site of about 100 m (330 feet).

These findings help researchers better understand the sources of nutrients that are driving excess periphyton growth in the nearshore. With this information we can better advise agencies about the best strategies for managing the nearshore environment.



The dots indicate the locations of deployed growth surfaces coinciding with individual UPWELL instruments. The colors refer to the degree of growth.

CURRENT RESEARCH

Forest health

Ecology and evolution

The iconic sugar pine experienced mortality in large parts of the Tahoe Basin during the recent drought. What are some of the ecological and evolutionary consequences of this?

There will likely be shifts in species composition and structure, as well as genetic shifts.

Is climate change already exerting a selective pressure for drought resilient forest trees? In our reforestation of sugar pine, we purposefully chose those sugar pine trees that survived drought and avoided attack by mountain pine beetle.

Mountain pine beetles (pictured above) are responsible for killing sugar pine above Crystal Bay, Nevada (pictured to the right). Photos: P. Maloney

CURRENT RESEARCH

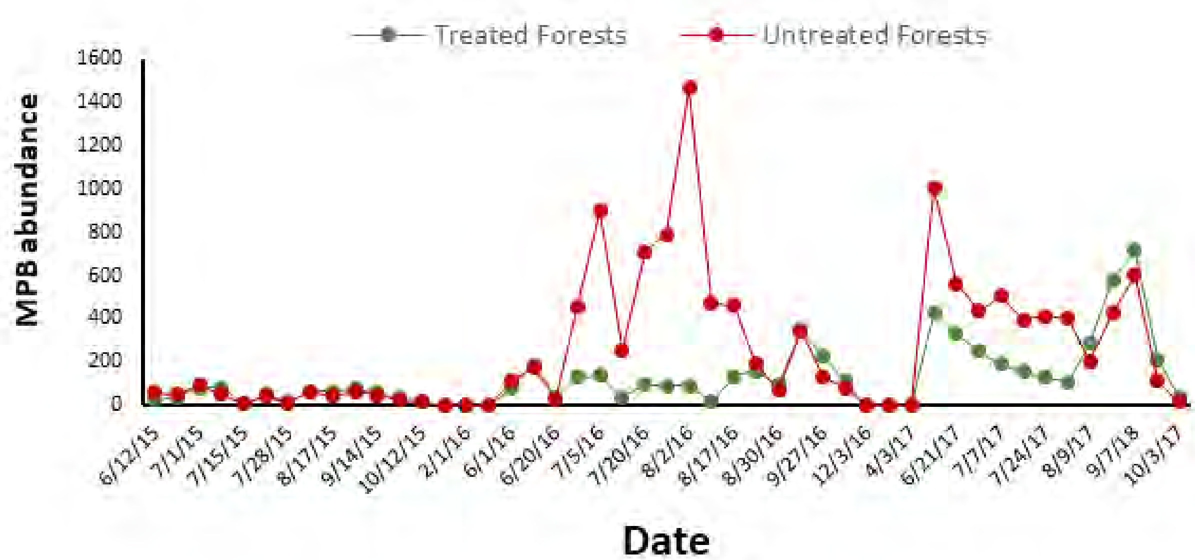
Forest health, continued

Host-bark beetle interactions

Mountain pine beetle (MPB) numbers (abundance) peaked in 2016 in the Lake Tahoe Basin. Bark beetles such as MPB are known to preferentially attack drought-stressed trees. Trees have a physical-based defense by producing resin or "pitching out."

Tree chemistry can either defend against bark beetle attack or aid beetles in locating a suitable host tree. When trees in the Sierra Nevada are drought stressed, they can emit chemicals such as ethylene that signal tree vulnerability when detected by MPB. TERC's forest biology lab is exploring the relationships between tree physiology, water-use efficiency, and susceptibility to MPB. Preliminary findings show that sugar pine trees that are more water-use efficient, and perhaps better adapted to drought, survived the recent MPB outbreak. In contrast, those sugar pines killed by MPB utilized water less efficiently and were most susceptible to MPB attack.

Forest surveys have shown the value of active forest management. Stands that receive no treatments such as thinning or prescribed fire had much higher numbers of MPB compared to stands that received treatments.



The impact of forest treatments on the abundance of MPB.

A sugar pine "pitching out" a mountain pine beetle. Drought-stressed trees are limited in their ability to do this. Photo: P. Maloney

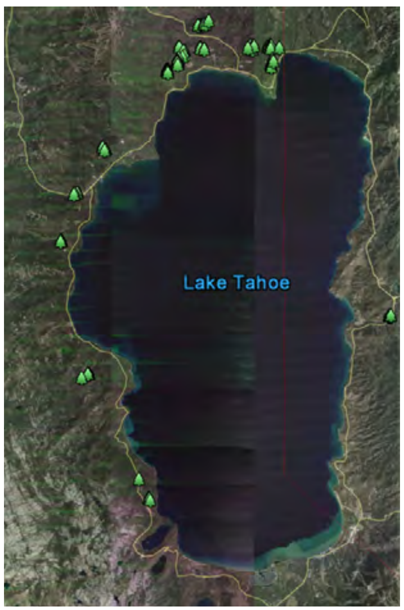
CURRENT RESEARCH

Forest health, continued

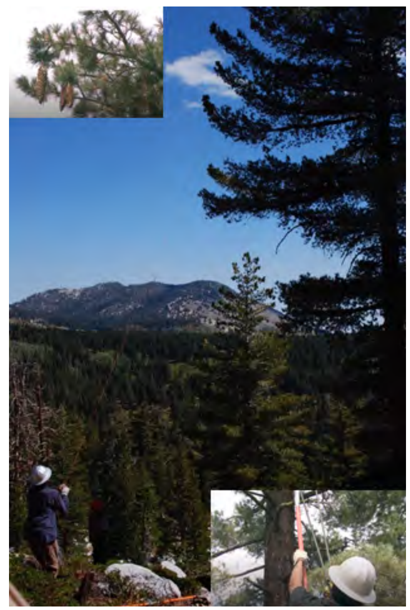
Reforestation

One solution to drought-mediated mortality is to reforest stands for bark beetle outbreak resilience. Despite high levels of sugar pine mortality, there were numerous surviving sugar pine trees on the north shore of the Lake Tahoe Basin. In September 2017, TERC's forest and conservation biology lab collected from 100 local and diverse seed sources mainly on the North Shore of Lake Tahoe. The seeds were germinated at the USDA Forest Service Placerville Nursery. The seedlings will be relocated to our Tahoe City Field Station in spring 2019.

Sugar pine reforestation will allow us to improve sugar pine population and facilitate sugar pine regeneration in mountain pine beetle impacted stands. This work is supported by the Tahoe Fund and the California Tahoe Conservancy.



Sites of seed collections.



Collecting cones at Incline Lake. Photo: P. Maloney

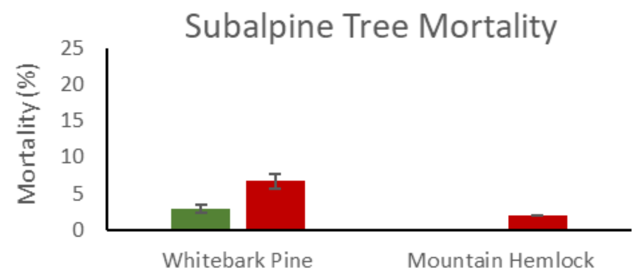
Sugar pine seedlings at Placerville nursery. Photo: P. Maloney

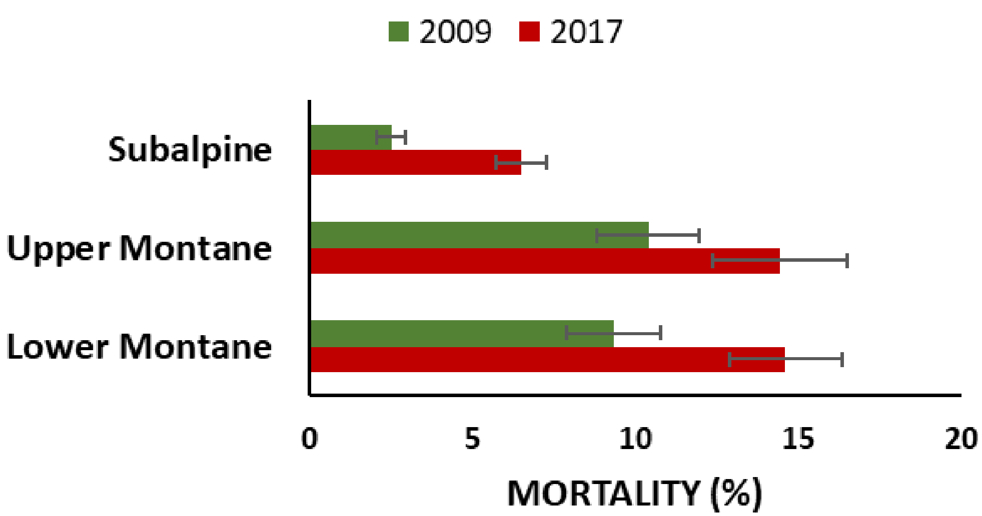
CURRENT RESEARCH

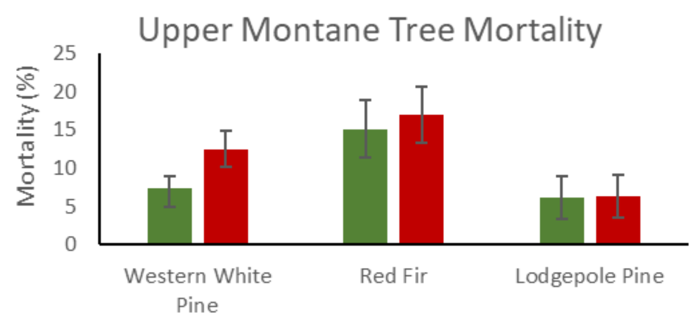
Forest health, continued

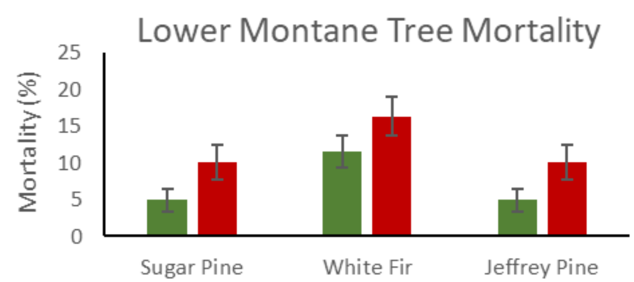
Tree mortality

In 2017, TERC's forest and conservation biology lab resurveyed a network of 84 long-term monitoring plots in the Lake Tahoe Basin to determine tree mortality across three elevation zones. On average, we found a 5% increase in cumulative tree mortality across all three elevation zones in between the two survey periods (2009 & 2017). Average tree mortality increased from 9% to 15%, 10% to 14%, and 2% to 6% in lower montane, upper montane, and subalpine forests, respectively. Primary causes of mortality were bark beetles, pathogens, and drought stress.









CURRENT RESEARCH

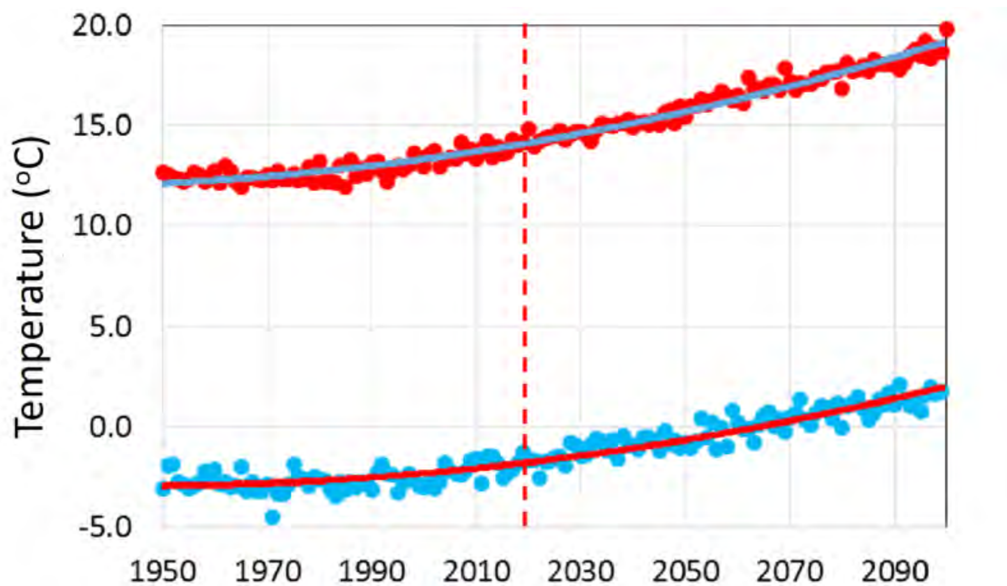
This is not your grandparents' climate

Climate modeling - air temperature

As part of its ongoing focus on climate change impacts on the Lake Tahoe watershed, TERC has been analyzing sets of future climate scenarios. The climate scenarios were produced by a research team from the Southwest Climate Center (SWC) as part of the project "Development, delivery, and application of data on climate extremes for the southwestern United States."

TERC's team of Goloka Sahoo, Robert Coats, Zack Coats, Jack Lewis, Mariza Costa-Cabral, and Geoff Schladow have been working with funding support from the California Tahoe Conservancy. The project will provide a set of climatic and hydrologic conditions for the Tahoe basin that capture the range of extreme events possible in the next one hundred years, based on the SWC projections. The information will assist in the planning and design of watershed restoration and stormwater projects.

The initial results are showing that the Lake Tahoe basin will be considerably warmer in the future. The figure below shows the average of daily maximum temperatures and minimum temperatures, averaged by year across the Basin for the modeled historic (1950-2005) period and the modeled future (2006-2100) using the future carbon scenario RCP 8.5. The results suggest a 9 °F (5 °C)rise in air temperature between now (dashed vertical line) and the end of the century for the maximum and a 7 °F (3.9 °C) rise for the minimum temperatures.



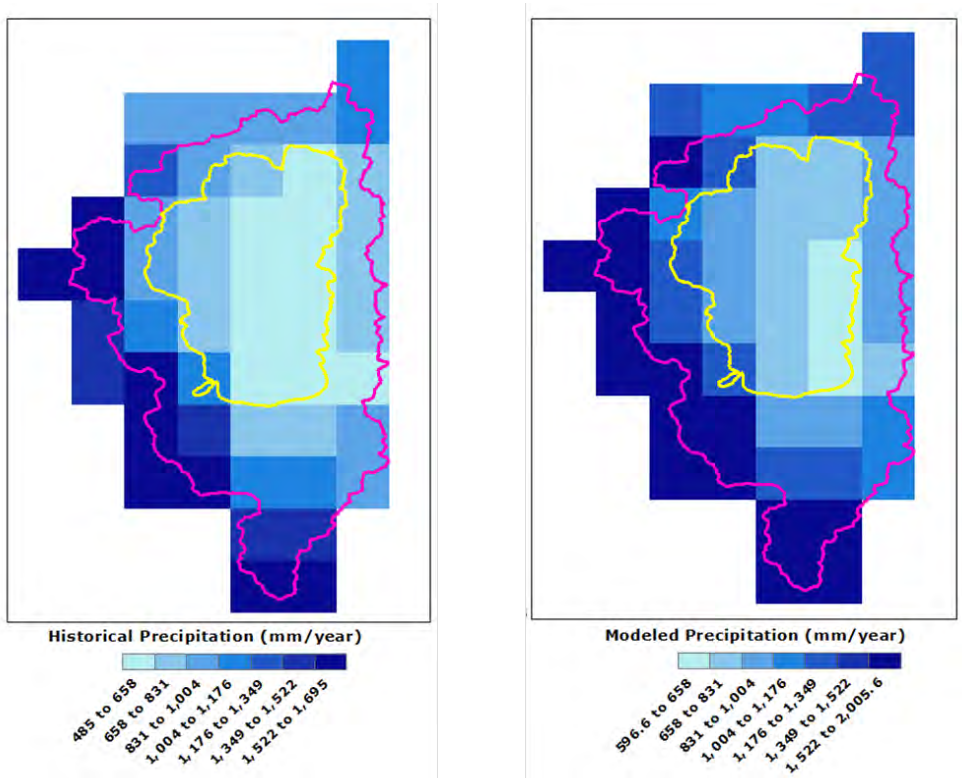
The trend of maximum and minimum temperatures averaged over the Tahoe Basin under RCP 8.5 for an ensemble of four models.

CURRENT RESEARCH

This is not your grandparents' climate, continued

Climate modeling - precipitation

Under the influence of climate change, the expected difference in the Lake Tahoe Basin's precipitation will be small, but statistically significant. Despite this increase in precipitation, the projected warmer air temperatures will mean that there will be less snow, continuing the historic measured trend (see page 7.7). The figure below compares the modeled historical precipitation 1950 to 2005 on the left, to the mean of a four-model ensemble of expected precipitation from 2070 to 2099 on the right. The expected rain shadow is present in both, with higher precipitation evident on the west side of the lake.



The modeled historical precipitation from 1950 to 2005 is on the left. The predicted precipitation from 2070 to 2099 is on the right. Both represent the mean values from a four-model ensemble.

CURRENT RESEARCH

This is not your grandparents' climate, continued

Climate modeling - climatic water deficit

The basin will also be drier in the coming decades. The "climatic water deficit" (CWD) is a measure of the amount of additional water that would have evaporated or transpired had it been present in the soil.

The figures below show the differences in CWD for the period 1950-2005 to the period 2070-2099. CWD can be seen to increase throughout the basin, and by over 100% on the north and east sides of the basin.

As the CWD increases, it leads to a drying of the forest soils and added stress to the forest. Such stress makes trees more prone to disease and insect attack, as well as increasing the wildfire hazard.

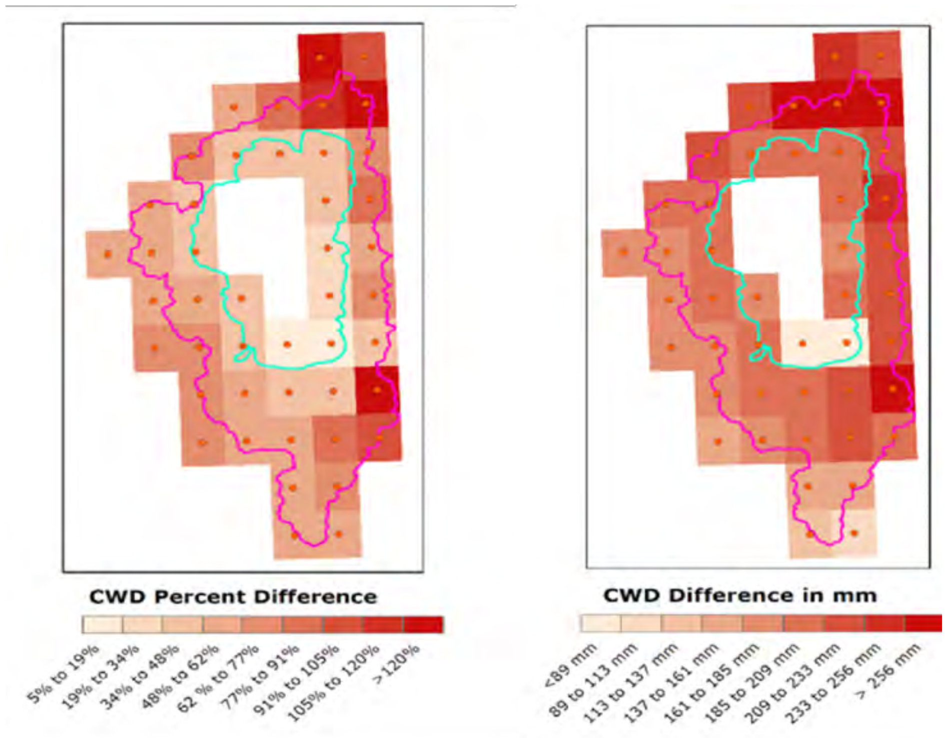


Figure 3 The difference in the spatial distribution of "climatic water deficit" (CWD) between the period 1950-2005 and 2070-2099.

CURRENT RESEARCH

What goes around, come around

A comparative study of two lakes

Gyres, or large-scale circulations, occur in Lake Tahoe and other large lakes. They are important because they can rapidly transport contaminants across the lake. How much they dilute contaminants requires an understanding of turbulence.

Researchers from TERC, led by Alex Forrest, are collaborating with the École Polytechnique Fédérale de Lausanne (EPFL, Switzerland) to measure turbulence in gyres in Lake Geneva using the UC Davis underwater glider. A newly acquired Rockland Scientific Microstructure sensor, mounted to the front of the glider, provides the very rapid measurements (512 measurements per second) of temperature which can be used to determine the turbulence level.

Next summer the measurements will be repeated in Lake Tahoe as the second part of this comparative study. Lake Geneva is where François-Alphonse Forel founded the field of limnology. Forel corresponded with John LeConte, the first limnologist at Lake Tahoe and the first professor hired by the University of California.

Oscar Sepúlveda mounting the microstructure package onto the glider at Lake Geneva. Photo: A. Bahr

TAHOE: STATE OF THE LAKE REPORT 2018

METEOROLOGY

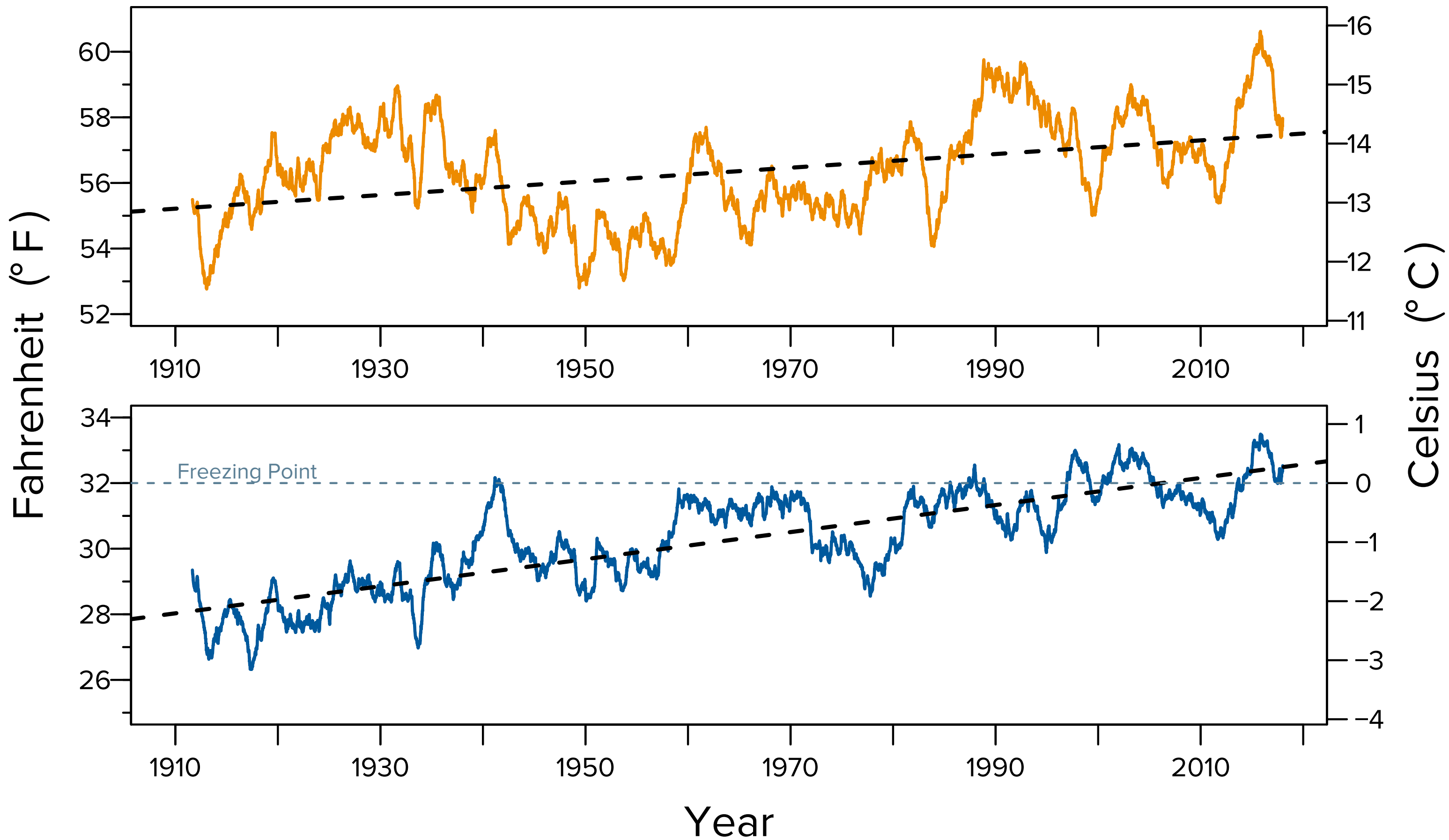
UC DAVIS
Tahoe Environmental Research Center

METEOROLOGY

Air temperature - smoothed daily maximum and minimum

Daily since 1911

Over the last 100 years, daily air temperatures measured at Tahoe City have increased. The long-term trend in average daily minimum temperature (bottom figure) has increased by 4.4 °F (2.4 °C), and the long-term trend in average daily maximum temperature (upper figure) has risen by 2.2 °F (1.2 °C). The trend line for the minimum air temperature now exceeds the freezing temperature of water, which is driving more rain and less snow, as well as earlier snowmelt at Lake Tahoe. These data have been smoothed by using a two-year running average to remove daily and seasonal fluctuations. Data source: the long-term NOAA daily maximum and minimum temperatures data set.

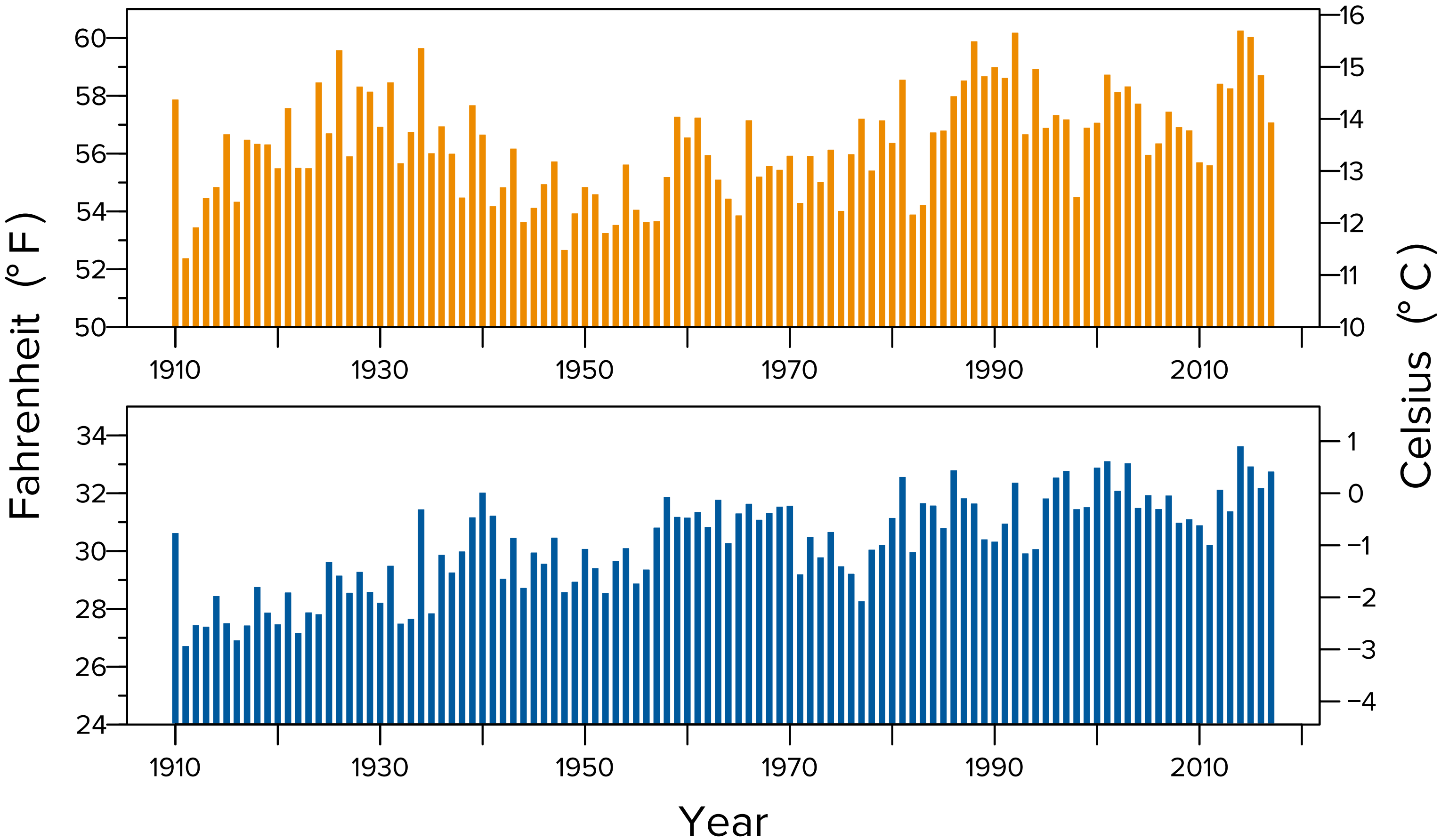


METEOROLOGY

Air temperature - annual average maximum and minimum

Since 1910

Annual average maximum (upper figure) and minimum (lower figure) air temperatures in 2017 were both well above the long-term average. The 2017 annual average minimum was 32.8 °F (0.4 °C) an increase of 0.6 °F over the previous year. The maximum temperature was 57.1 °F (13.9 °C) a decrease of 0.6 °F over the previous year. The long-term means for the minimum and the maximum are 30.3 °F (-0.96 °C) and 56.4 °F (13.6 °C), respectively. Data source: the long-term NOAA daily maximum and minimum temperatures data set.



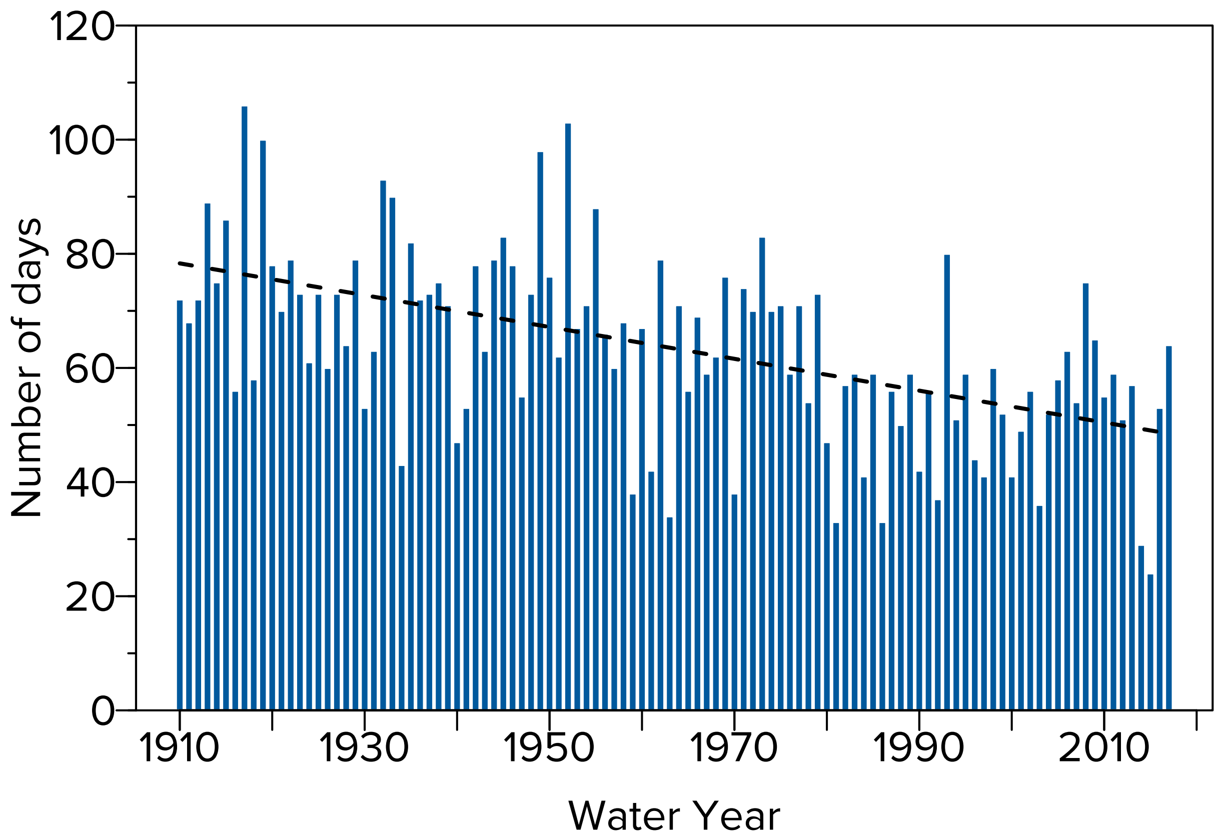
METEOROLOGY

Below-freezing air temperatures

Yearly since 1910

The method used for this analysis sums the number of days with daily average temperatures below freezing between December 1 and March 31 for each Water Year (WY). Although year-to-year variability is high, the number of days when air temperatures averaged below freezing has declined by about 30 days since 1911. In WY 2017, the number of freezing days was 64, reflective of the high snow year. Data source: the long-term NOAA daily maximum and minimum temperatures data set.

Note: The Water Year extends from October 1 through September 30.

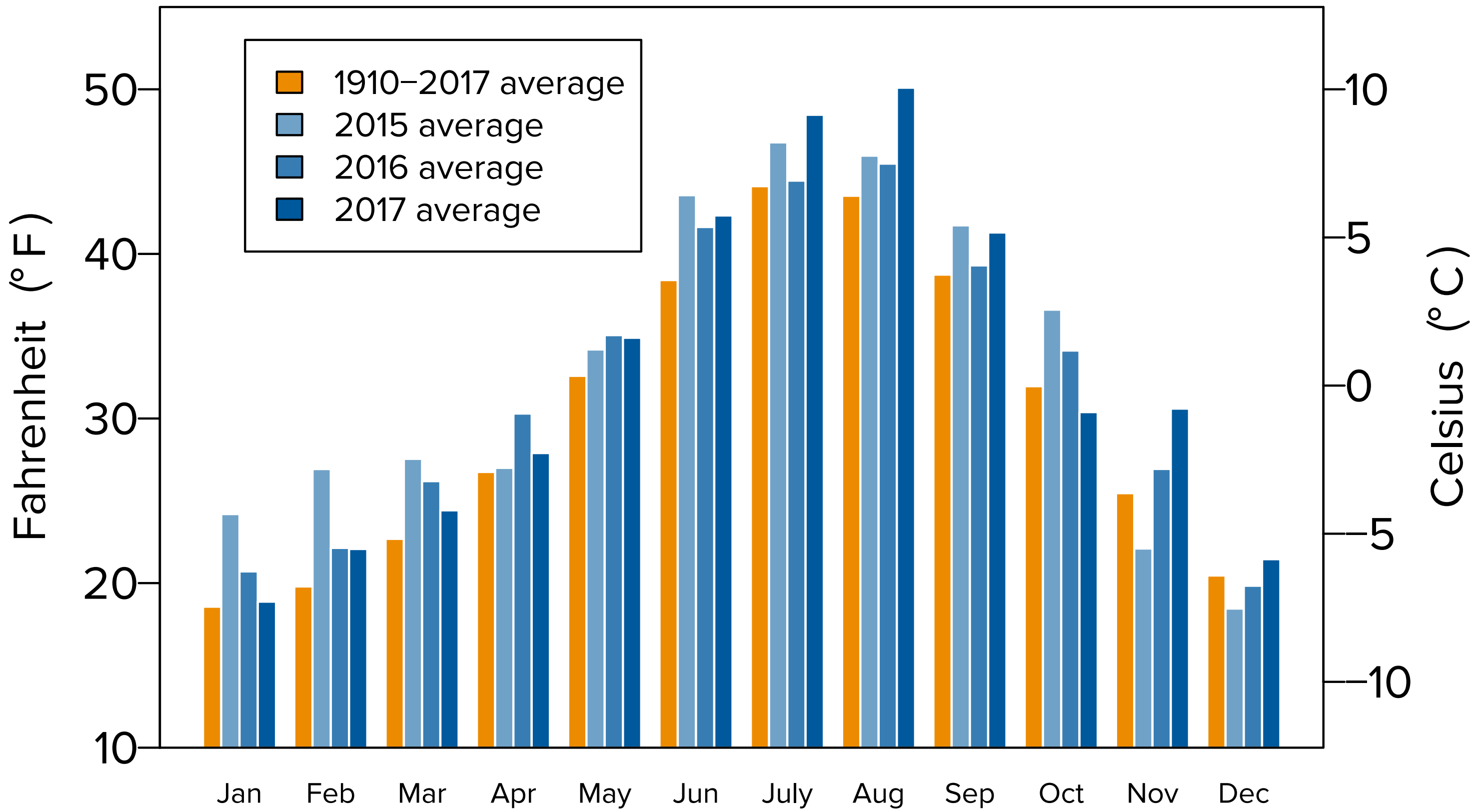


METEOROLOGY

Monthly air temperature

Since 1910

In 2017, monthly air temperatures were generally cooler than recent years during the winter months, but warmer during the summer. In 11 out of 12 months, the monthly air temperature was higher than the 1910-2017 average, and in four of those months it was warmer than the previous two years. Data source: the long-term NOAA daily maximum and minimum temperatures data set.

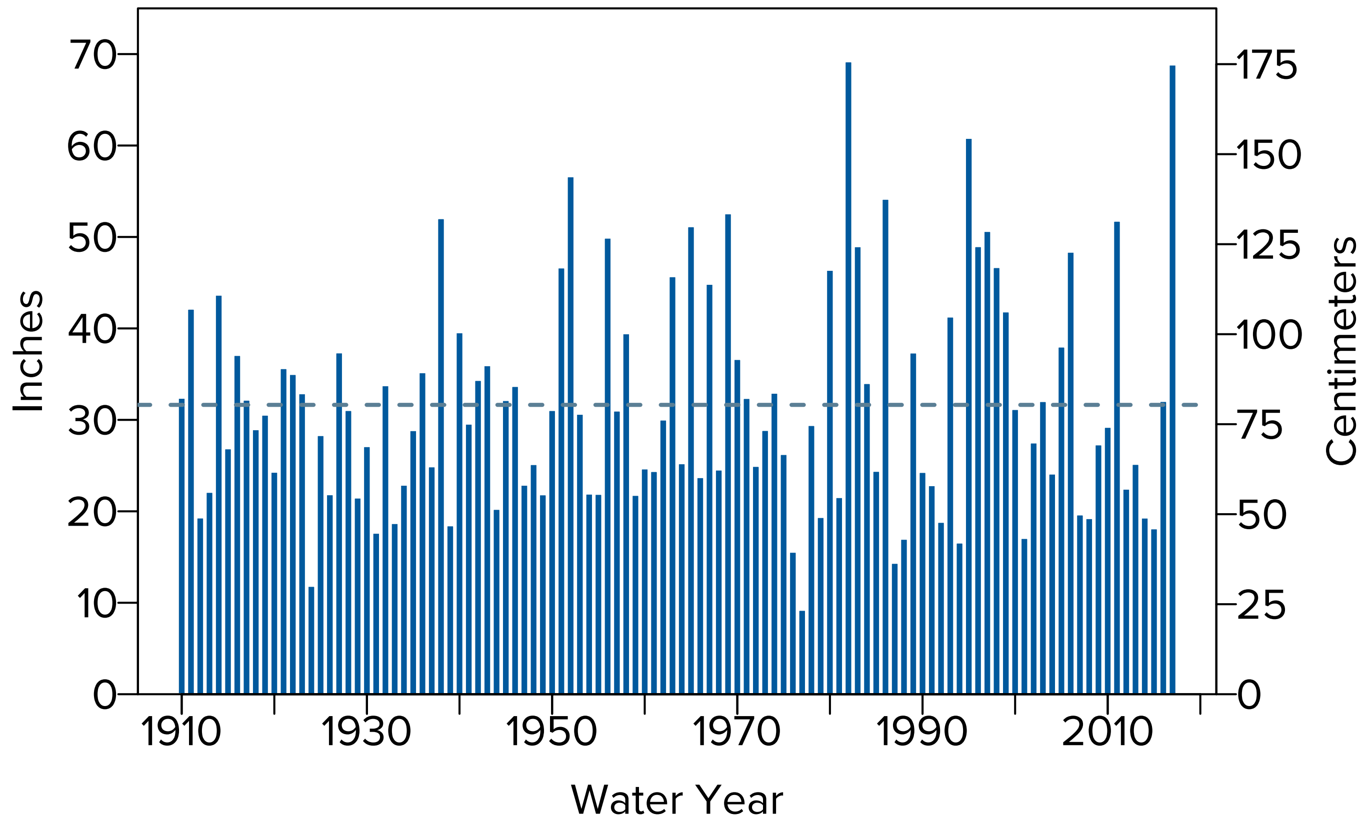


METEOROLOGY

Annual precipitation

Yearly since 1910

From 1910 to 2017, average annual precipitation (water equivalent of rain and snow) at Tahoe City was 31.6 inches. The maximum was 69.2 inches in 1982. The minimum was 9.2 inches in 1977. 2017 was the second highest recorded year, with 68.9 inches, following the five previous dry years. The long-term average of 31.6 inches is shown by the dashed line. Generally there is a gradient in precipitation from west to east across Lake Tahoe, with almost twice as much precipitation falling on the west side of the lake. Precipitation is summed over the Water Year, which extends from October 1 through September 30. Data source: the long-term NOAA daily precipitation data set.

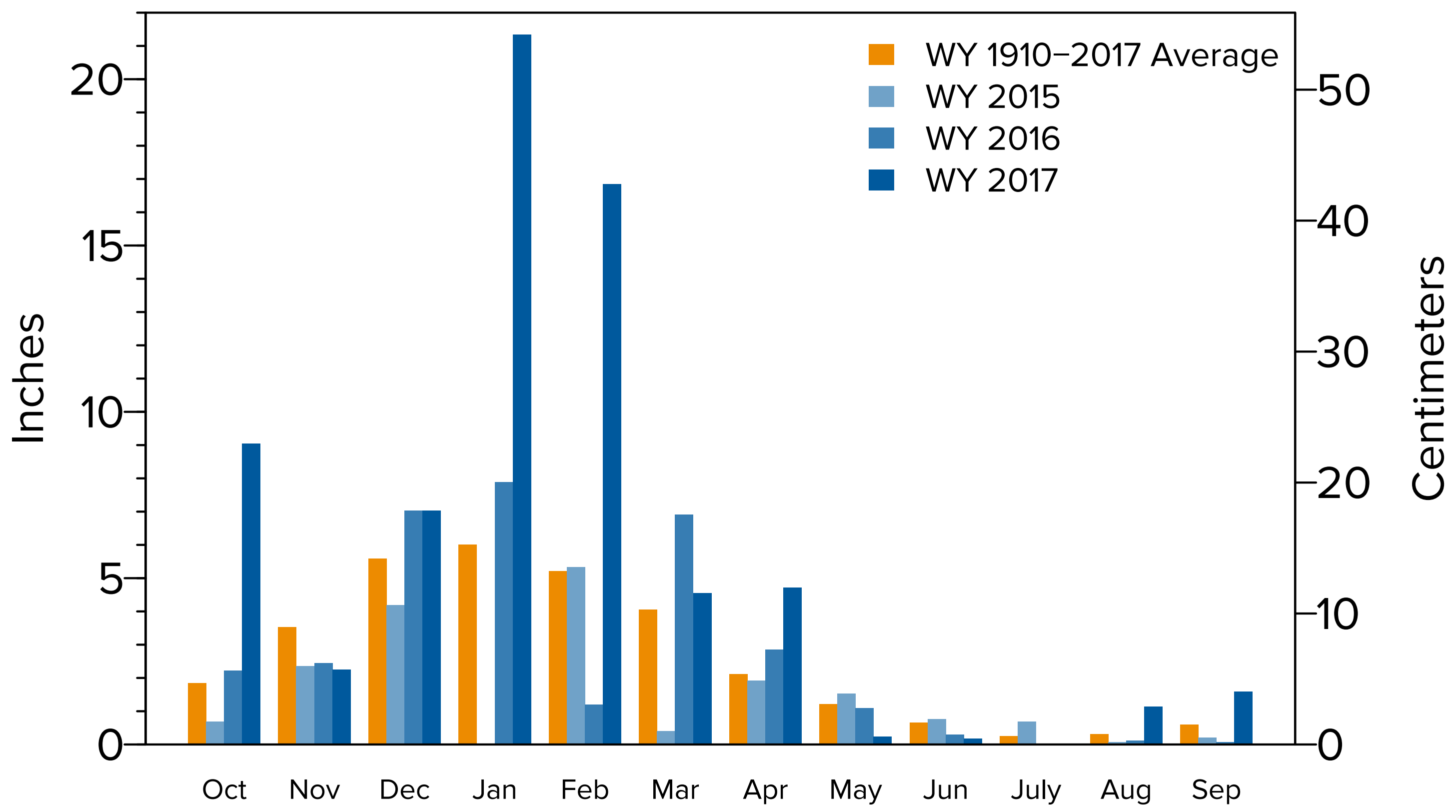


METEOROLOGY

Monthly precipitation

2015, 2016, 2017 and 1910 to 2017

2017 was well above average in total precipitation at 68.9 inches over the Water Year, compared with the long-term average of 31.4 inches. Monthly precipitation was above the long-term average in eight months of the year. The monthly precipitation for January and February were particularly large. Months with more than 25 percent of days missing are omitted from the figure below. The 2017 Water Year extended from October 1, 2016 through September 30, 2017. Data source: the long-term NOAA daily precipitation data set.



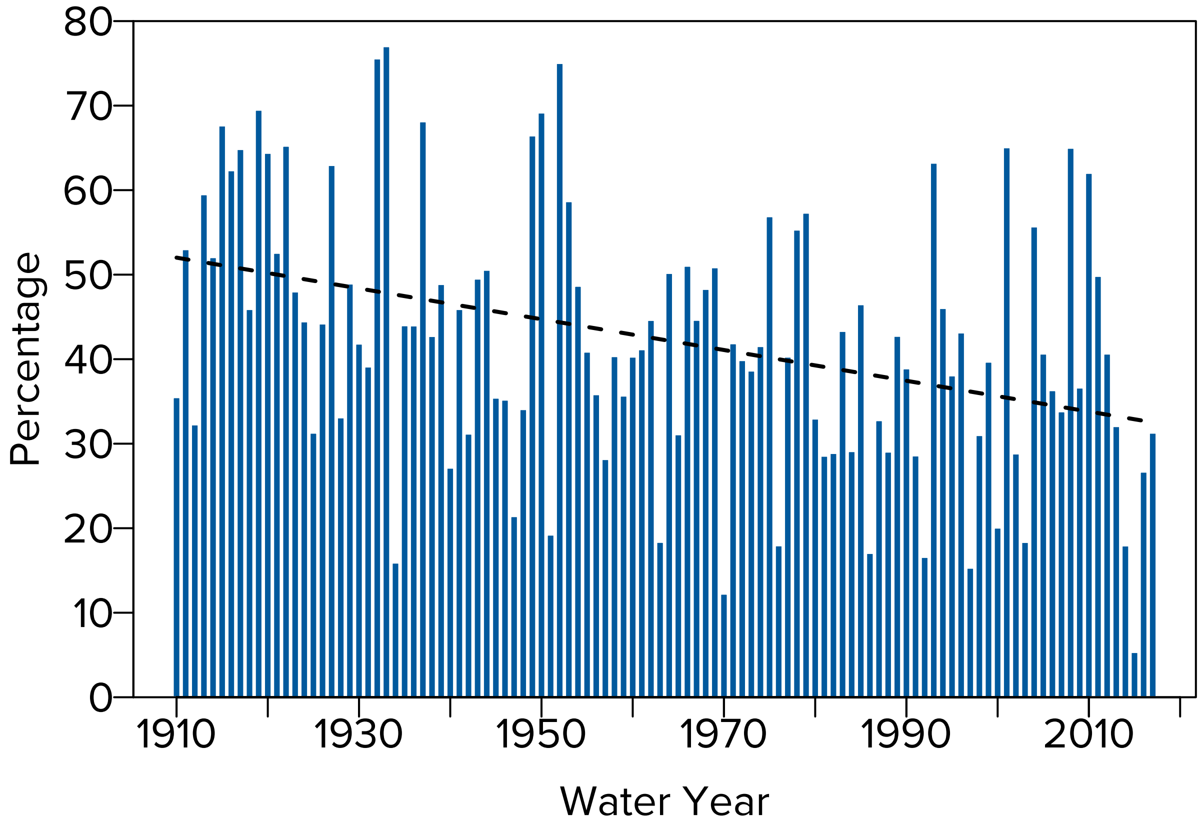
METEOROLOGY

Snow as a fraction of annual precipitation

Yearly since 1910

Snow has declined as a fraction of total precipitation, from an average of 52 percent in 1910 to 32 percent in present times, according to the line of best fit. In Tahoe City, snow represented 31.3 percent of the 2017 total precipitation.

These data are calculated based on the assumption that precipitation falls as snow whenever the average daily temperature (the average of the daily maximum and minimum temperatures) is below-freezing. (Precipitation is summed over the Water Year, which extends from October 1 through September 30.) Data source: long-term NOAA daily air temperature and precipitation data sets.

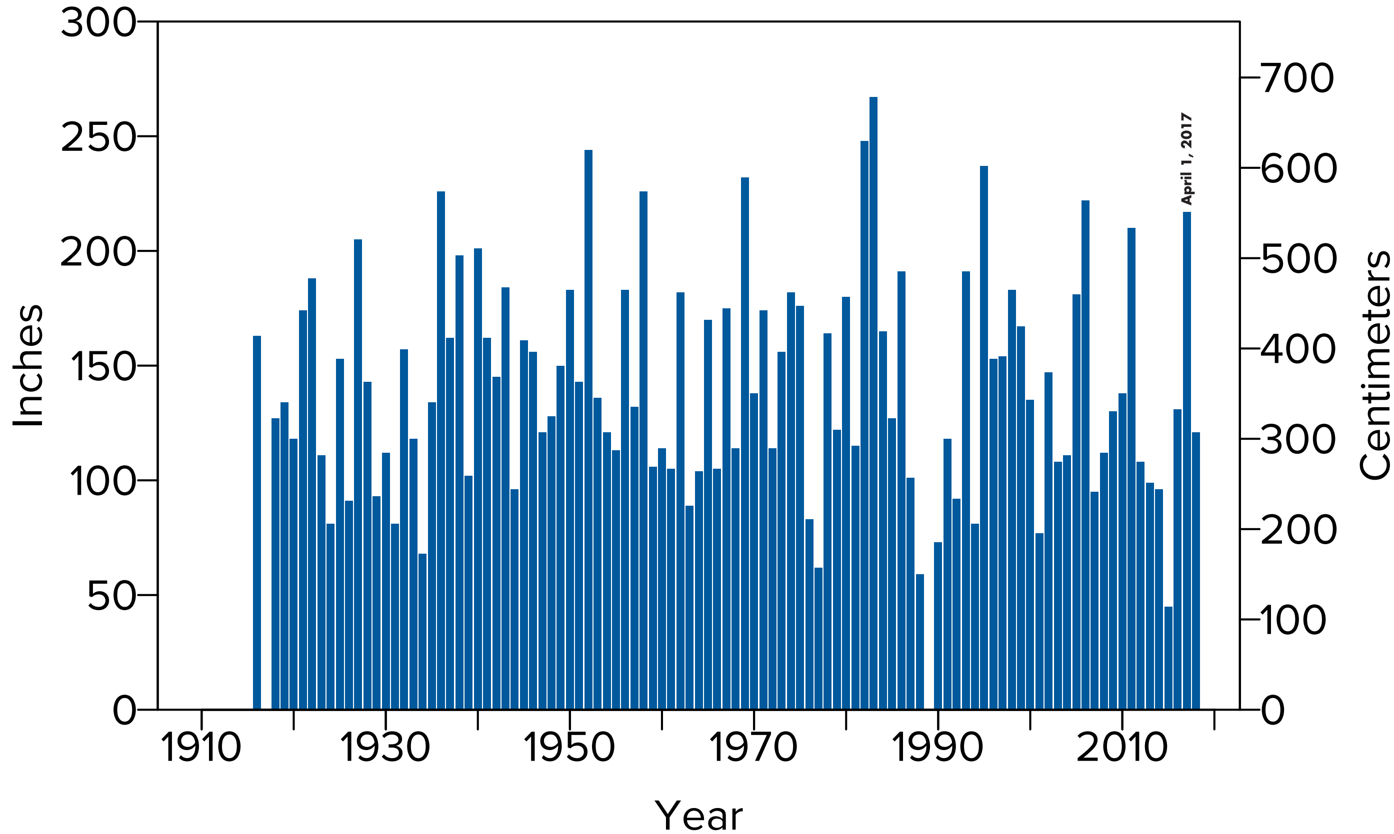


METEOROLOGY

April snowpack

Since 1916

The depth of the snowpack is measured at multiple locations throughout the Sierra over the year. Shown here are the readings taken on approximately April 1 since 1916 at the Lake Lucille Snow Course Station (located in Desolation Wilderness, elevation 8,188 feet, Lat 38.86 Long -120.11). Note: April snow depth data are not available for 1917 and 1989. The snow depth on April 1, 2017 was 217 inches, the highest value since 2006. The highest value on record is 267 inches on April 5, 1983. The average snow depth over the period 1916-2017 was 142.3 inches. Data source: USDA Natural Resources Conservation Service, California Monthly Snow Data.

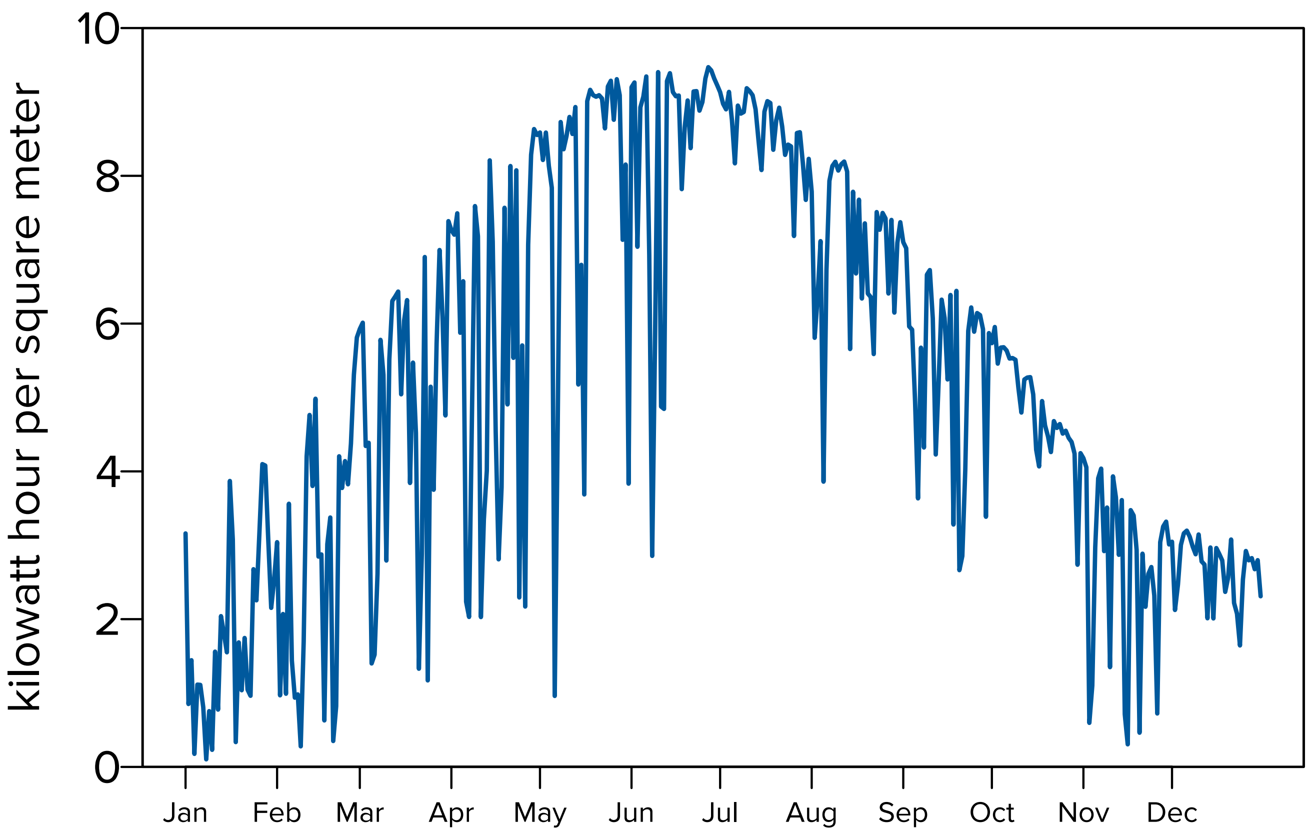


METEOROLOGY

Daily solar radiation

In 2017

Solar radiation showed the typical annual pattern of increasing then decreasing sunlight, peaking at the summer solstice on June 21 or 22. Dips in daily solar radiation are due primarily to clouds. Smoke and other atmospheric constituents play a smaller role. It is noteworthy that solar radiation on a clear day in mid-winter can exceed that of a cloudy day in mid-summer. The TERC meteorological station where these data are collected is located on the U.S. Coast Guard dock at Tahoe City.



TAHOE: STATE OF THE LAKE REPORT 2018

PHYSICAL PROPERTIES

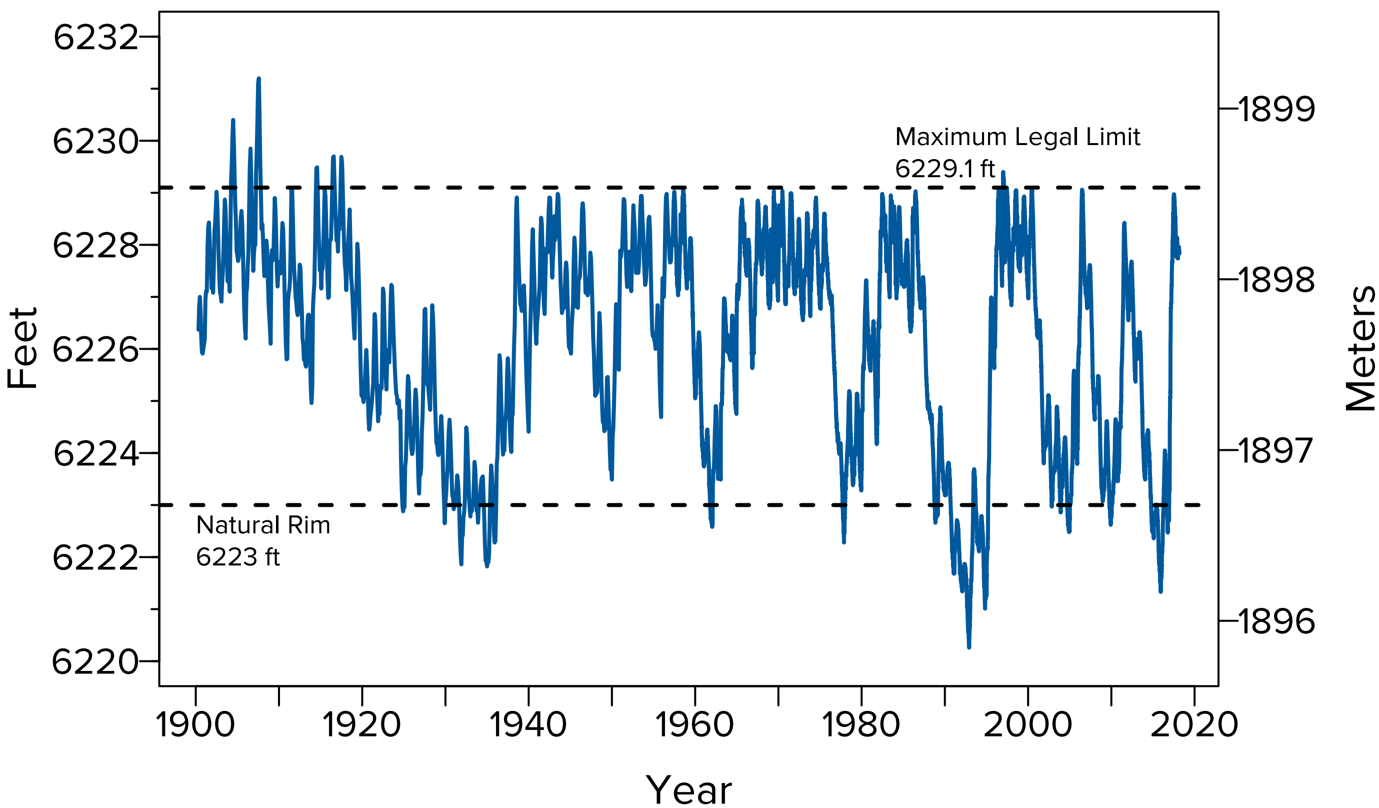
UC DAVIS
Tahoe Environmental Research Center

PHYSICAL PROPERTIES

Lake surface level

Daily since 1900

Lake surface level varies throughout the year. Lake level rises due to high stream inflow, groundwater inflow, and precipitation directly onto the lake surface. It falls due to evaporation, in-basin water withdrawals, groundwater outflows, and outflow via the Truckee River at Tahoe City. Overall, lake level rose 5.7 feet during 2017. The highest lake level was 6,229.0 feet on July 7, and the lowest was 6,223.3 feet on January 1. The natural rim of the lake is at an elevation of 6,223 feet. Lake Tahoe was above its rim for the entire year. When the lake is below its rim, outflow via the Truckee River ceases. Several episodes of lake level falling below the natural rim are evident in the last 114 years. The frequency of such episodes appears to be increasing.

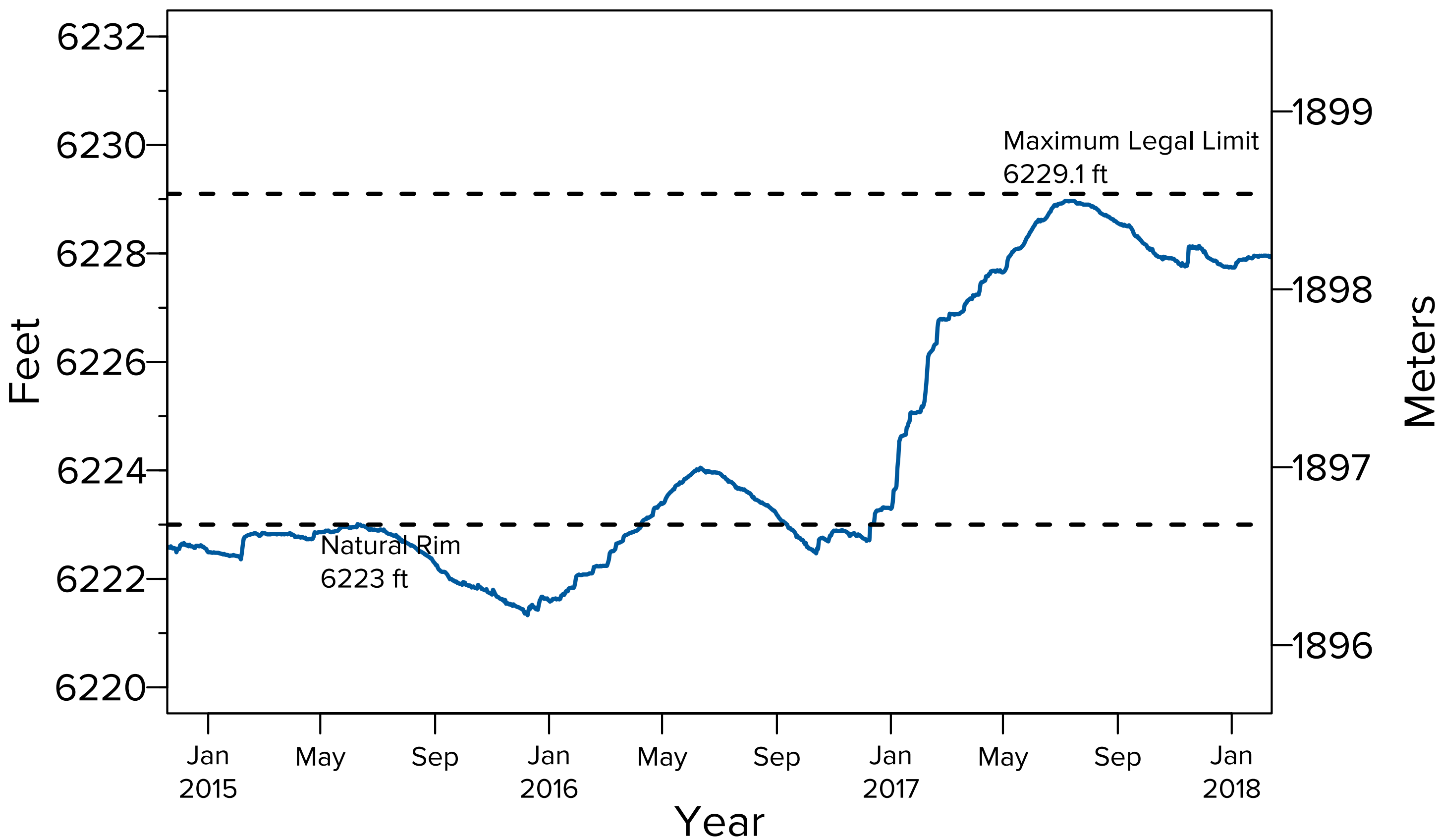


PHYSICAL PROPERTIES

Lake surface level, continued

Daily since 2015

Displayed below is the lake surface data from 2015-2017 extracted from the same data on page 8.1. This more time-restricted presentation of recent lake level data allows us to see the annual patterns of rising and falling lake level in greater detail. Data clearly show the effects of the five-year drought with the lake below the natural rim, and then the rapid rise during the first six months of 2017. The fall off in lake level in the latter half of the year was primarily due to evaporation.

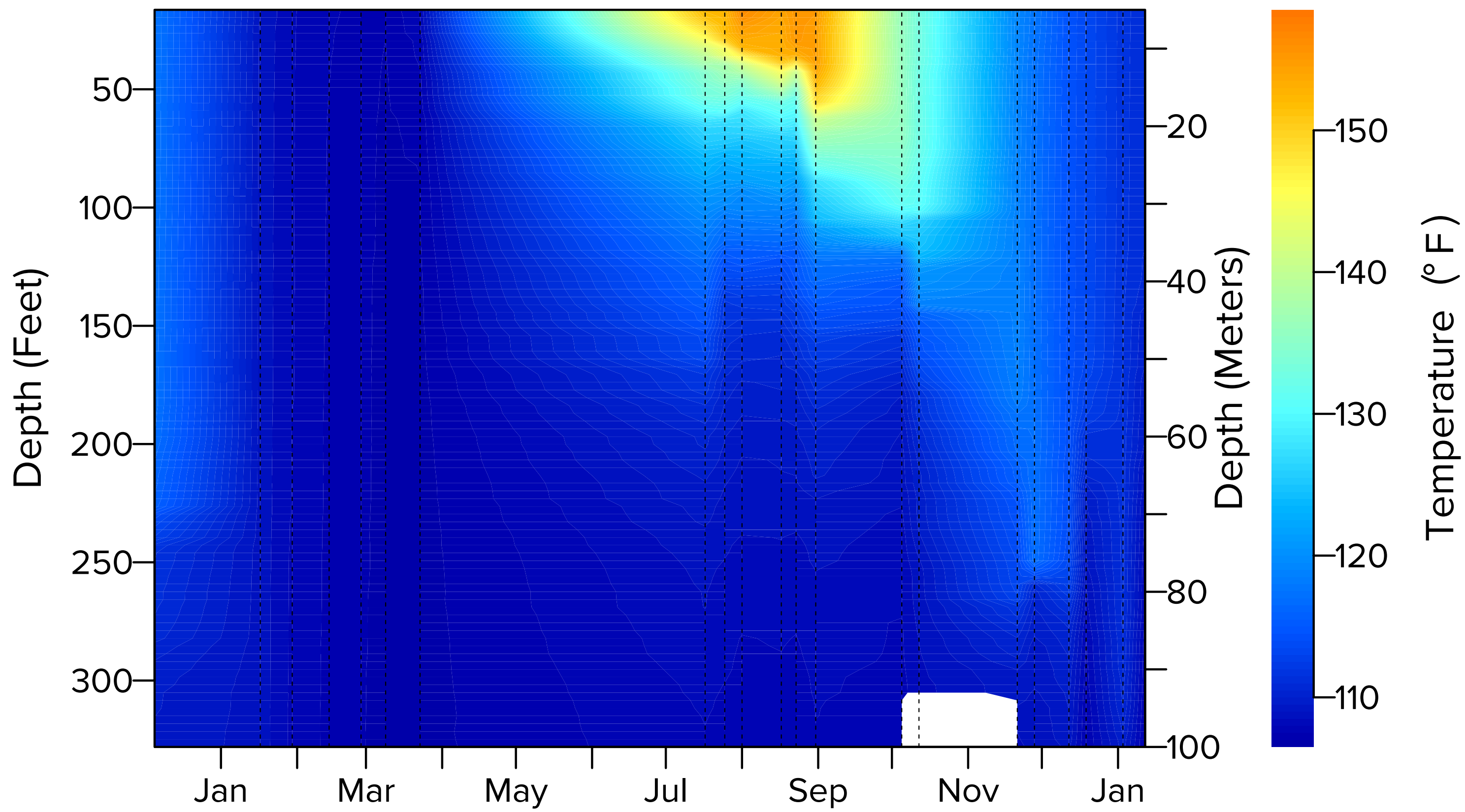


PHYSICAL PROPERTIES

Water temperature profile

In 2017

Water temperature profiles are measured in the lake using a Seabird CTD (conductivity, temperature, depth) profiler at the times indicated by the dashed vertical lines. The temperature is accurate to within 0.005 °F. Here the temperature in the upper 330 feet (100 m) is displayed as a color contour plot. In 2017, the lake temperature followed a typical seasonal pattern. In February-March, the lake surface was at its coldest, while it was at its warmest at the end of August. The deepening of the warm water zone toward the end of the year is the result of winter mixing, although in 2017, the fall mixing was reduced from earlier years. Profiles from April to July were discarded due to instrument malfunctions.

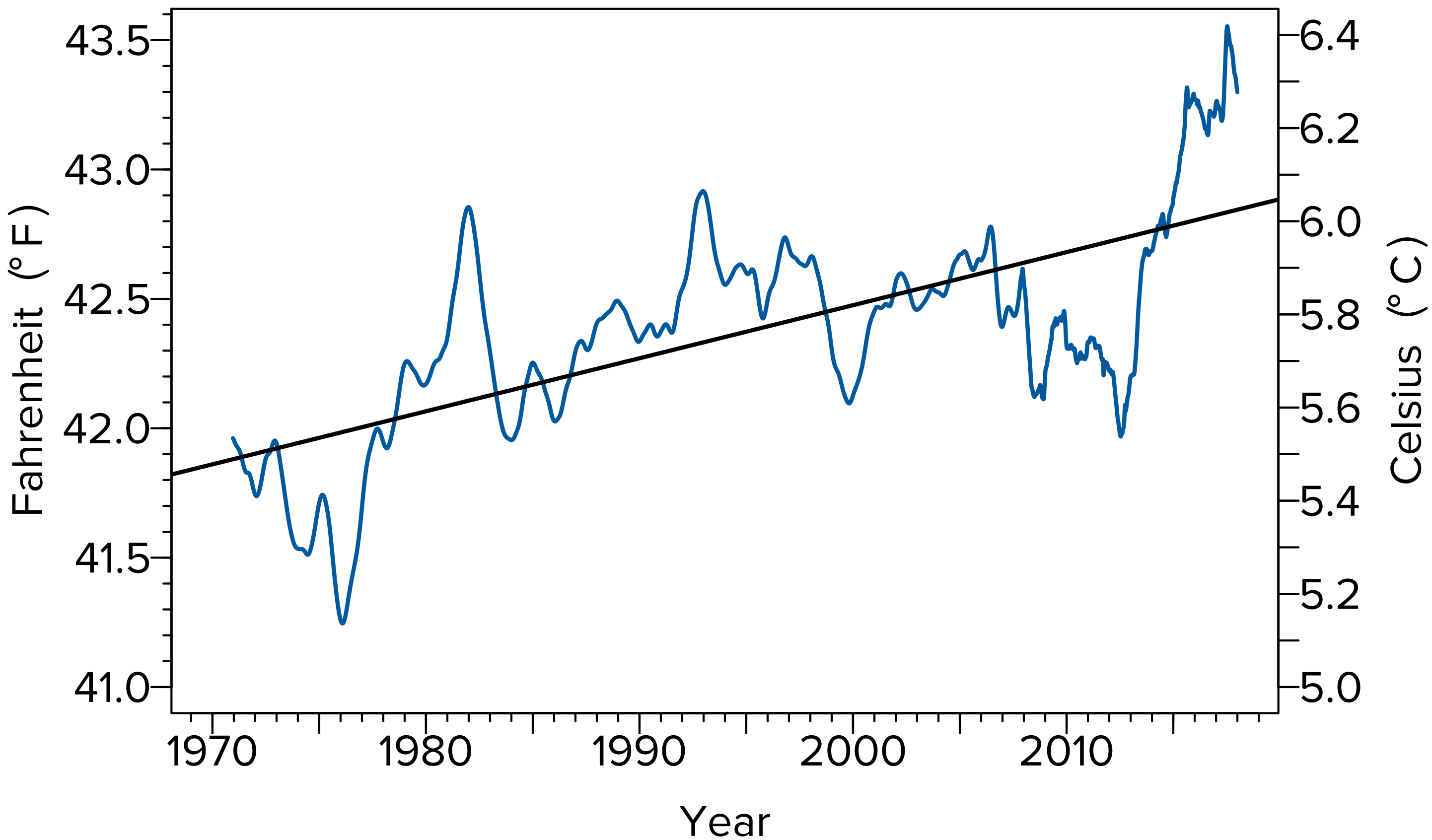


PHYSICAL PROPERTIES

Average water temperature

Since 1970

The trend in the volume-averaged temperature of Lake Tahoe has increased by approximately 0.96 °F since 1970. The annual rate of warming is 0.020 °F/year (0.011 °C/year). The monthly temperature profile data from the top to the bottom of the lake has been smoothed and seasonal influences removed to best show the long-term trend. Up until the late 1990s, the warming rate was high, but the large number of deep mixing years between 1997 and 2011 caused the lake temperature to cool. Since that time, warming has accelerated to its highest recorded rate.

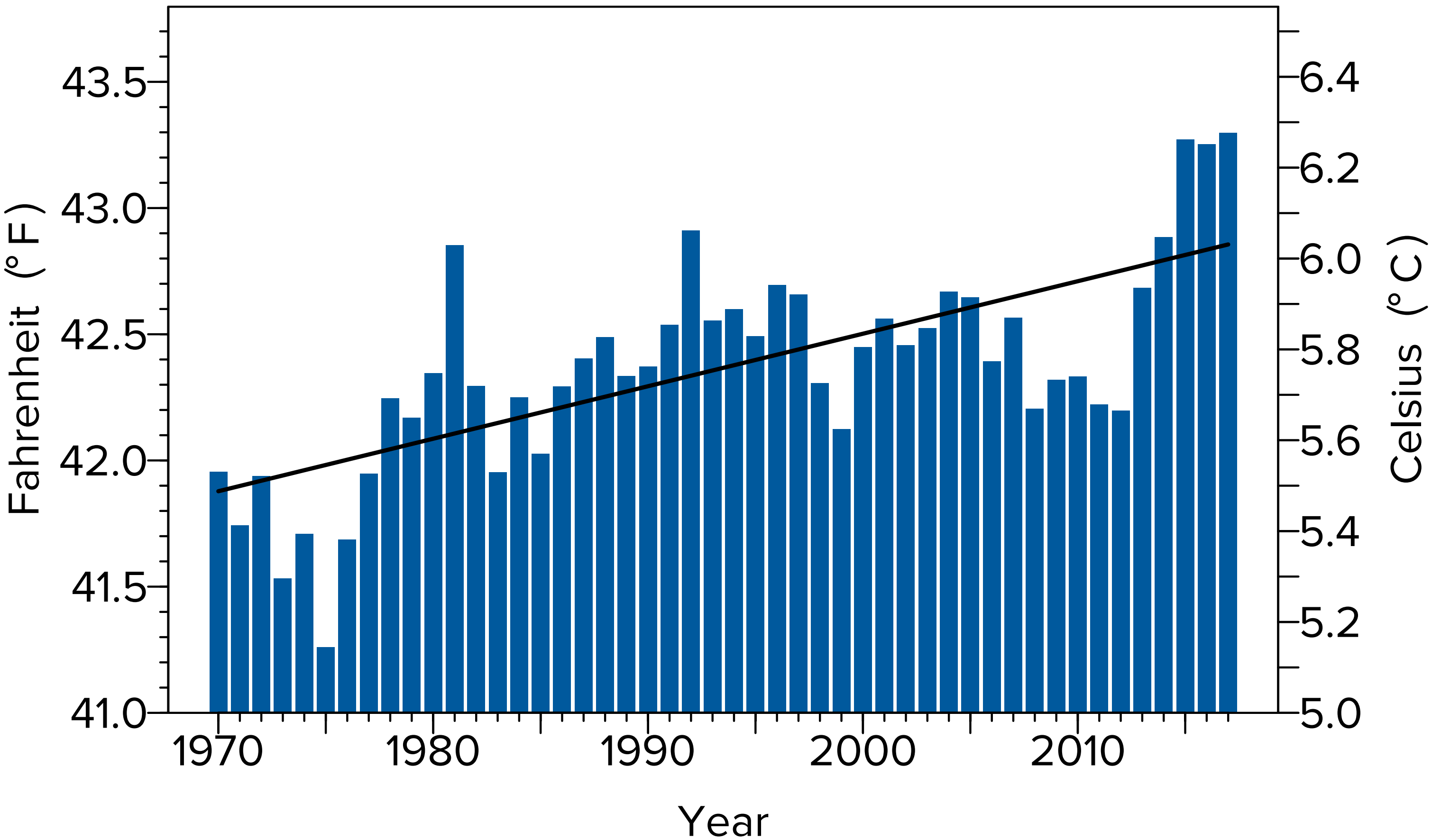


PHYSICAL PROPERTIES

Annual average water temperature

Since 1970

The volume-averaged temperature of the lake for each year since 1970 is shown. In 2017, the volume-averaged temperature increased by only 0.04 °F (0.02 °C) over the previous year, but bringing it to the warmest value recorded. Since 2012, the average temperature of the lake has warmed by 1.1 °F (0.61 °C). Increases in temperature generally correspond to those years in which deep mixing did not occur. In 2017, deep mixing did not occur for the sixth year in a row.

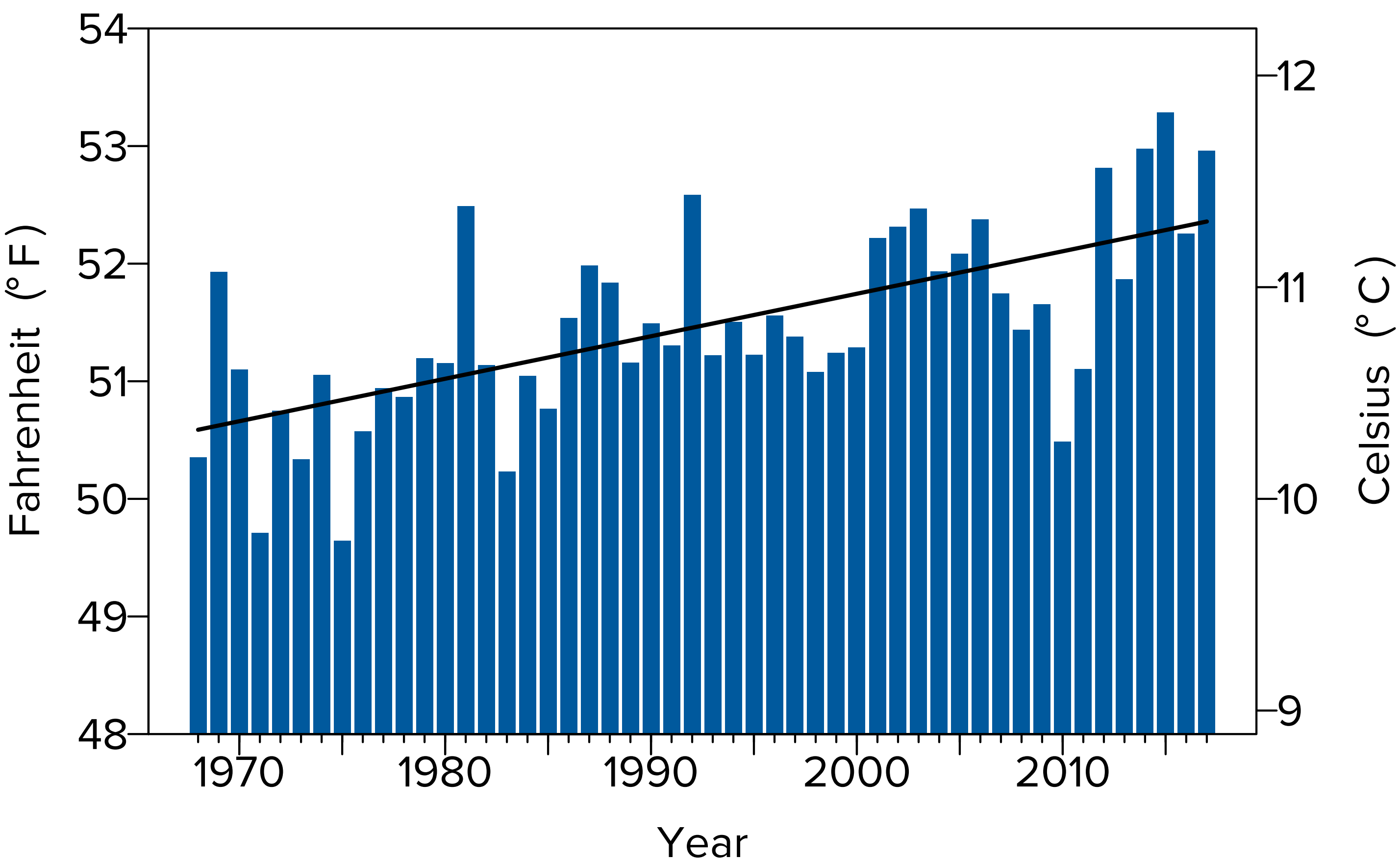


PHYSICAL PROPERTIES

Surface water temperature

Yearly since 1968

Surface water temperatures have been recorded monthly at the Mid-lake and Index stations since 1968 from the R/V John LeConte and the R/V Bob Richards. Despite year-to-year variability, the annual average surface water temperatures show an increasing trend. The average surface water temperature in 1968 was 50.3 °F (10.2 °C). For 2017, the average surface water temperature was 53.0 °F (11.6 °C). The overall rate of warming of the lake surface is 0.036 °F (0.020 °C) per year.

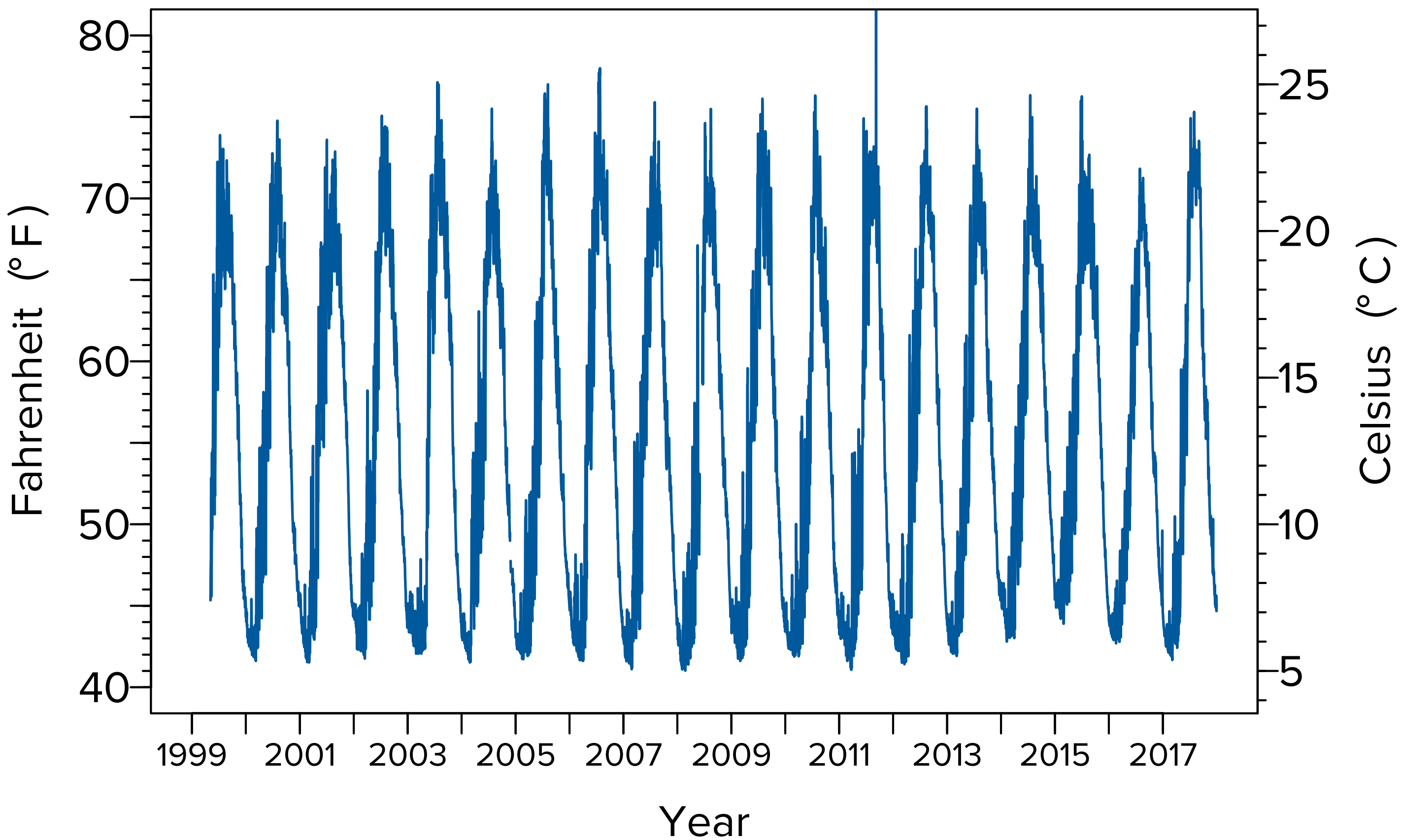


PHYSICAL PROPERTIES

Maximum daily surface water temperature

Surface temperature measured since 1999 every 2 minutes

The daily surface water temperature records are based on continuous (every 2 min.) data collection. In 2017, the highest maximum daily surface water temperature (summer) was 75.31 °F, which was recorded on August 1, 2017. This was 2.27 °F warmer than the previous year. The lowest maximum daily surface water temperature (winter) was 41.68 °F, which was recorded on March 6, 2017. This was 0.72 °F cooler than the previous year. These data are collected in real-time by NASA-JPL and UC Davis from 4 buoys located over the deepest parts of the lake.

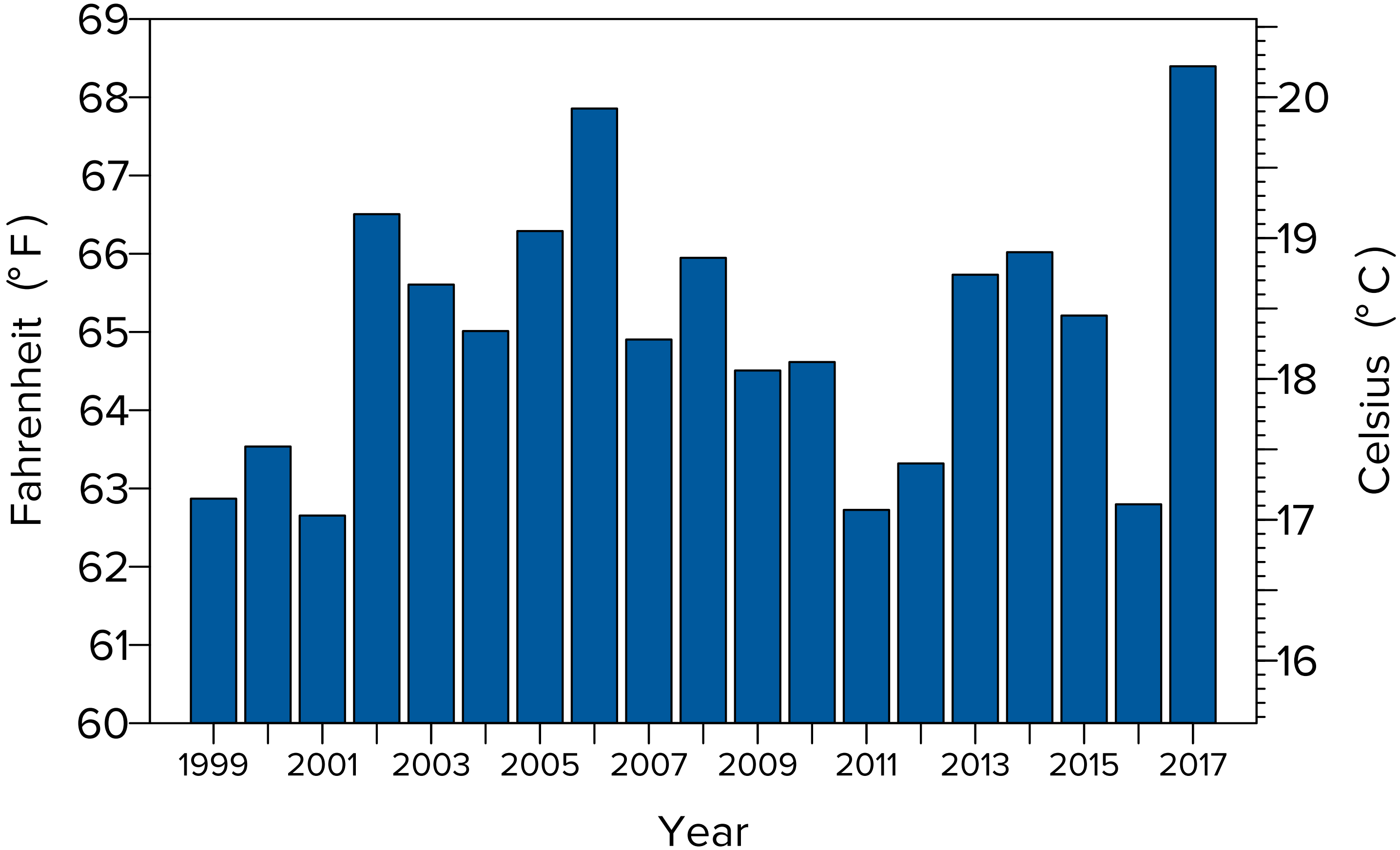


PHYSICAL PROPERTIES

July average surface water temperature

Measured since 1999 every 2 minutes

Since 1999, surface water temperature has been recorded every two minutes from four NASA/UC Davis buoys. Shown here are 19 years of average surface water temperatures in the month of July, when water temperatures are typically warmest. In 2017, July surface water temperature averaged 68.4 °F, an astounding 6.1 °F above the 2016 value. It was the warmest July on record. Low winds combined with elevated air temperatures in July were responsible for the warm water temperatures. The average July surface water temperature for the 19-year period is 65.0 °F.

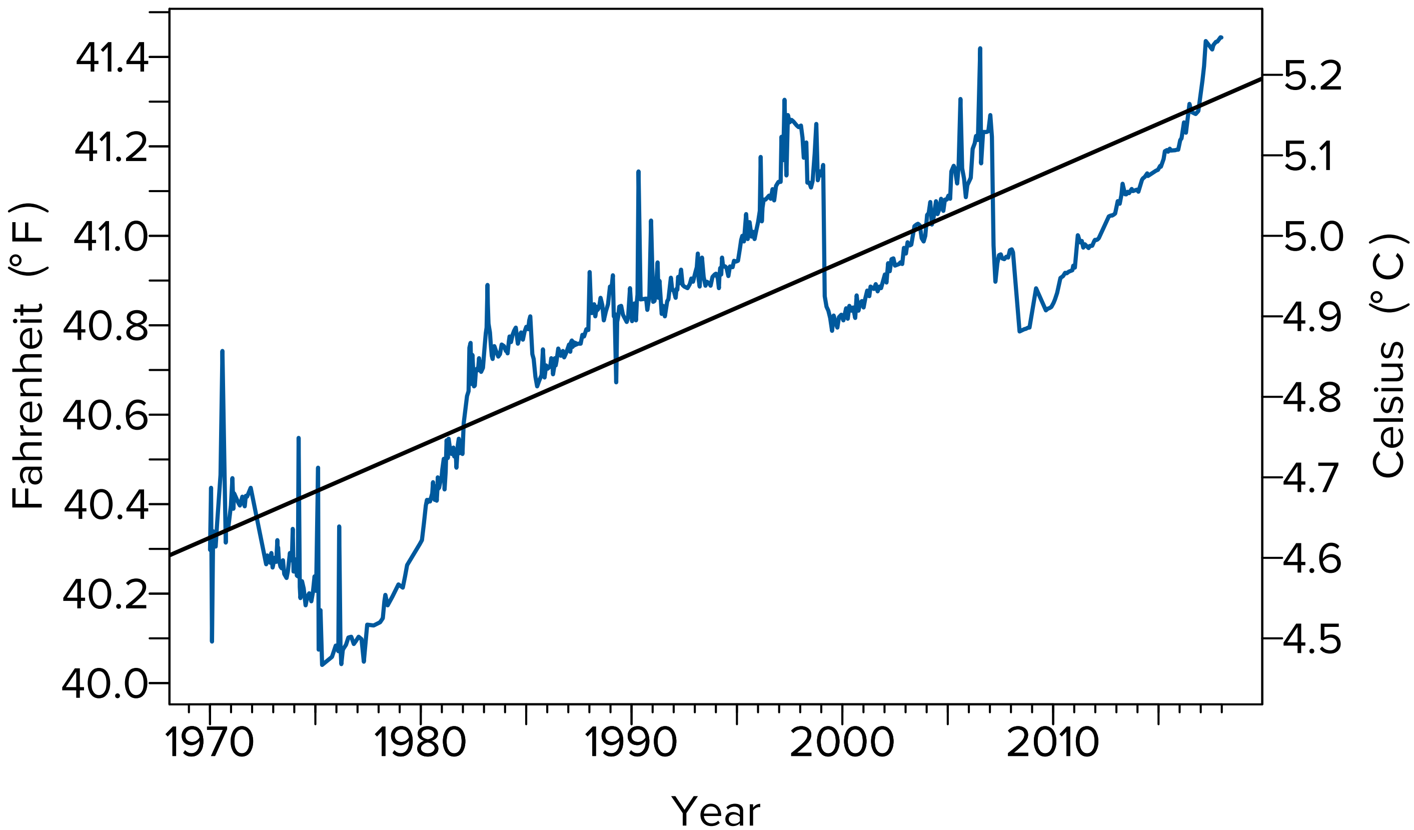


PHYSICAL PROPERTIES

Deep water temperature

Monthly since 1970

The water temperature at a depth of 1,320 feet (400 m) is indicative of conditions in the deeper waters (hypolimnion) of Lake Tahoe. Since 1970, the deep water temperature has increased by 0.95 °F (0.53 °C), at an annual rate of 0.020 °F (0.011 °C), a rate of warming that is half that of the surface water. This increase has not been steady and is punctuated by occasional drops in temperature. These coincide with times when the lake completely mixes to the bottom, an event which allows a huge amount of heat to escape from the lake. The impact of Lake Tahoe's lack of deep mixing in the last seven years is evident by the accelerating increase in bottom warming. The short spikes of temperature increase are temporary effects caused by the motions of internal waves (or seiches) and other transient phenomena.

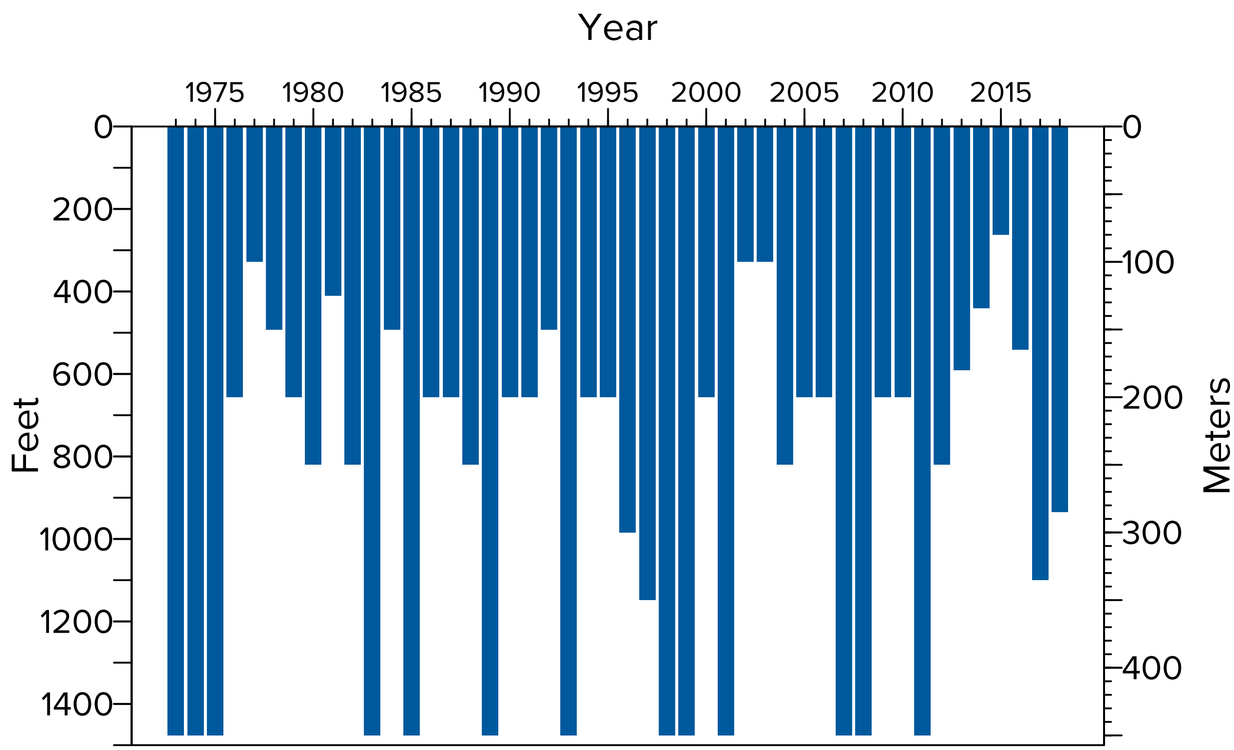


PHYSICAL PROPERTIES

Depth of mixing

Yearly since 1973

Lake Tahoe mixes each winter as surface waters cool and sink downward. In a lake as deep as Tahoe, the wind energy and intense cooling of winter determine how deep the lake mixes. Mixing depth has profound impacts on lake ecology and water quality. Deep mixing brings nutrients to the surface, where they promote algal growth. It also moves oxygen to deep waters, promoting aquatic life throughout the water column. The deepest mixing typically occurs between February and March. In 2017, Lake Tahoe mixed to a depth of 1,099 feet (335 m). In 2018, Lake Tahoe mixed to a depth of only 935 feet (285 m), a little more than half of the total depth. This lack of deep mixing most likely contributed to the warm surface and bottom temperature, the continuing buildup of nitrate in the lake, and the generally lower clarity. Beginning in 2013, the determination of the depth of mixing has been based on high-resolution temperature profiles rather than nitrate concentration sampled at discrete depths.



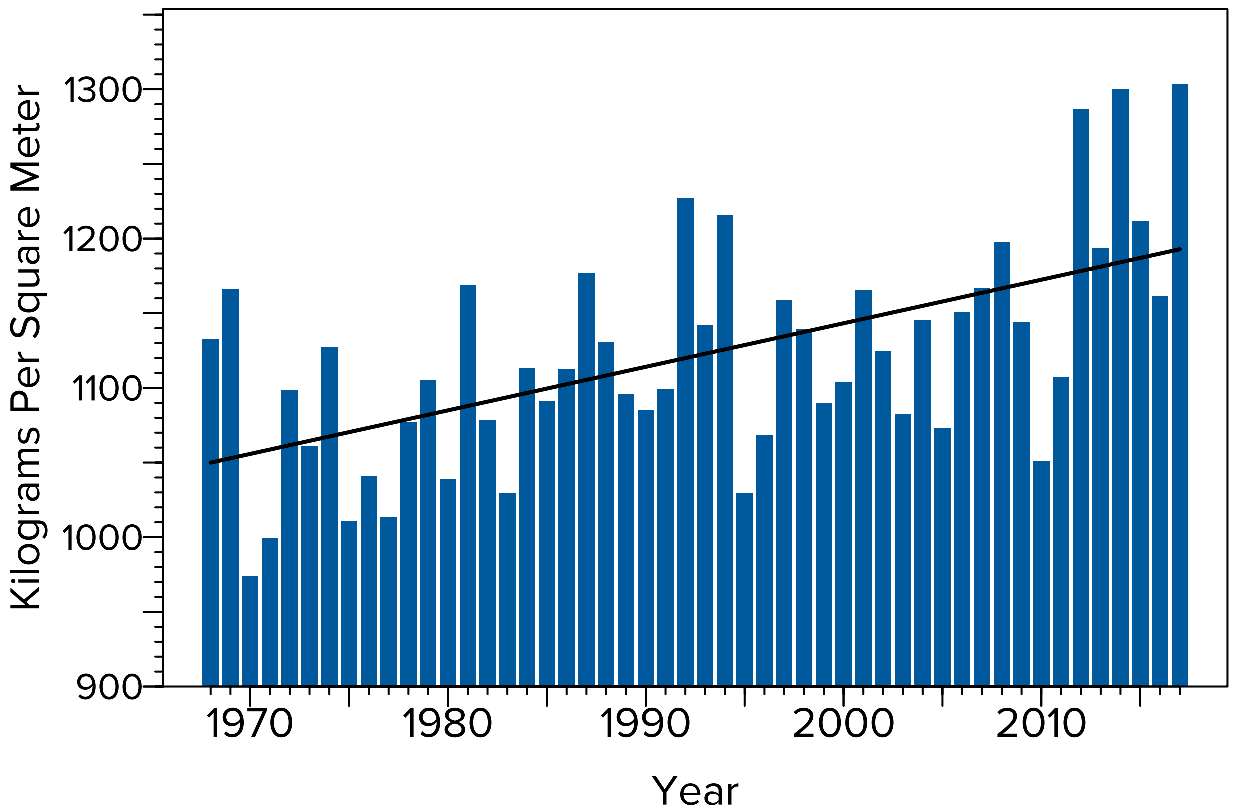
PHYSICAL PROPERTIES

Lake stability

Since 1968

When the lake has a vertical distribution of temperature, it has a corresponding density distribution, with warm and lighter water at the surface and colder, heavier water at depth. The stability index is a measure of the energy required to fully mix the water column when its density is stratified. The average stability index for the upper 330 feet (100 m) of Lake Tahoe is plotted for the period of May through October each year. The values are derived from temperature profiles taken at the Index Station at approximately 10-20 day intervals.

There has been an overall increase in lake stability by over 13 percent in the last 50 years. In 2017, the stability of the lake reached its highest recorded value. This is consistent with the continued absence of deep mixing, the warm surface temperatures and the reduced clarity.

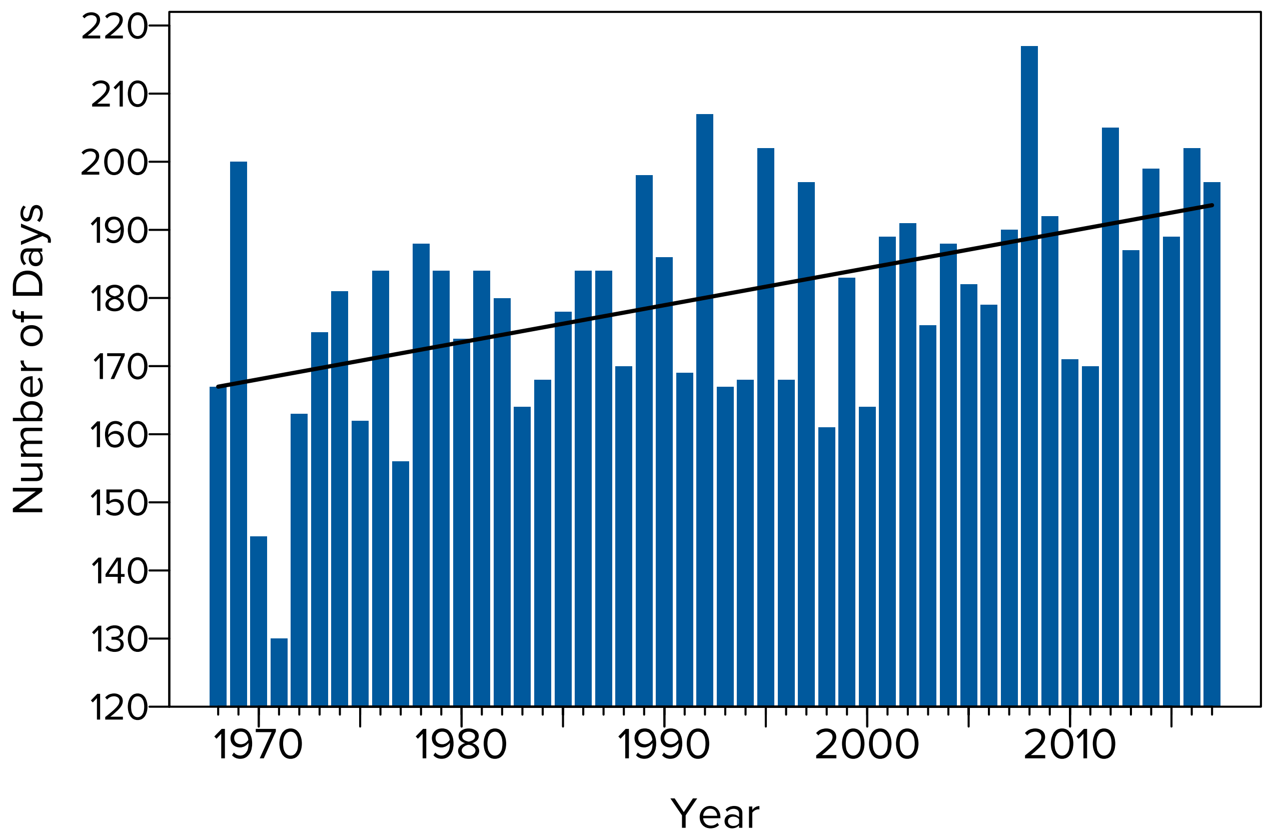


PHYSICAL PROPERTIES

Stratified season length

Since 1968

The stability index, a measure of the energy required to fully mix the lake, can be evaluated for every day of the year. We define the stratification season as the length of time when the stratification index exceeds a value of 600 kilograms per square meter. Since 1968, the length of the stratification season has increased, albeit with considerable year-to-year variation. Overall, the stratification season has lengthened by 26 days. In 2017, the length of the stratified season was 197 days.

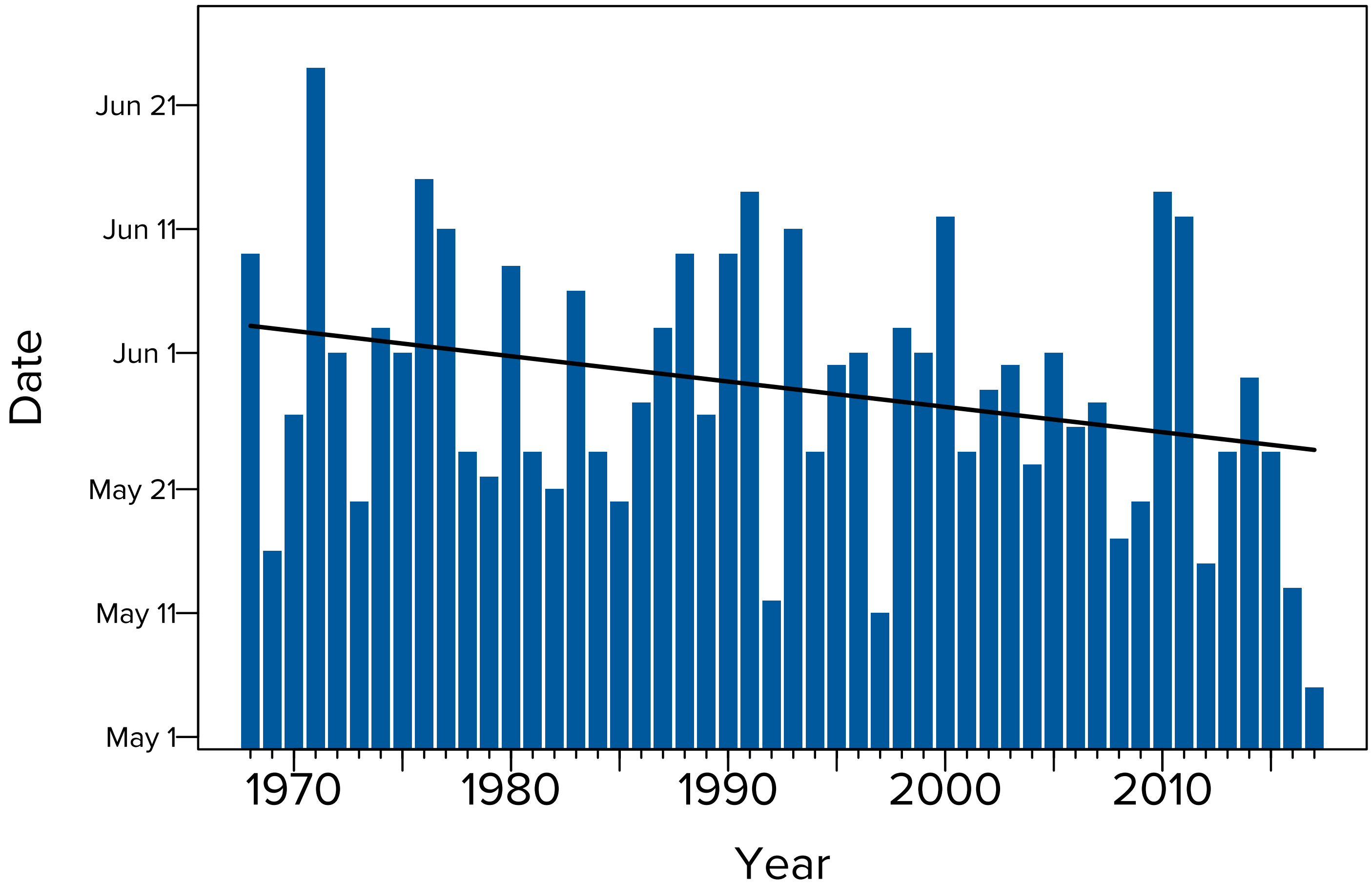


PHYSICAL PROPERTIES

Beginning of the stratification season

Since 1968

The amount of time that Lake Tahoe is stratified has been lengthening since 1968. One reason for this is the increasingly early arrival of spring as evidenced by the earlier commencement of stratification. Stratification occurs approximately ten days earlier than it did in 1968. The commencement of the stratification season is typically in late May or early June. In 2017, stratification began on Day 126 (May 5), the earliest such date on record.

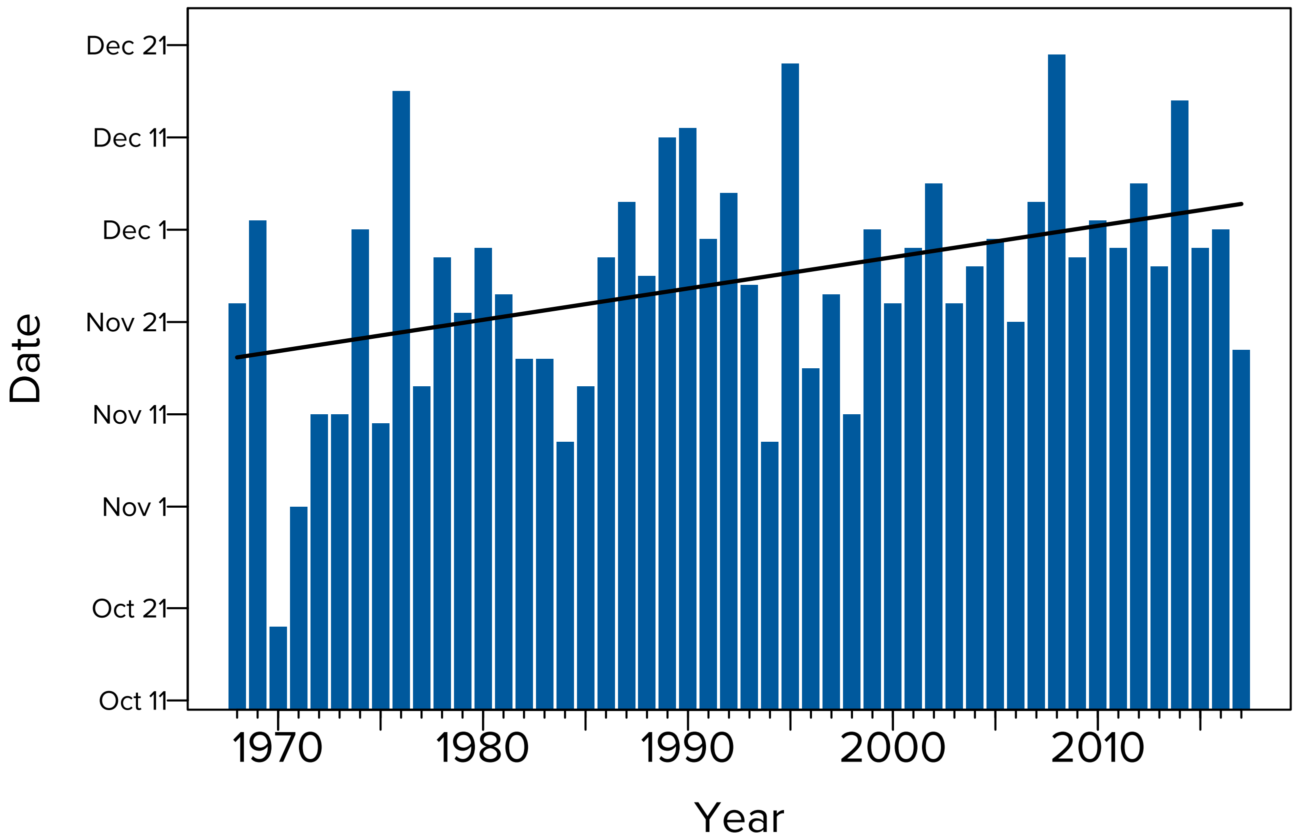


PHYSICAL PROPERTIES

End of stratification season

Since 1968

The amount of time that Lake Tahoe is stratified has lengthened since 1968 by almost four weeks. The end of stratification appears to have been extended by approximately 17 days on average. In other words, the fall season for the lake has been considerably extended. In the late 1960s, stratification ended in mid-November. Now it often ends in December. In 2017, stratification actually ended on Day 322 (November 18), on account of an early winter storm.

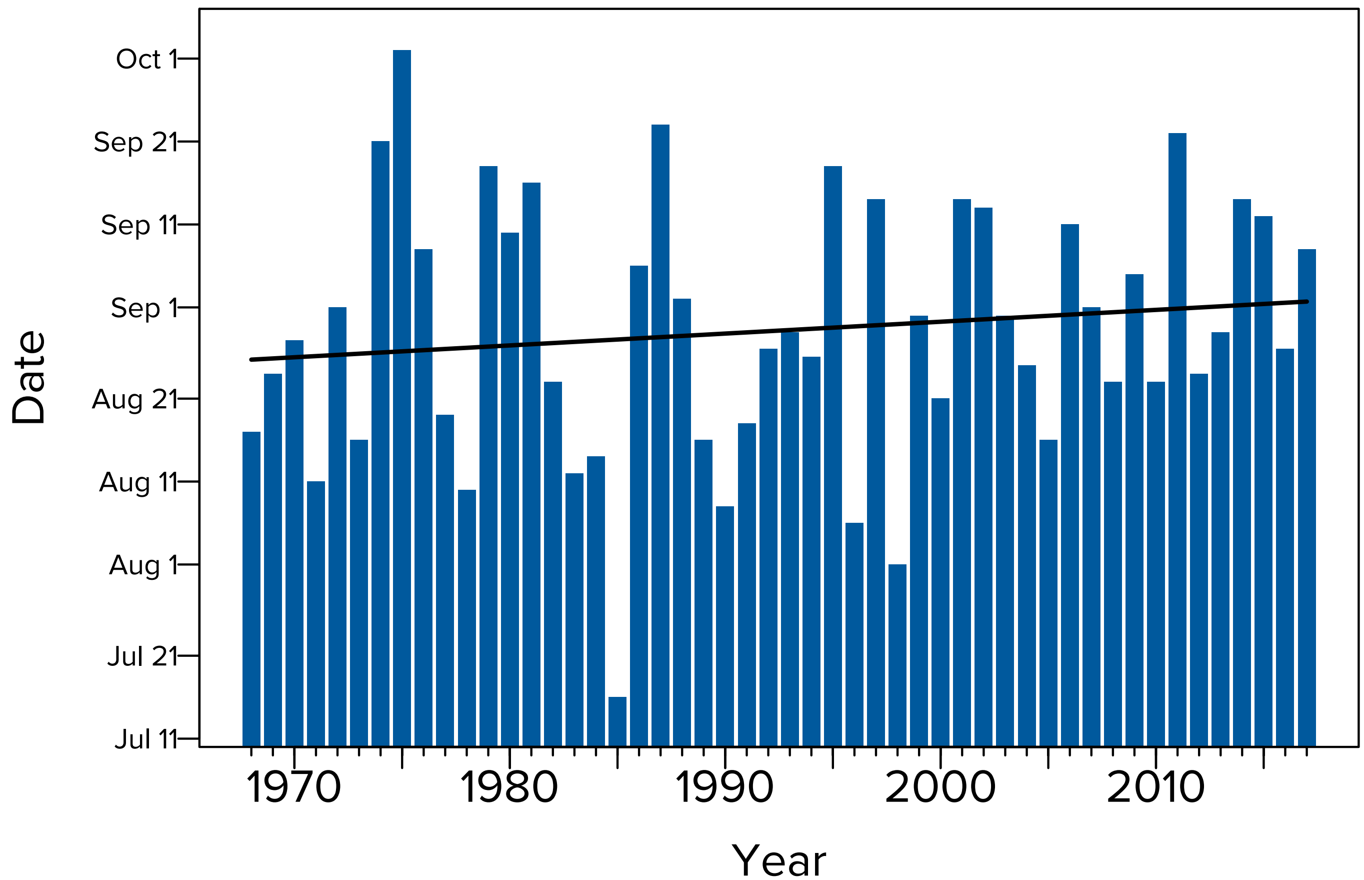


PHYSICAL PROPERTIES

Peak of stratification season

Since 1968

The day of the year when lake stratification reaches its maximum value has been plotted. There is considerable year-to-year variation, but over time there has been only a slight delay in when the peak occurs. In 2017, the peak occurred on September 8, later than the previous year. This was 7 days later than the long-term trend would have indicated.



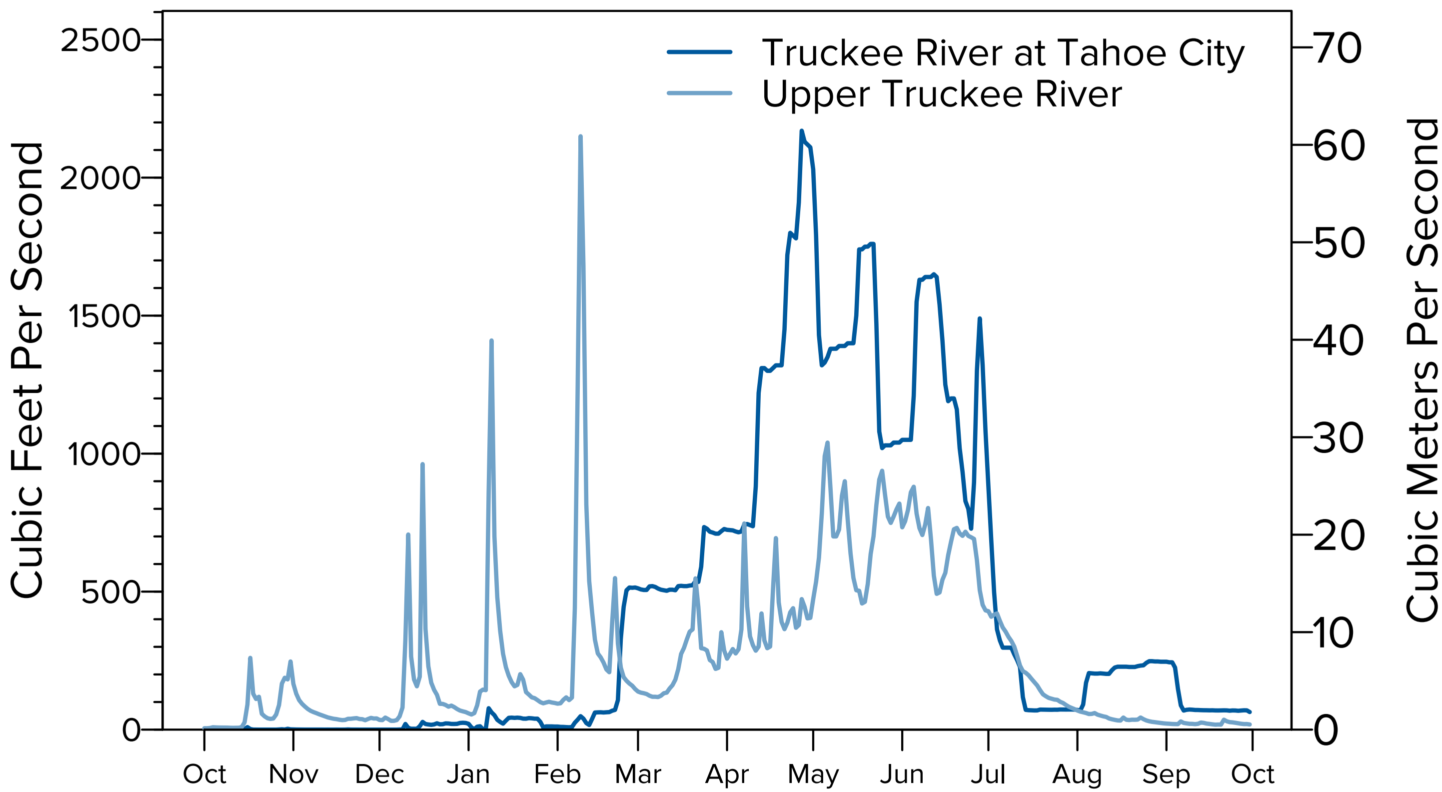
PHYSICAL PROPERTIES

Mean daily streamflow of Upper Truckee River vs. Truckee River

Water Year 2017

The largest stream flowing into Lake Tahoe is the Upper Truckee River. The small peaks in the hydrograph generally represent rain events or short warm periods in winter or spring. The extended seasonal increase (March-July) represents the snowmelt. The peak snowmelt flow was approximately 1040 cfs, compared to the long-term average of 300 cfs. The Upper Truckee River is estimated to represent about 25% of the stream inflow to Lake Tahoe.

The Truckee River is the only outflow from Lake Tahoe. It is a regulated flow, with release quantity controlled by the Federal Water Master. Typical maximum summer discharge is approximately 300 cfs in mid-June. In 2017, the peak daily discharge was 2170 cfs on April 27. Large outflows were necessary to make storage volume available in the lake in case of unexpectedly rapid snowmelt. Streamflow data are collected by the U.S. Geological Survey under the Lake Tahoe Interagency Monitoring Program (LTIMP).

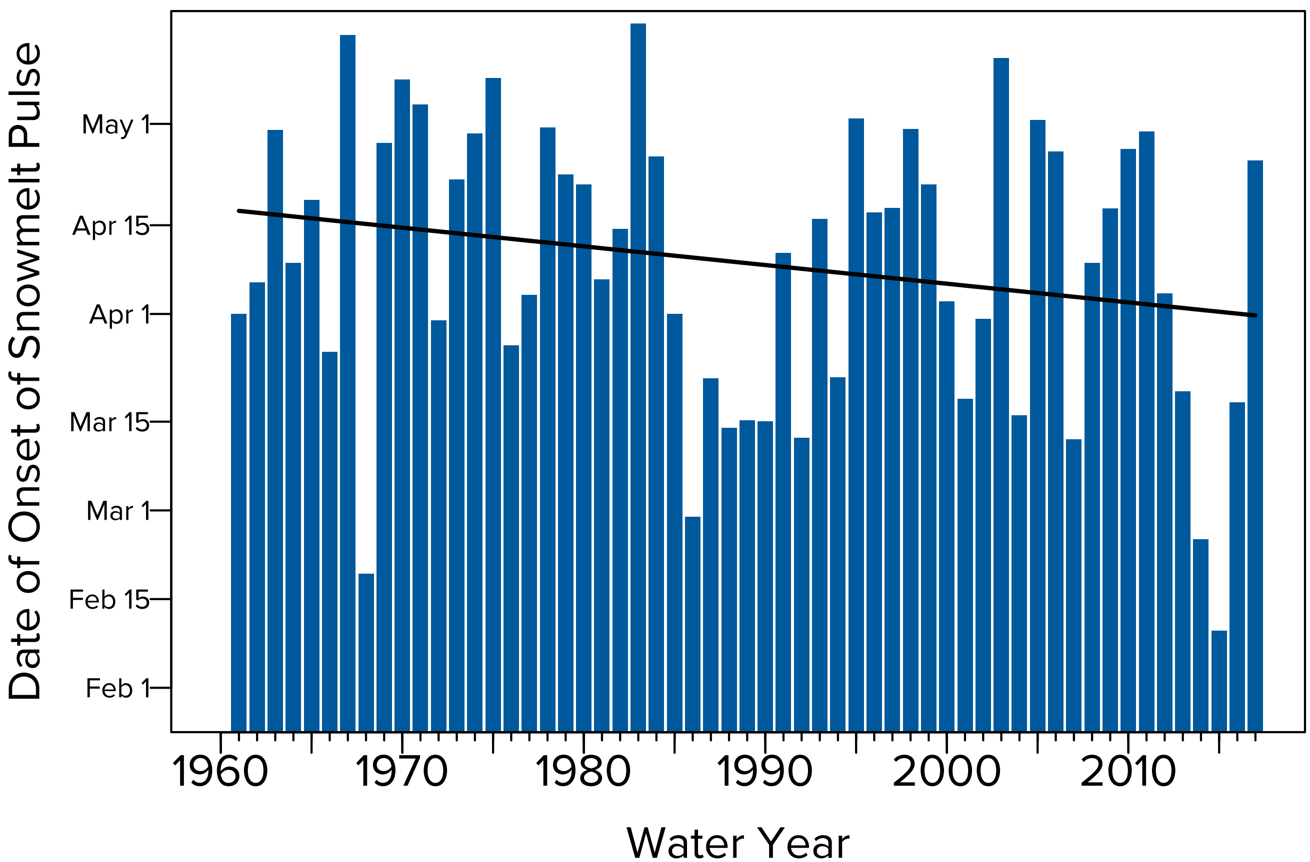


PHYSICAL PROPERTIES

Onset of snowmelt pulse

Yearly since 1961

Although the date on which snowmelt commences varies from year to year, it has shifted earlier an average of 16 days since 1961. This shift is statistically significant and is one effect of climate change at Lake Tahoe. In 2017, peak snowmelt occurred on April 25, over 5 weeks later than the previous year. The onset of the pulse is calculated as the day when flow exceeds the mean flow for the period Jan. 1 to July 15. The value for five gauged streams are averaged. In the past, we used the peak of the stream hydrograph to estimate this property.



TAHOE: STATE OF THE LAKE REPORT 2018

NUTRIENTS AND PARTICLES

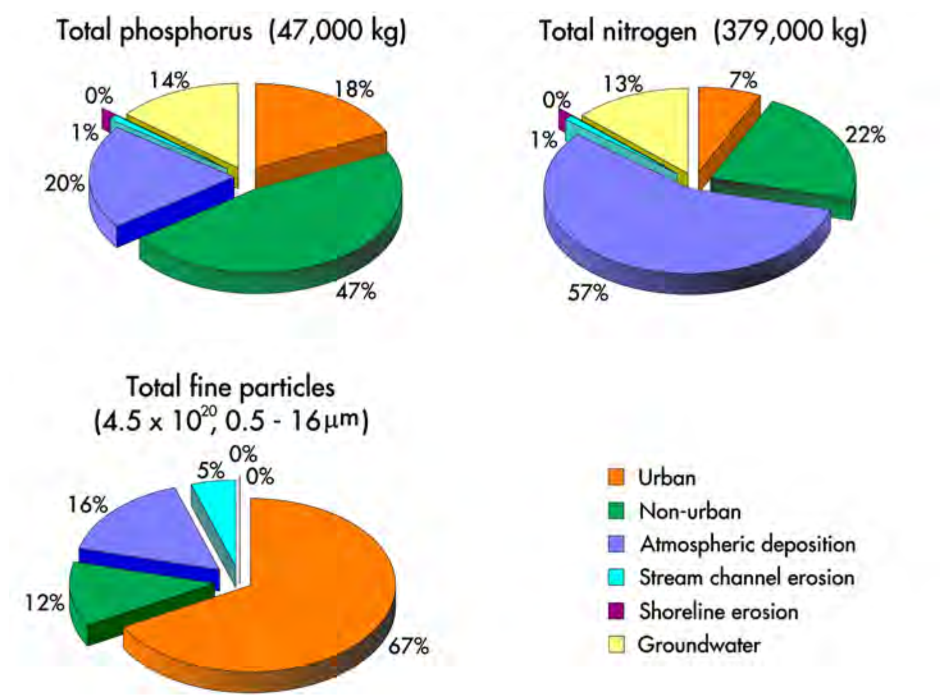
UC DAVIS
Tahoe Environmental
Research Center

NUTRIENTS AND PARTICLES

Sources of clarity-reducing and blueness-reducing pollutants

In 2017

Research has quantified the primary sources of nutrients (nitrogen and phosphorus) and particulate material that are causing Lake Tahoe to lose clarity and blueness in its upper waters. One of the major contributors to clarity decline are extremely fine particles in stormwater that originate from the urban watershed (67 percent), even though these areas cover only 10 percent of the basin's land area. Part of the atmospheric particle load is from these urbanized areas. For nitrogen, atmospheric deposition is the major source (57 percent). Phosphorus is primarily introduced by the urban (18 percent) and non-urban (47 percent) watersheds. These categories of pollutant sources form the basis of a strategy to restore Lake Tahoe's open-water clarity by agencies including the Lahontan Regional Water Quality Control Board, the Nevada Division of Environmental Protection, and the Tahoe Regional Planning Agency. Data were originally generated for the Lake Tahoe TMDL Program. These results are revised from the original estimates as they are based on a longer time series of monitoring data.



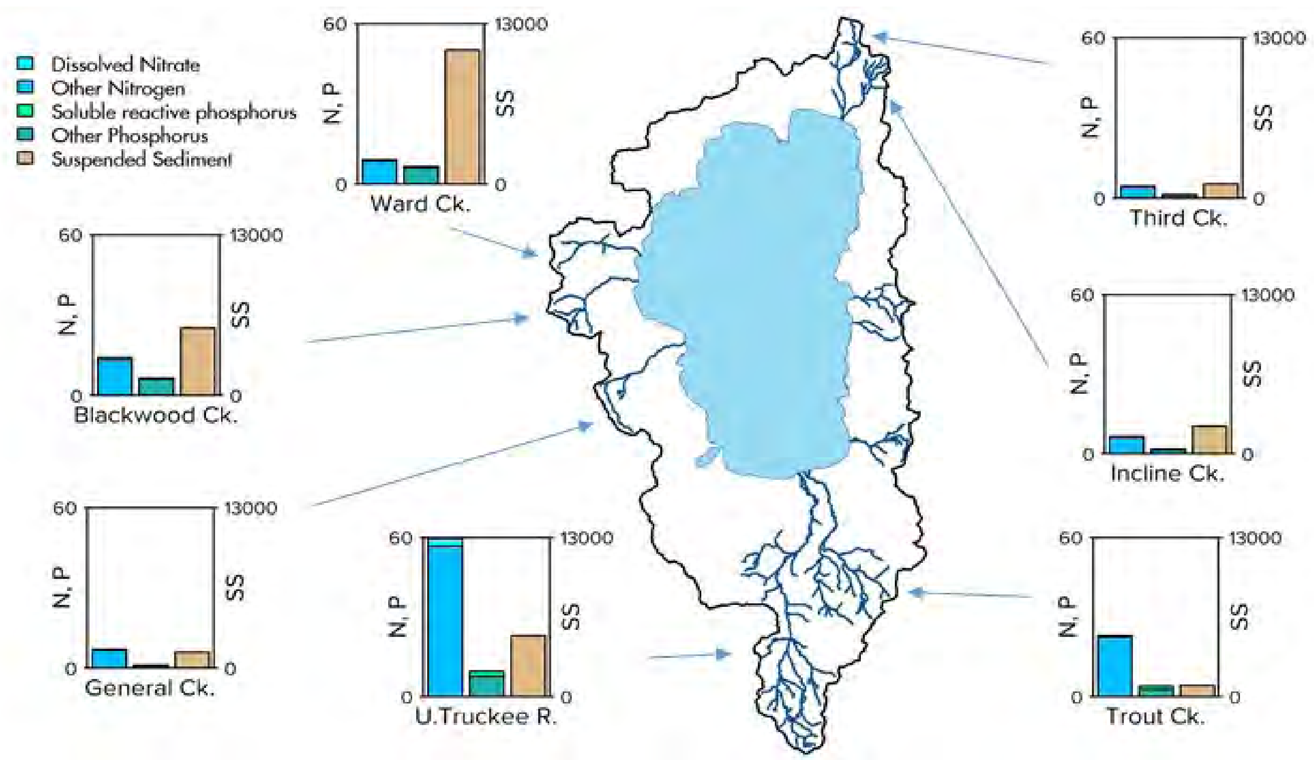
NUTRIENTS AND PARTICLES

Pollutant loads from seven watersheds

In 2017

The Lake Tahoe Interagency Monitoring Program (LTIMP) measures nutrient and sediment input from seven of the 63 watershed streams – a reduction of three streams since 2011. The majority of stream phosphorus and nitrogen comes from the Upper Truckee River, Trout Creek, Blackwood Creek and Ward Creek (in that order). Suspended sediment came primarily from Ward Creek, Blackwood Creek, the Upper Truckee River, and Incline Creek (in that order). Trout Creek was markedly lower despite the high precipitation.

The LTIMP stream water quality program is supported by the U.S. Geological Survey in Carson City, Nevada, UC Davis TERC, the California Tahoe Conservancy, the Lahontan Regional Water Quality Control Board, and the Tahoe Regional Planning Agency.

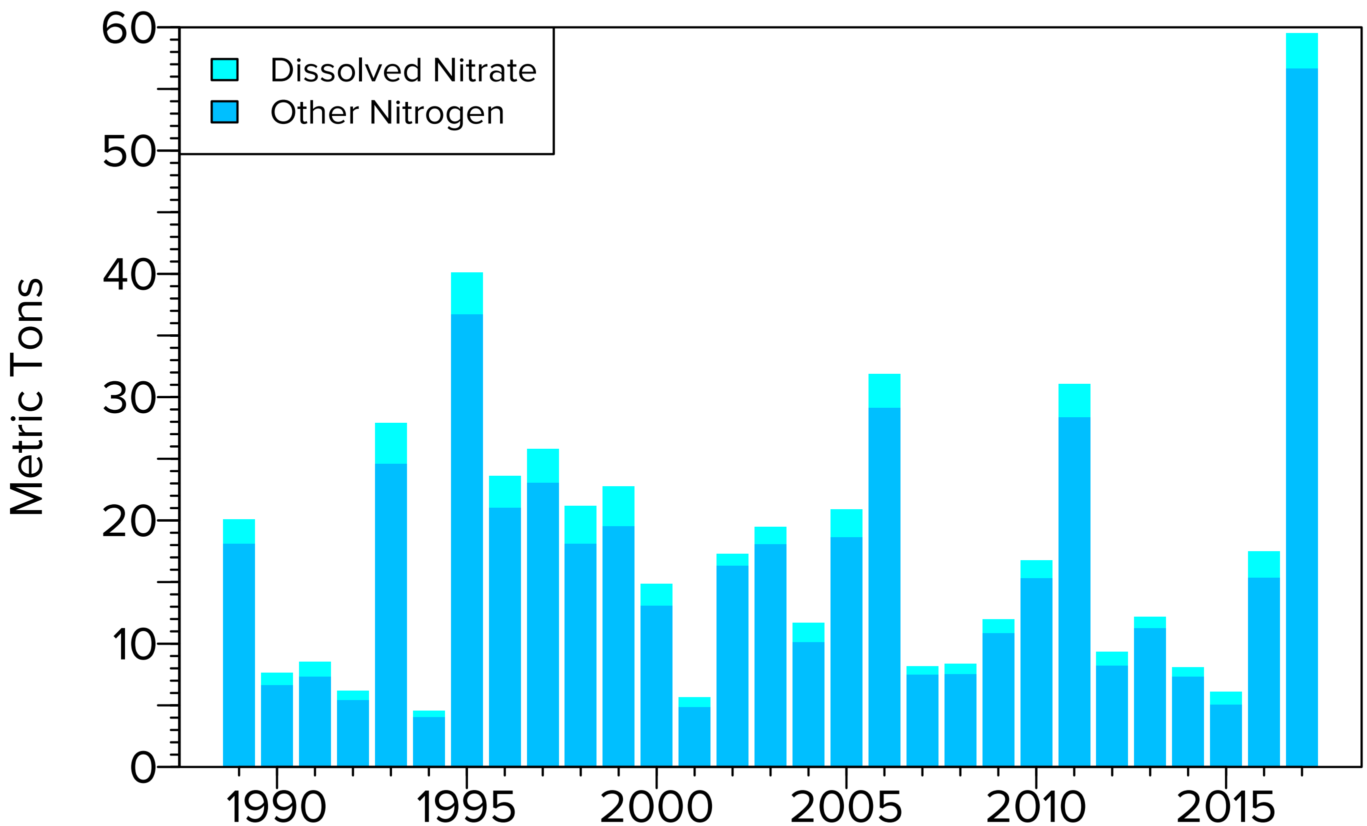


NUTRIENTS AND PARTICLES

Nitrogen contribution by Upper Truckee River

Yearly since 1989

Nitrogen (N) is important because it, along with phosphorus (P), stimulates algal growth. The Upper Truckee River is the largest of the 63 streams that flow into Lake Tahoe, contributing about 25 percent of the inflowing water. The river's contribution of dissolved nitrate and the remainder of the total nitrogen load are shown here. The year-to-year variations primarily reflect changes in precipitation. 2017 saw the largest load of nitrogen ever recorded. This was due to the extraordinarily high flows following five years of drought. (One metric ton = 2,205 pounds.)



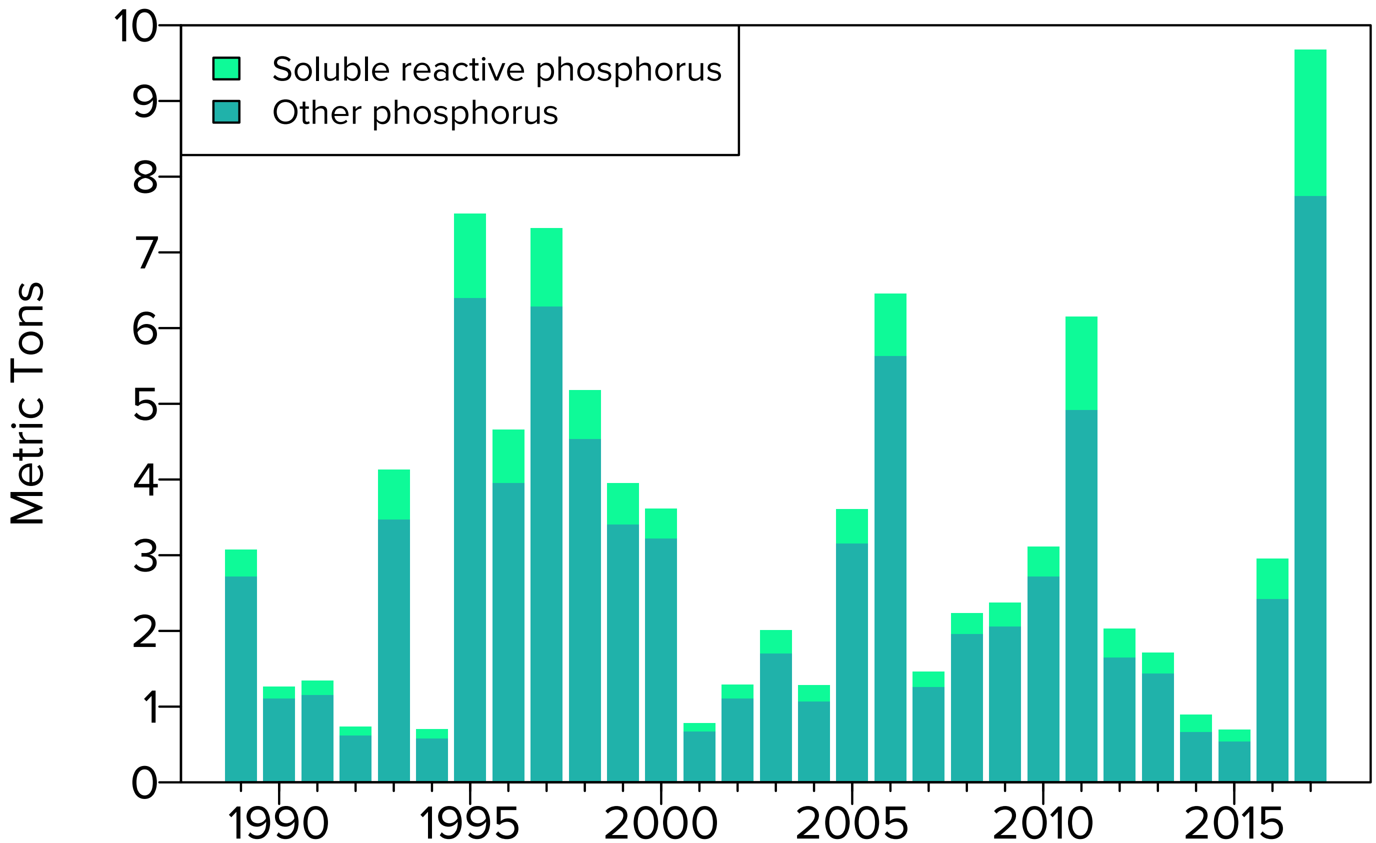
NUTRIENTS AND PARTICLES

Phosphorus contribution by Upper Truckee River

Yearly since 1989

Soluble reactive phosphorus (SRP) is the fraction of phosphorus immediately available for algal growth. As with nitrogen (Page 9.3), the year-to-year variation in load largely reflects the changes in precipitation. The extremely high precipitation in 2017 resulted in a Total phosphorus level of 9.68 MT and an SRP load of 1.93 MT, both the highest values recorded. These compare with the long-term averages of 3.18 and 0.48 MT respectively. The long-term decrease in nutrient inputs is fundamental to restoring Lake Tahoe's ecosystem health.

Total phosphorus is the sum of SRP and other phosphorus, which includes organic phosphorus and phosphorus associated with particles.
(One metric ton (MT) = 2,205 pounds.)

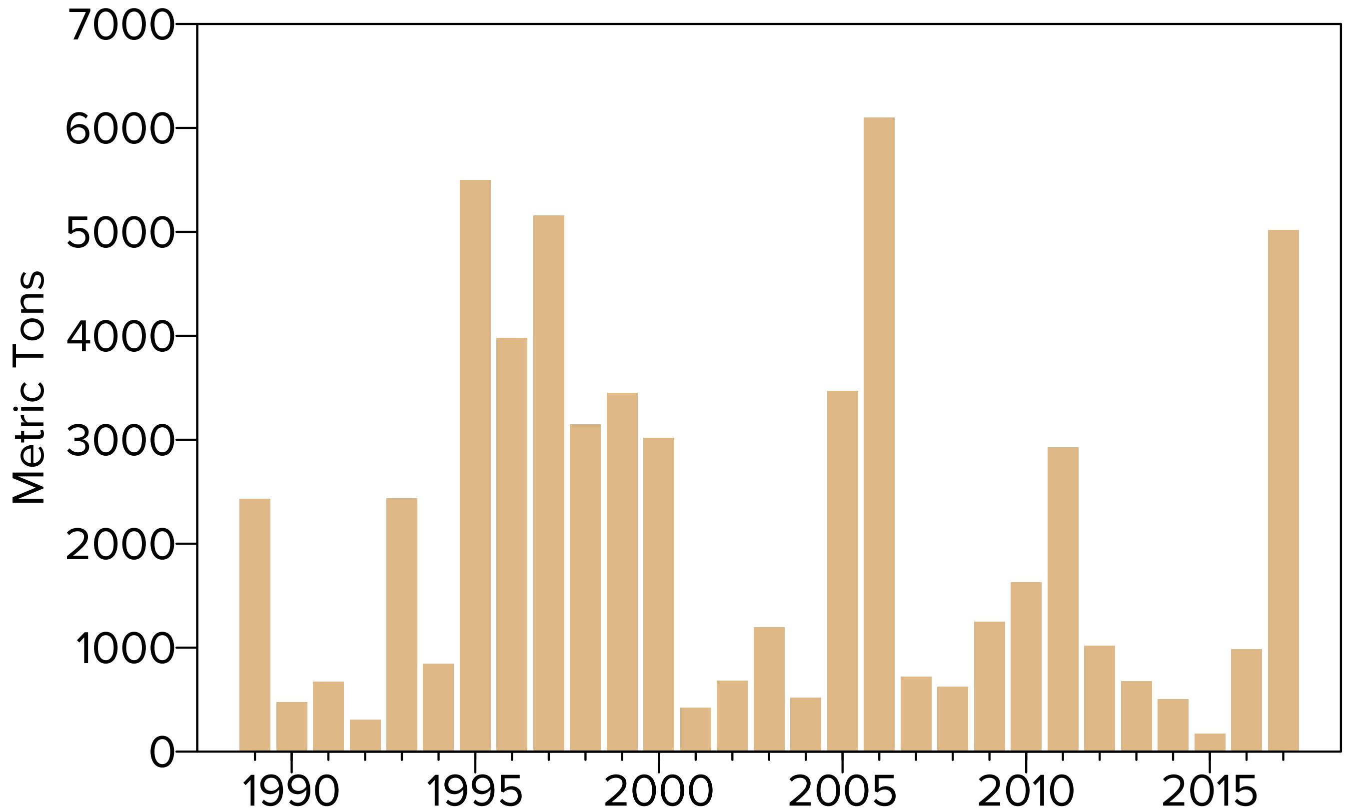


NUTRIENTS AND PARTICLES

Suspended sediment contribution by Upper Truckee River

Yearly since 1989

The load of suspended sediment delivered to the lake by the Upper Truckee River is related to landscape condition and erosion as well as to precipitation and stream flow. Inter-annual variation in sediment load over shorter time scales is more related to the latter. Plans to restore lake clarity emphasize reducing loads of very fine suspended sediment (less than 20 microns in diameter) from urbanized areas. Efforts to restore natural stream function and watershed condition focus on reducing loads of total sediment regardless of size, as well as restoration of habitat for plants and wildlife. In 2017, the suspended sediment load from the Upper Truckee River was 5,019 metric tons, the fourth highest load recorded. The load greater than the sum of all annual loads from the previous five years. The high loads were the result of the high precipitation ending a five-year drought. The average annual load is 2,046 metric tons.

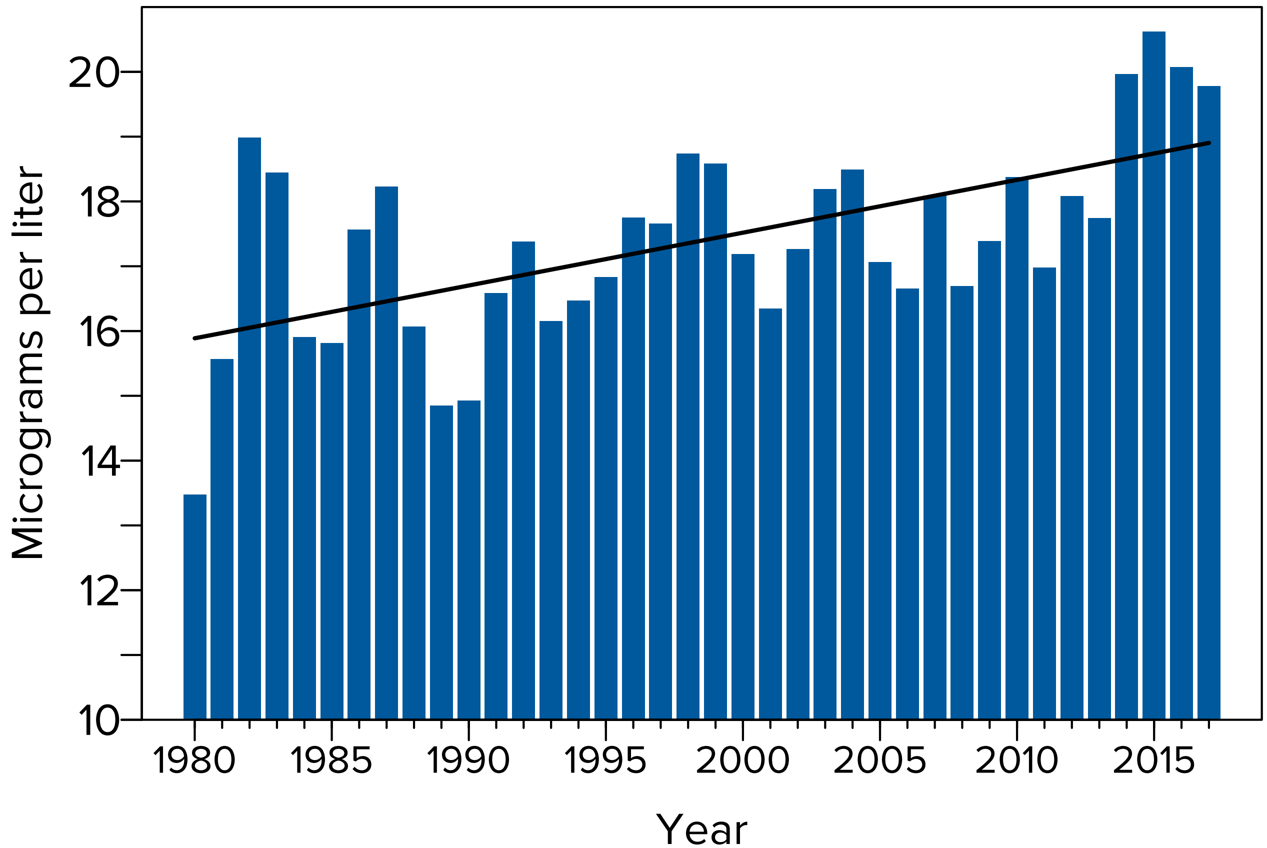


NUTRIENTS AND PARTICLES

Lake nitrate concentration

Yearly since 1980

Since 1980, the volume-weighted annual average concentration of nitrate-nitrogen has gradually been increasing, ranging between 13 and 20 micrograms per liter. In 2017, the volume-weighted annual average concentration of nitrate-nitrogen was 19.8 micrograms per liter. This high value is in part due to the sixth successive year in which deep mixing did not take place, allowing for a continued buildup of nitrate in the deep water. The average annual concentration is 17.4 micrograms per liter. Water samples are taken at the MLTP (mid-lake) station at 13 depths from the surface to 450 meters.

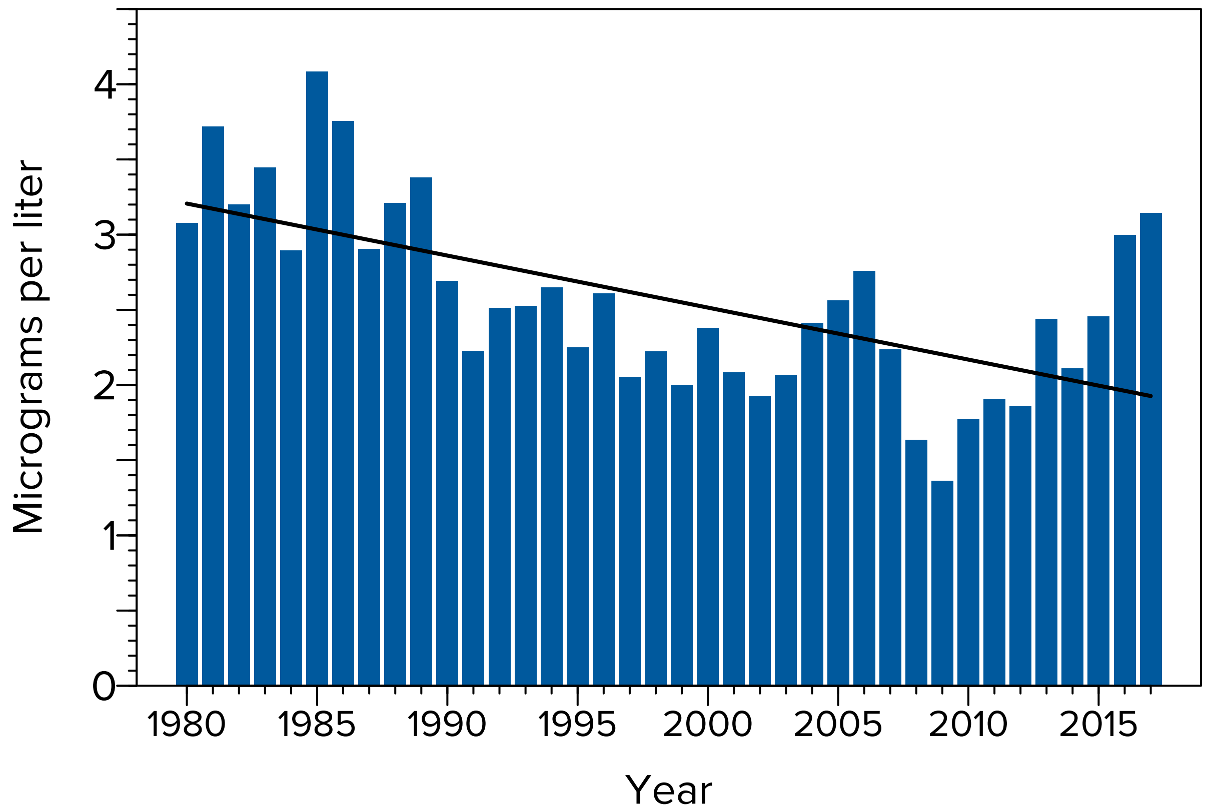


NUTRIENTS AND PARTICLES

Lake phosphorus concentration

Yearly since 1980

Phosphorus naturally occurs in Tahoe Basin soils and enters the lake from soil disturbance and erosion. Total hydrolyzable phosphorus, or THP, is a measure of the fraction of phosphorus that algae can use to grow. It is similar to the SRP that is measured in the streams. Since 1980, THP has trended towards a decline, although in the last eight years the values have been increasing toward levels that were present in the 1980s. The high stream loads in 2017 contributed to this increasing trend. In 2017, the volume-weighted annual average concentration of THP was 3.15 micrograms per liter, the highest level since 1989. The average annual value is 2.57 micrograms per liter. Water samples are taken at the MLTP (mid-lake) station at 13 depths from the surface to 450 meters.



NUTRIENTS AND PARTICLES

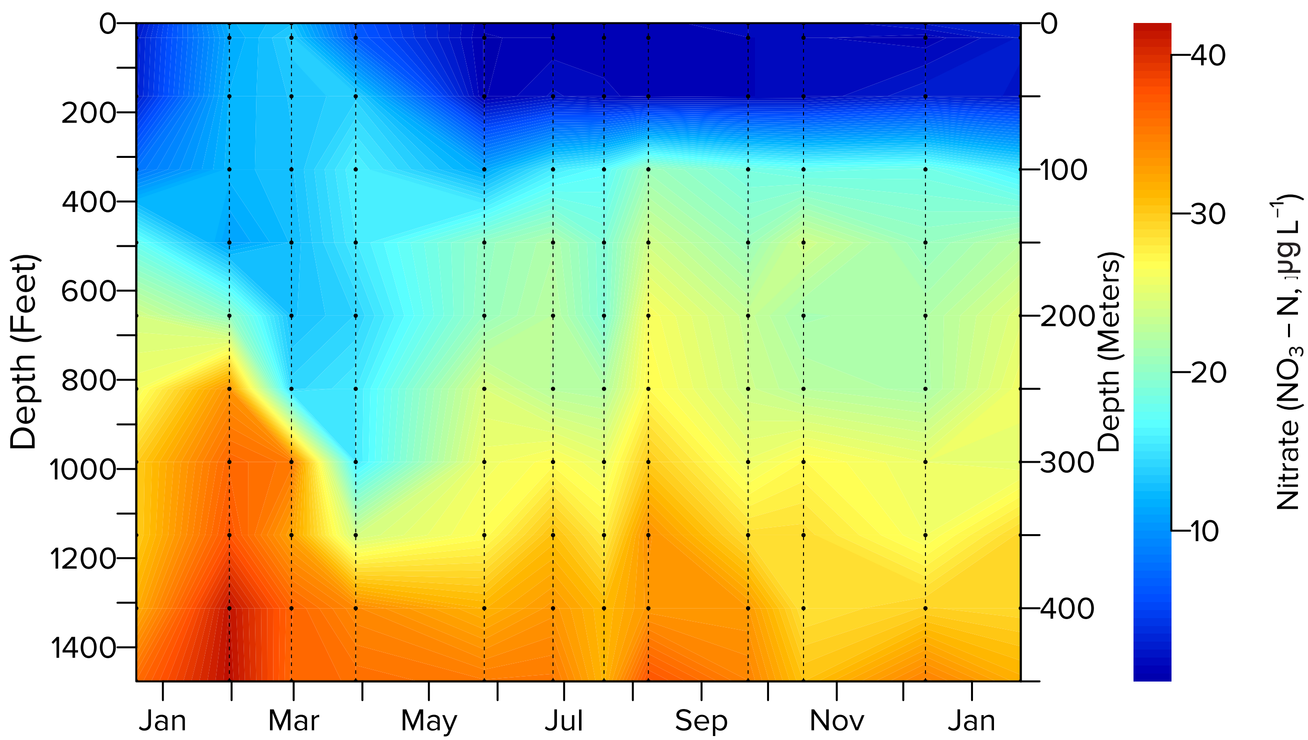
Nitrate distribution

In 2017

Water samples are collected approximately every month (on dates indicated by the dashed lines) at 13 depths (indicated by the dots) at the middle of the lake and analyzed in the TERC laboratory for nutrient concentrations. Here the nitrate concentration is shown in the form of color contours.

Most evident is the vertical distribution of nitrate. Concentrations below a depth of about 300 feet are generally high. The surface waters, where sunlight enables algae to take up nitrogen as they grow, usually have low concentrations of nitrate. Although most of the nitrate enters at the surface through atmospheric deposition, it is rapidly taken up by the algae and surface concentrations are generally low. As algae sink and decompose, the nitrate they consumed reappears deep in the lake. At these depths, there is insufficient light for algae to grow and to use these nutrients.

Deep lake mixing will bring the deep nitrate back to the surface. 2017 was a year where mixing extended to 1,099 feet, just two-thirds of the full depth. Consequently, a substantial amount of nitrate remained trapped in the deepest water. The annual nitrate concentration at a depth of 1,485 feet was 35.7 micrograms per liter.



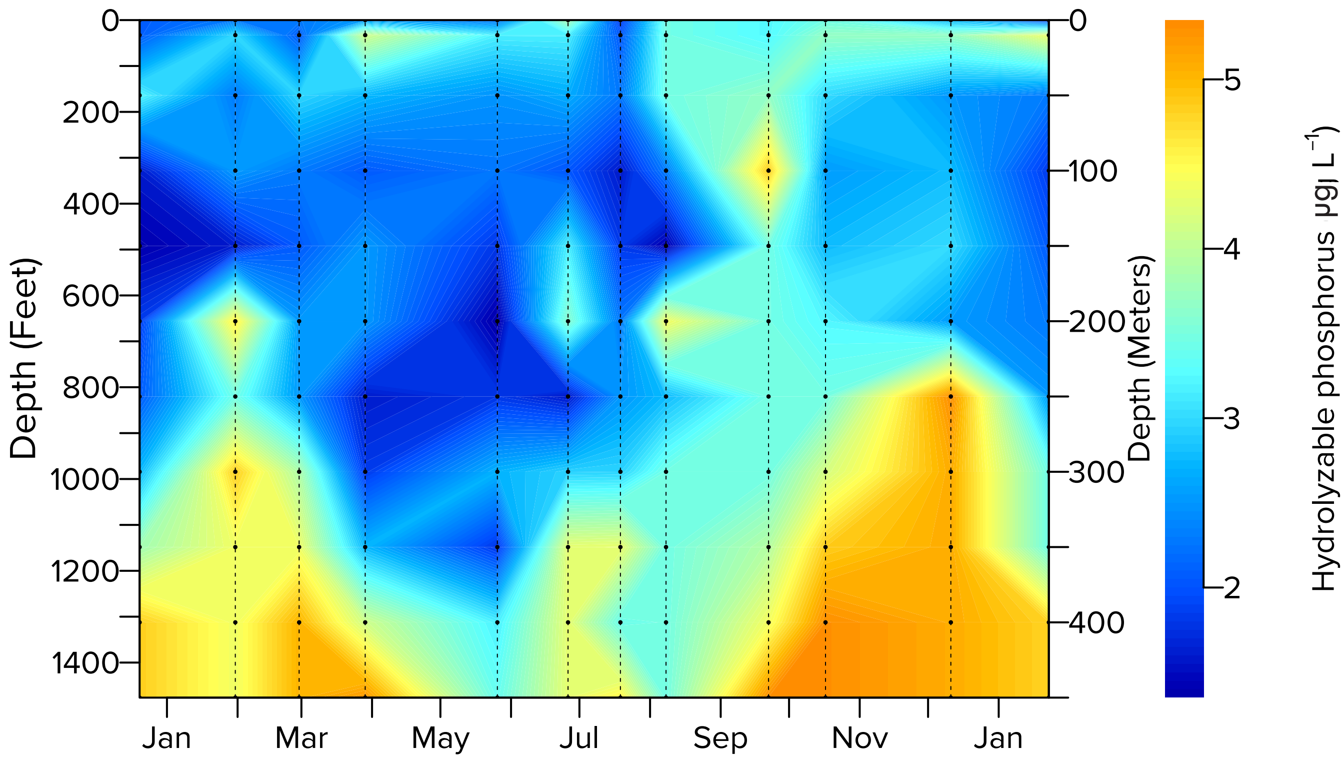
NUTRIENTS AND PARTICLES

Orthophosphate distribution

In 2017

Water samples are collected approximately every month (on dates indicated by the dashed lines) at 13 depths (indicated by the dots) at the middle of the lake and analyzed in the TERC laboratory for nutrient concentrations. Here the total hydrolyzable phosphorus (THP) concentration (the fraction of phosphorus that can be readily used by algae) is shown in the form of color contours.

Phosphorus mainly enters the lake in association with fine particles during runoff events. The high values near the surface between June and September, and then again in December correspond to the timing of inflows. The high concentrations of phosphorus deep in the lake during summer are the result of algae sinking and then decomposing. Eventually the THP attaches to particles and settles to the lake bottom. The annual THP concentration at a depth of 1,485 feet was 4.6 micrograms per liter.



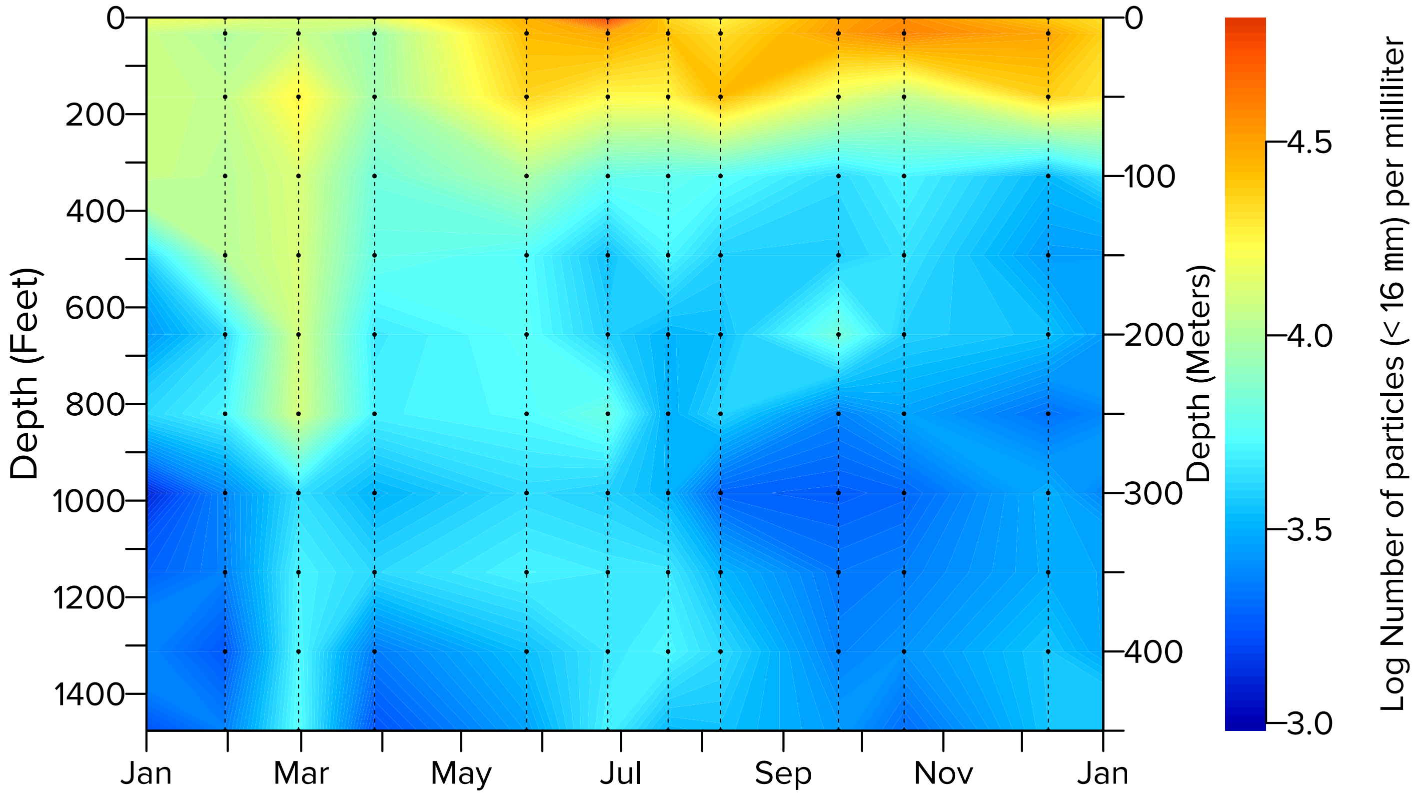
NUTRIENTS AND PARTICLES

Fine particle distribution

In 2017

Water samples are collected approximately monthly (on dates indicated by the dashed lines) at 13 depths (indicated by the dots) at the middle of the lake, and analyzed in the TERC laboratory for the concentration of fine particles in 15 different bin sizes. Here the distributions of the finest particles (in the range of 0.5 to 8 microns) are shown in the form of color contours.

Clearly evident is that the highest concentrations of fine particles (red tones) are concentrated in the upper part of the lake. This high concentration band of particles persists through the end of the year, and at concentrations higher than previous years. The particle concentration is highest from September onwards, which coincides with the annual variation in Secchi depth n 2017



TAHOE: STATE OF THE LAKE REPORT 2018

BIOLOGY

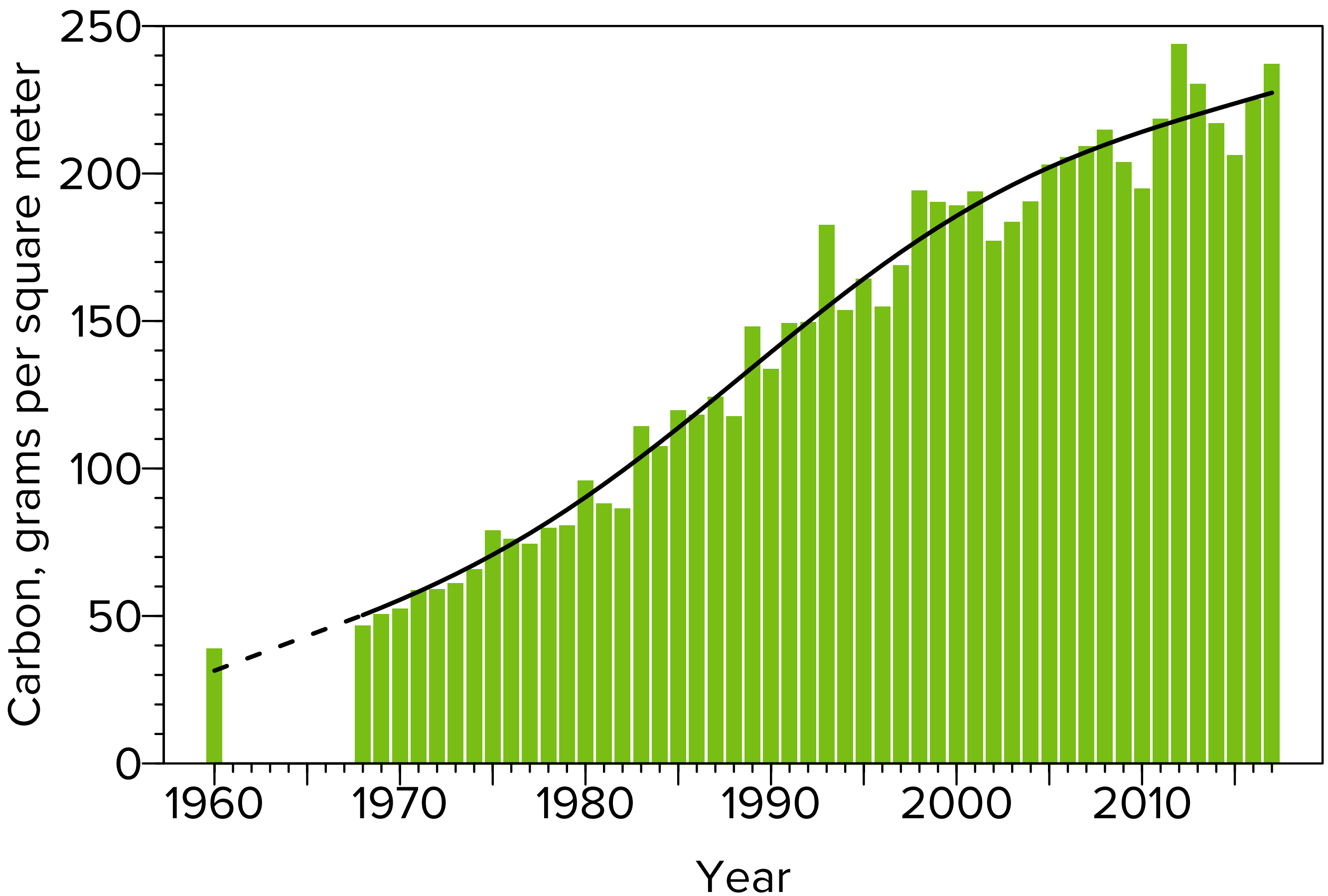
UC DAVIS
Tahoe Environmental Research Center

BIOLOGY

Algae growth (primary productivity)

Yearly since 1959

Primary productivity is a measure of the rate at which algae produce biomass through photosynthesis. It was first measured at Lake Tahoe in 1959 and has been continuously measured since 1968. Supported by nutrient loading into the lake, changes in the underwater light environment, and a succession of algal species, the trend shows primary productivity has increased substantially over time. In 2017, there was an increase in primary productivity to 237.2 grams of carbon per square meter.

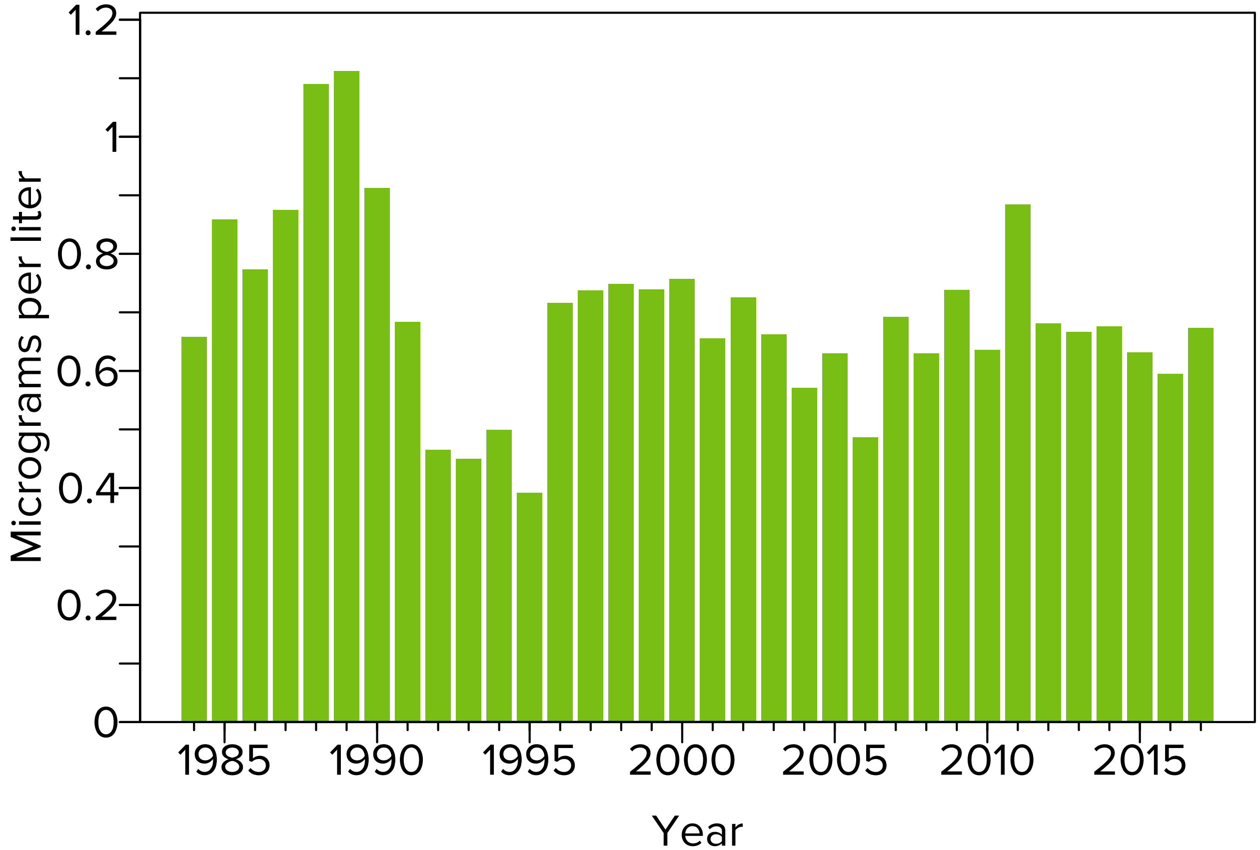


BIOLOGY

Algae abundance

Yearly since 1984

Algae (phytoplankton) are the base of the Lake Tahoe food web, and essential for lake health and the well-being of the entire ecosystem. The amount or biomass of free-floating algae in the water is determined by extracting and measuring the concentration of chlorophyll-*a*, a photosynthetic pigment that allows plants to convert energy from the sun. Though the value varies annually, aside from an increase in the later 1980s the amount has generally stayed near-constant. The average annual concentration for 2017 was 0.67 micrograms per liter, higher than the previous year's value of 0.59 micrograms per liter. For the period of 1984-2017 the average annual chlorophyll-*a* concentration in Lake Tahoe was 0.70 micrograms per liter.



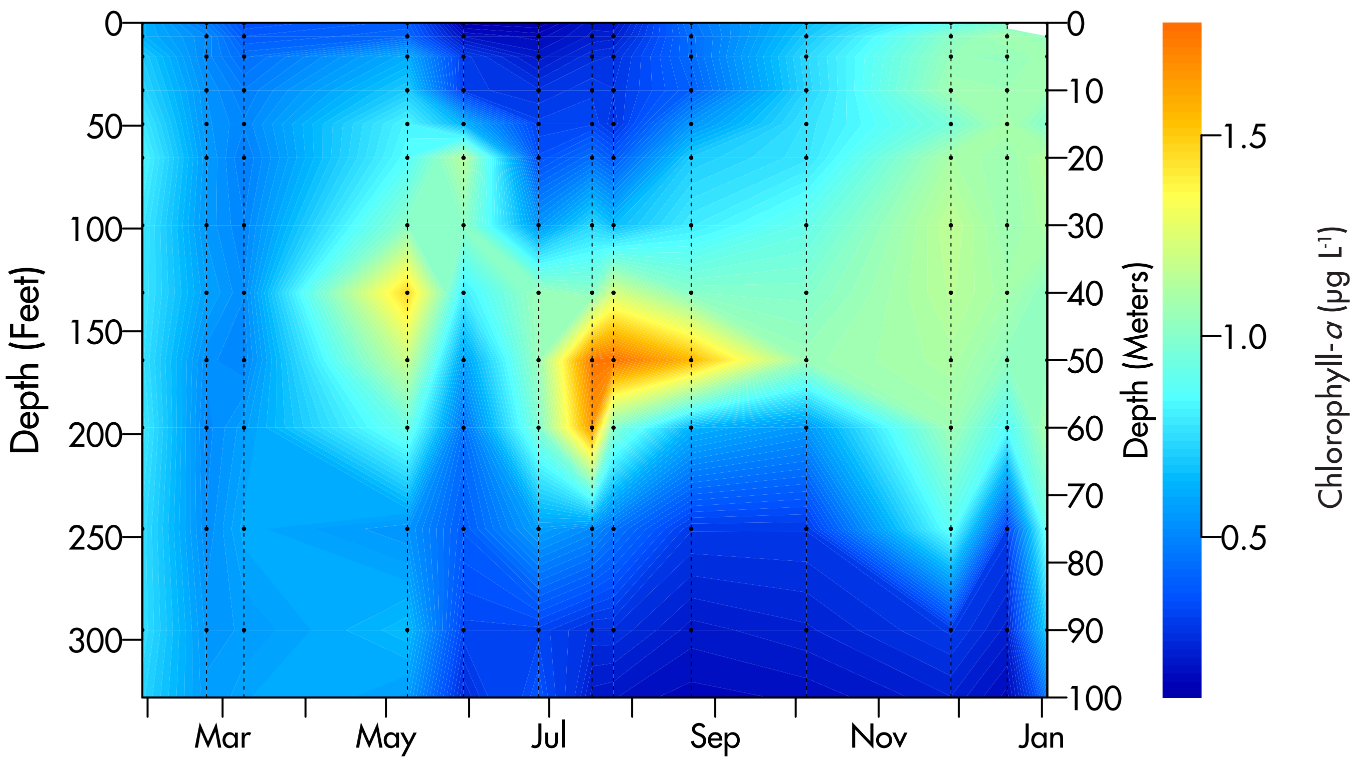
BIOLOGY

Chlorophyll-*a* distribution

In 2017

The distribution of algae (measured as chlorophyll-*a*) is the result of a combination of light availability, nutrient availability, mixing processes, and to a lesser extent, water temperature. This figure shows color contours of chlorophyll-*a* concentration down to a depth of 350 feet. Below this depth chlorophyll-*a* concentrations are near zero due to the absence of light. Lake Tahoe has a "deep chlorophyll maximum" in the summer that occupies the range of 150-300 feet in the water column. In that depth range, the light and nutrient conditions are most favorable for algal growth.

With the onset of thermal stratification in spring, the majority of the algae were confined to a discrete band. Throughout the summer and fall, concentrations decreased as nutrients were depleted. In December, the commencement of mixing again redistributed the algae over a broader depth range.

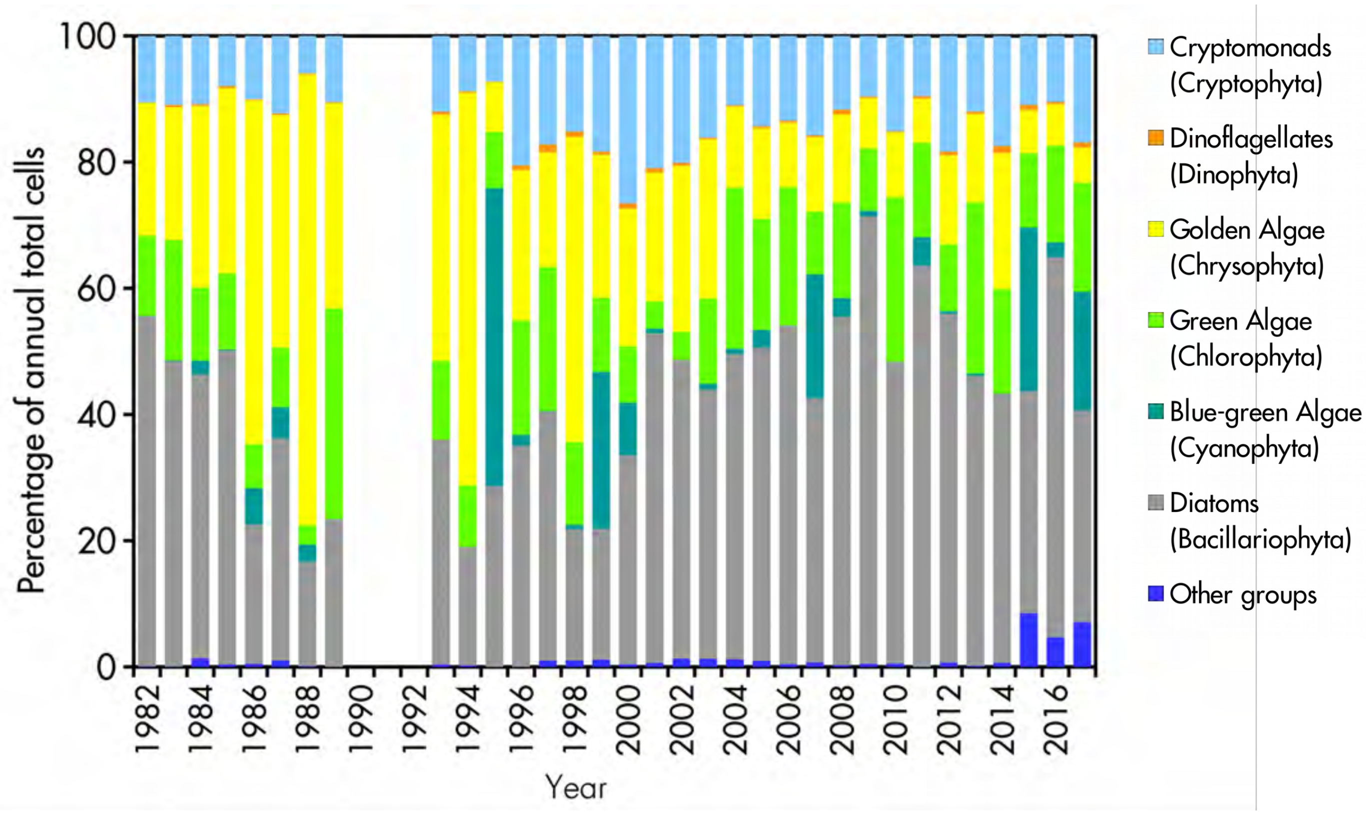


BIOLOGY

Annual distribution of algal groups

Yearly since 1982

The amount of algal cells from different groups varies from year to year. Diatoms are the most common type of alga, comprising over one-third of the total abundance of algal cells in 2017. Blue-green algae (19%), green algae (17%), and dinoflagellates (17%) were next most common in abundance. While the proportion of the major algal groups show a degree of consistency from year-to-year, TERC research has shown that the composition of individual species within the major groups is changing both seasonally and annually in response to lake conditions.

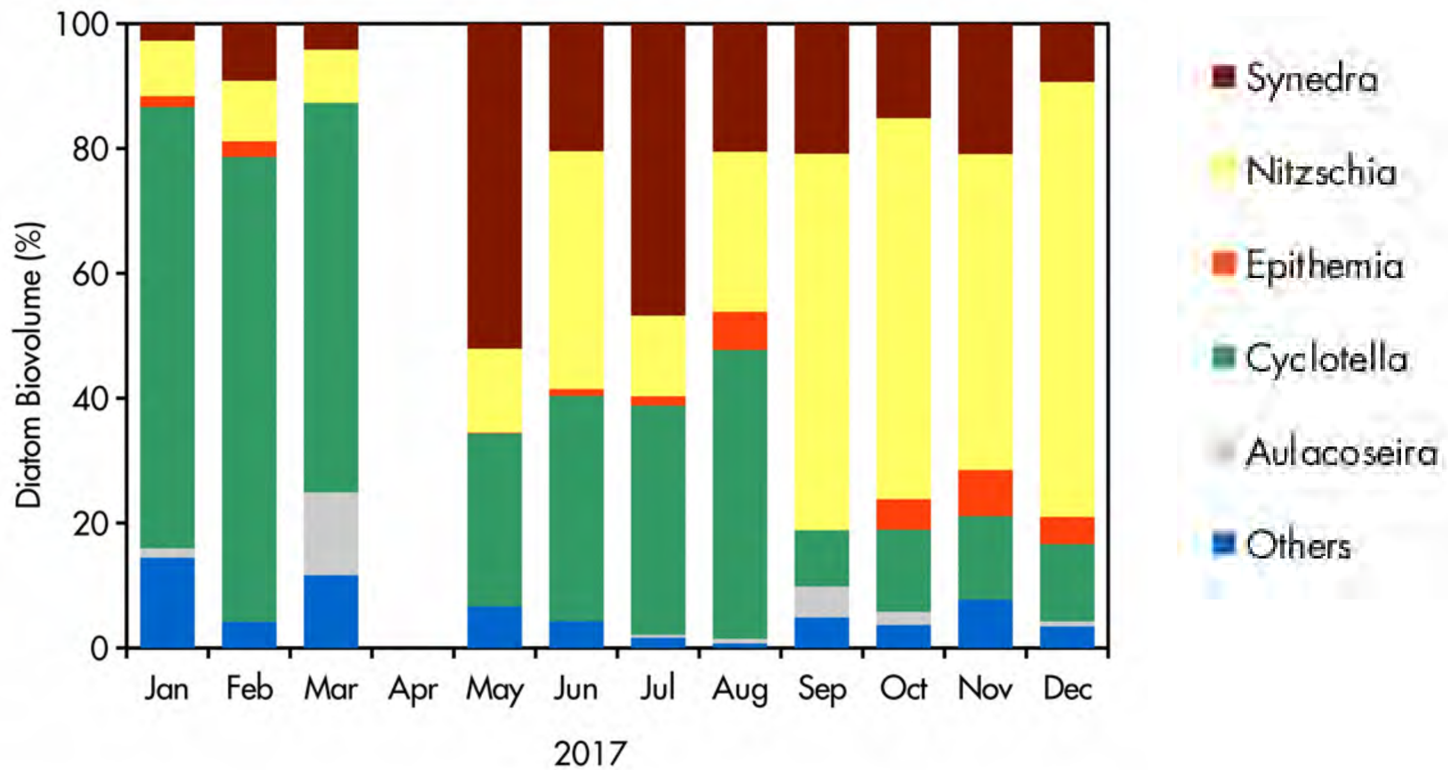


BIOLOGY

Abundance of dominant diatom species

Monthly in 2017

Diatoms have been the dominant algal group at Lake Tahoe for all but a few years since 1982. Diatoms are unique in that they are enclosed within a cell wall made of silica, called a frustule. Here the dominant diatom species at Lake Tahoe in 2017 are shown. Large variations are evident by month in the relative composition. Throughout the year, the dominant species varies from *Cyclotella* to *Synedra* to *Nitzschia*. Of note is the fact that *Cyclotella*, which has been responsible for clarity decreases in Lake Tahoe, was only a minor contributor to clarity reduction in the second half of 2017.

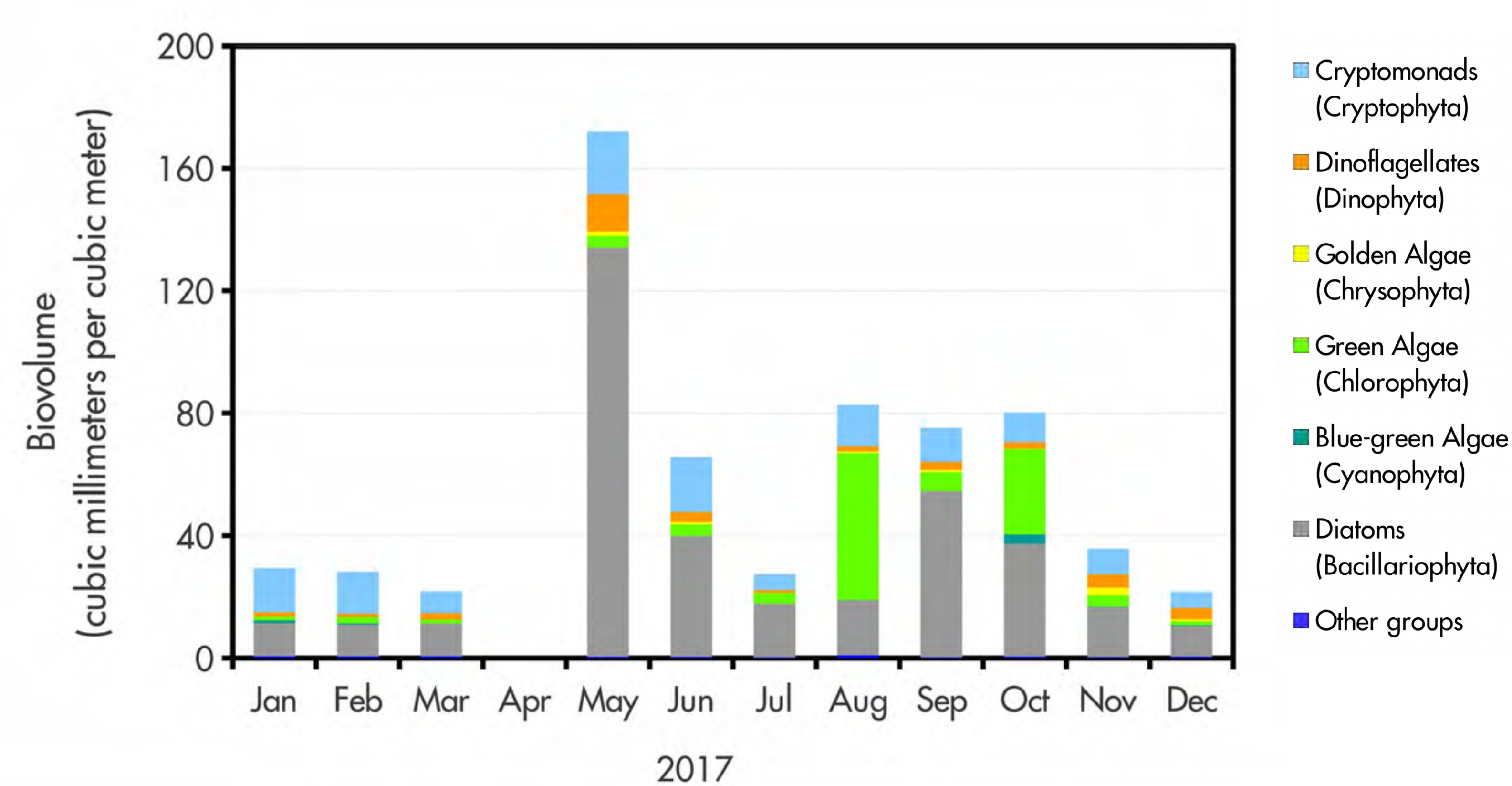


BIOLOGY

Algal groups as a fraction of total biovolume

Monthly in 2017

The biovolume of algal populations vary month to month, as well as year to year. In 2017, diatoms again dominated the biovolume of the phytoplankton community, especially in the summer. The peak in the biovolume (the "spring bloom") occurred a month earlier in May rather than June. The large influx of stream nutrients may have contributed to this early high point. Even at the peak of the bloom, algal cells occupied only one ten-millionth of the water in the lake. The peak biovolume in 2017 was 170 cubic millimeters per cubic meter.

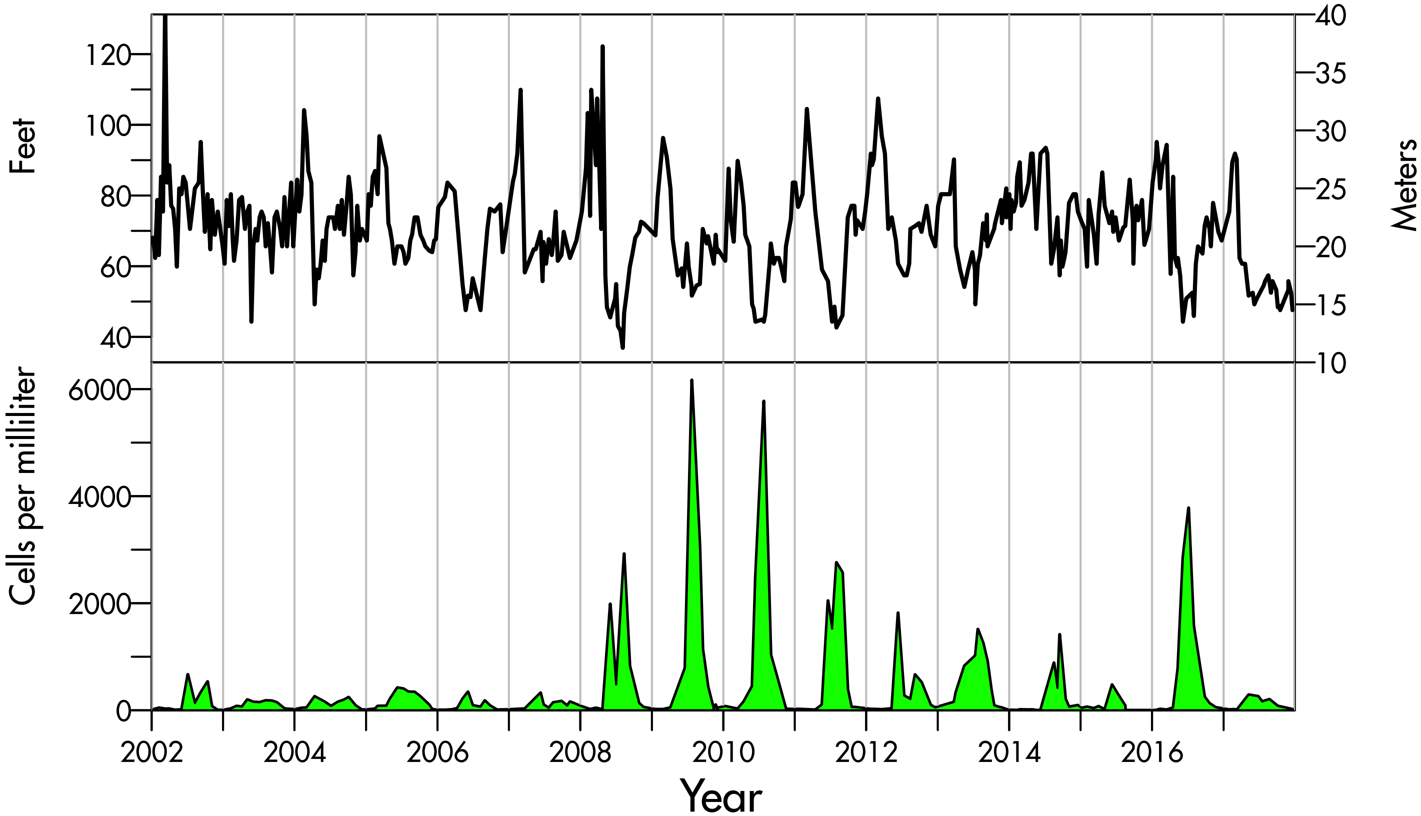


BIOLOGY

Predominance of *Cyclotella gordonensis*

From 2002 through 2017

In 2008, one species of algae, *Cyclotella* gordonensis, started to dominate the make-up of algae at Lake Tahoe. The cells range in size from 4-30 microns in diameter. During the summer, the smallest cells, 4-5 microns, control the community in the upper euphotic zone. This size range, which is similar to inorganic particles, is ideal for light scattering. The growing numbers of *Cyclotella* between 2008-2011 were believed to be responsible for the major decline in summer clarity in those years. In 2017, the concentration of *Cyclotella* cells returned to their pre-2008 range, where they had little impact on the lake's clarity. The lower panel indicates the concentrations of *Cyclotella* at a depth of 16.5 feet (5 m). The black line in the upper panel indicates the individual Secchi depths taken since 2002. While 2017 clarity levels were very low, it is clear that *Cyclotella* was not a major factor.

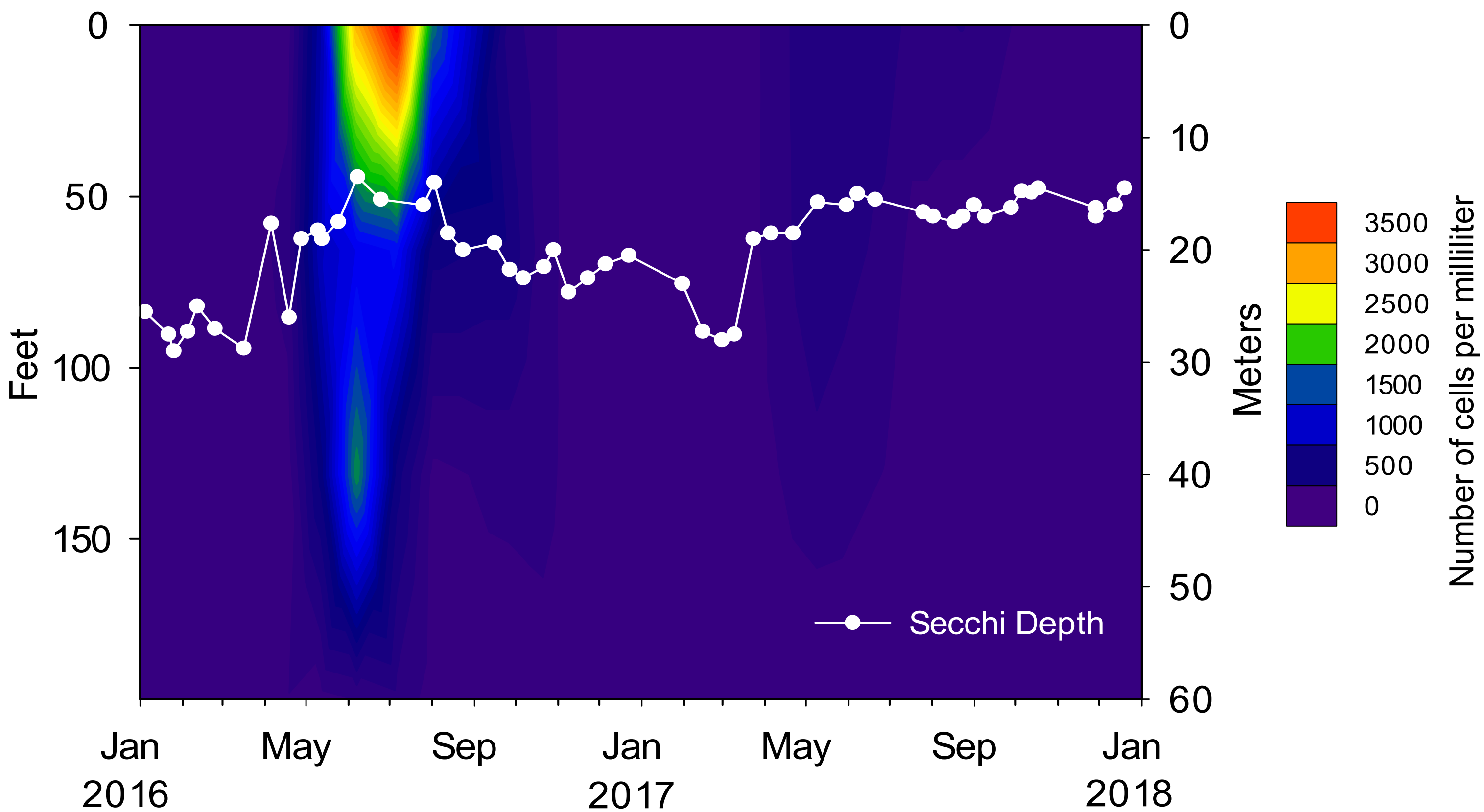


BIOLOGY

Distribution of *Cyclotella gordonensis*

In 2016 and 2017

In 2017, *Cyclotella gordonensis* was found in Lake Tahoe in low numbers especially when compared to 2016. These numbers were so low that the data are barely visible in the color contour plot. The color contours of the number of cells per milliliter are shown along with the individual Secchi depth measurements. In 2017, lake clarity was consistently low from May through the end of the year. As described in other sections of the report, the main contributor to low clarity was the exceptionally large influx of fine, inorganic particles.

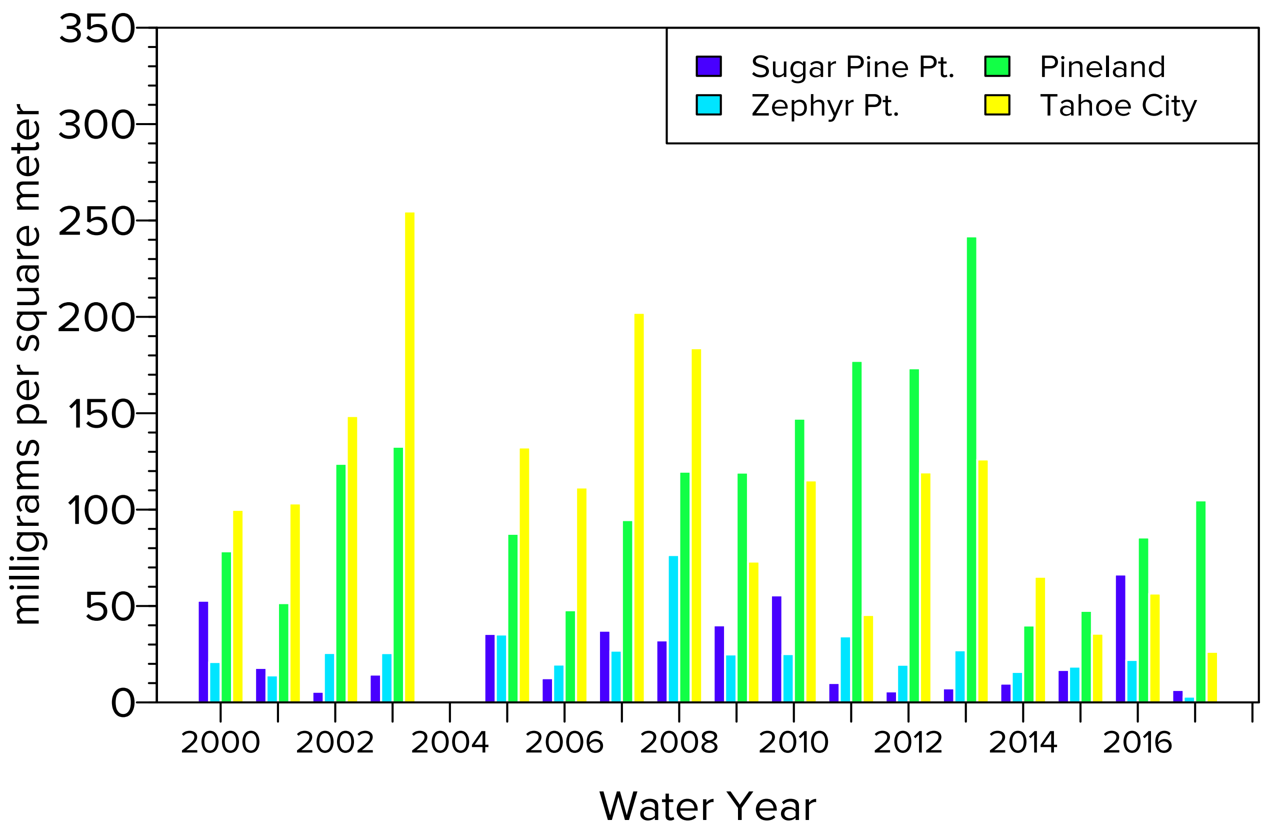


BIOLOGY

Peak shoreline algae concentrations

Yearly since 2000

Periphyton, or attached algae, makes rocks around the shoreline of Lake Tahoe green and slimy, or sometimes like a very plush, white carpet. Periphyton is measured five to eight times each year, and this graph shows the maximum biomass measured at four sites for the period from January to June. In 2017, concentrations at the four sites shown were again close to their historic lows. The two most urbanized sites, Tahoe City and Pineland, were less than half of their values in comparison with the period 2011-2013. Part of the reason for the low values in 2017 was the rapidly rising lake level during spring. These data were from a depth of 1.5 feet below the water surface on substrate that had been above water for two years. While monitoring periphyton is an important indicator of nearshore health, these data do not shed information on what is controlling year-to-year changes.



BIOLOGY

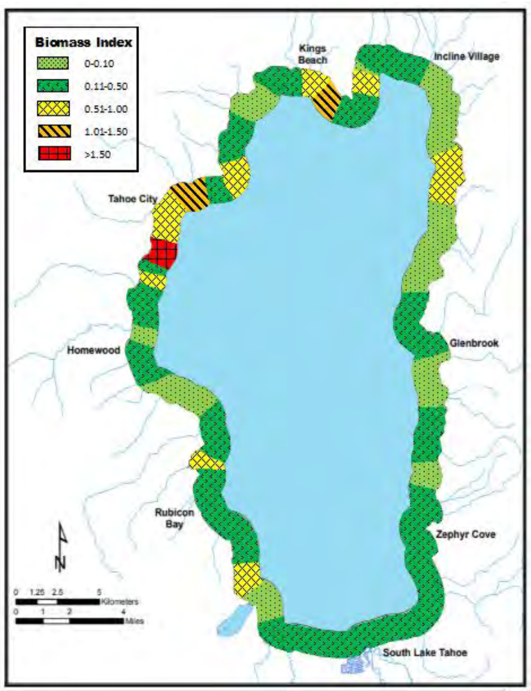
Shoreline algae distribution

In 2017

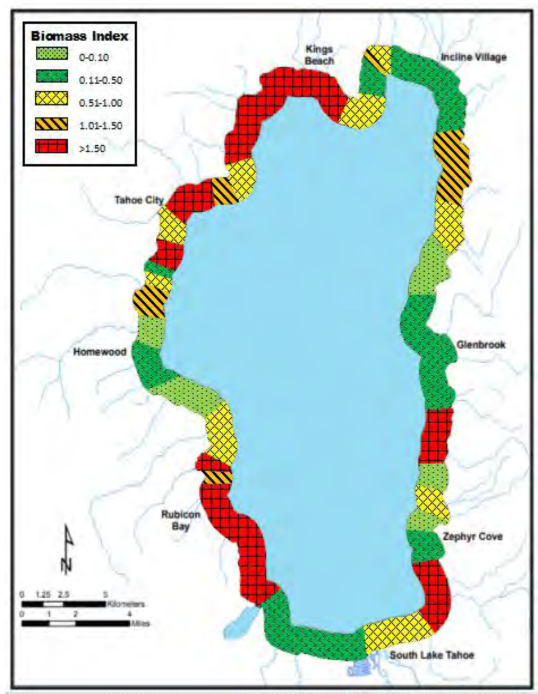
Periphyton biomass was surveyed around the lake during the spring of 2017, the time of the annual maximum. Nearly 45 locations were inspected by snorkel and scuba survey at depths of 1.6 feet (0.5 m) and 3.3 feet (1.0 m). A Periphyton Biomass Index (PBI), defined as the fraction of the local bottom area covered by periphyton multiplied by the average length of the algal filaments, is assessed at each location. During spring 2017, water level rose rapidly and submerged substrate at 1.6 feet which had been out of the water for several years and therefore supported little periphyton growth. By contrast, the PBI was much higher at a 3.3 feet depth, with many sites having a PBI > 1.5. This variation in lake level and the impact of prior conditions are part of what makes quantifying periphyton growth so challenging.

Note: The width of the colored band does not represent the actual dimension of the onshore-offshore distribution. Similarly, its length does not represent the precise longitudinal extent.

Distribution of Periphyton Biomass at 1.6 feet Depth, Spring 2017



Distribution of Periphyton Biomass at 3.3 feet Depth, Spring 2017



TAHOE: STATE OF THE LAKE REPORT 2018

CLARITY

UC DAVIS
Tahoe Environmental
Research Center

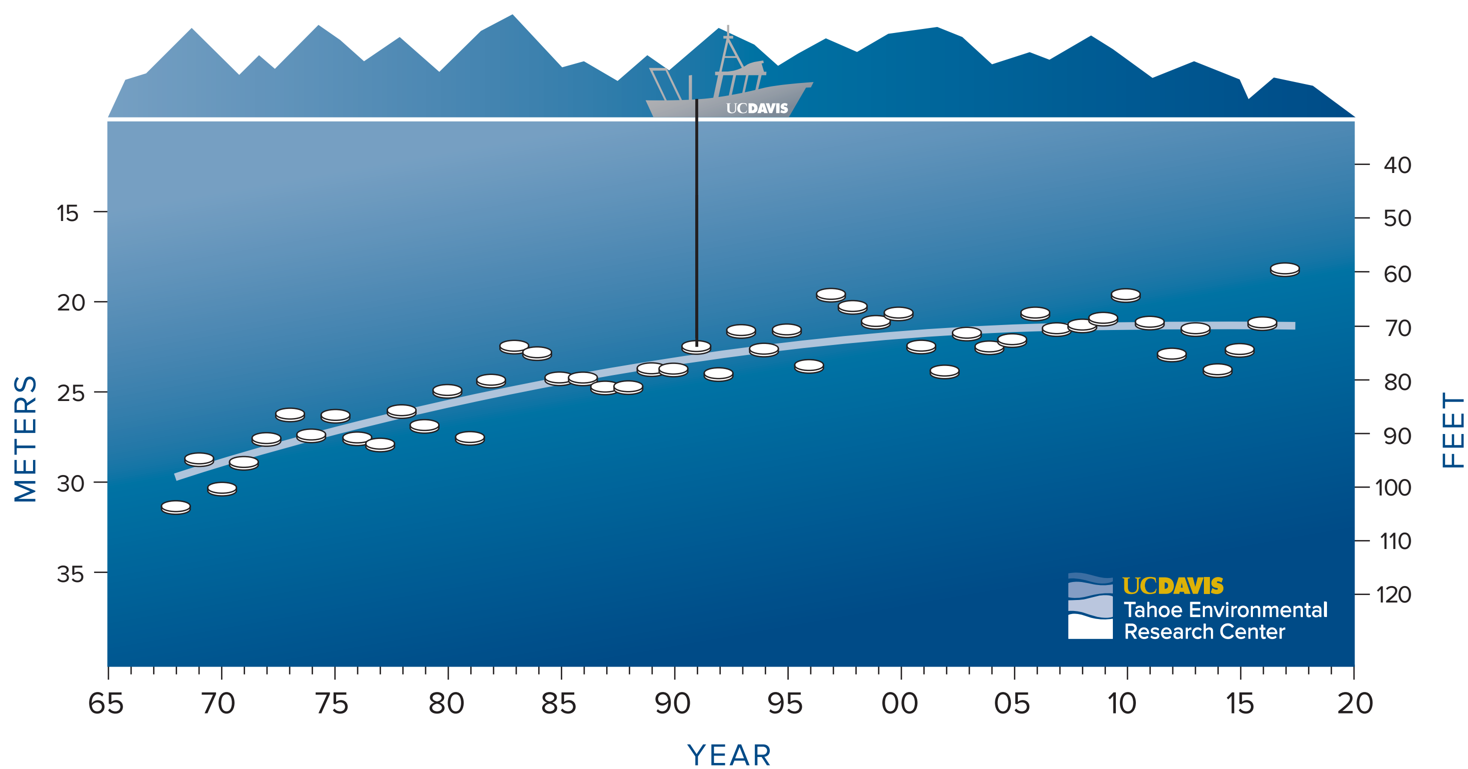
CLARITY

Annual average Secchi depth

Yearly since 1968

The Secchi depth is the depth at which a 10-inch white disk, called a Secchi disk, remains visible when lowered into the water. In 2017, the annual average Secchi depth was 59.7 feet (18.2 m), a 9.5 feet decrease from the previous year. This was the lowest value recorded historically at Lake Tahoe, however, as detailed in the Special Section on 2017 Lake Clarity, the year was highly anomalous and this extreme value does not represent a departure from the trend of the last two decades. The highest individual value recorded in 2017 was 90.2 feet on March 9, and the lowest was 47.6 feet on October 17. The decline this year is largely attributable to the record wet winter that followed the five-year drought. A change in the timing of snowmelt and lake warming also played a role. The clarity restoration target of 97.4 feet was set by federal and state regulators, a goal agencies and the Tahoe Basin community continue to work toward.

ANNUAL AVERAGE SECCHI DEPTH

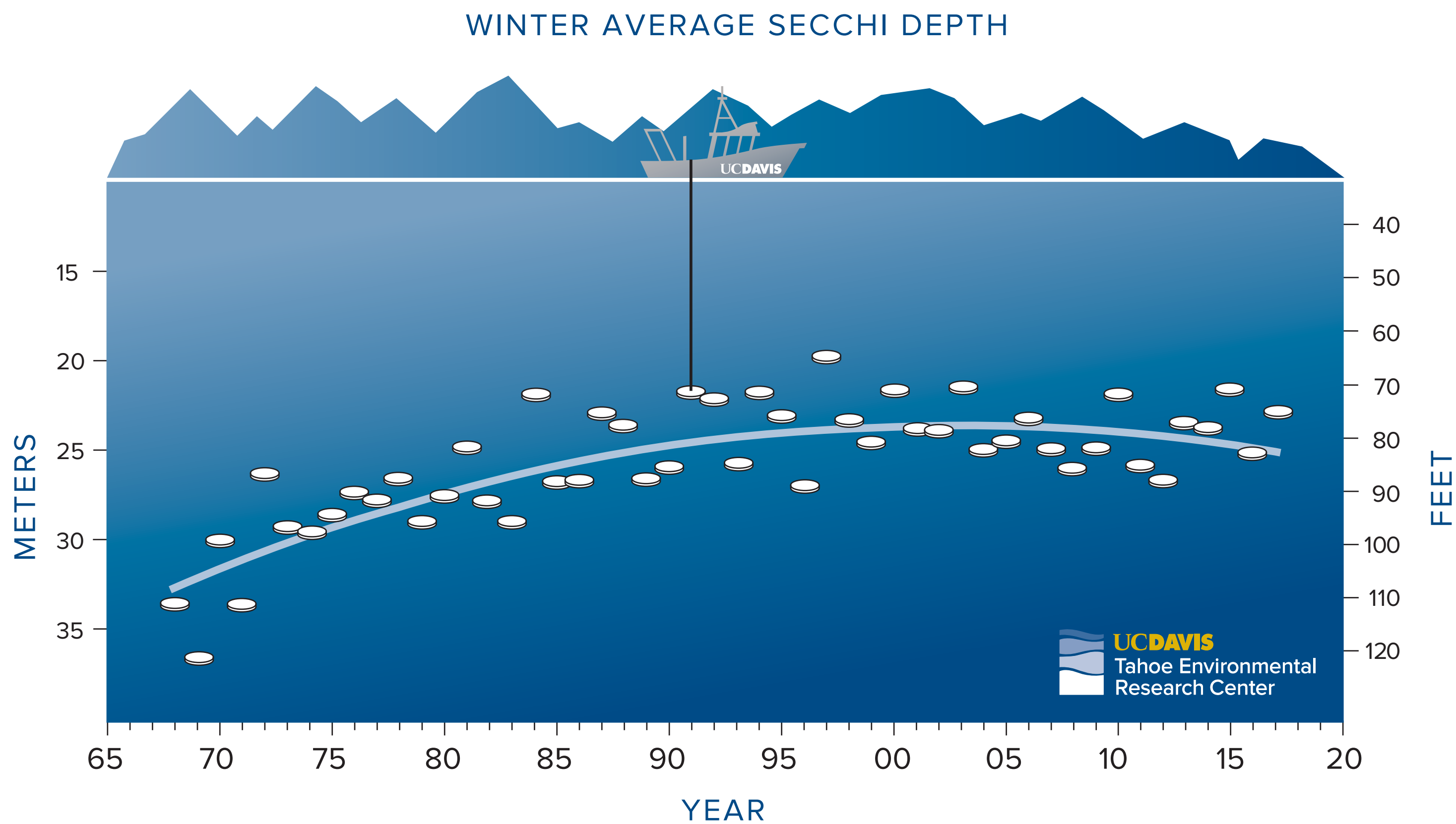


CLARITY

Winter Secchi depth

Yearly since 1968

Annual winter (December-March) Secchi depth measurements from 1968 to the present indicated that winter clarity at Lake Tahoe declined, although not to its lowest level. In 2017, winter clarity decreased by 7.0 feet. The winter average of 76.4 feet (23.3 m) was still above the worst winter average, 65.6 feet (20.0 m), seen in 1997.

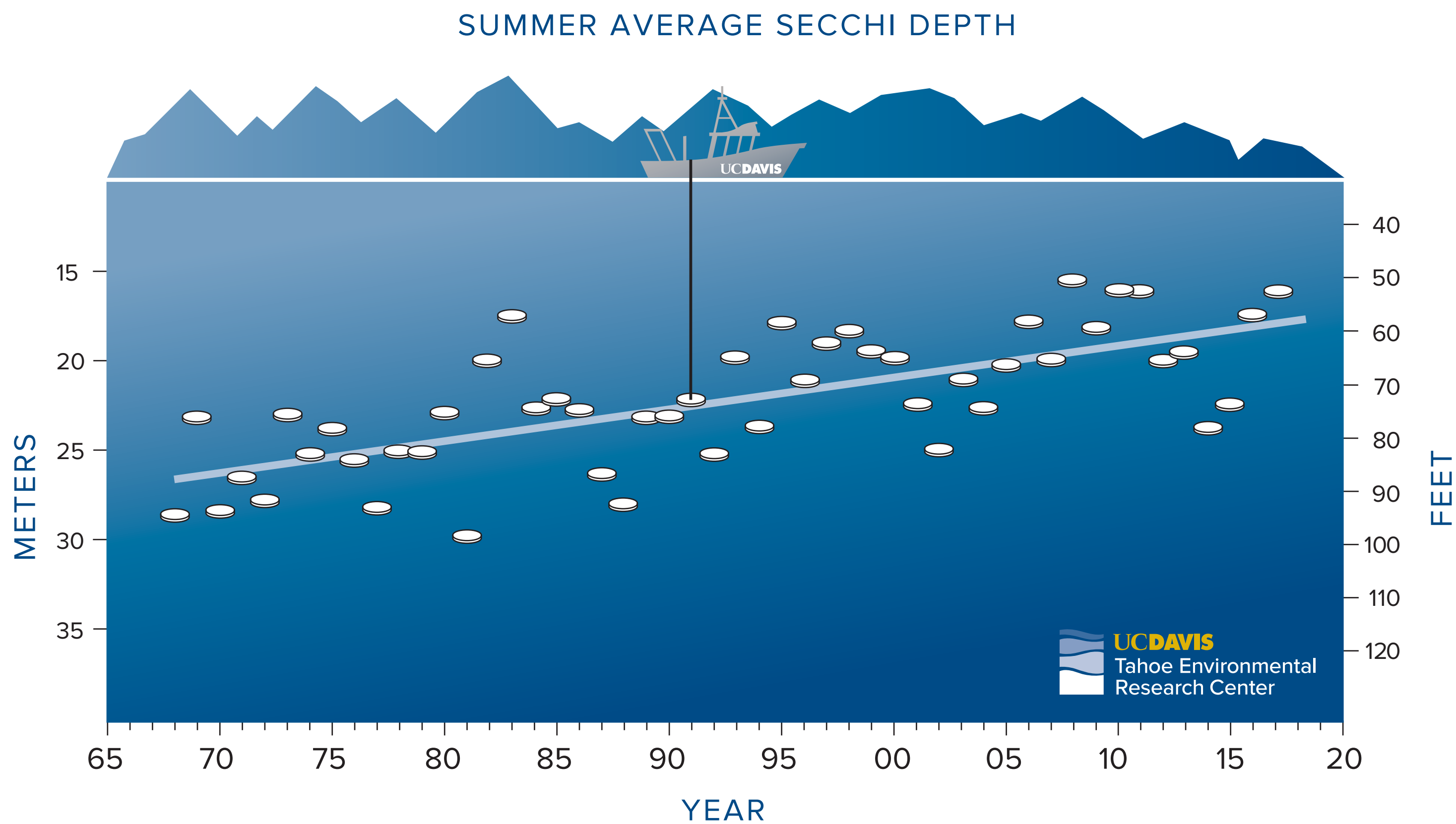


CLARITY

Summer Secchi depth

Yearly since 1968

The 2017 summer (June-September) clarity in Lake Tahoe in 2017 was 53.5 feet (16.3 m), a 2.9 feet decline from 2016. The summer trend is dominated by a consistent long-term degradation but punctuated with a noticeable 10-15 year cyclic pattern. The drivers behind the ongoing decline in summer clarity are an active area of research.



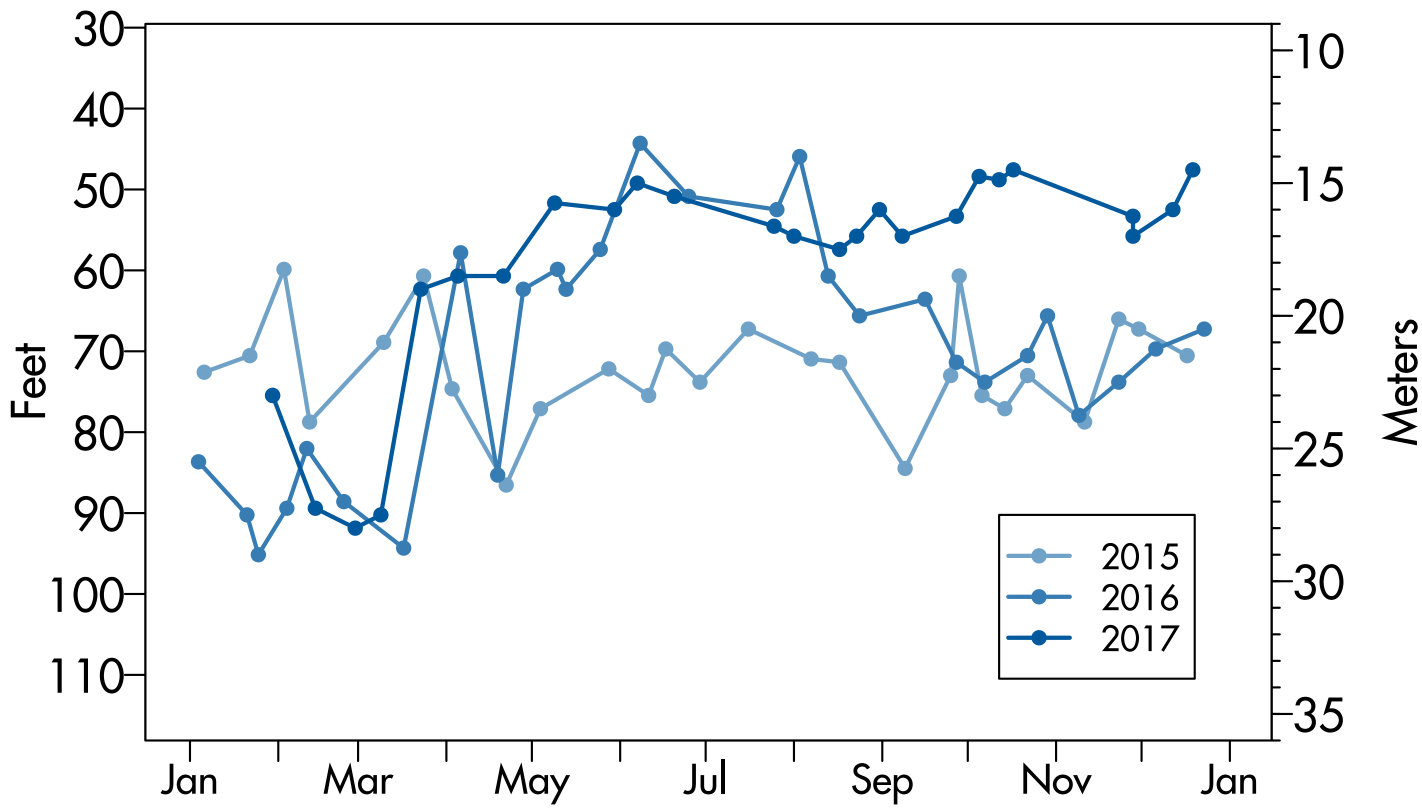
CLARITY

Individual Secchi depths

2015, 2016, 2017

In the figure below, the individual Secchi depth reading from the Index station on the west side of the lake for 2015, 2016, and 2017 are plotted. 2017 can be seen to deviate from the usual pattern of improving clarity between September and December. Instead, the clarity in 2017 remains consistently poor during this period.

Secchi values can be seen to sometimes vary considerably over short time intervals. This is evident on March 9 and March 23, 2017 where the Secchi depth changed from 90 feet to 62 feet respectively. Such short-term variability is common in lakes. The sudden change is often due to episodes of strong wind.



TAHOE: STATE OF THE LAKE REPORT 2018

EDUCATION AND OUTREACH

UC DAVIS
Tahoe Environmental Research Center

EDUCATION AND OUTREACH

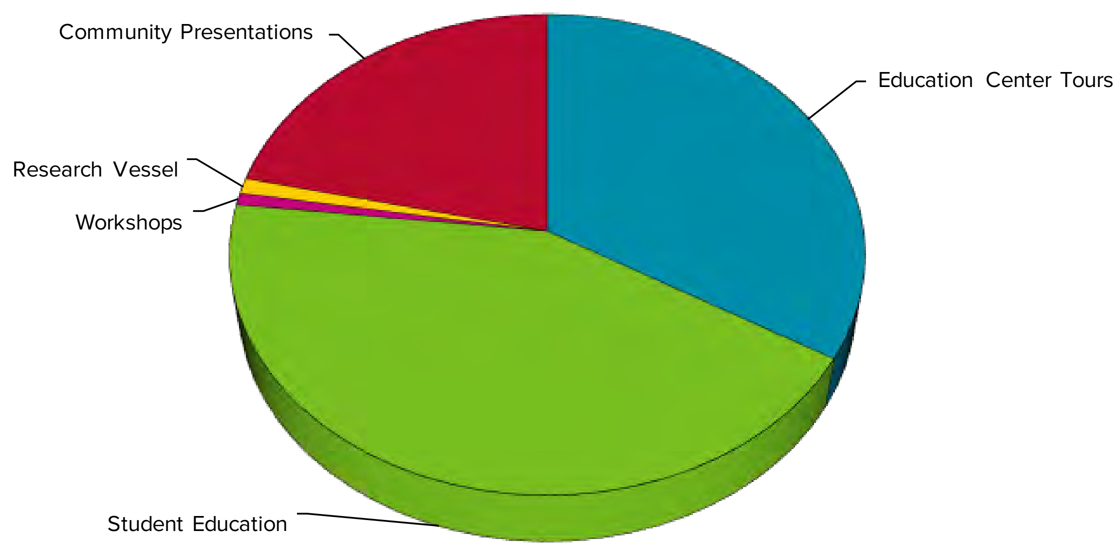
TERC education and outreach

In 2017

Part of TERC's mission is education and outreach. Our public, K-12, teacher professional development, and volunteer programs are designed to provide science-based information about the Lake Tahoe region in order to foster responsible action and stewardship.

During 2017, TERC recorded 14,204 individual visitor contacts. The majority represented student field trips and visitors to the Tahoe Science Center at Incline Village. In addition, TERC hosts monthly public lectures and workshops, makes presentations to local community organizations, and takes a limited number of visitors out on our research vessels. TERC organizes and hosts annual events and programs including the North Lake Tahoe Science Expo, South Lake Tahoe Science Expo, Youth Science Institute, Trout in the Classroom teacher training program, and a volunteer docent training program.

TERC also partners with numerous groups to deliver environmental science education in the Tahoe basin. In 2017, these included AmeriCorps, Lake Tahoe Outreach Committee, North Tahoe Environmental Education Coalition, Sierra Nevada College, Sierra Watershed Education Partnerships, South Tahoe Environmental Education Coalition, Tahoe Fund, and many others.



Total Visitor Contacts = 14,204

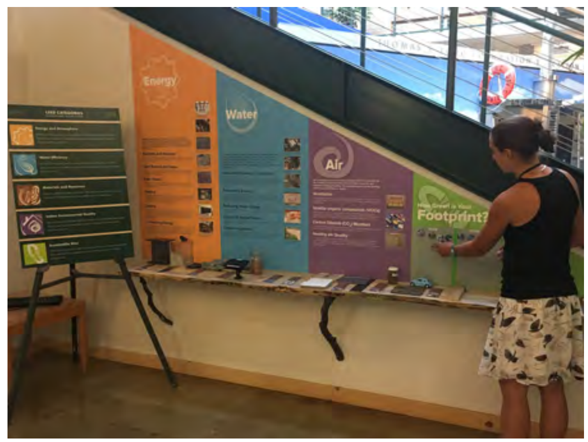
EDUCATION AND OUTREACH

TERC educational exhibits

In 2017

Each year, TERC works to improve our exhibits and increase the offerings available in the UC Davis Tahoe Science Center. During 2017, we developed a new "Fire in Lake Tahoe's Forests" wall exhibit, updated the "Green Building" exhibit, expanded the "Take Care Tahoe" exhibit, and improved other signage. These activities all aid in our mission to provide engaging exhibits and interactive hands-on educational activities.

The "Fire in Lake Tahoe's Forests" wall exhibit funded by the Tahoe City Rotary Club describes changes in Tahoe's forests due to clear-cutting and fire suppression, impacts of climate change, actions to prevent wildfires, and common tree killers including bark beetles, with actual beetles on display. Photo: H. Segale



The new "Green Building" exhibit highlights the U.S. Green Building Council LEED categories, specific green features of the Tahoe Center for Environmental Sciences building, including energy-saving, water-conserving, and indoor environmental air-quality features, and includes samples of the recycled building materials used. Photo: B. Harris

Utilizing the Take Care™ (TakeCareTahoe.org) stewardship messages, TERC staff created a pledge bin so that visitors can commit to various stewardship actions such as Be Bear Aware, Drink Tahoe Tap™, Leave No Trace®, and more ways to take care. Photo: A. Toy

EDUCATION AND OUTREACH

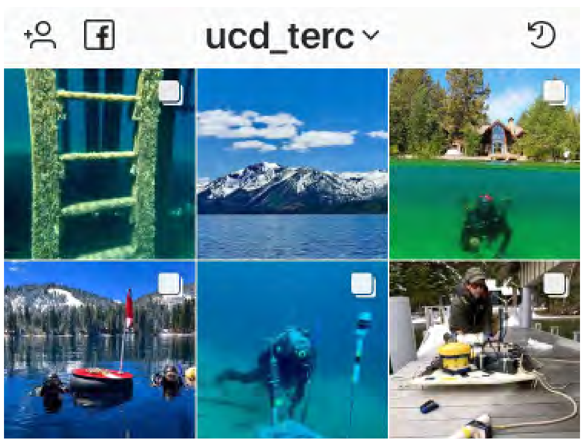
TERC outreach

In 2017

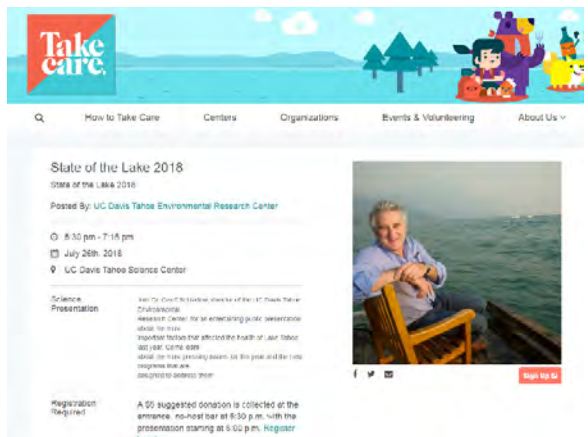
TERC and our partners continue to promote the smartphone app, "Citizen Science Tahoe," to encourage beach-goers to "add a splash of science" to their beach day. We need citizen scientists of all ages to help us understand conditions around the lake and share what they observe (CitizenScienceTahoe.com).

We promote the work of the UC Davis Tahoe Environmental Research Center through various methods including our website (http://tahoe.ucdavis.edu), Facebook page (https://www.facebook.com/terc.ucdavis/), Twitter (https://twitter.com/UCD_TERC), and Instagram (https://www.instagram.com/ucd_terc/).

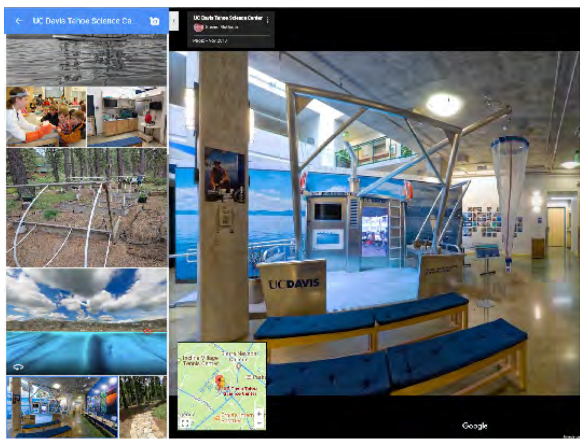
You can also check out the amazing photosphere images (360-degree panoramas) taken by Steven McQuinn and Joe Proudman in Google Maps or Google Streetview by going to http://maps.google.com and searching for the UC Davis Tahoe Science Center or UC Davis Tahoe City Field Station.



See some amazing photos from the UC Davis TERC field research team hard at work on the lake and underwater @ucd_terc on Instagram.



Visit the new Take Care Tahoe website at www.TakeCareTahoe.org for information on the latest environmental events and volunteer opportunities around the lake. TERC events are now being posted on the TakeCareTahoe.org website.



At http://maps.google.com, photosphere images (360-panoramas) take you on a virtual tour of our science centers and demonstration garden. Click on the little yellow "peg man" in the bottom right corner of the screen. All of those little blue dots are photospheres. Some of them inside and outside the science center building are connected to take you on a virtual tour.

EDUCATION AND OUTREACH

TERC educational programs

In 2017

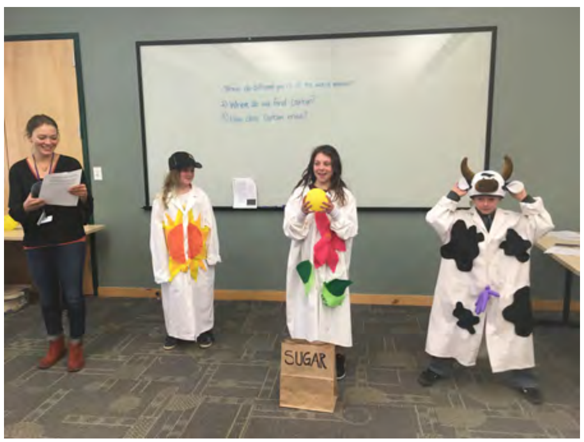
TERC provides various educational programs for the public, K-12 students, teachers, and volunteers. Public programs include science center tours, monthly lecture series, citizen science programs, and garden workshops.

Our K-12 education programs include school field trips, Trout in the Classroom program, the Youth Science Institute afterschool program for high school students, and the annual Science Expo.

The TERC education team provided informal science education to more than 5,919 third- through twelfth-grade students by hosting over 100 field trips during the 2017 calendar year.

During the summer months, we offer programs at the Tahoe City Field Station and Native Plant Demonstration Garden.

2017 marked the second annual High Elevation Gardening workshop series at the Tahoe City Field Station. Topics included potatoes, onions, raspberries/gooseberries, kale/lettuce, and tomatoes.



Our field trip activities are continually improved with the goal of increasing student engagement and linking learning goals to the science standards. One of our favorite field trips is "Earth System Science" which highlights how energy flows, matter cycles, and all organisms on the planet are connected.
Photo: L. Bronson

Students witness the early life stages of Lahontan cutthroat trout as part of the Trout in the Classroom program. Students (pictured above) are releasing their small Lahontan cutthroat trout into Lake Tahoe in hopes that they will thrive in their native Lake Tahoe.
Photo: A. Toy

Each year a small group of select high school students participate in the annual Youth Science Institute from January through May. During this after-school program participants work with scientists, conduct experiments, and share science activities with other students. Photo: A. Toy

EDUCATION AND OUTREACH

TERC educational programs, continued

In 2017

TERC hosts monthly lectures throughout the year on various environmental issues, new scientific research, and related regional topics of interest. Some of the topics during 2017 included “Political Polarization,” “Global Climate Change,” “Recovering the Endangered Mountain Yellow-legged Frog,” “Winter is Coming,” and “Ice Shelf Collapse.”

During the summer months, we offer programs at the Tahoe City Field Station. Led by volunteer docent Dave Long, TERC hosted High Elevation Gardening workshops bringing specific varieties of fruits and vegetables to Tahoe gardeners who submit phenology data based on what does well in their own garden.

Each year we train new volunteer docents at our annual June Docent Training. Volunteer docents become local experts and lead public tours at our two science centers. This year, all of the Docent Training presentations were recorded and are available on the TERC website at http://tahoe.ucdavis.edu/ed-outreach/ed-programs/docents.html.

Thanks to a philanthropic donation to purchase the equipment needed, the TERC monthly science lectures are now being recorded and select lectures are available online at http://tahoe.ucdavis.edu/events/archive-events/. Photo: A. Toy

The High Elevation Gardening workshops at the Tahoe City Field Station and native plant demonstration garden were highly attended. Participants learned about different growing strategies and harvesting techniques in addition to taking home a variety of seedlings. Photo: A. Toy

The TERC docent training program is held annually each June and provides new volunteers with all of the information they need to be Lake Tahoe experts and to successfully share their love of Lake Tahoe with others. Photo: A. Toy

EDUCATION AND OUTREACH

TERC special events

In 2017

Special events hosted annually include the Science of Cocktails (February), North Tahoe Science Expo (March), South Tahoe Science Expo (April), Garden workshops (June - August), Summer Teacher Institute (June - July), and Children's Environmental Science Day (August).

The Science of Cocktails event was a sold out event this year. Tickets went fast for this fundraising event.

TERC also hosted "The Last Straw" community event with partners from IVGID Waste Not, League to Save Lake Tahoe, Keep Truckee Green, SOS Outreach, Sierra Watershed Education Partnerships, and Tahoe Institute for Natural Science. Local students joined the regional and global movement to eliminate plastic drinking straws from our landfills, streams, oceans, and beaches. Students hosted educational tables, presented on local programs to reduce single-use plastic waste, and hosted screenings of the short films "Straws" and "Everything Connects."

At the second annual Science of Cocktails event, themed drinks taught about fluid dynamics (shown here), density, pH, fluorescence, sublimation, polymers, latent heat, fermentation, and alcohol science. Photo: J. Markle

At the 13th annual North Tahoe Science Expo (Life Science and Health) students learned about organisms and ecosystems, inheritance and adaptation, health and nutrition. This year was also the 3rd annual Science Expo held at Lake Tahoe Community College. Photo: A. Toy

Local students get active in the community and host an event at the Tahoe Science Center. At "The Last Straw" event, local students showcase their community outreach efforts to enlist businesses to stop giving out plastic straws, unless requested, in order to minimize single-use plastic waste. Photo: H. Segale