TAHOE: STATE OF THE LAKE REPORT 2017

UC DAVIS
TAHOE ENVIRONMENTAL RESEARCH CENTER

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CONTENTS, CONTINUED

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 2016. The data shown reveal a unique record of trends and patterns—the result of natural forces and human actions that operate at time scales ranging from minutes to decades. These patterns clearly indicate that Lake Tahoe is a complex ecosystem, behaving in ways that cannot always be predicted. This was exemplified in 2016 by the decline in clarity due to a change in the algal community and the unusually cool summer water temperatures. 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 among those 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 all provide indications 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 time scales of decades. Is Lake Tahoe continuing to warm? Are the inputs of algal nutrients to the lake declining? How is the end of the drought affecting Lake Tahoe? And, of course, how do all these changes affect the lake's famous clarity? We also present updates on some of our current research. This 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, Sudeep Chandra, Bob Coats, Richard Cobb, Teagan Dolan, Bill Fleenor, Alex Forrest, Charles Goldman, Marcus Gabe Griffiths, Scott Hackley, Tina Hammell, Bruce Hargreaves, Alan Heyvaert, Simon Hook, Camille Jensen, Yufang Jin, Amelia Jones, Anne Liston, Patricia Maloney, George Malyj, Elisa Marini, Tom Mathis, Jasmin McInerney, Patricio Moreno, Bob Richards, Gerardo Rivera, Derek Roberts, Steve Sadro, Goloka Sahoo, Heather Segale, Katie Senft, Lidia Tanaka, Raph Townsend, Alison Toy, Denise Tran, Susan Ustin, and Shohei Watanabe to this year's report. In particular, Shohei Watanabe was responsible for most 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 Lahontan Regional Water Quality Control Board, the Tahoe Regional Planning Agency, the U.S. Geological Survey and UC Davis. Our monitoring is frequently done in collaboration with other research institutions and agencies. In particular, we would like to acknowledge the U.S. Geological Survey (USGS), the Desert Research Institute (DRI), the University of Nevada, Reno (UNR), the National Aeronautics and Space Administration (NASA), the U.S. Forest Service (USFS), the Nevada Division of Environmental Protection (NDEP), and the Tahoe Resource Conservation District (TRCD). Some data are also collected as part of research projects funded through a variety of sources. Without these data there are many questions that could not even be asked let alone answered.

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

Sincerely,

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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 essential 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, while at the same time building our understanding of the natural processes that drive the ecosystem.

The UC Davis Tahoe Environmental Research Center (TERC) is increasingly using new approaches to enrich the long-term data record for Lake Tahoe. These include real-time measurements at over 25 stations around the basin; remote sensing from autonomous underwater vehicles, satellites, and aerial drones; and the deployment of a suite of numerical models. These tools are all focused on quantifying the changes that are happening, and at the same time, 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 2016 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 that is being driven by the important questions of the day. These include: the causes of the increasing levels of filamentous algae seen on the shoreline; the health of Lake Tahoe's forests in response to drought; climate change and its impacts on the lake physics and the entire lake ecosystem; the driving force behind the variability of water quality around the lake's nearshore regions; a first look at what is happening in the very deepest parts of the lake; and the threat of invasive species spread by in-lake boating activities.

In recent years Tahoe has been subject to an increase in algal mats washed up on its shoreline. These algae, or metaphyton, are likely the result of changing nutrient conditions that favor their growth. While the precise cause is still being studied, there appears to be an association with areas of high Asian clam density, such as the south shore. Through filter feeding, Asian clams can effectively concentrate the available nutrients, providing ideal conditions for species such as *Zygnema* and *Spirogyra*.

While the Agency-led boat inspection program is doing an excellent job in preventing new invasive species from entering Lake Tahoe, recent data are showing that boating activities may be exacerbating the spread of species that are already in the lake. While the role of in-lake transport has long been recognized for the spread of aquatic plants, the discovery and treatment of a satellite population of Asian clams adjacent to the boat ramp at Sand Harbor indicate that certain boating activities (such as filling and emptying ballast tanks) may also be important vectors.

The number of dead and dying

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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 2017 report, water year data are from Oct. 1, 2015 through Sept. 30, 2016. Calendar year data are from Jan. 1, 2016 through Dec. 31, 2016.

EXECUTIVE SUMMARY

(CONTINUED FROM PAGE 2.1)

trees at Tahoe and throughout the Sierra Nevada have been increasing as a result of interacting, complex factors. Drought stress, insect attack, and disease all interact to contribute to this decline in forest health, with direct implication for fire safety, carbon sequestration, and biological diversity. A network of 84 forest monitoring sites throughout the basin is helping our understanding of the drivers of change. A new NASA instrument headed for the International Space Station in 2018, ECOSTRESS, is likely to provide further data to help understand these changes.

Climate change is an overarching factor. The long-term record shows that the warming that has been recorded since 1911 is impacting the watershed, the streams and the lake itself in numerous, interconnected ways. Summers are lasting longer and the winter period for lake mixing is becoming shorter. While the average water temperature in the lake continues its warming trend, the July water temperatures fell by 2.9 degrees this year. Because of the availability of our extensive data set, we can show that this was due simply to a large increase of winds in June and July and cooler than usual air temperatures.

What is harder to understand is the impact of climate change on the lake's ecology and how this ties in with lake clarity. In 2016 the tiny alga, *Cyclotella gordonensis*, returned in very high concentration in the upper 50 feet of the lake during summer. Its reappearance always coincides with a major decline in clarity, and it was responsible for the 17-foot decline in summer clarity. The fact that winter clarity improved by almost 12 feet, in what was an average precipitation year, provides support that many of the stormwater improvement projects around the lake are working.

It is sometimes believed that a poor measure of water quality at a location along Tahoe's nearshore is the result of poor management, a leaking pipe, or a problem waiting for a solution. What the Nearshore Network shows, using data measured continuously from around the lake, is that part of what we may be experiencing is normal system behavior. Combining the measured data with a wave model, we have been able to produce the first maps showing the variation in turbidity (water cloudiness) around the lake for each season. In many parts of the lake, turbidity standards may be exceeded simply by natural processes such as wave breaking.

New technology is allowing us to venture to the bottom of the lake and "see" it in greater detail than ever before. Layers of sediment that are coating rock formations are clearly evident. Temperature measurements from over 1,500 feet deep show just how quiescent the water is, with temperature fluctuations only one one-hundredth (1/100) of a degree. At the same time, however, heat from the earth is gradually warming the bottom of the lake at a rate of 0.054 °F per year.

Precipitation during Water Year 2016 was at the long-term average for Lake Tahoe. Lake level rose over 20 inches in 2016 bringing the lake back above its natural rim and allowing flow into the Truckee River. With

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EXECUTIVE SUMMARY

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summer evaporation, however, lake levels briefly dropped below the rim again, before winter caused the lake to rise again.

The volume-averaged lake temperature continues on a rising trend. In the last four years, the lake has warmed at an alarming rate of 0.5 degrees per year, 14 times faster than the long-term warming rate. The absence of deep mixing for the fifth year in a row contributed to the storage of heat. At the same time, the maximum daily summer temperature was the coolest recorded in the last 18 years. The length of the stratified season (the period of time when the lake exhibits summer-like conditions) also continues to increase. Since 1968 this period has increased by almost 26 days. The date on which spring snowmelt started was March 29. This date has moved up by 19 days since 1961.

The input of stream-borne nutrients (nitrogen and phosphorus) to the lake increased in 2016 due to the higher precipitation over the previous four years. However, the levels of nutrients building up at the bottom of the lake continues to rise, due to the absence of deep mixing. This internal cycling is an important source of nutrients, particularly nitrate. When this factor is combined with the generally declining rate of lake phosphorus, it appears as if the lake may be transitioning to a point where nitrogen is once again becoming the limiting nutrient for algal growth.

Biologically, the primary productivity of the lake has increased dramatically since 1959. In 2016, there was an increase in primary productivity to 225.1 grams of carbon per square meter. By contrast, the biomass (concentration) of algae in the lake has remained relatively steady over time. The annual average concentration for 2016 was 0.59 micrograms per liter, slightly lower than the previous eight years. For the period of 1984-2015, 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 (60 percent of the cells). Of these, *Cyclotella gordonensis* was by far the most common, representing 90 percent of the biovolume during summer. This impacted summer clarity with a large decline in Secchi depth.

This year the annual average Secchi depth, a measure of lake clarity, continued the long-term halt in clarity degradation. The value for 2016 was 69.2 feet (21.1 m), a decrease of 3.9 feet over 2015, but this is well above the lowest value recorded in 1997 of 64.1 feet (19.5 m). Year-to-year fluctuations are the norm, and the long-term goal should be viewed as attaining a level of clarity that on average meets the basin's standards. Winter (December-March) clarity improved by 11.7 feet to 83.3 feet (25.4 m), despite the average amount of precipitation. Summer (June-September) clarity in Lake Tahoe in 2016 was 56.4 feet (17.2 m), a 16.7-foot decline over the value from 2015. The large concentrations of *Cyclotella* are the direct cause of this.

This report is available on the UC Davis Tahoe Environmental Research Center website (http://terc.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: 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
- The number of algal cells in Lake Tahoe is approximately 30 million trillion
- All of Tahoe's algae stacked on a football field, would stand 9 feet tall and weigh 15,500 tons
- 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. Significant flows from Lake Tahoe to the Truckee River resumed on April 9, 2016 when the lake level exceeded its natural rim.
- 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 Tahoe Science Center, an educational resource for K-12 students and learners of all ages, that is free and open to the public.

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.

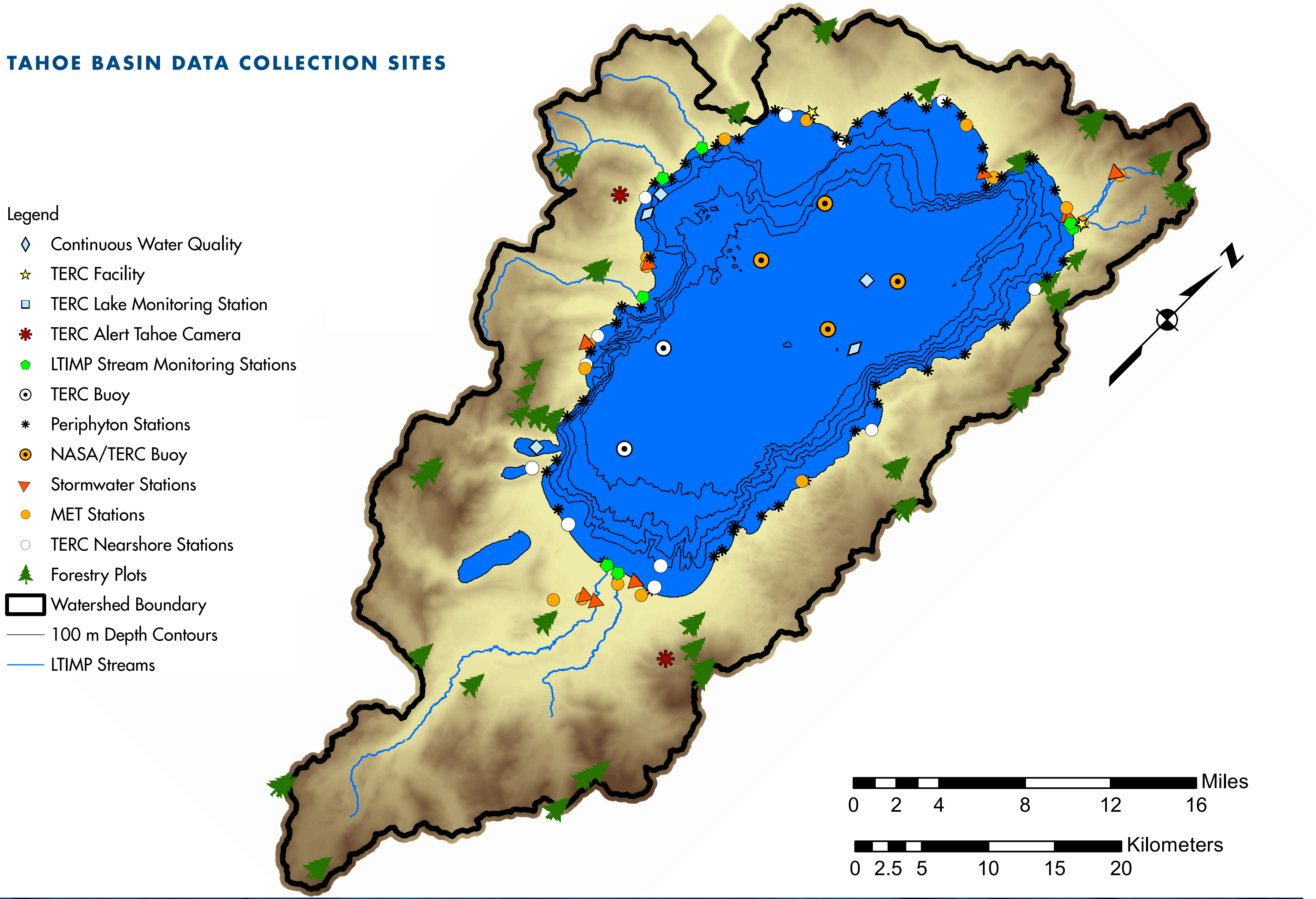
Our secondary laboratories and offices are located on the UC Davis campus at the Center for Watershed Sciences and in Wickson Hall.

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://terc.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 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 2017

CURRENT RESEARCH

CURRENT RESEARCH

Metaphyton at Lake Baikal and Lake Tahoe

Lake Baikal in Russia and Lake Tahoe on the California-Nevada stateline, have a special relationship. For over 20 years, students from both the United States and Russia participated in a unique summer program at both lakes through the Tahoe-Baikal Institute, assisting with environmental research and shadowing resource managers. The two lakes are very different. Lake Tahoe is clearer and at a higher altitude. Lake Baikal is much bigger and deeper, and spends part of the year under a thick cover of ice. While different, these two great, once pristine lakes, experience the same threats ranging from local impacts to those imposed by climate change.

In recent years, both lakes have been subject to increasing growth of algae near their shorelines. This increase in algae, or metaphyton, are the result of changing environmental conditions which favor their growth. At Lake Baikal, the mats of metaphyton are mainly comprised of *Spirogyra* and are believed to be a result of an increase in nutrients from sewage inputs associated with a growth in tourism and development.

Spirogyra washed up on the shore of Lake Baikal, Russia.
Photo: http://mobile.nytimes.com/2016/11/15/science/lake-baikal-russia

CURRENT RESEARCH

Metaphyton at Lake Baikal and Lake Tahoe, continued

At Lake Tahoe, the metaphyton mats are much smaller, but have been particularly noticeable along some shallow beach areas in recent summers. *Spirogyra* is also one of the species present along with other types of filamentous green algae. Planners at Tahoe had the foresight in the 1960s to divert sewage from entering the lake, no doubt helping control nutrient loading. However, changing internal processes within the lake are likely acting to concentrate nutrients in particular areas. Warming associated with climate change, the arrival of invasive species, and extreme fluctuations in lake level associated with drought may all play a role. Efforts are currently underway to develop effective monitoring methods for algae and ultimately we hope to better understand the primary factors controlling metaphyton growth in Tahoe.

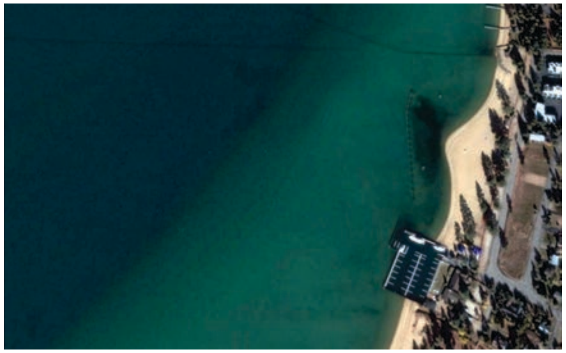
In 2017, a thick mat of filamentous *Spirogyra* and *Zygnema* was observed offshore near Lakeside, an area invaded by Asian clams. Asian clams, which are filter feeders, concentrate nutrients by a factor of ten and provide a potential source of enriched nutrients for the metaphyton. This apparent linkage between Asian clams and metaphyton is evident in a time series of satellite images taken from Google Earth and the most recent image taken of the same area from a helicopter in 2017.

Spirogyra and *Zygnema* on the shore of Lake Tahoe at Regan Beach in August, 2014. Photo: Scott Hackley

CURRENT RESEARCH

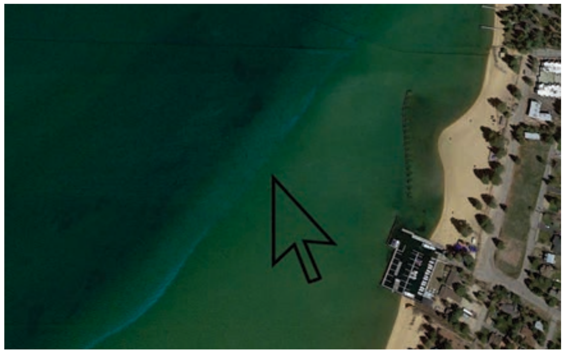
Metaphyton at Lake Baikal and Lake Tahoe, continued

Google Earth satellite images from 2007-2016 as compared with a recent helicoper photo from 2017 of Lakeside area in South Lake Tahoe. These images document the appearance of a band of clam shells in 2010 and an eventual transition to supporting metaphyton growth in this area.


Lakeside area 10/31/07 - no line of clamshells or metaphyton


Lakeside area 8/30/10 - line of clamshells apparent


Lakeside area 8/28/12 - distinct line of clamshells


Lakeside area 4/29/14 - distinct line of clamshells


Lakeside area 7/13/16 - line of clamshells co-located with metaphyton


Lakeside area 6/25/17 - Helicopter image showing band of metaphyton overlaid on clamshell region

CURRENT RESEARCH

Forest health

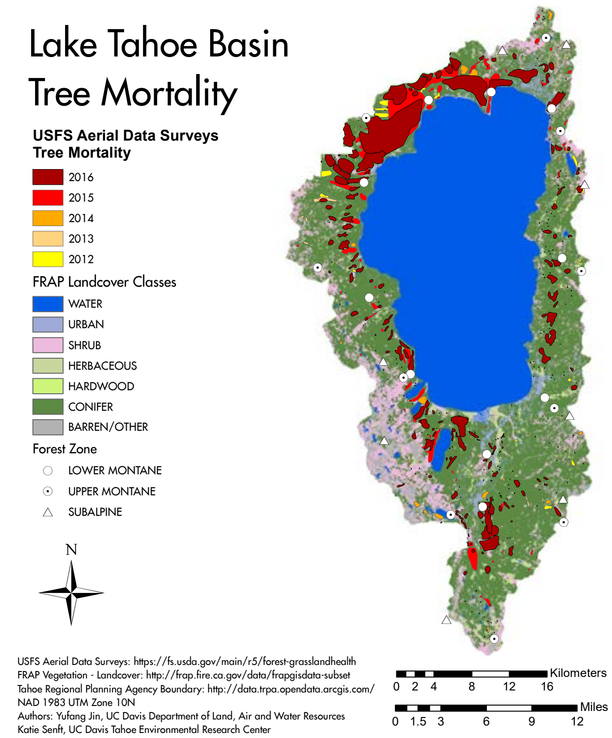
Tree mortality is a huge threat throughout the Sierra Nevada. During the drought, areas of the Tahoe basin that had large numbers of dead trees increased dramatically and tree mortality doubled from 35,000 in 2015 to 72,000 in 2016. The primary causes of mortality were water stress, and insect and fungal infestations (exacerbated by the drought-weakened trees). The north shore of Lake Tahoe had the largest increases in tree mortality, although significant areas of the east shore were also impacted.

The health of the forest is also having an effect on its ability to sequester carbon. UC Davis and TERC scientists are investigating the effects of forest insects and pathogens on carbon dynamics in the Lake Tahoe Basin through a grant from CalFire's Greenhouse Gas Reduction Fund Program. Although pests and pathogens kill many trees in the Sierra Nevada, little is known about how these biological disturbances, along with fuel reduction programs, alter the capacity of forests to mitigate greenhouse gas emissions.

This research will result in a forest-level carbon budget with direct measurements of stand carbon pools, soil respiration, and carbon sequestration within the living forest biomass.

Research to date shows that Basin forest soils release, on average, 4.8 g CO_2-C/sq. m/day, which is typical of western forests. In addition, Tahoe Basin forests have shown consistent consumption of atmospheric methane, an important greenhouse gas

Dead and dying trees are a familiar sight in the Tahoe basin.



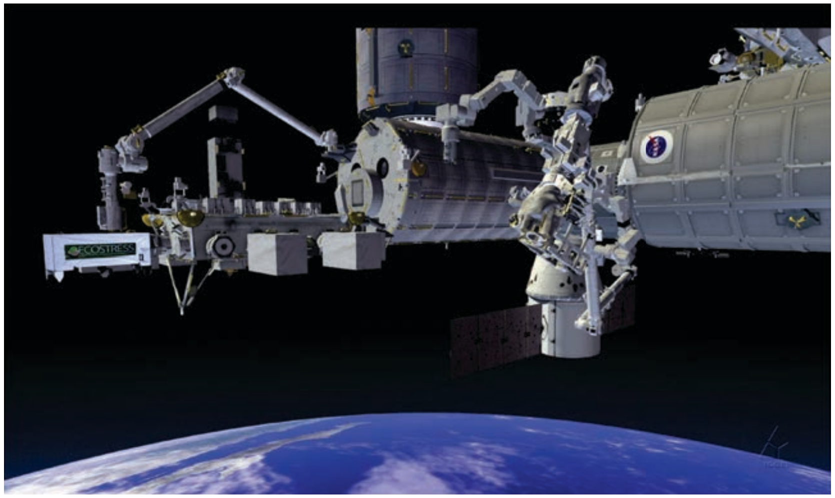
The area of tree mortality markedly grew in 2016.

CURRENT RESEARCH

ECOSTRESS

The ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station or ECOSTRESS (https://www.youtube.com/watch?v=ALZTMLH9boY&feature=youtu.be), will measure the temperature of plants and use that information to better understand how much water plants (including tress of the Sierra) need and how they respond to stress. Led by long-time TERC collaborator Dr. Simon Hook of the NASA Jet Propulsion Laboratory (JPL), the special instruments developed for this experiment will be launched for deployment on the International Space Station in early 2018.

TERC researcher Dr. Tricia Maloney is planning on using her network of 84 forest monitoring sites to help ground truth data from ECOSTRESS. These sites, from all around the Tahoe Basin and at a range of elevations, provide ongoing measurements of stand conditions, physiological and phenological assessments, forest health indices, as well as the impacts of heat stress and evaporative stress on a range of forest tree species.



The ECOSTRESS radiometer will be deployed on the International Space Station on the Japanese Experiment Module, at the far left of the image.

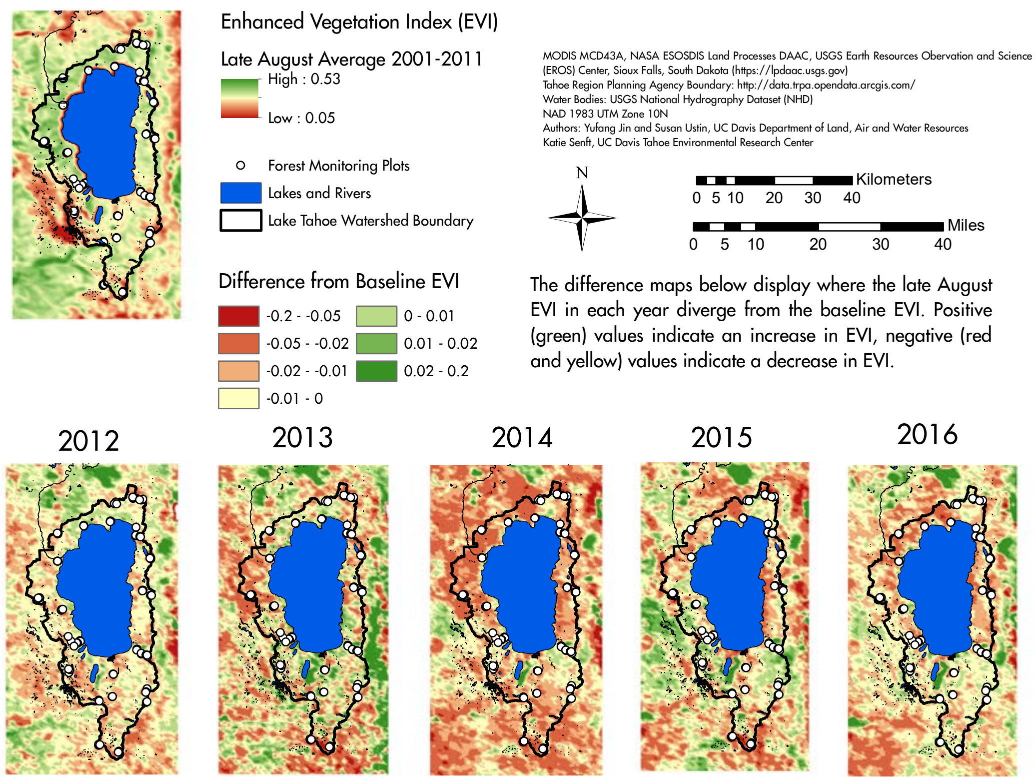
Camille Jensen sampling pine needles at a forest monitoring site. Photo: Patricia Maloney

CURRENT RESEARCH

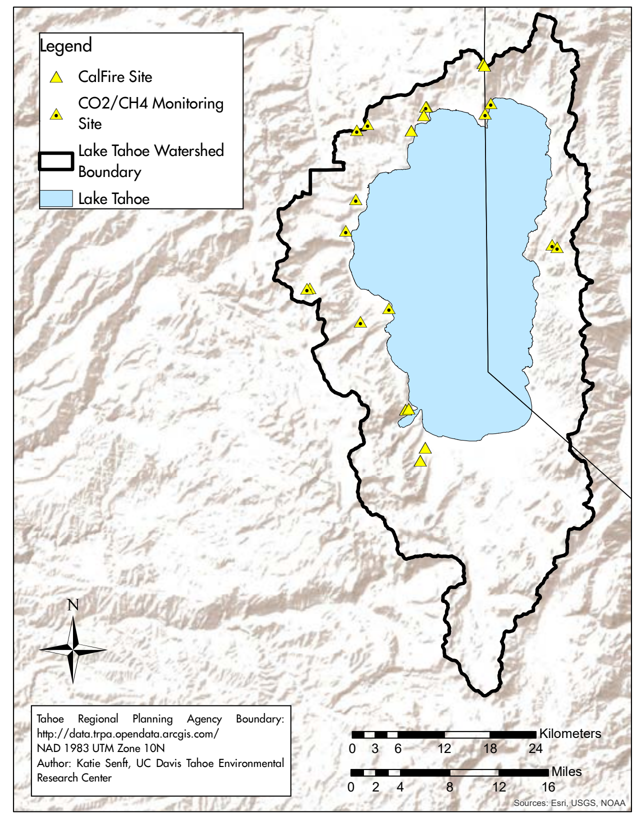
ECOSTRESS, continued

Linking satellite data from ECOSTRESS to the field-based data will provide a direct validation of the satellite data, and may advance our capabilities for predicting forest health and tree species responses to future environmental change.

The remotely sensed data from ECOSTRESS is just the latest collaboration between NASA-JPL and TERC. It will add to an already vast trove of data resulting from this 20-year partnership. The research buoys on Lake Tahoe have been used to calibrate thermal sensors on many international satellites and are an important part of the global efforts to accurately measure the rising temperatures of the world's oceans and lakes.



Tahoe Basin EVI Differences 2012-2016

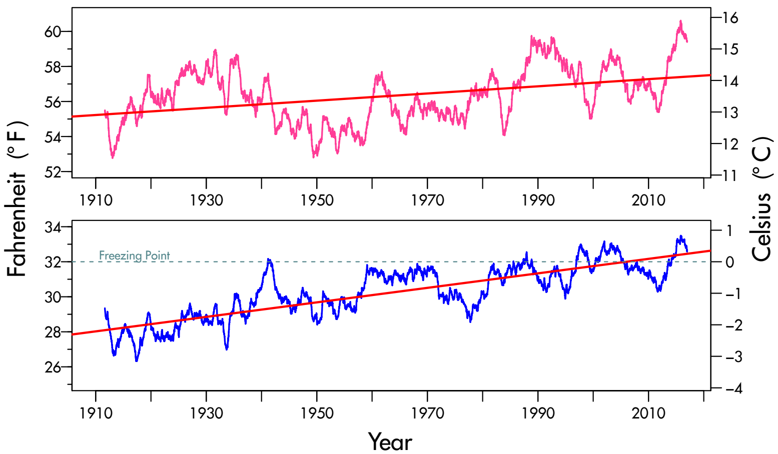


CalFire Greenhouse Gas Reduction Study Sites.

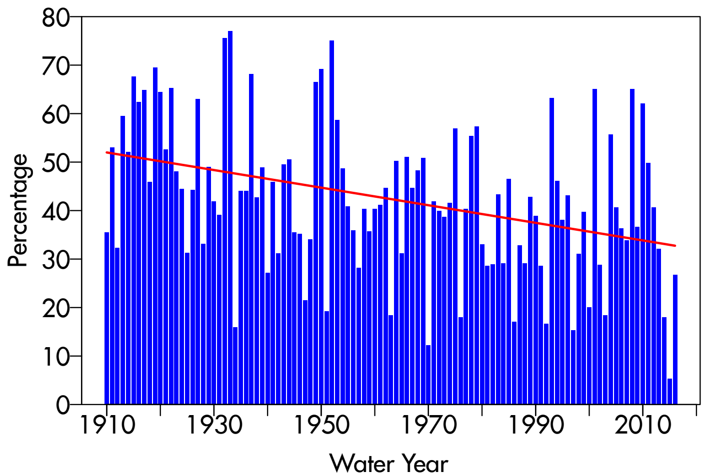
CURRENT RESEARCH

Impacts of climate change

Climate change is exerting a huge impact globally. One of the areas prone to the largest impacts in the nation is the West. The data supporting the changes in Lake Tahoe's climate are evident in the 106 year record of air temperature (see figure on the left). Other changes to the climate include a declining trend in the fraction of precipitation that falls as snow (see figure on the right). What impact does the changing climate have on the lake itself?



Maximum and minimum air temperatures at Lake Tahoe



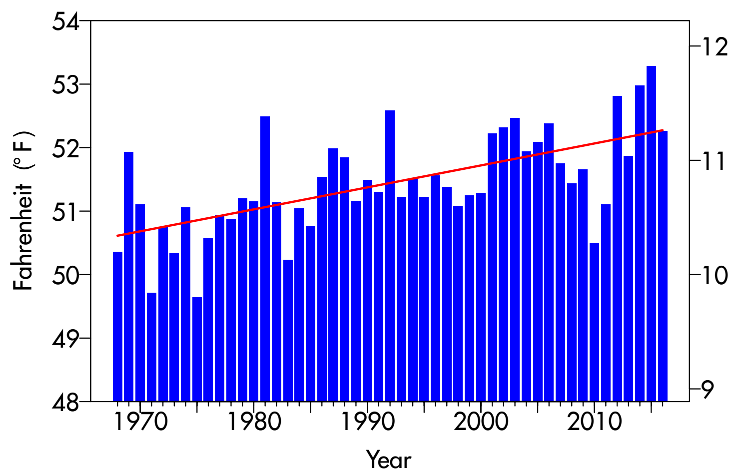
Reduction in percentage of snow as part of total precipitation

CURRENT RESEARCH

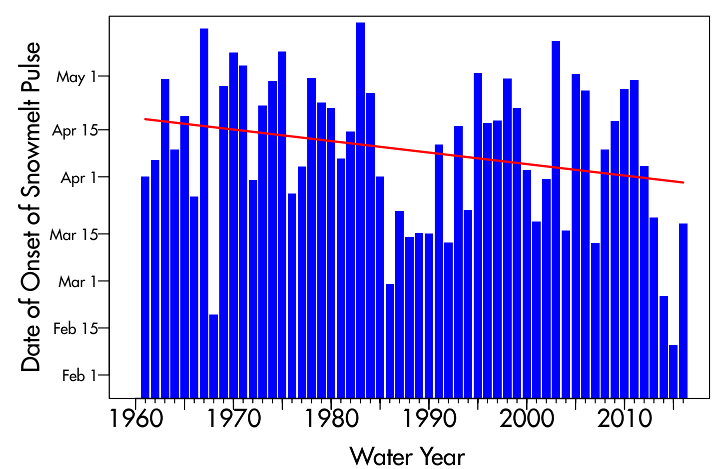
Impacts of climate change, continued

There is clear evidence that the lake itself is warming at all depths, but particularly at the surface. This warming is not continuous, but displays variability depending on the weather in each year. Warming water has a number of ecological consequences for the lake. These include the creation of niches for species that previously could not survive in the lake but could now survive if introduced; potentially disadvantaging native species that have evolved under Tahoe's clear, cold water conditions and are adapted to a specific set of predators; and increasing metabolic rates of organisms, from plankton to fish.

Climate change is also producing other physical changes beyond lake warming that may have even larger impacts on lake ecology and water quality. One of these is advancing the onset of spring and delaying the arrival of fall. Evidence of this can be found in the fact that snowmelt is starting sooner. Additionally, the lake is staying stratified longer (meaning that the surface waters are staying warm and floating on top of cold bottom waters for longer).



Annual average surface temperature of Lake Tahoe.

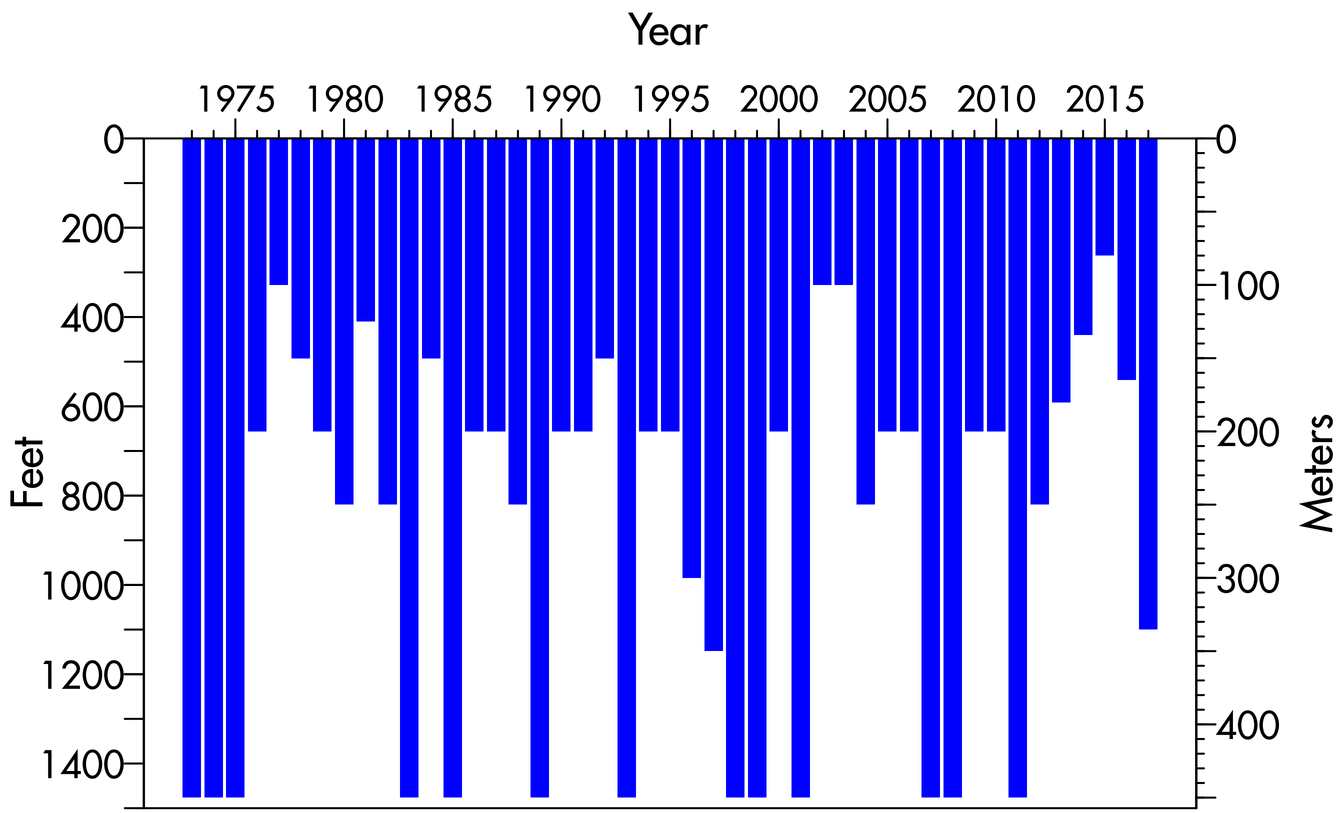


Advance of the onset of spring, as indicated by the stream snowmelt pulse.

CURRENT RESEARCH

Impacts of climate change, continued

The impacts of this are subtle, but profound. With a lengthening summer stratified season, winter is shortening. Winter is when the lake surface naturally cools, a process that makes the surface water denser. This heavy water sinks, and is the primary reason that lakes mix in the winter. This mixing is essential for transferring oxygen to the bottom of the lake where it is needed to sustain life, and for removing the accumulation of nutrients that would otherwise build up deep in the lake {see Section 9.8-9.9}. With shorter winters there will be fewer weeks in the year for mixing to progress all the way to the bottom of the lake before the next spring begins.



Depth of mixing in Lake Tahoe by year.

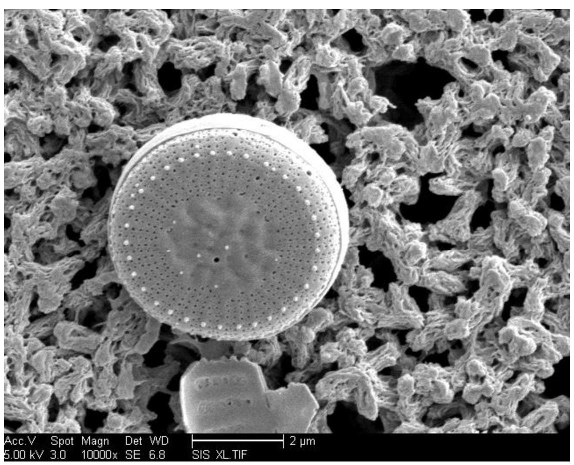
CURRENT RESEARCH

Impacts of climate change, continued

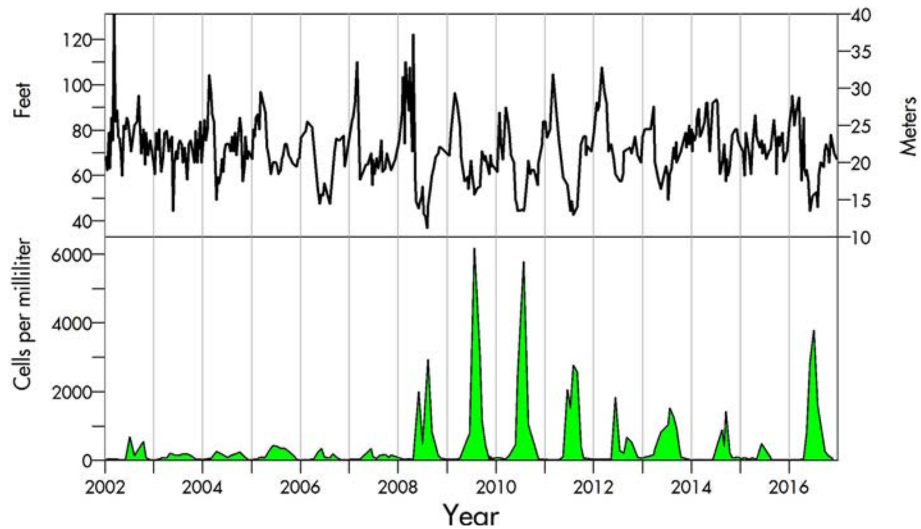
The ecology of the lake is changing in response to the changes in the stratification. Algae in a lake form the base of the food web. Most are free-floating, microscopic plants of varying types and sizes, that exist in a turbulent environment that keeps them from sinking out of the sunlight. Turbulence suppression, due to stratification, causes the larger algae to sink out of the euphotic zone, leaving only the very smallest, slow sinking algae at the surface with no competition for nutrients. One of the most common algae is *Cyclotella gordonensis*, a tiny (4 micron) diatom.

In 2016, it was present in exceptionally high numbers when the lake was strongly stratified in summer, corresponding to a decrease in Secchi depth. Because *Cyclotella gordonensis* is so small, it acts like a clay particle, remaining suspended in the water column for extended lengths of time, scattering light and decreasing Tahoe's exceptional clarity. Years with high concentrations of *Cyclotella gordonensis* generally correspond to years with low Secchi depth. While the more frequent appearance of *Cyclotella gordonensis* is not the only cause of clarity decline, it does present an additional, climate-induced challenge. To make matters worse, as clarity decreases, greater warming of the surface water takes place, increasing stratification and the likelihood of more small algal cells like *Cyclotella gordonensis*. It is a very vicious cycle.

What can be done to control the deleterious impacts of *Cyclotella gordonensis* on lake clarity? In the long-term, addressing climate change is critical. In the short-term algae are best controlled by either reducing the availability of the nutrient that is limiting its growth ("bottom up control"), or by altering the food web, to increase grazing by the lake's zooplankton ("top down control"). Both of these strategies are currently high priorities for further research.



The silicon frustule of *Cyclotella gordonensis* – this cell is 4 microns in diameter



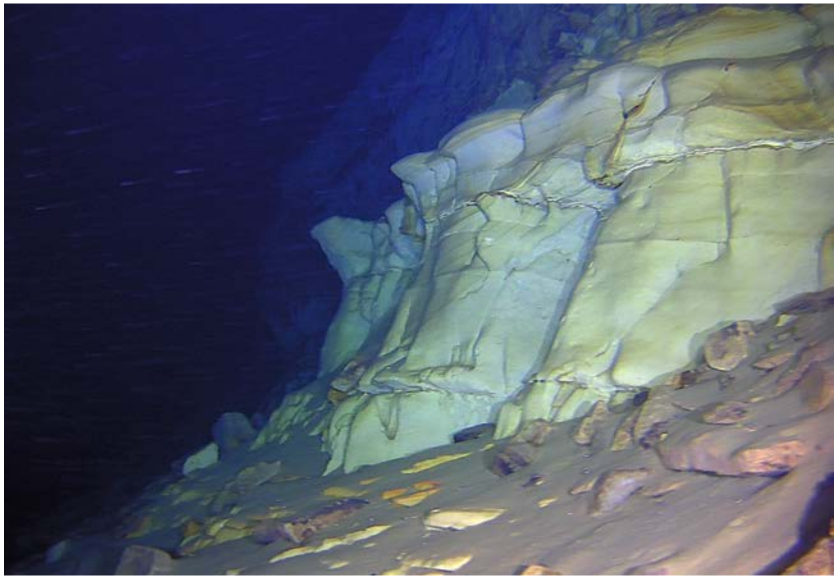
Secchi depth since 2002 along with concentration of *Cyclotella gordonensis* at a depth of 16.5 feet (5 m).

CURRENT RESEARCH

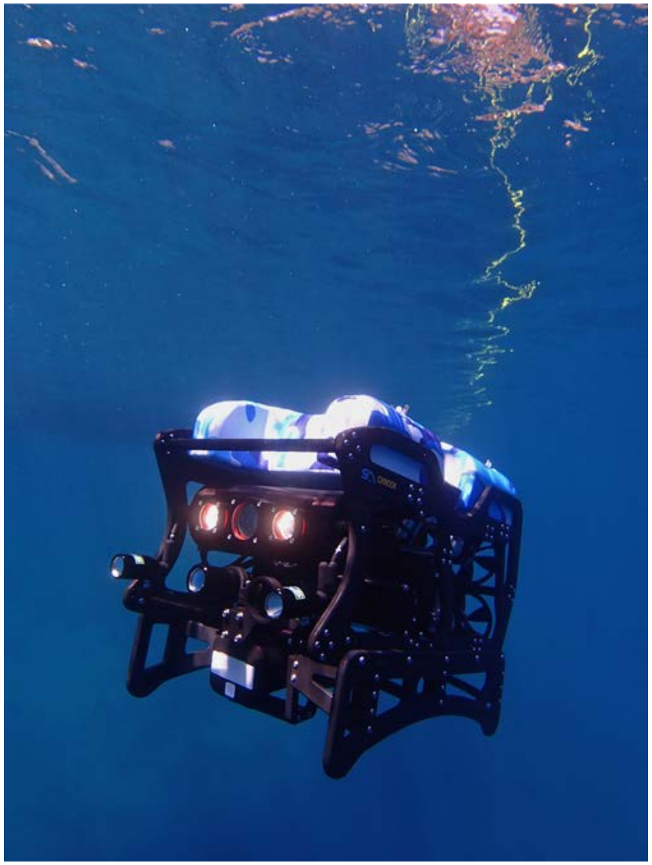
The bottom of the lake

Over 1600 feet below its surface, lies the bottom of Lake Tahoe, a place unimaginable by most. On April 14, 2017, TERC researchers had an opportunity to "see" the bottom of the lake using a Remotely Operated Vehicle (ROV) being demonstrated by Seamor Marine Ltd.

The center of Lake Tahoe is dominated by several huge outcroppings some up to a mile across and hundreds of feet tall. These are remnants of a massive underwater landslide that took place thousands of years ago.



The edge of an underwater mound in Lake Tahoe at a depth of over 400 m. The layering indicates its origin as the sedimentary shelf on the west side of Lake Tahoe. In the foreground is a blanket of sediment that has built up over thousands of years. Photo: Seamor Marine Ltd.



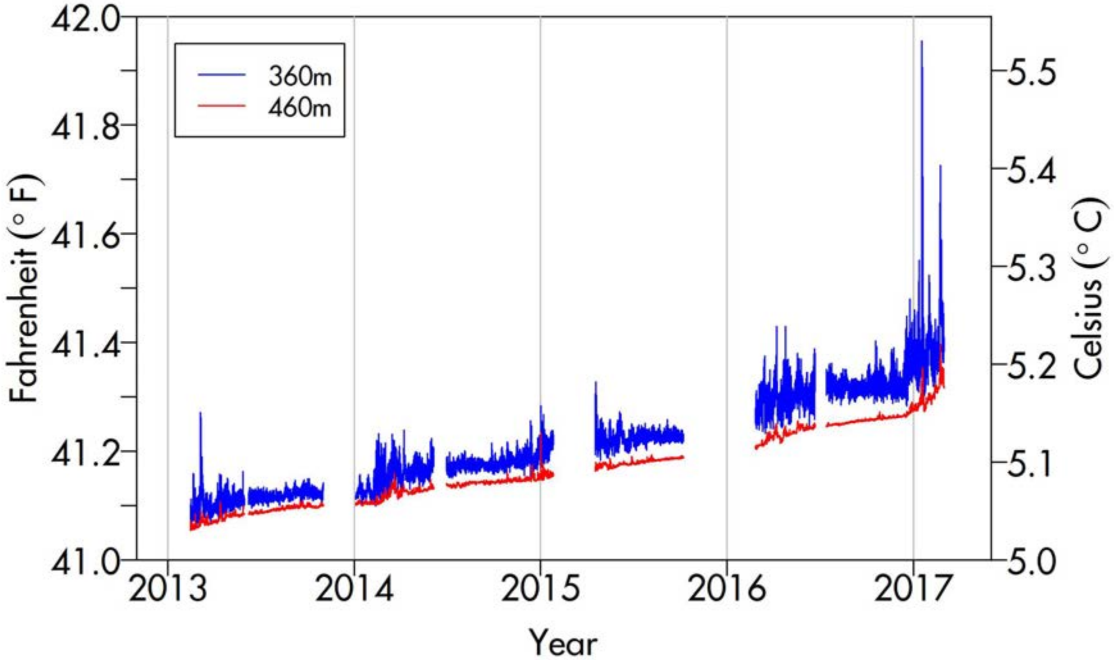
The ROV commencing its descent to the bottom of Lake Tahoe. Photo: Brant Allen

CURRENT RESEARCH

The bottom of the lake, continued

A vertical array of thermistors (temperature measurement instruments) is located a few miles from where the ROV descended. Data from the bottom thermistor at 1,500 feet (460 meters) and a higher thermistor at 1180 feet (360 meters) provides us with some new perspectives into what conditions are like near the bottom of the lake. The thermistors, which take a measurement every 30 seconds, have been deployed for 4 years (gaps in data are periods where the array was removed for servicing).

It is clearly a very quiescent environment, particularly at the very bottom. Fluctuations in temperature at the very bottom are less than 1/100 °F. The temperature difference over the 320 feet separating the two instruments is only 5/100 °F. However, conditions are slowly changing, as evidenced by the fact that both temperature traces are warming. Up till the end of 2016, this was a period when deep mixing did not occur, so the warming is not coming from climatic change. Rather, it is due to geothermal heating that takes place at the bottom of Lake Tahoe. This very slight amount of warming, on average 0.054 °F per year, is sufficient to drive a very slight amount of motion at the very bottom of the lake. The role of this motion in controlling conditions at the bottom is currently being studied.



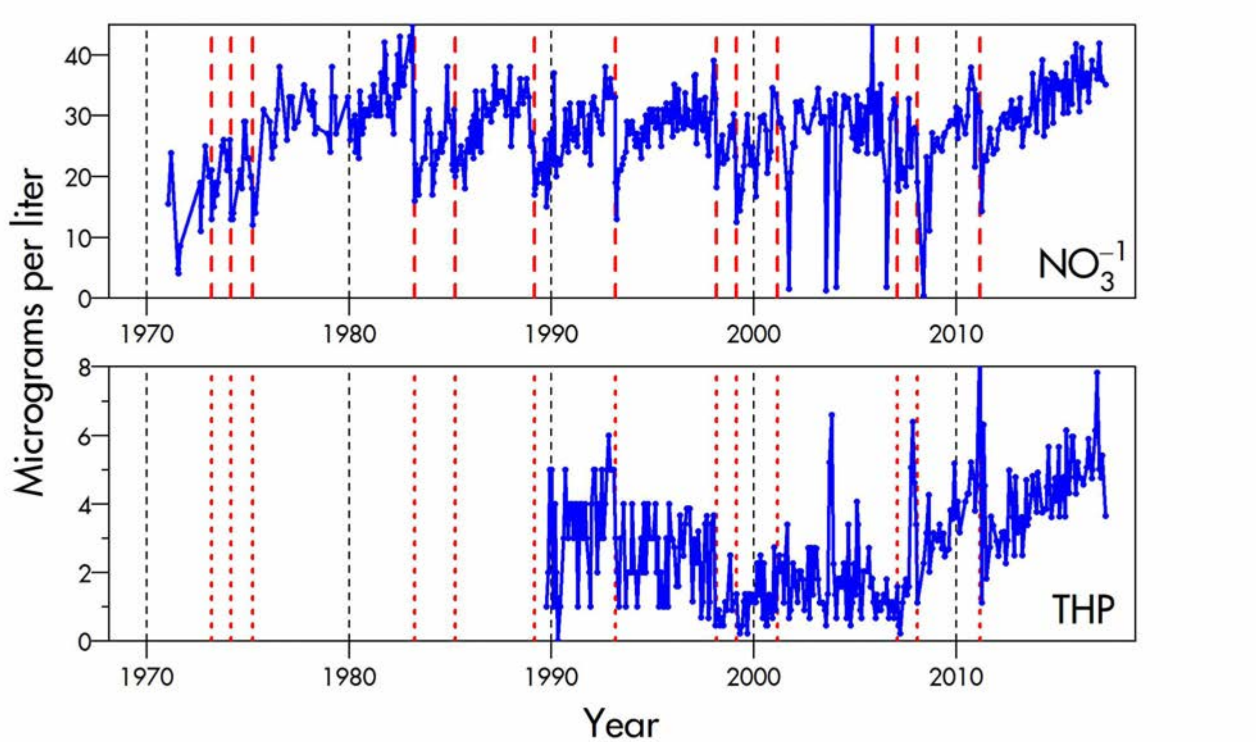
Temperature at 460 m (1500 ft.) and 360 m (1180 ft) from the Glenbrook thermistor chain.

CURRENT RESEARCH

The bottom of the lake, continued

The lack of deep mixing allows for nutrients to accumulate at the bottom of the lake. The nutrients are from the decomposition of algae and other organic matter that sink to the bottom of the lake. The long-term data for nitrate (NO3) and total hydrolysable phosphorus (THP) show this effect very clearly. The dashed red lines indicate times of complete lake mixing. In years when complete mixing occurs both the NO3 and the THP drop, as the bottom waters get diluted through mixing with the overlying waters. When it does not occur, the mean concentration tends to increase.

Both NO3 and THP are increasing in the lower portions of the lake since the last deep mixing in 2011, creating a reservoir of nutrients that will become available when the lake undergoes deep mixing. The sudden decreases in both are clearly evident in 2011 when mixing occurred. The same type of buildup in NO3 was evident between 1975 and 1983, when deep mixing was absent for years.



NO3 and THP measured at a depth of 1480 feet (450 m). Both build up when deep mixing does no occur. Dashed red lines are times of deep mixing.

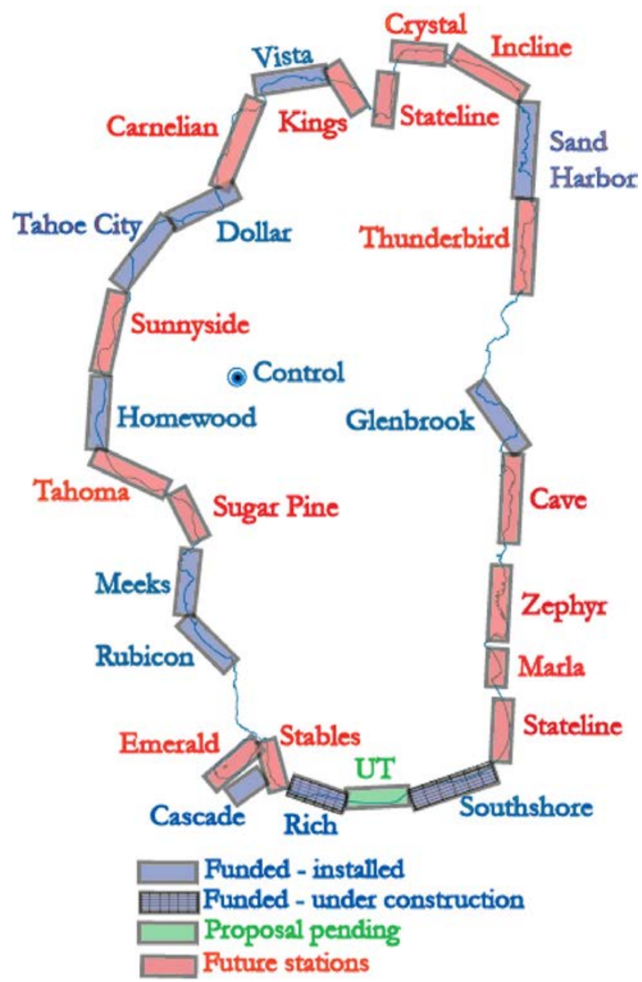
CURRENT RESEARCH

The nearshore of Lake Tahoe

The nearshore of Lake Tahoe is the most varied and least studied part of the lake. There are 63 streams and a greater number of stormdrains and culverts that flow into the lake, each one bringing a unique mixture of contaminants. Each part of the shoreline is oriented differently and each has different uses such as private homes, public beaches, or marinas. This is also where people come to use the beaches, where waves break, and where the land meets the lake.

To what extent do natural processes cause variations in water quality along the shoreline? To what extent are impacts in nearshore water quality caused by our human activities? Knowing the answers to these questions is important in setting meaningful and achievable water quality standards.

TERC's Nearshore Water Quality Network (the Nearshore Network) is helping to provide answers. The Nearshore Network currently comprises 11 stations around the shore of Lake Tahoe and Cascade Lake. These sensor stations are being funded by a growing group of lakefront property owners, private citizens, homeowner associations, and regulatory agencies. Each station measures water quality variables every 30 seconds at a water depth of approximately 7 feet and at a location several inches above the lake bed.



Location of nearshore stations at Lake Tahoe.

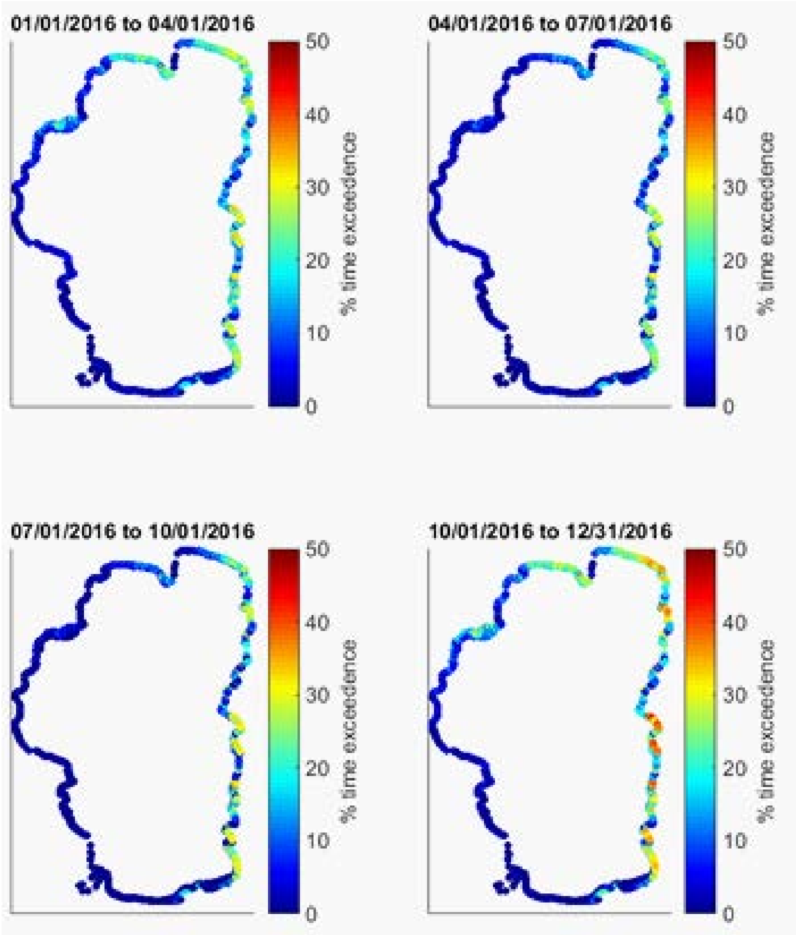
CURRENT RESEARCH

The nearshore of Lake Tahoe, continued

The utility of the Nearshore Network can be demonstrated using turbidity, a measure of the cloudiness of the water caused by the presence of fine particles. The water quality standard for turbidity at Lake Tahoe is 1 NTU, except in the vicinity of stream mouths where it is 3 NTU. Using turbidity measurements from the Nearshore Network together with a model of wind-generated waves, graduate student Derek Roberts and his Chilean collaborator Dr. Patricio Moreno were able to make estimates of wave-induced turbidity at any point around the shoreline. The results showed that turbidity at the measurement point varies considerably around the lake, largely in response to the exposure to prevailing winds (from the west-southwest). There was also considerable variability between seasons.

Most importantly the results showed how frequently a particular turbidity value is exceeded in the nearshore region due to waves. The colored dots around the shore indicate the percentage of time that turbidity exceeds the standard of 1 NTU at a depth of 7 ft near the lake bed. For example a pale green dot indicates that the standard was exceeded 25% of the time in a given season. It is evident that the eastern shore, because of its exposure to winds, has the highest number of exceedances, particularly during the Fall cooling period from October-December.

If we look at the results for 10 NTU, exceedances occur less often, but they are still surprisingly high. For example, there are numerous sections of the shore where 10 NTU is exceeded near the bed for more than 20% of the time in certain seasons.



Percentage of time that turbidity exceeds 1 NTU near the sediment bed, at a depth of 7 ft.

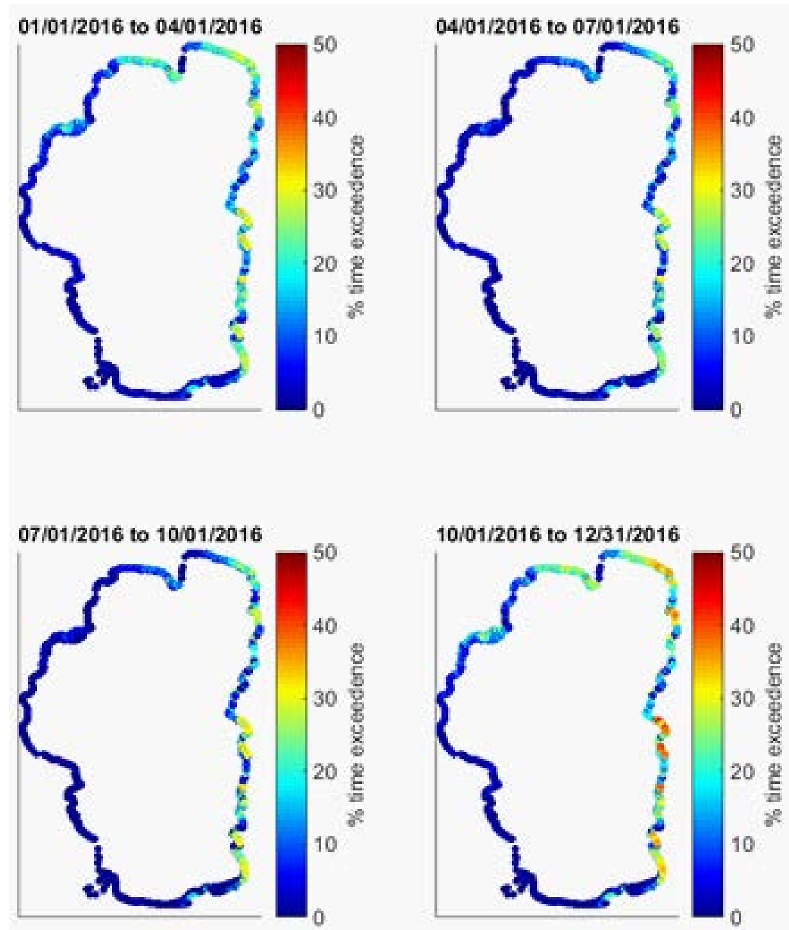
CURRENT RESEARCH

The nearshore of Lake Tahoe, continued

One of the clear messages from these results is that water quality around the shoreline is inherently variable in both space and time. It is not possible for a single scientist to be taking measurements everywhere, but it is possible for an army of citizen scientists to come close to doing just this.

TERC's Citizen Science Tahoe app has been redesigned and upgraded to enable everyone to become a citizen scientist and help gather observations around the lake. Anybody with a smartphone can download the mobile app from CitizenScienceTahoe.org, and in a matter of minutes can make observations about algae, local species, water quality, and beach conditions. Observations from around the shore of Lake Tahoe will allow us to see how conditions are changing over time and at different locations around the lake. This will include the cloudiness of the water, the presence of washed up weeds, invasive species, and the slipperiness of the rocks. This data is incredibly important to us. It is the only way we can be in more places at more times.

The TERC Citizen Science Tahoe app is providing data from all around the lake for all seasons. Photo: Alison Toy



Percentage of time that turbidity exceeds 10 NTU near the sediment bed, at a depth of 7 ft.

CURRENT RESEARCH

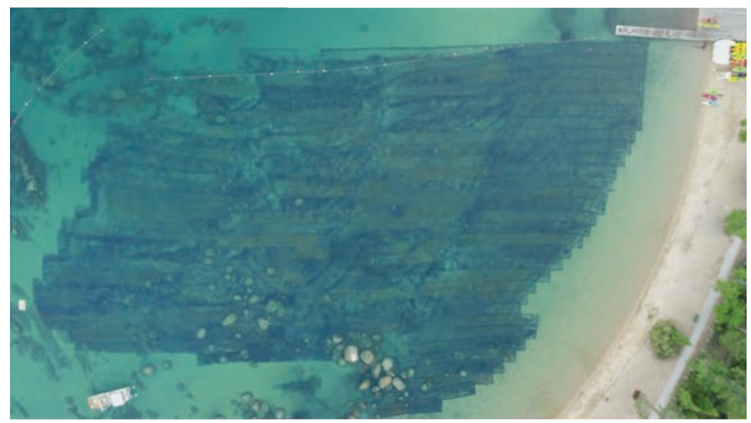
Invasive species and the role of boating

The Nevada Division of State Lands has commenced a project to control the emergence of a satellite population of Asian clams adjacent to the boat ramp at Sand Harbor State Park, Nevada. While Asian clams are now widespread along the southern shore of Lake Tahoe, their recent appearance at one of the most scenic locations on the north shore would seem puzzling. A multi-agency boat inspection program prevents new invasive species from entering the lake from outside. The currents in the lake are such that the rapid transport from south to north is inconceivable.

The most likely scenario is that Asian clams are now being transported within Lake Tahoe by boats. The boating activity that seems to have the greatest potential for this is wakeboarding. A boat outfitted for wakeboarding would typically fill its ballast tanks with up to 600 gallons of water. If this water happened to be drawn from a clam infested area in summer, it is very possible that veligers (the larval offspring) would also be drawn in. At the end of a fun day, if the ballast tanks were emptied at a different, clam-free area, then in-lake transport would have occurred.

Two obvious actions can prevent this accelerated spread from occurring. First, all filling and emptying of ballast tanks should take place at least one mile from shore. The deep waters there are less likely to contain veligers, and any would invariably sink to the cold depths where they cannot reproduce. Secondly, it would be extremely prudent to require that all ballast tanks be equipped with filters that can effectively remove all particulate material.

Sand Harbor demarcated Asian clam area.



Bottom barriers partially installed at Sand Harbor for Asian clam control.

TAHOE: STATE OF THE LAKE REPORT 2017

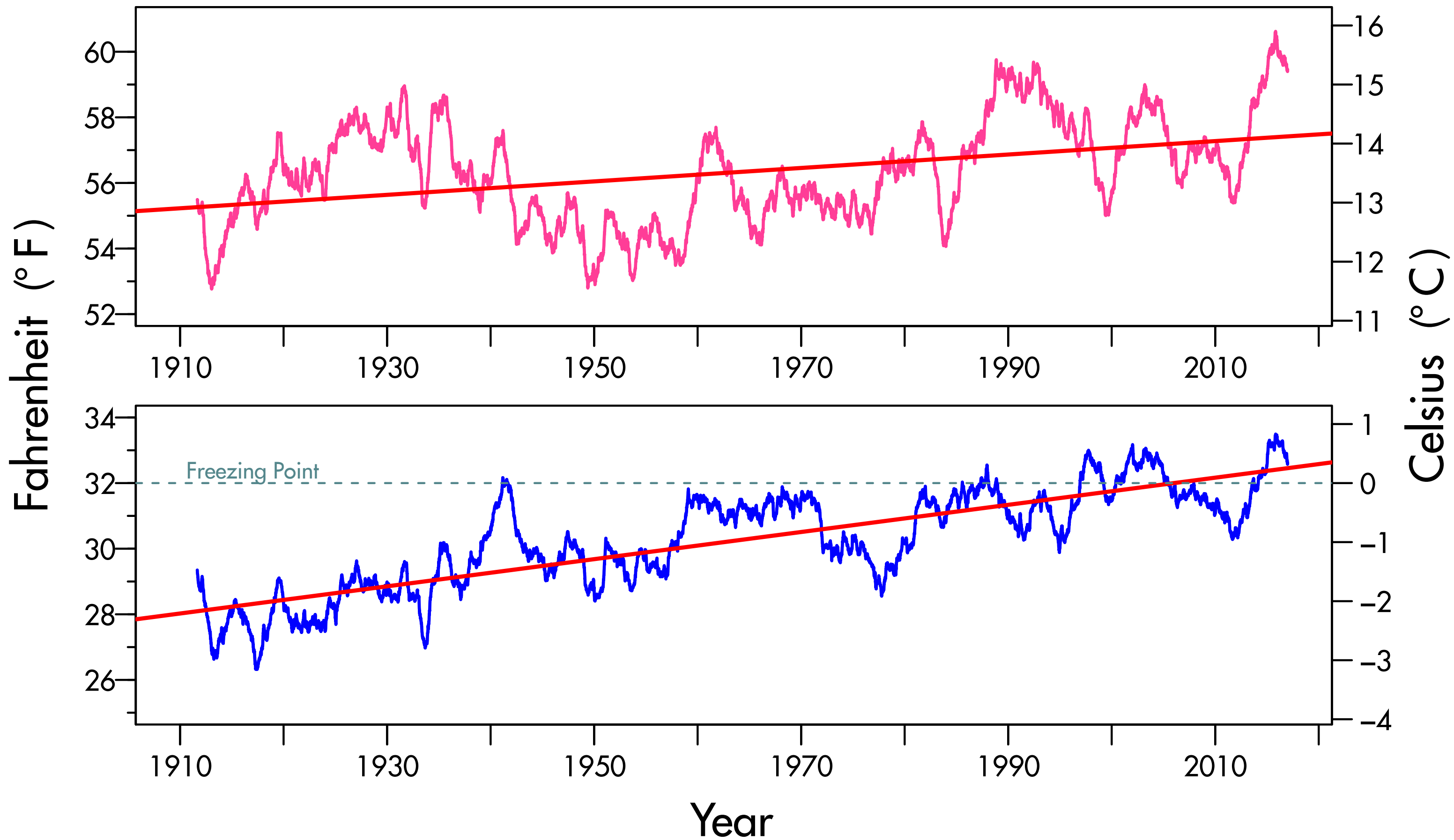
METEOROLOGY

METEOROLOGY

Air temperature

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 4.3 °F (2.4 °C), and the long-term trend in average daily maximum temperature (upper figure) has risen by 2.0 °F (1.1 °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.

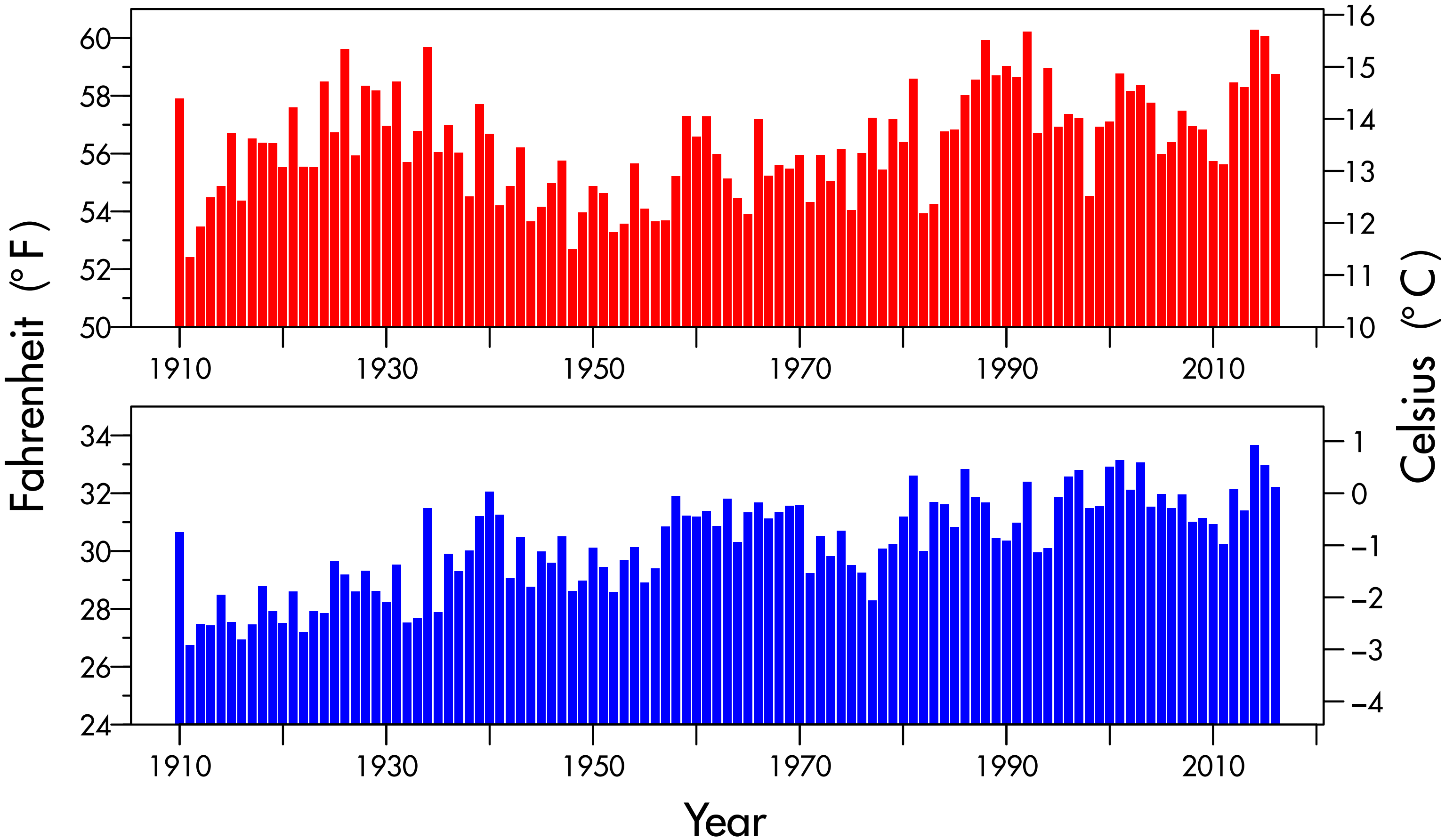


METEOROLOGY

Air temperature - annual average maximum and minimum

Since 1910

Annual average maximum (red) and minimum (blue) air temperatures in 2016 were both well above the long-term average. The 2016 annual average minimum was 32.2 °F (0.56 °C) a decrease of 0.8 °F over the previous year. The maximum temperature was 58.8 °F (14.9 °C) a decrease of 1.3 °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.



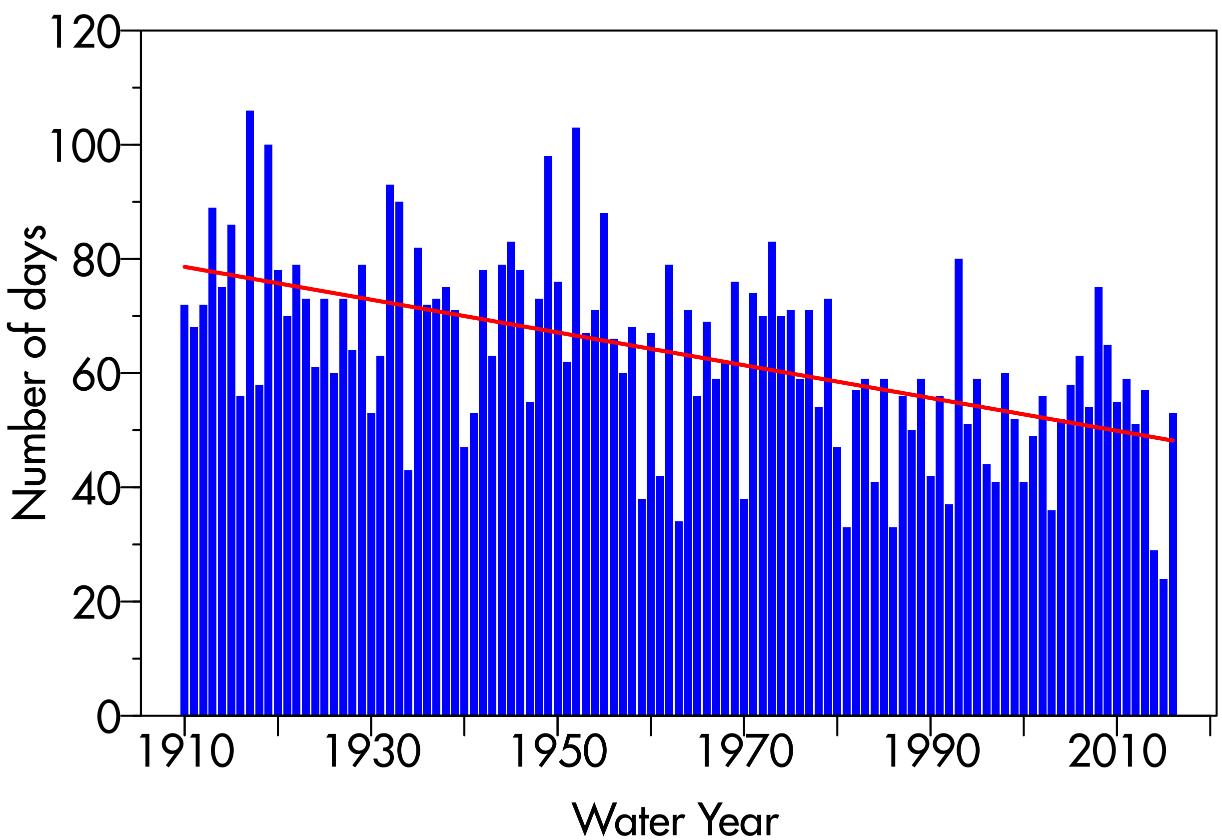
METEOROLOGY

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 2016, the number of freezing days was 53, reflective of the generally cooler year compared with the previous two years.

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

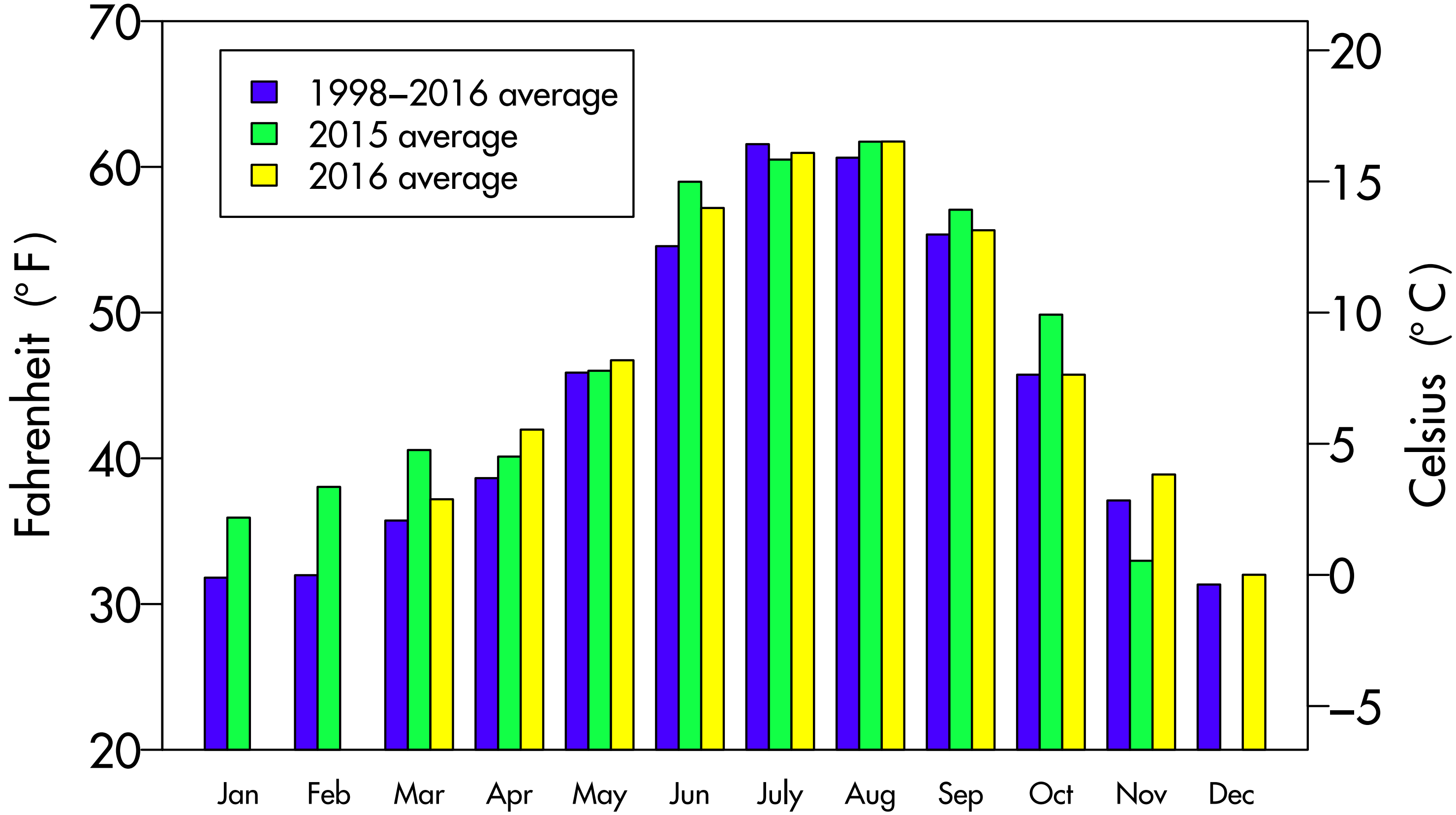


METEOROLOGY

Monthly air temperature

Since 1998

In 2016, monthly air temperatures were largely indistinguishable from the 1998-2016 average. Months with more than 25 percent of days missing are omitted from the figure below.

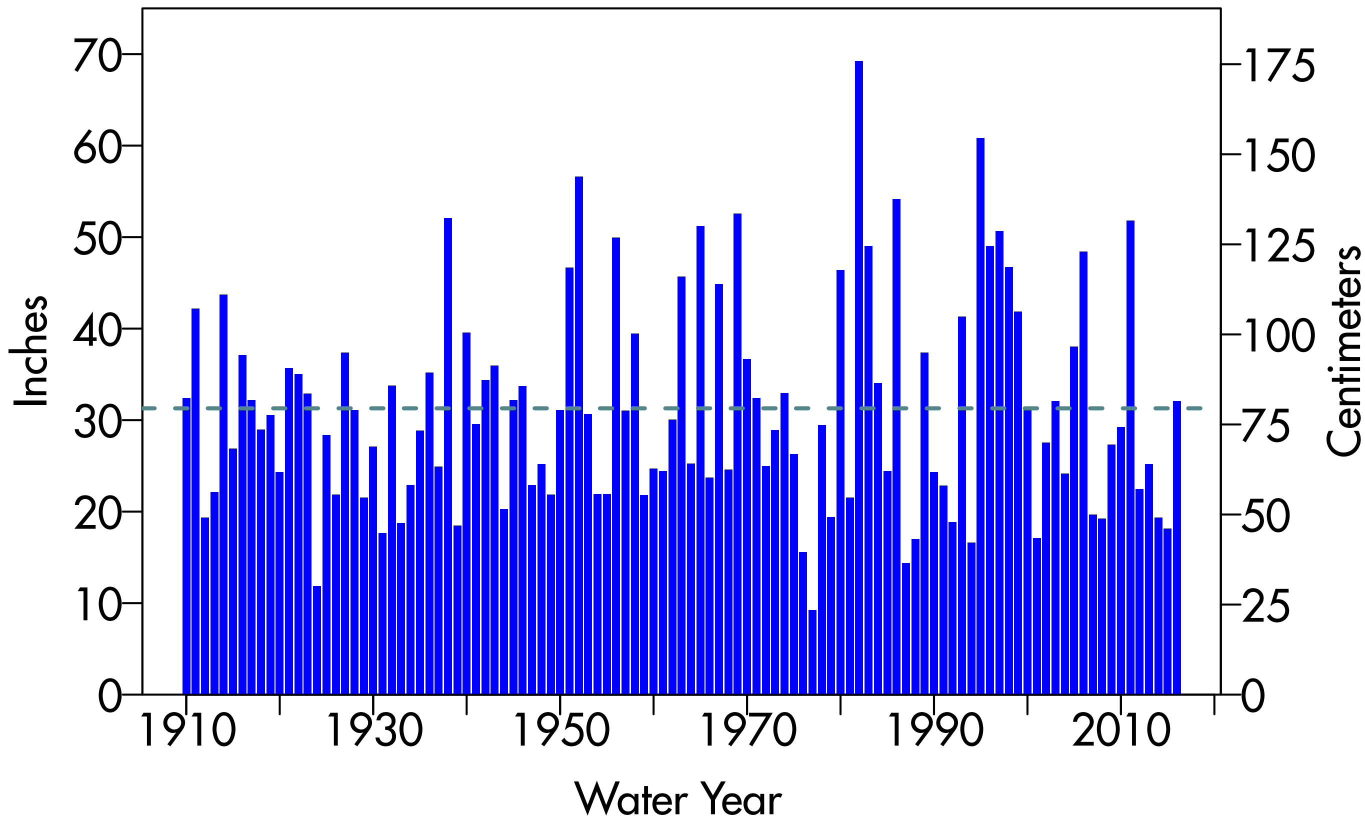


METEOROLOGY

Annual precipitation

Yearly since 1910

From 1910 to 2016, average annual precipitation (water equivalent of rain and snow) at Tahoe City was 31.3 inches. The maximum was 69.2 inches in 1982. The minimum was 9.2 inches in 1977. 2016 was close to the average, with 32.1 inches, following the three previous dry years. The long-term average of 31.3 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.)

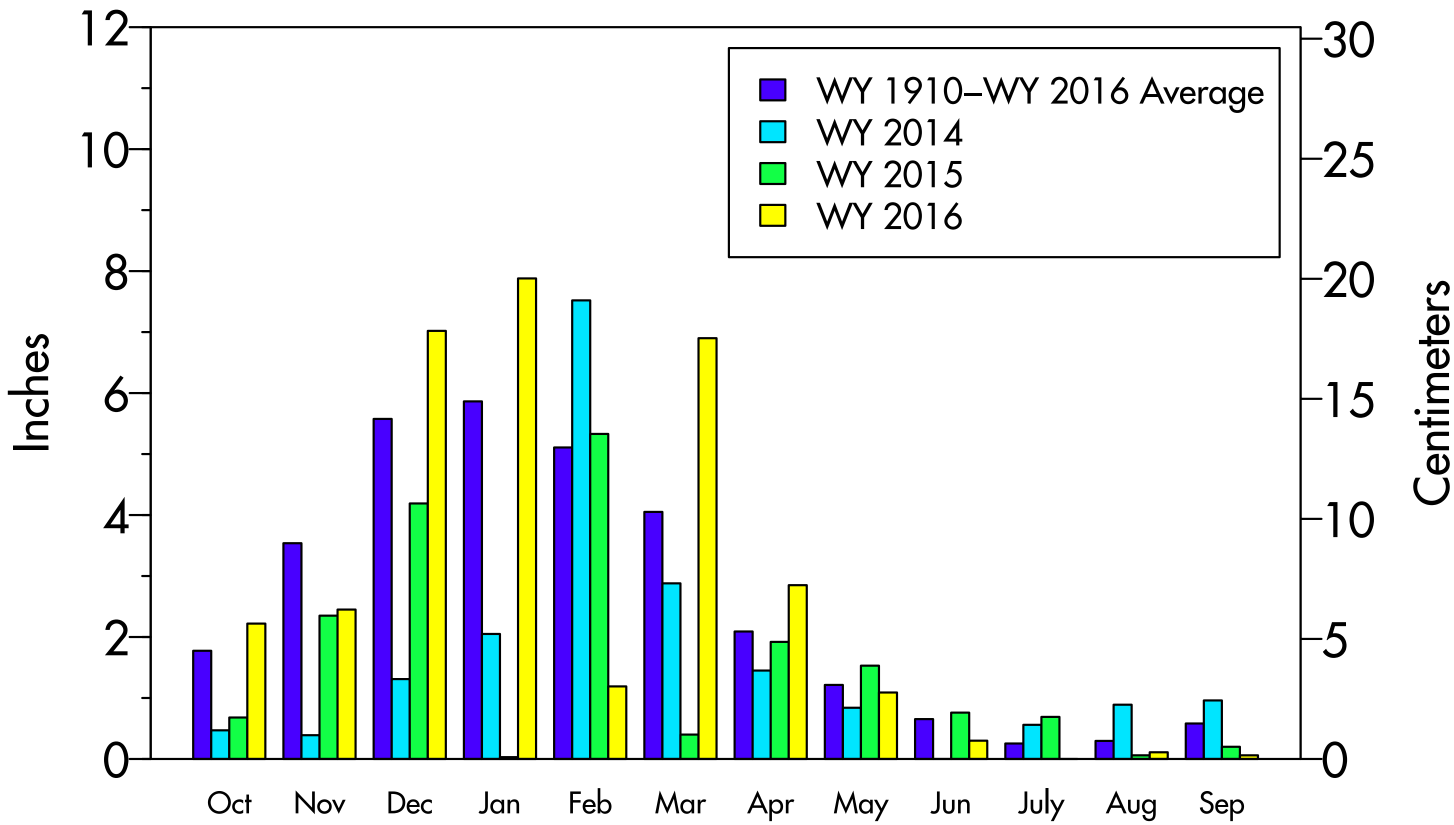


METEOROLOGY

Monthly precipitation

2014, 2015, 2016 and 1910 to 2016

2016 was close to the average in total precipitation but was much higher than the previous two drought years. This is clearly evident in the comparison of the monthly precipitation with 2014 and 2015 and the long-term average. Monthly precipitation in WY 2015 was noticeably lower than the long-term average during summer, especially in July, August, and September. The monthly precipitation for Jul-2016 (WY 2016) was 0 inches. The 2016 Water Year extended from October 1, 2015 through September 30, 2016.

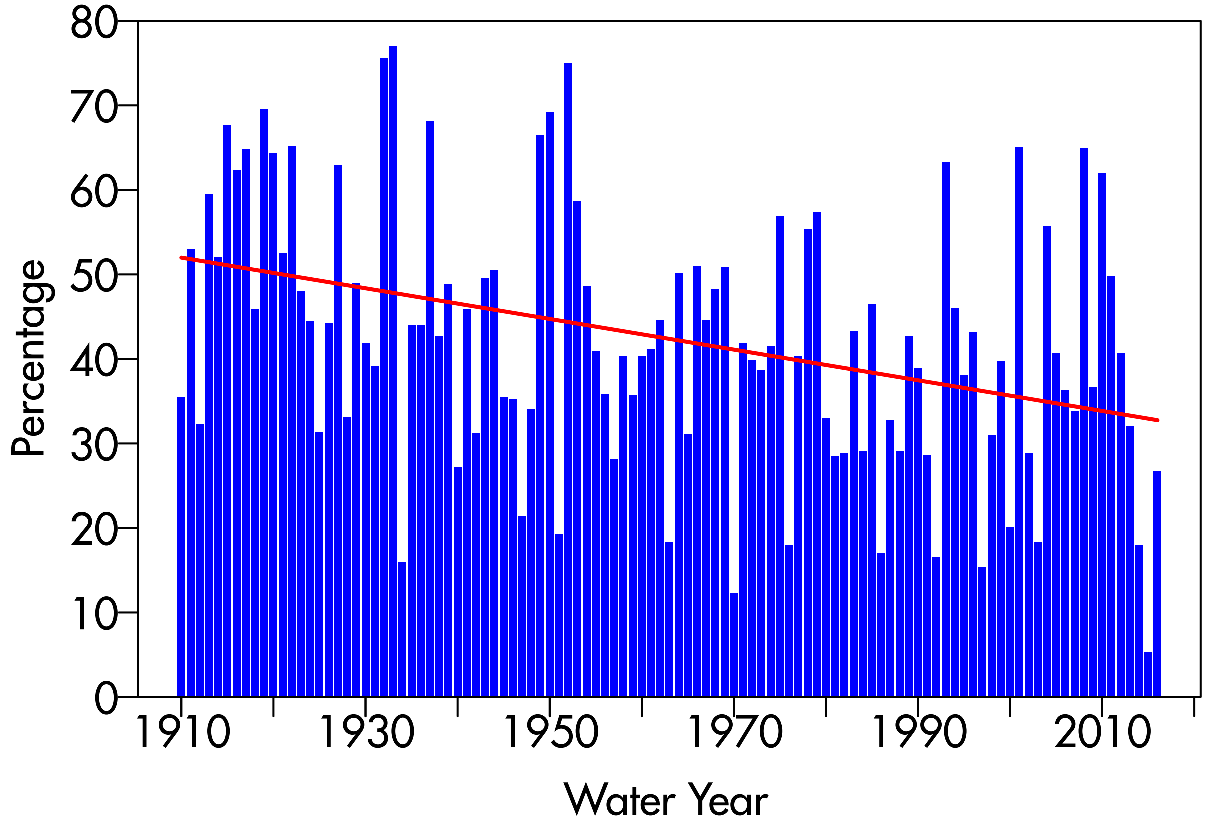


METEOROLOGY

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 33 percent in present times according to the line of best fit. In Tahoe City, snow represented 26.7 percent of the 2016 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.)

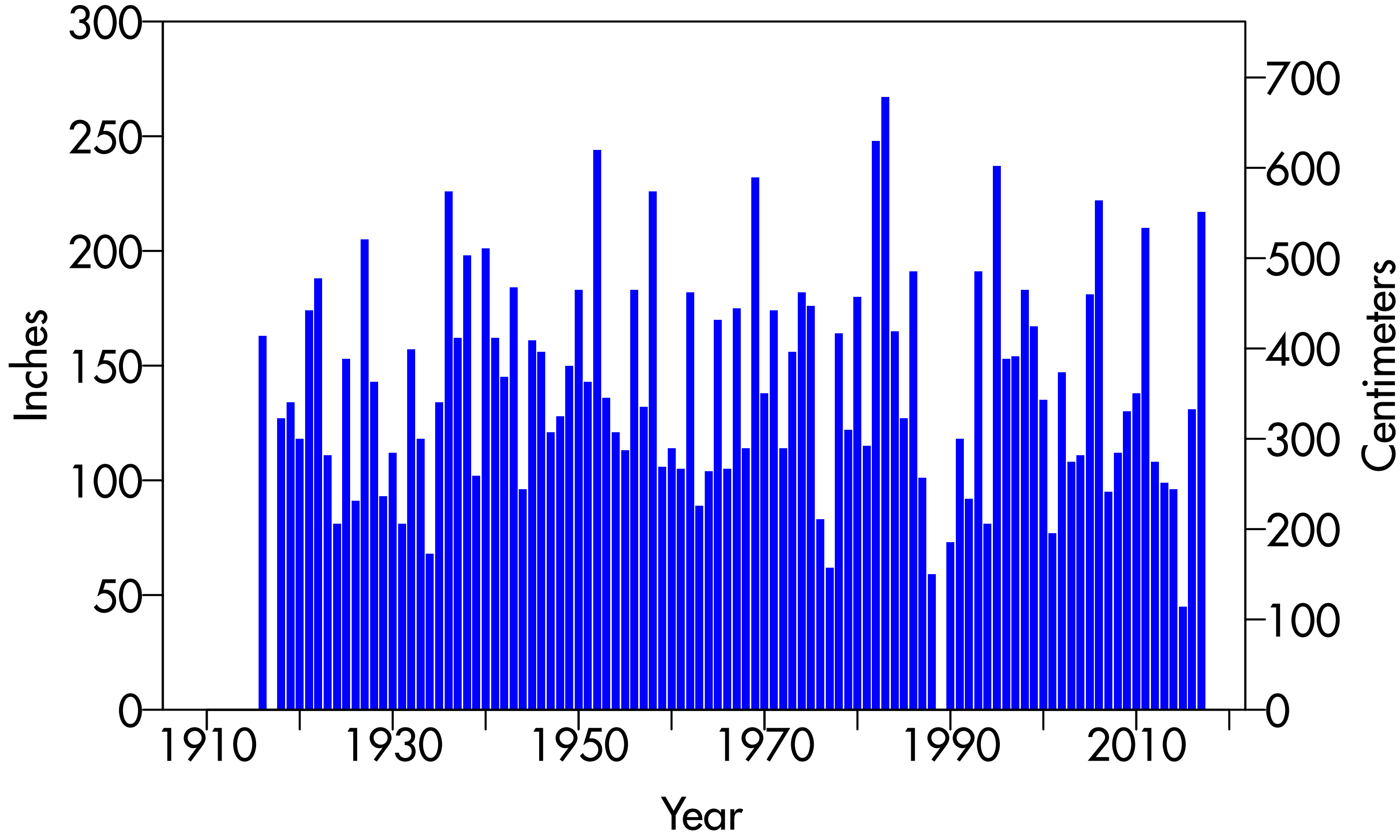


METEOROLOGY

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 for the period 1916 to 2017 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, representing a high snow year compared to the record low value in 2015. The average snow depth over the period 1916-2017 was 143 inches. Data source: USDA Natural Resources Conservation Service, California Monthly Snow Data.

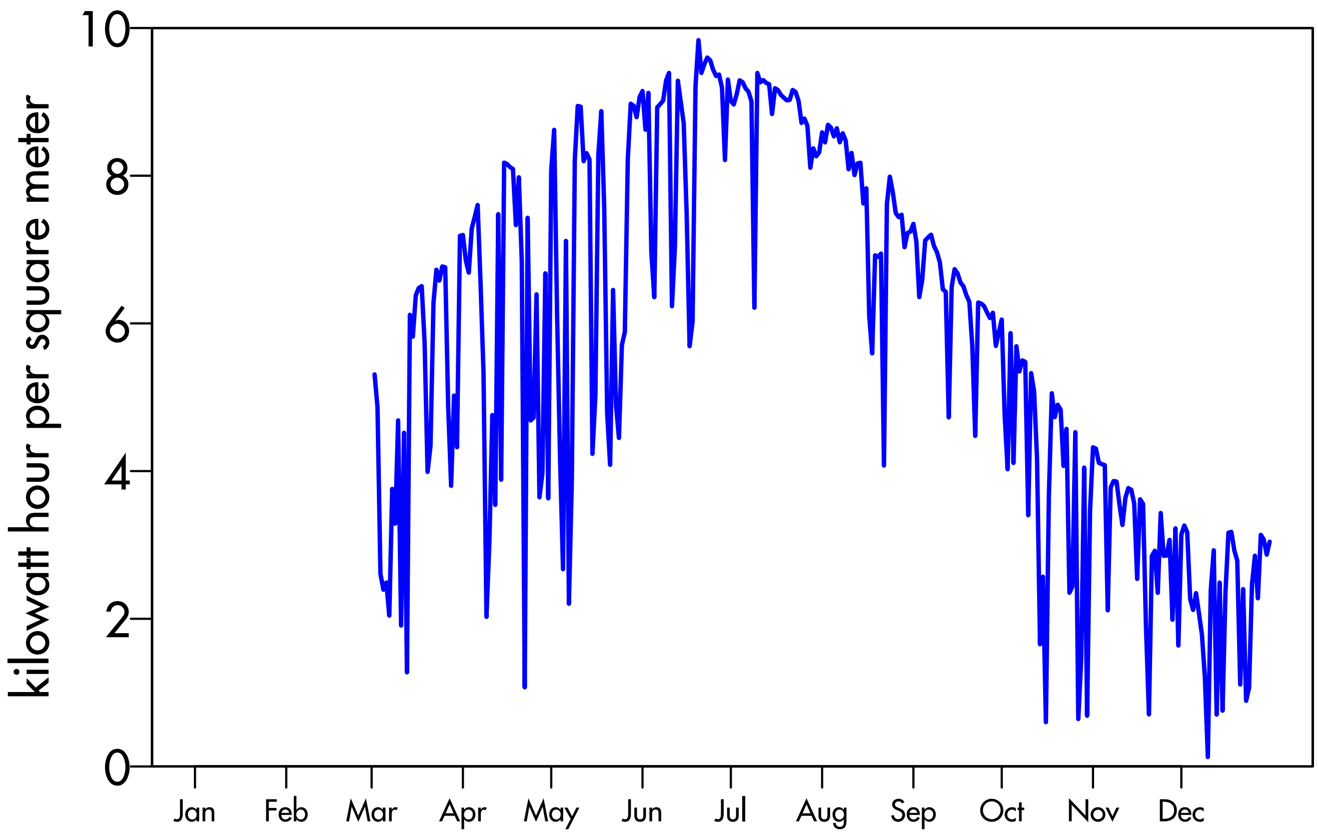


METEOROLOGY

Daily solar radiation

In 2016

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 station where these data are collected is located on the U.S. Coast Guard dock at Tahoe City. The instrument was not operating for the first three months of 2016.



TAHOE: STATE OF THE LAKE REPORT 2017

PHYSICAL PROPERTIES

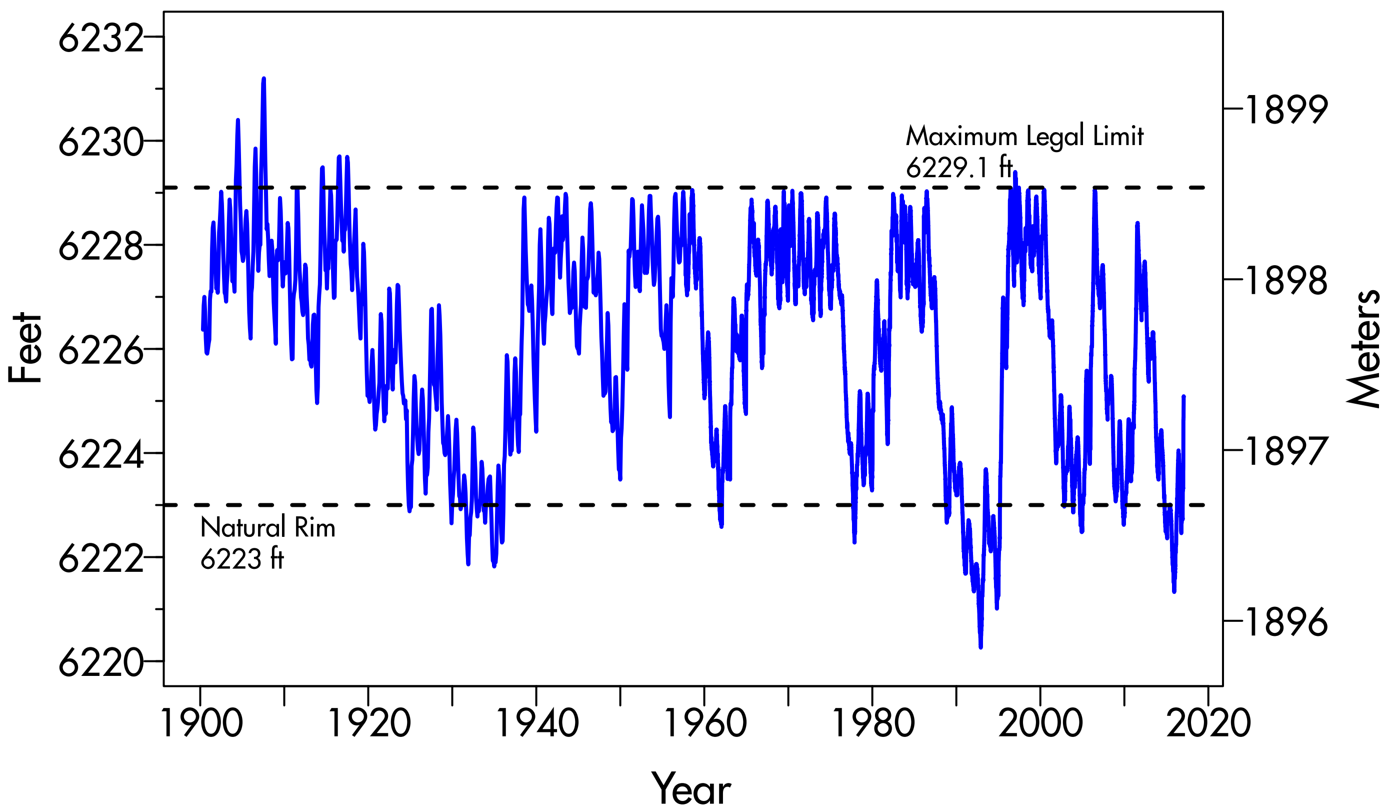
UC DAVIS
TAHOE ENVIRONMENTAL RESEARCH CENTER

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 over 20 inches during 2016. The highest lake level was 6223.01 feet on June 10, and the lowest was 6221.58 feet on December 9. The natural rim of the lake is at an elevation of 6223 feet. Lake Tahoe was below its rim for almost the entire year, except for one day on January 2, 2016. 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.

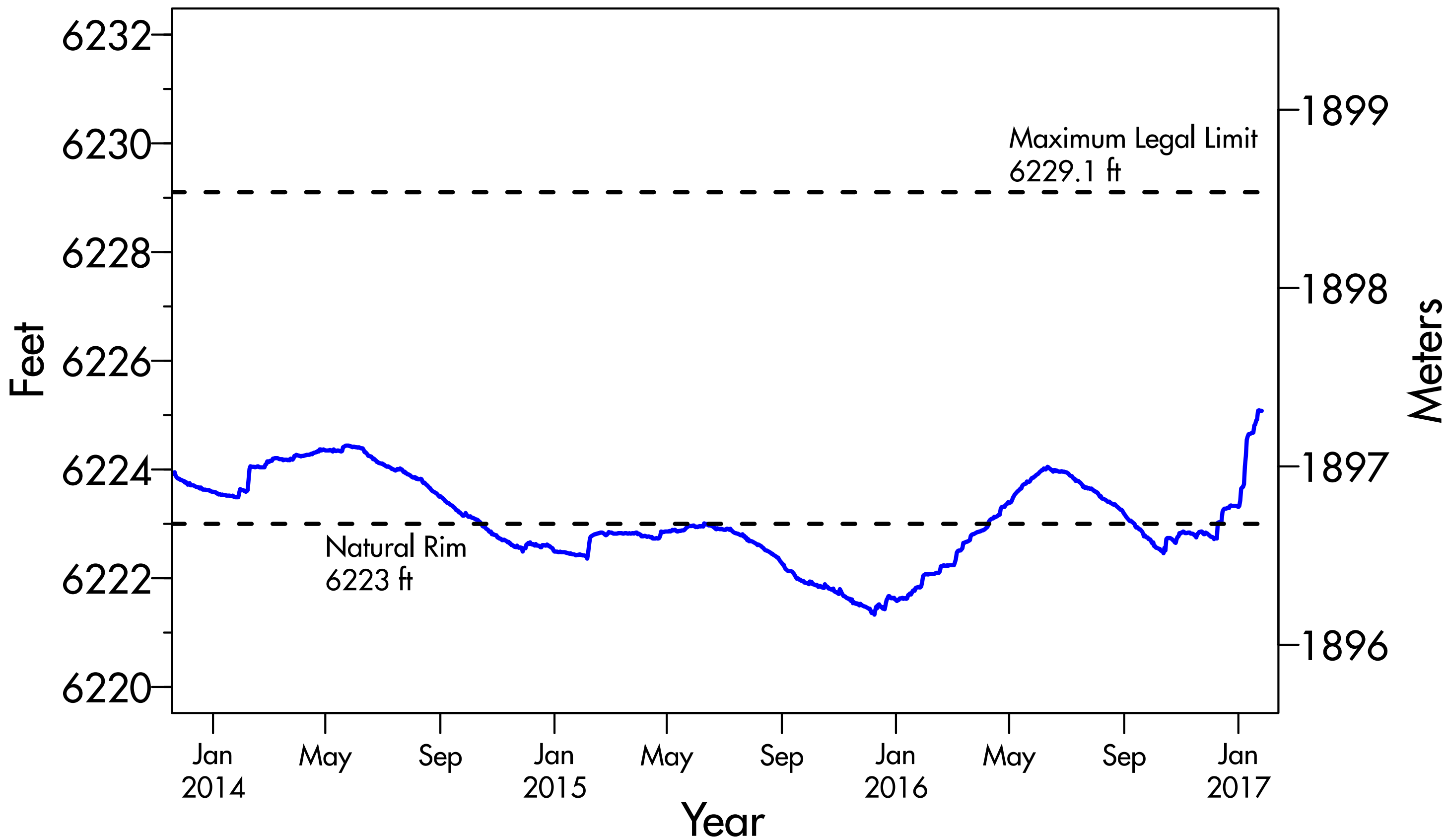


PHYSICAL PROPERTIES

Lake surface level, continued

Daily since 2014

Displayed below is the lake surface data from 2014-2016 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 lake level falling below the natural rim in October 2014 and its two periods of being below the rim in 2016. The effects of the drought on overall lake water level is evident, as is the beginning of a rapid rise in lake level in 2017.

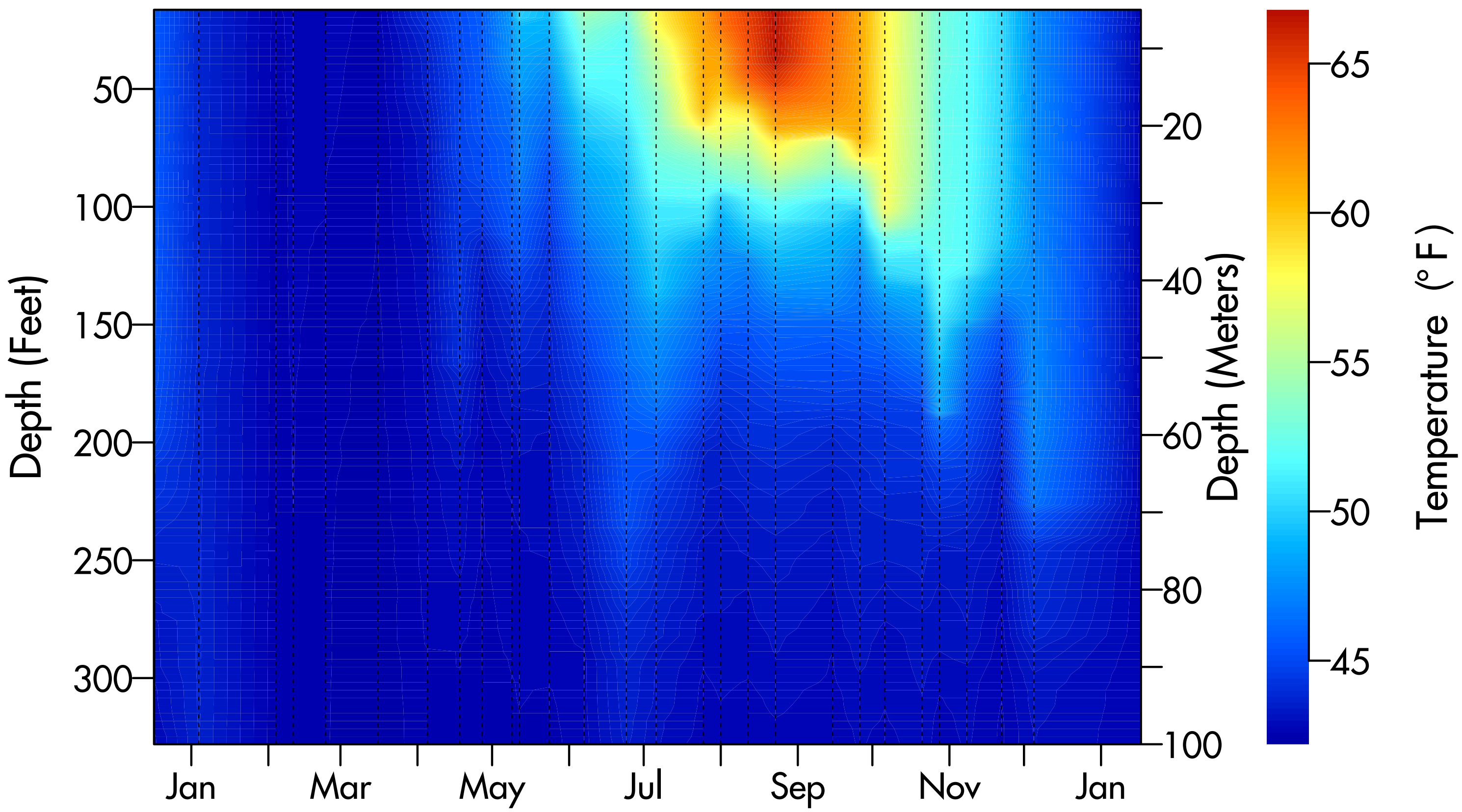


PHYSICAL PROPERTIES

Water temperature profile

In 2016

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 2016, 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, a process that is important in bringing oxygen to the deeper parts of the lake.

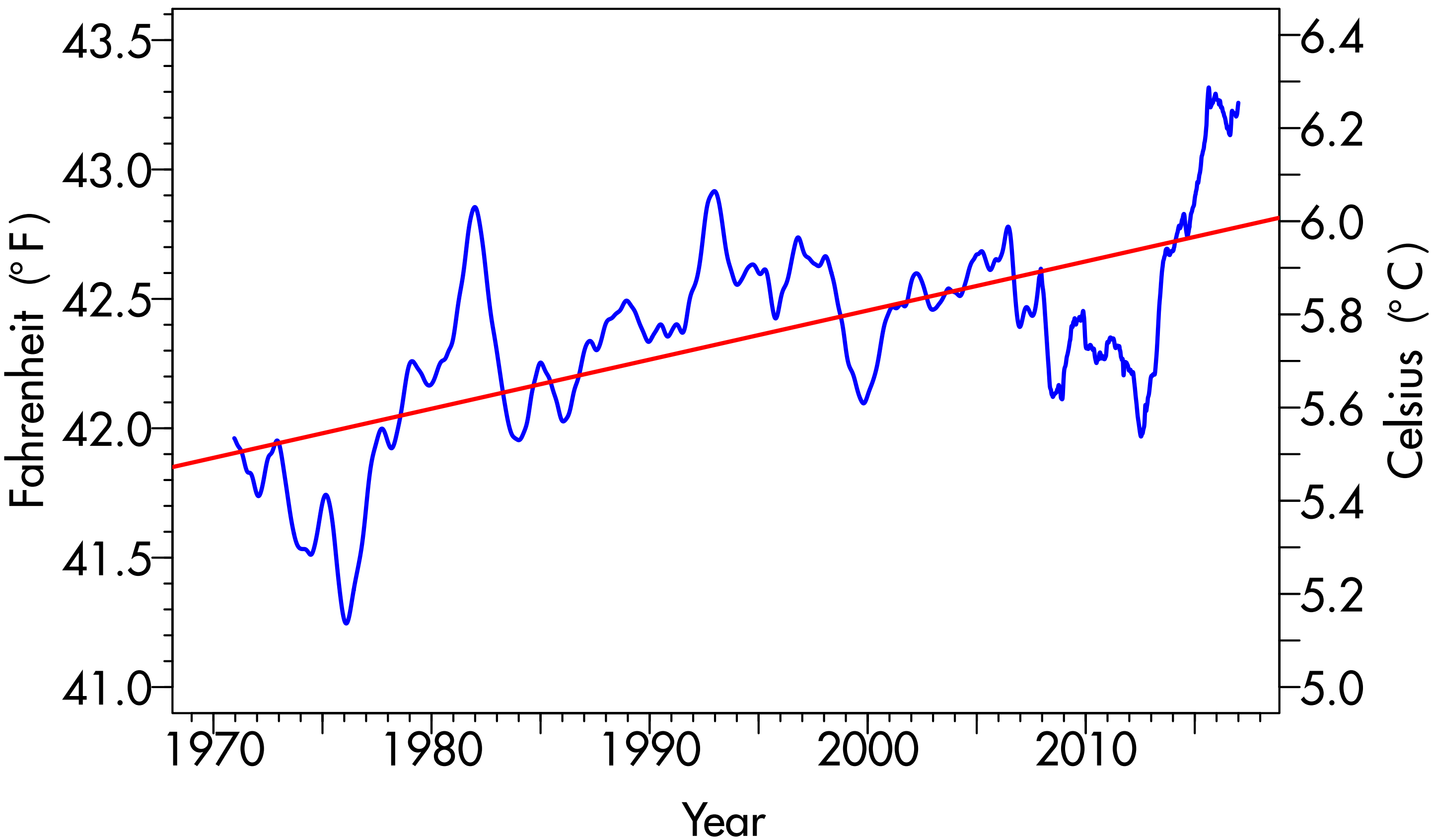


PHYSICAL PROPERTIES

Average water temperature

Since 1970

The trend in the volume-averaged temperature of Lake Tahoe has increased by approximately 0.87 °F since 1970. The annual rate of warming is 0.019 °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 a high 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.

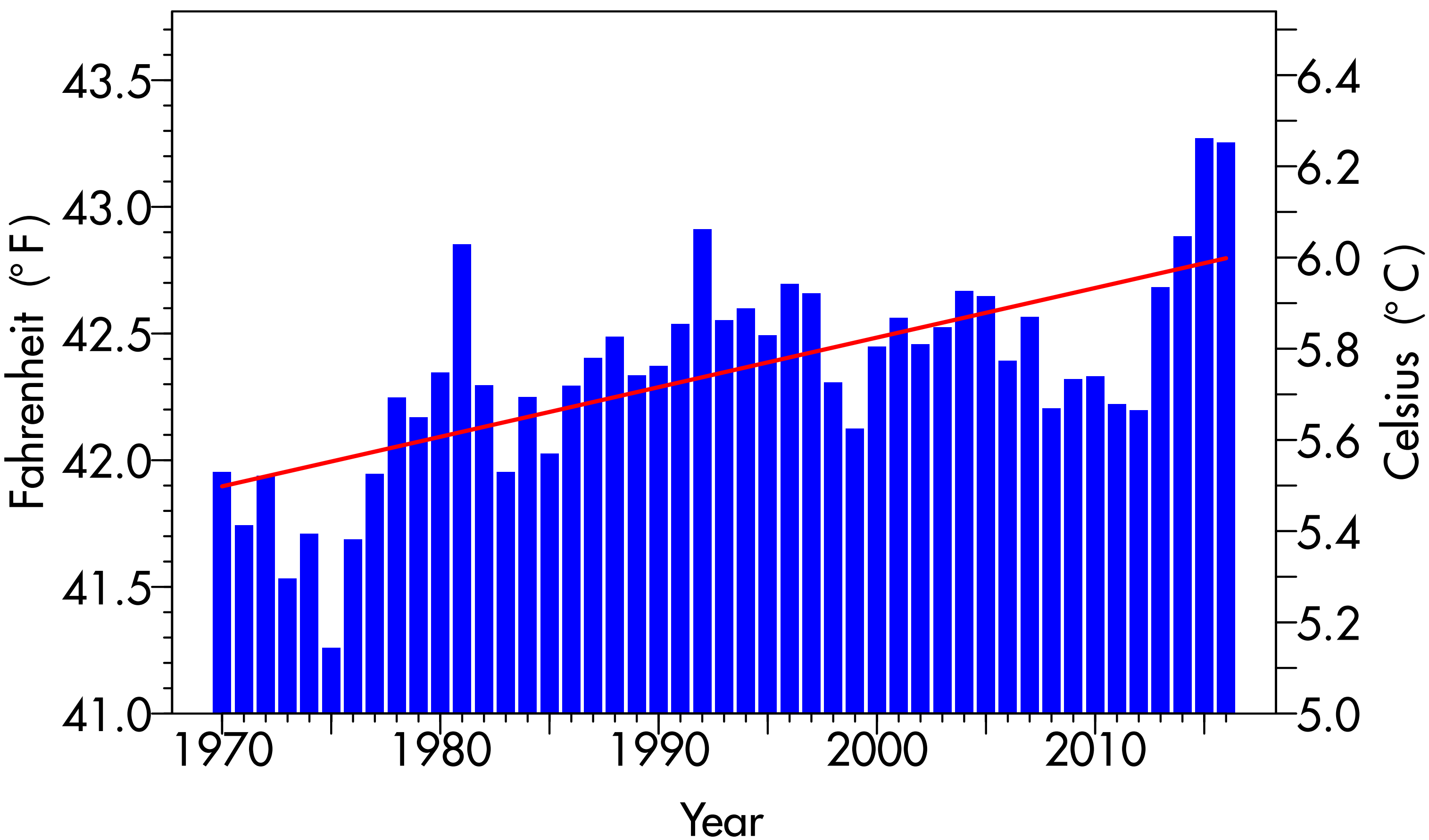


PHYSICAL PROPERTIES

Annual average water temperature

Since 1970

The volume-averaged temperature of the lake for each year since 1970 is shown. In 2016, the volume-averaged temperature decreased by 0.02 °F (0.01 °C) over the previous year. In the last 4 years the lake has warmed at an alarming rate of over 0.5 °F/year, 14 times faster than the long-term warming rate. Increases in temperature generally correspond to those years in which deep mixing did not occur. In 2016, deep mixing did not occur for the 5th year in a row.

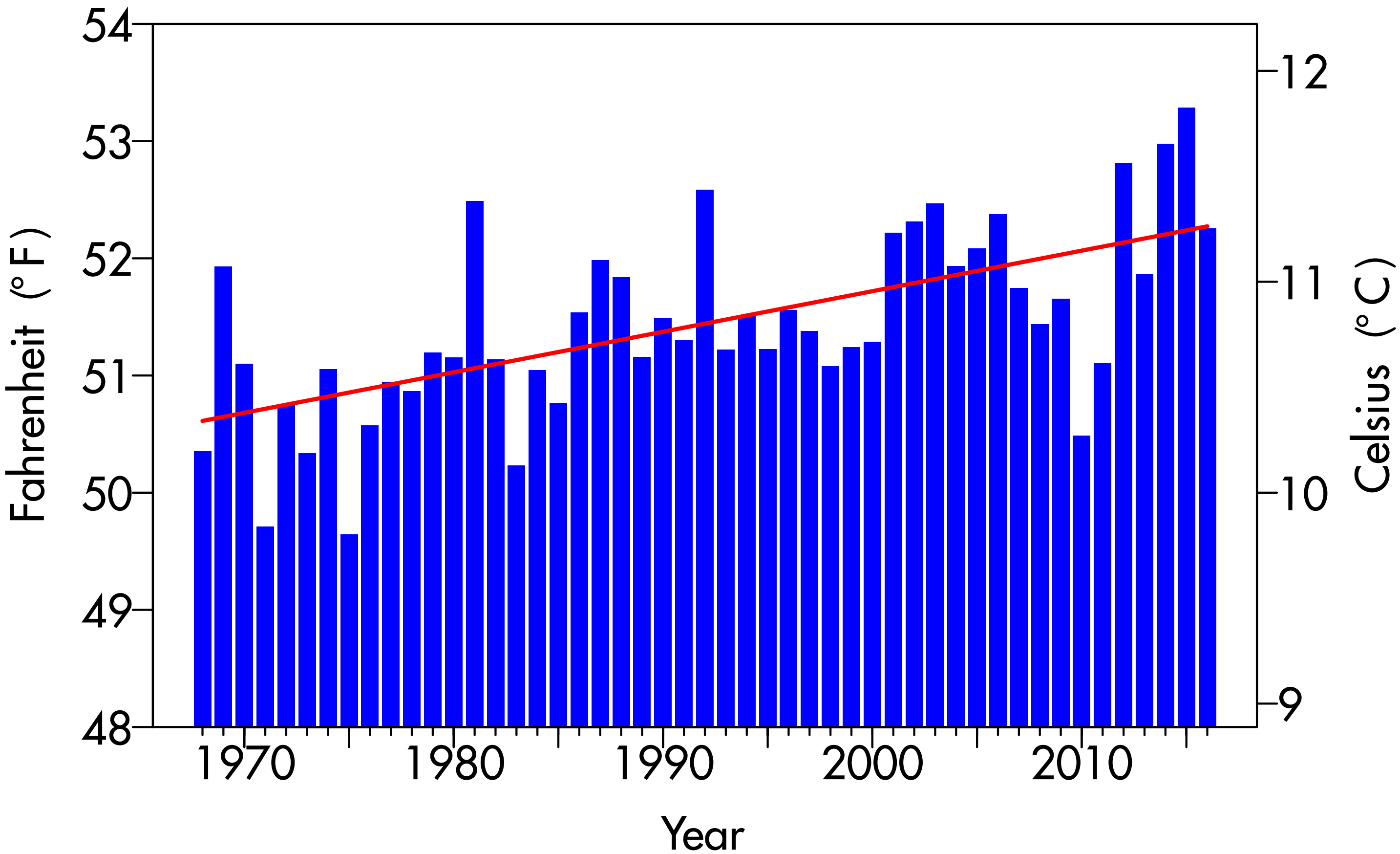


PHYSICAL PROPERTIES

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 temperature in 1968 was 50.3 °F (10.2 °C). For 2016, the average surface water temperature was 52.3 °F (11.3 °C). The overall rate of warming of the lake surface is 0.035 °F (0.019 °C) per year.

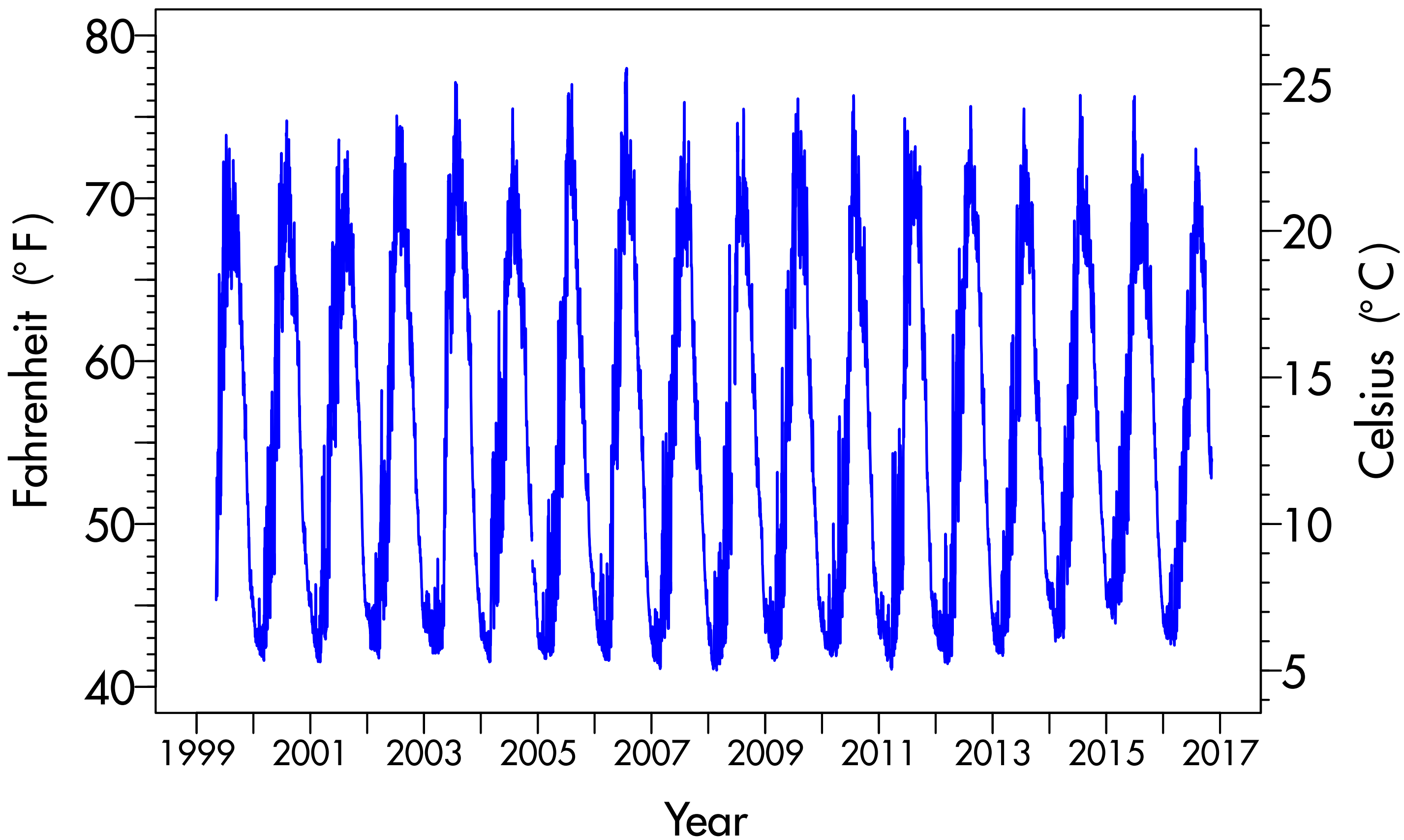


PHYSICAL PROPERTIES

Maximum daily surface water temperature

Surface temperature measured since 1999 every 2 minutes

The maximum daily summer surface water temperature in 2016 was the lowest observed since continuous (every 2 min.) data collection commenced in 1999. The primary reason for the lower temperatures are high winds in June and July. The highest maximum daily surface water temperature (summer) was 73.04 °F, which was recorded on July 29, 2016. The lowest maximum daily surface water temperature (winter) was 42.5 °F, which was recorded on March 14, 2016. These data are collected in real-time by NASA-JPL and UC Davis from 4 buoys located over the deepest parts of the lake.

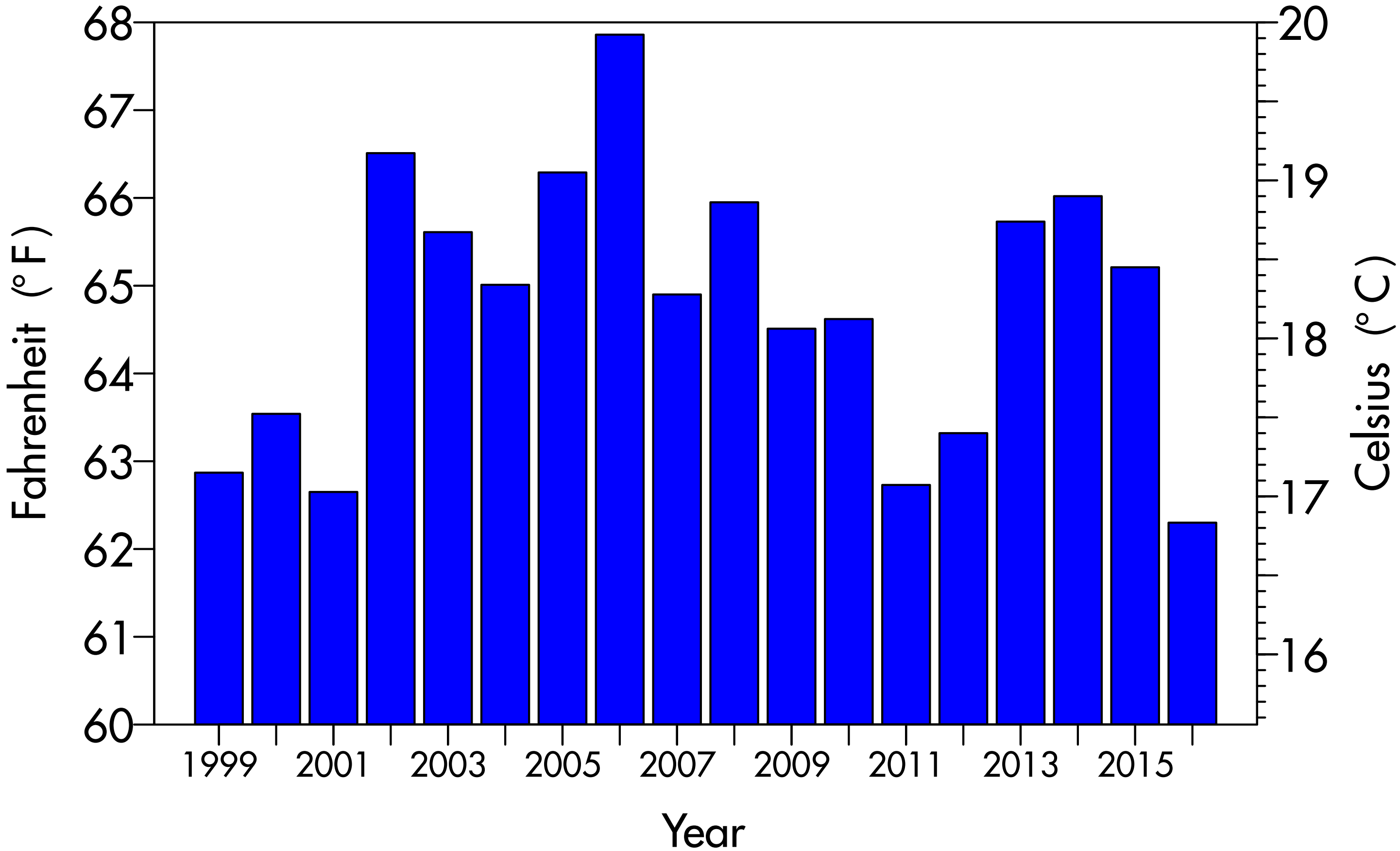


PHYSICAL PROPERTIES

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 18 years of average surface water temperatures in the month of July when water temperatures are typically warmest. In 2016, July surface water temperature averaged 62.3 °F. High winds in June and July were responsible for the cold July water temperatures. The warmest July temperatures were 67.9 °F in 2006. The average July surface water temperature for the 18 year period is 64.8 °F.

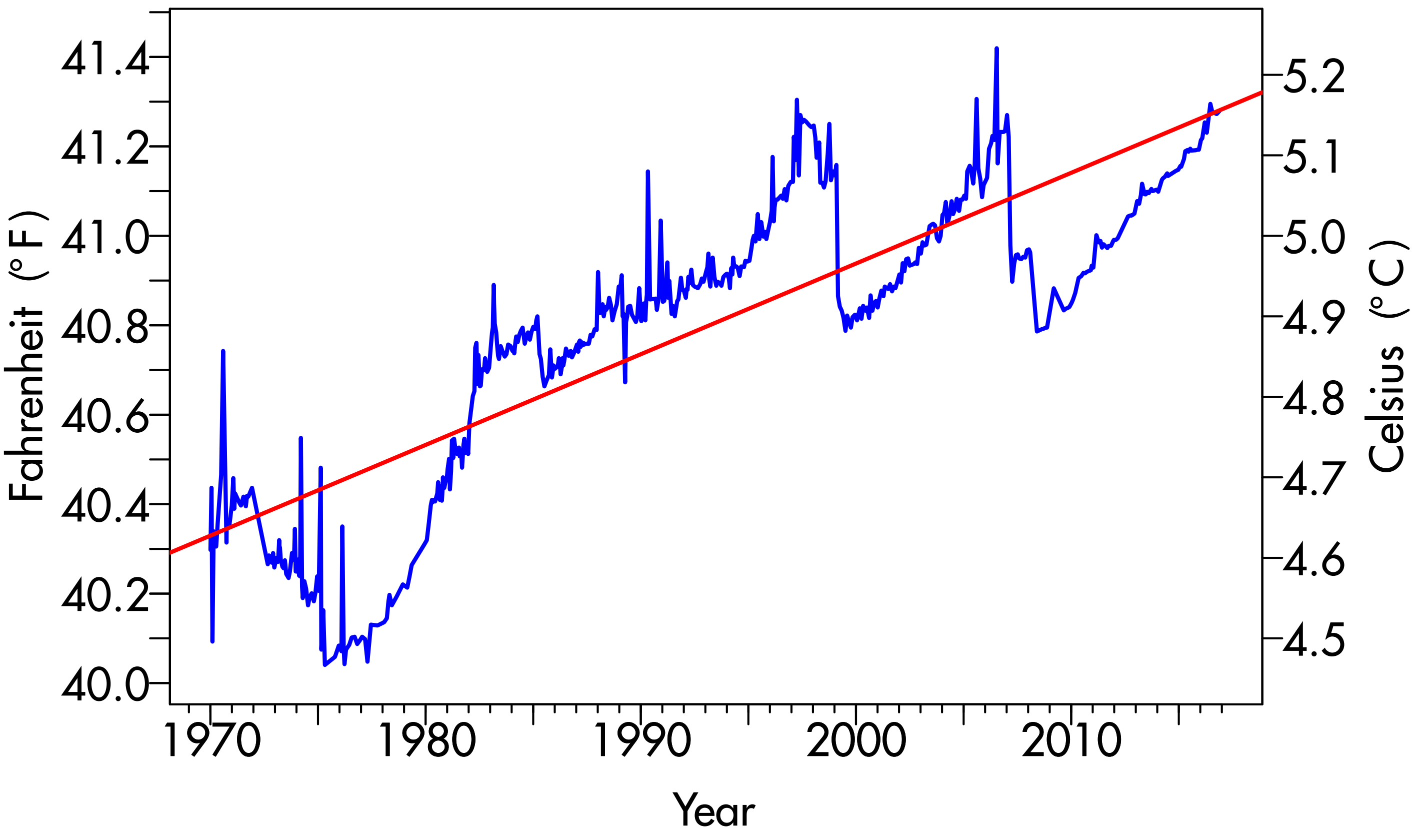


PHYSICAL PROPERTIES

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 but 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 short spikes of temperature increase are temporary effects caused by the motions of internal waves (or seiches).

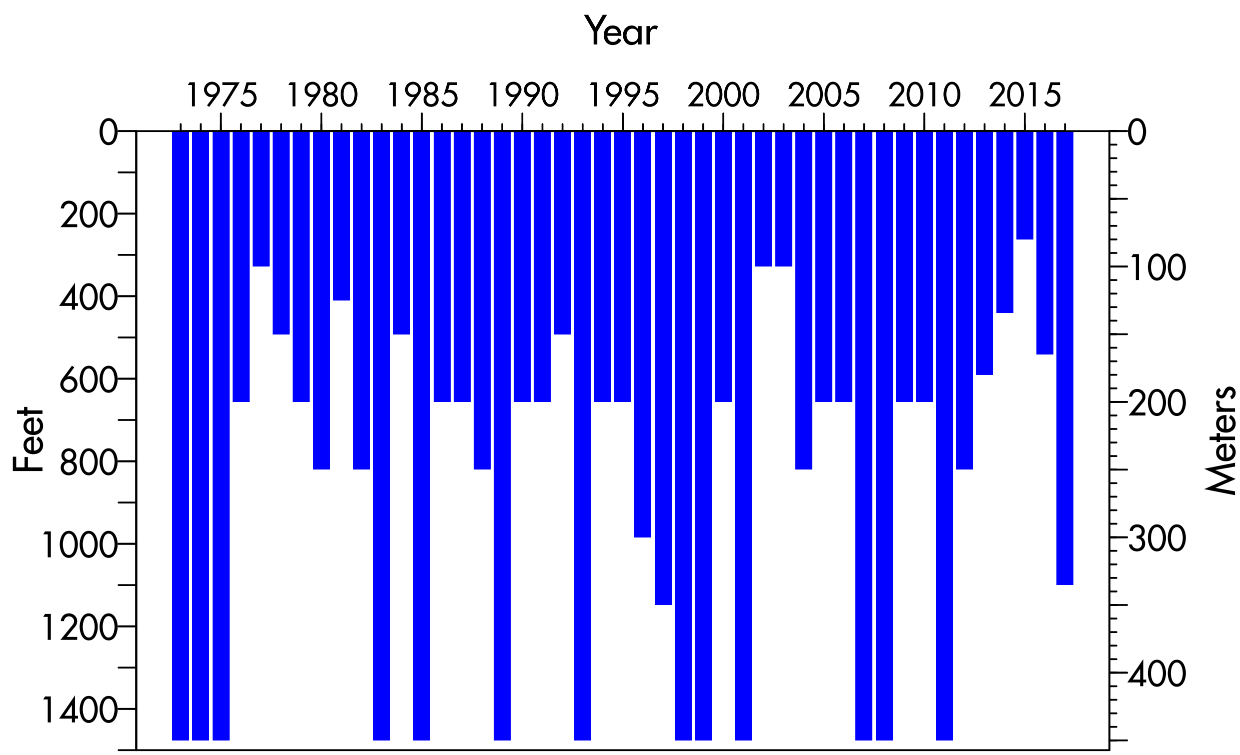


PHYSICAL PROPERTIES

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 helps to 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 2016, Lake Tahoe mixed to a depth of only 540 feet (165 m). 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. In March 2017 deep mixing occured to a depth of 1100 ft (335 m) 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.



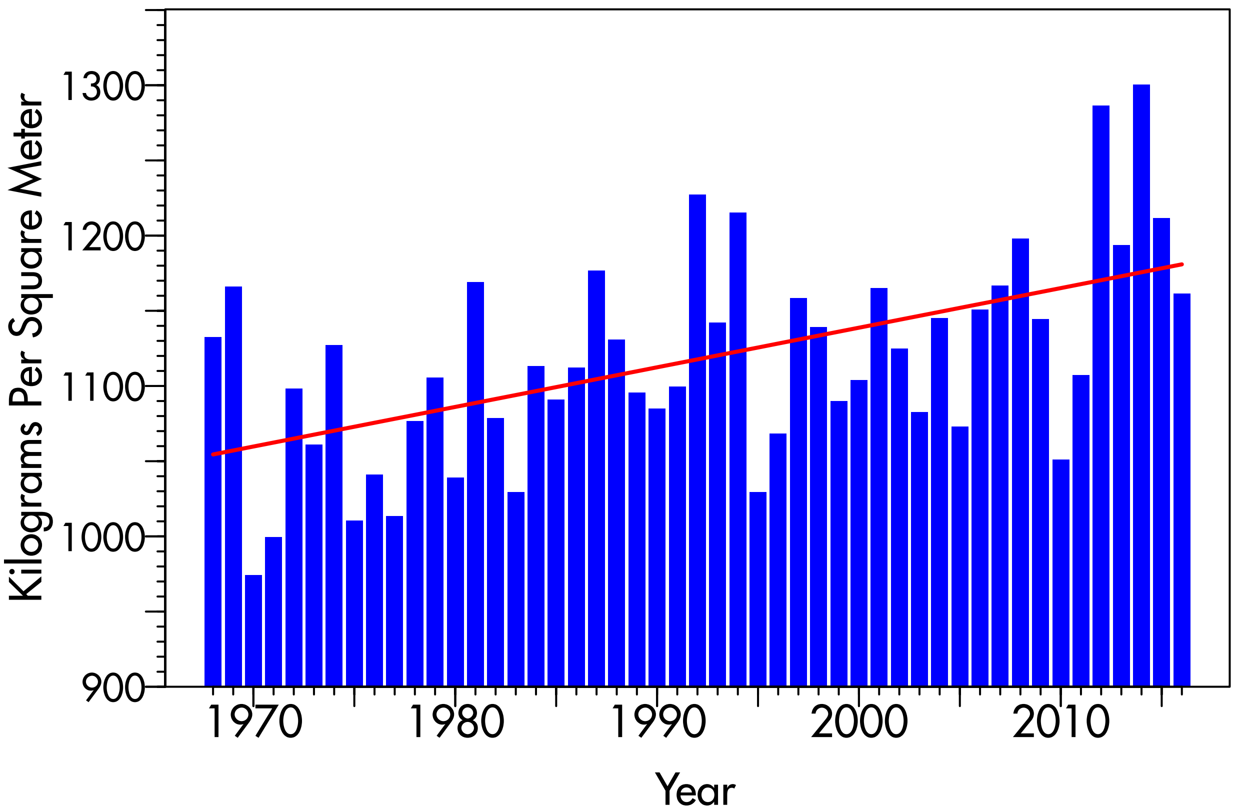
PHYSICAL PROPERTIES

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, denser 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 10% in the last 45 years.

In 2016, the stability of the lake fell, but it was still above the long-term rate of increasing stability. This is reflected in the relatively deep mixing in early 2017.

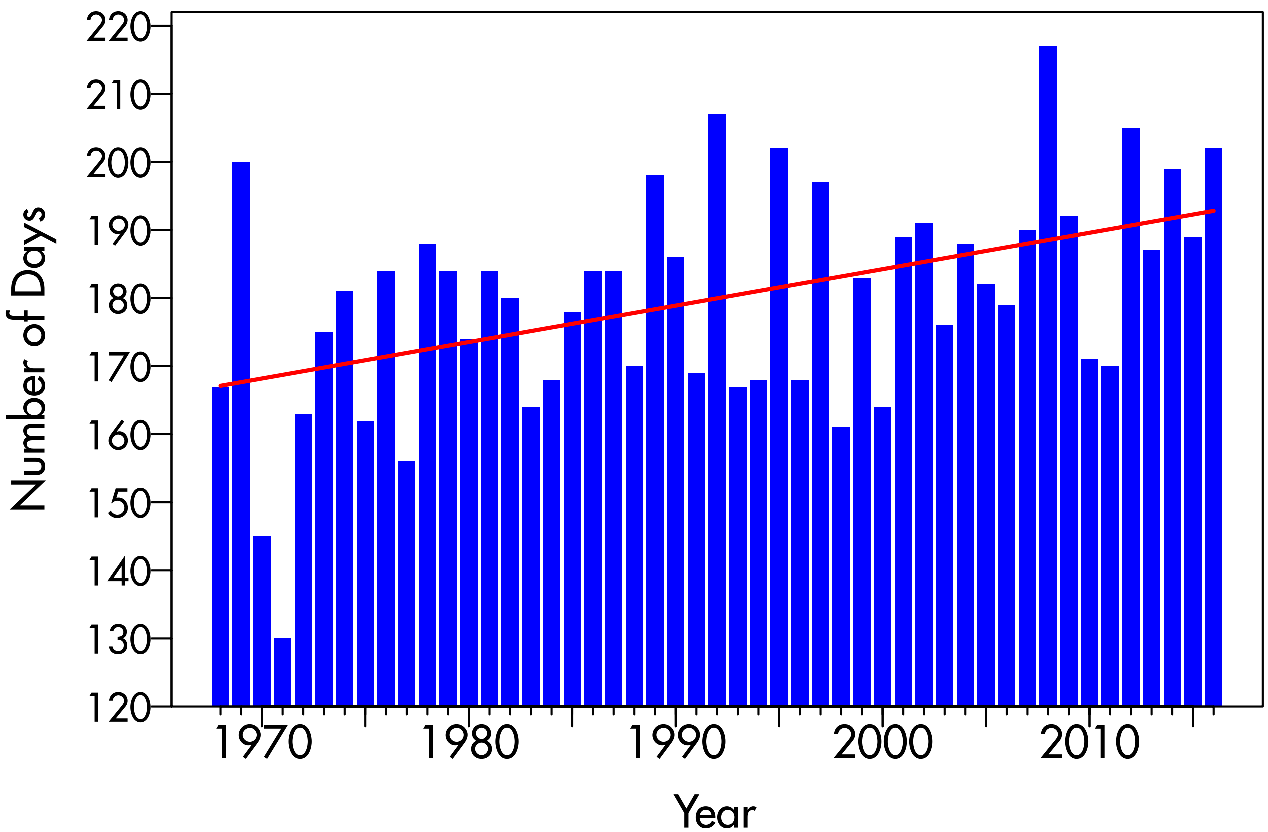


PHYSICAL PROPERTIES

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 almost 26 days. In 2016, the length of the stratified season was 202 days.

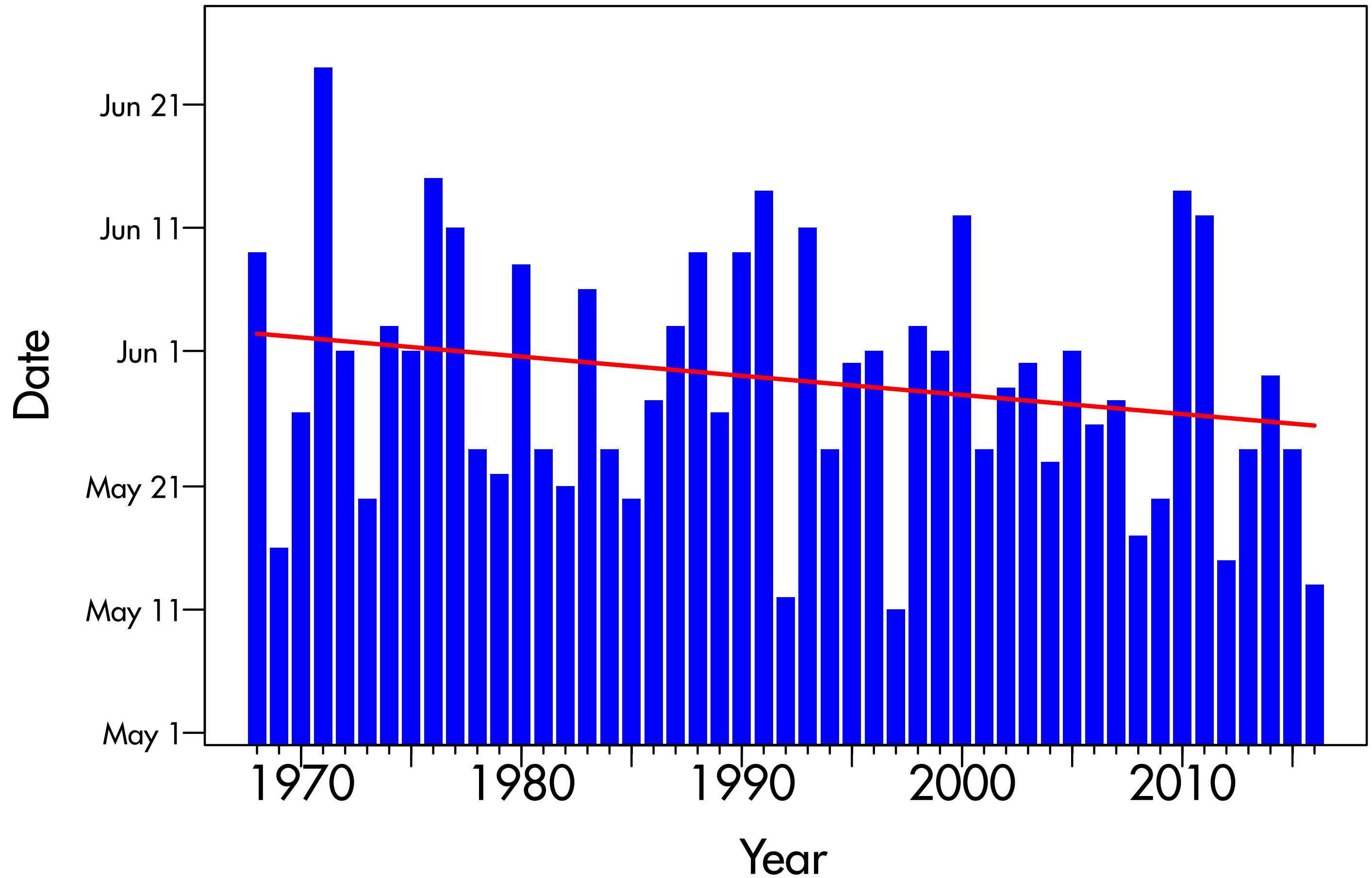


PHYSICAL PROPERTIES

Beginning of the stratification season

Since 1968

The length 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 eight days earlier than it did in 1968. The commencement of the stratification season is typically in late May or early June. In 2016 stratification began on Day 133 (May 12).

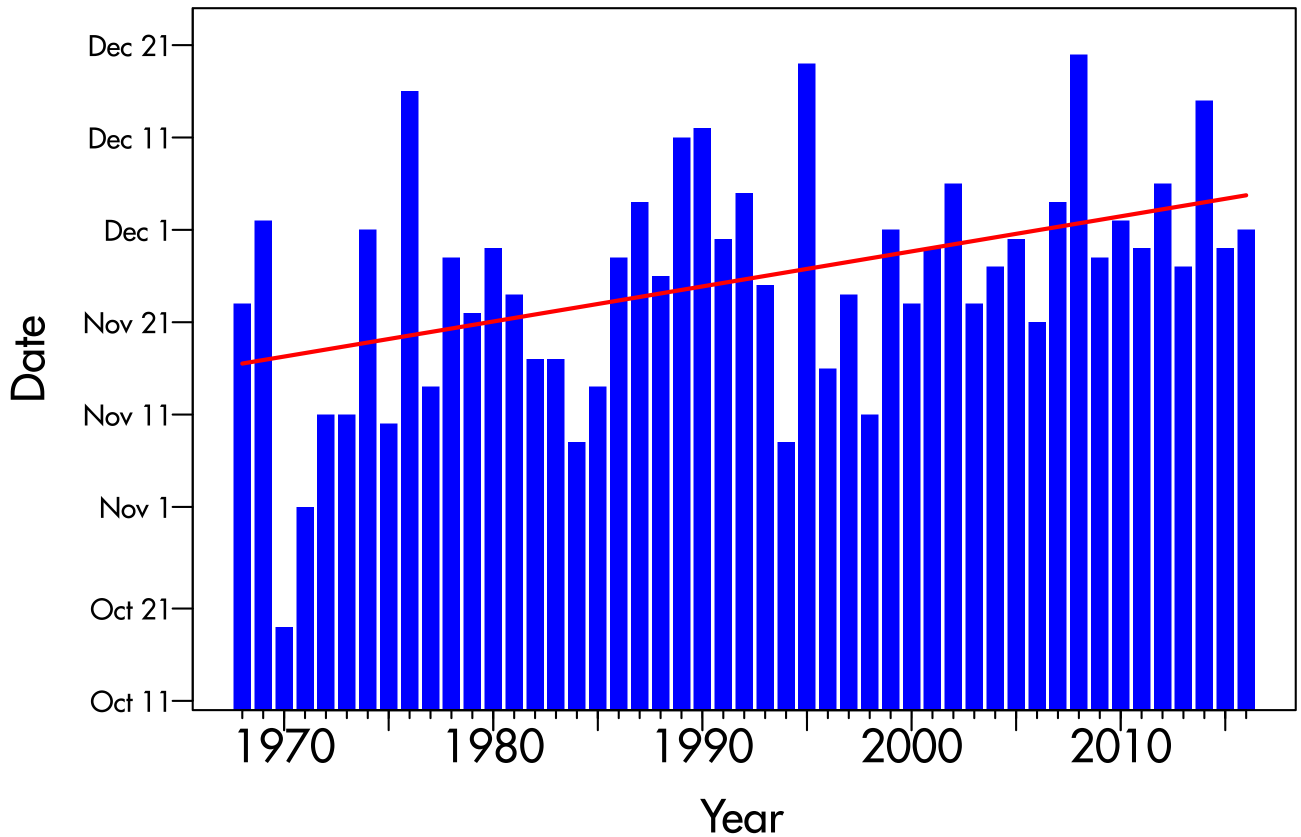


PHYSICAL PROPERTIES

End of stratification season

Since 1968

The length 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 18 days on average. In other words, the fall season for the lake has been considerably extended. In the late 1960's stratification ended in mid-November. Now it often ends in December. In 2016, stratification ended on Day 335 (November 30) This has important implications for lake mixing and water quality, such as the buildup of nitrate at the bottom of the lake.

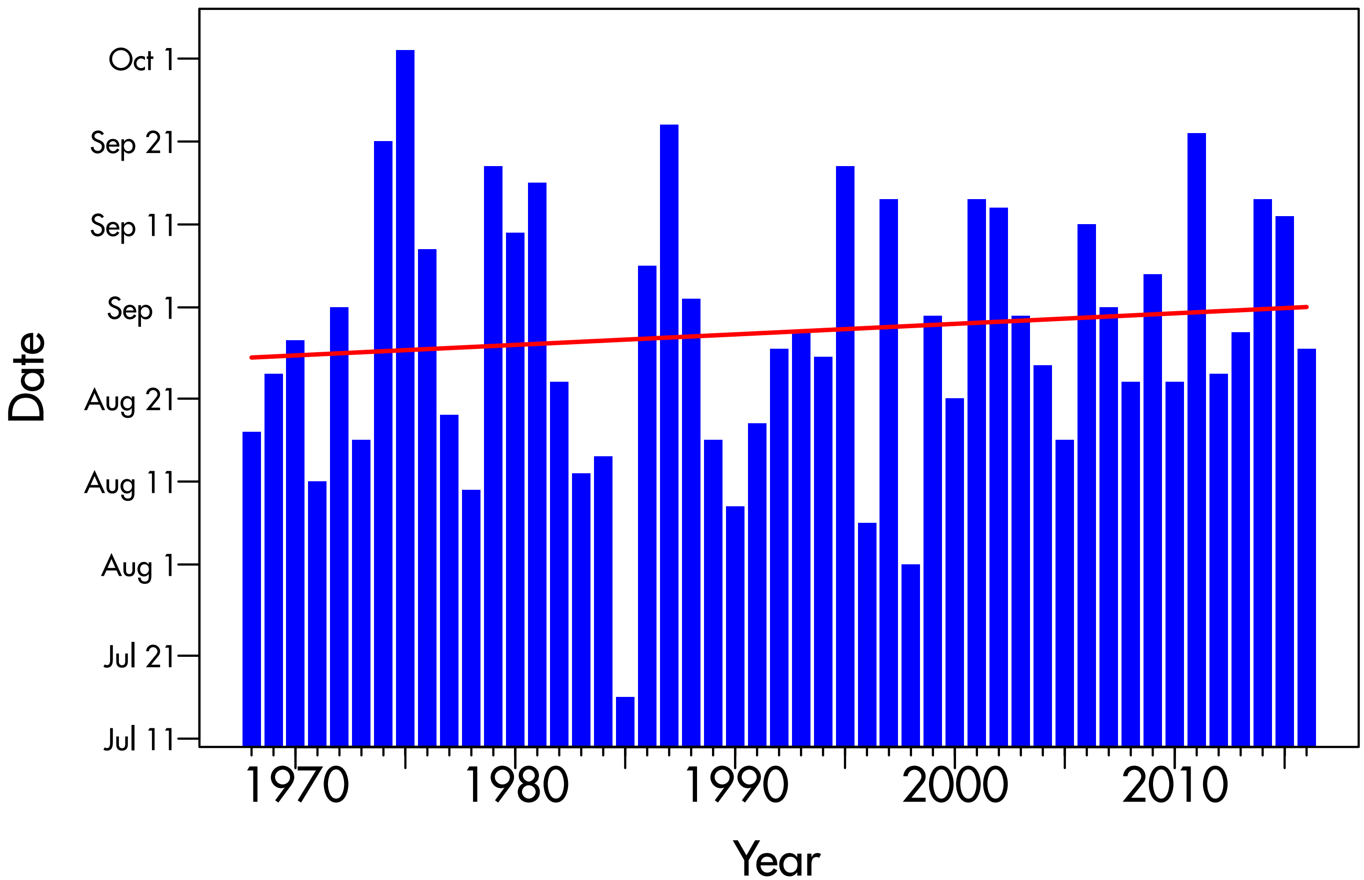


PHYSICAL PROPERTIES

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 2016, the peak occurred relatively early on August 31. This was five days earlier than the long-term trend would have indicated.



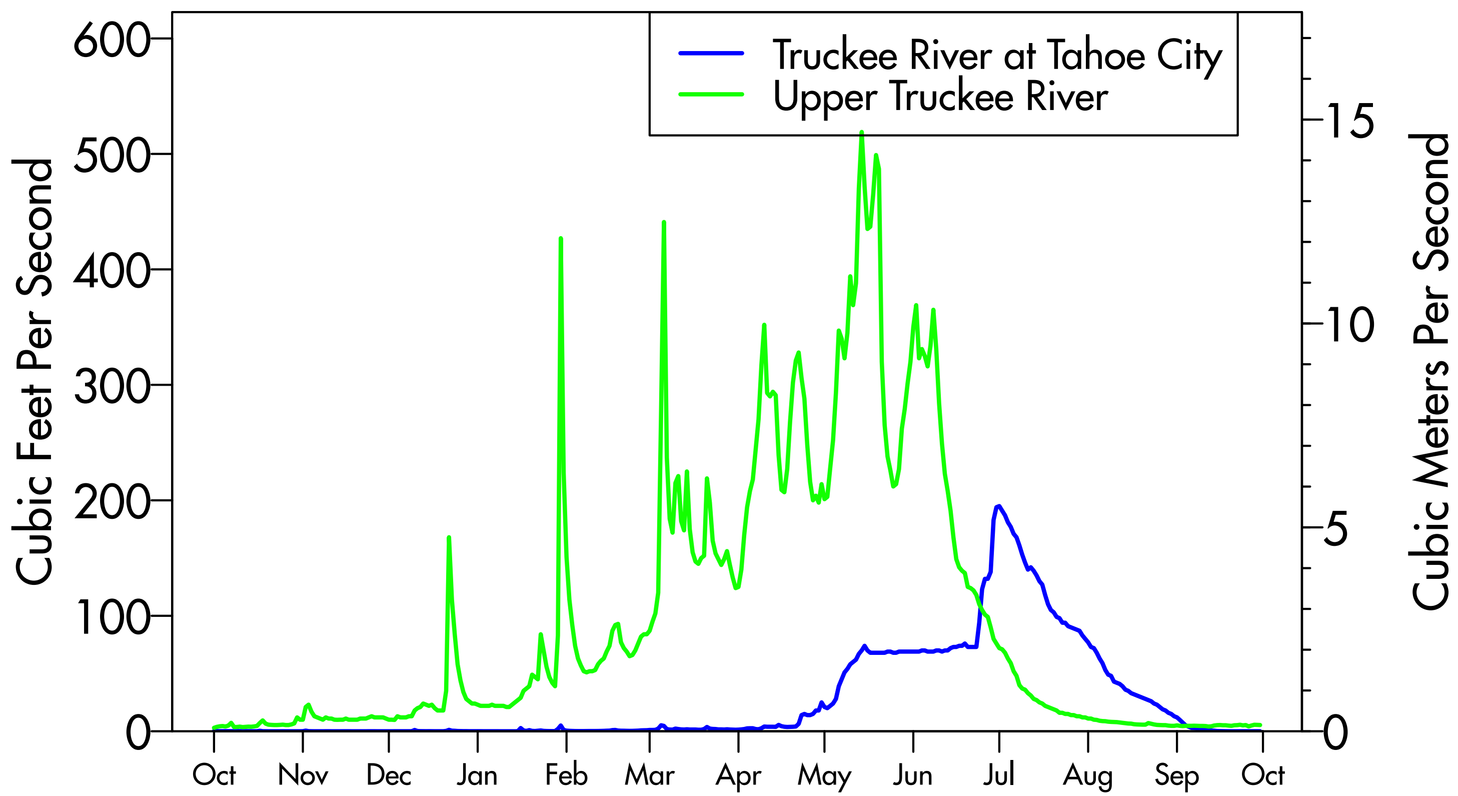
PHYSICAL PROPERTIES

Mean daily streamflow of Upper Truckee River vs. Truckee River

Water Year 2016

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-June) represents the snowmelt. The peak snowmelt flow was approximately 499 cfs, compared to the long-term average of 300 cfs.

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 2016, the lake level was below the lake's rim for much of the year, so outflow was essentially zero until April. Streamflow data are collected by the U.S. Geological Survey under the Lake Tahoe Interagency Monitoring Program (LTIMP).

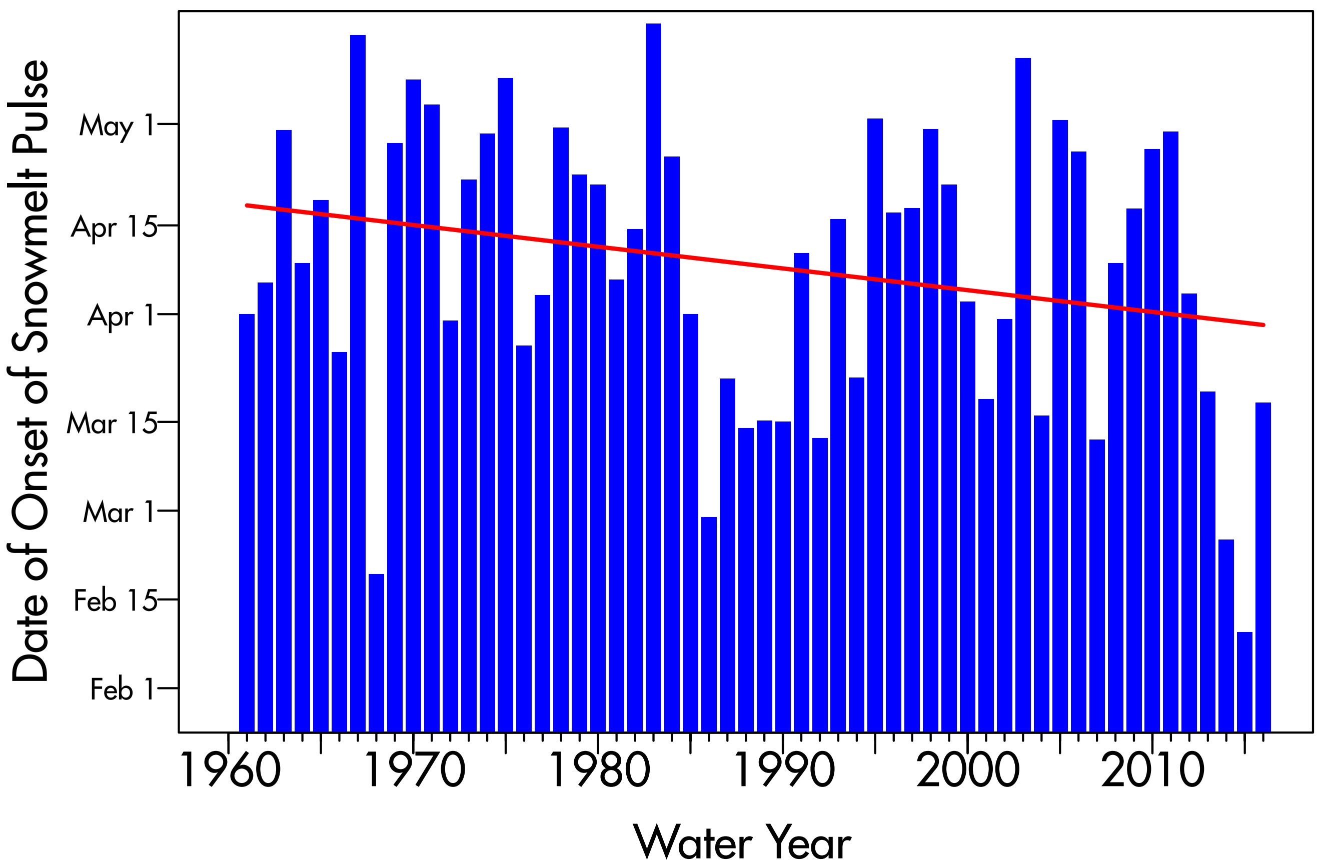


PHYSICAL PROPERTIES

Onset of snowmelt pulse

Yearly since 1961

Although the date on which snowmelt commences varies from year to year, since 1961 it has shifted earlier an average of almost 3 weeks (19 days). This shift is statistically significant and is one effect of climate change at Lake Tahoe. In 2016, peak snowmelt occured on March 29. The onset of the pulse is calculated as the day when flow exceeds the mean flow for the period Jan. 1 to Jul 15. The value for 5 gauged streams are averaged. In the past, we used the peak of the stream hydrograph to estimate this property.

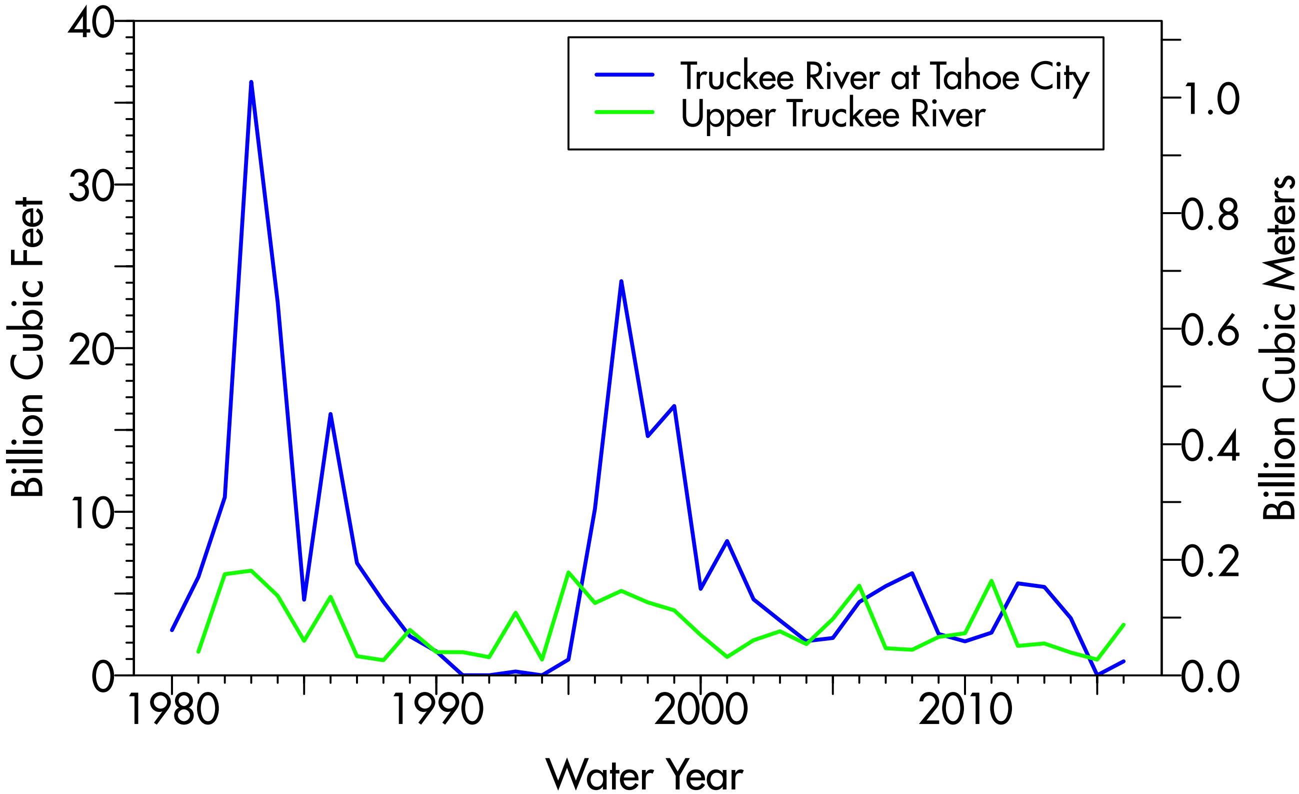


PHYSICAL PROPERTIES

Annual discharge volume for upper Truckee River and Truckee River

Since 1980

Flow into Lake Tahoe (e.g. Upper Truckee River) and discharge out of Lake Tahoe (Truckee River at Tahoe City) have shown considerable variation. The large peaks in discharge from the lake correspond to years when precipitation (and therefore total inflow) was the greatest, e.g. 1982-1983, 1986, 1995-1999. Similarly, the drought-like conditions in the early 1990s and the low precipitation years in the beginning of the 2000s culminating in the recent drought year also stand out. Since many of the pollutants of concern for Lake Tahoe's clarity enter along with surface flow, year-to-year changes in clarity are influenced by precipitation and runoff. The average annual Upper Truckee inflow since 1981 is 2.95 billion cubic feet, while the average annual outflow through the Truckee River is 6.75 billion cubic feet. In 2016, discharges into and out of the lake were well below the long-term averages. The Upper Truckee River inflow volume was 3.10 billion cubic feet. The Truckee River discharge was 0.86 billion cubic feet.

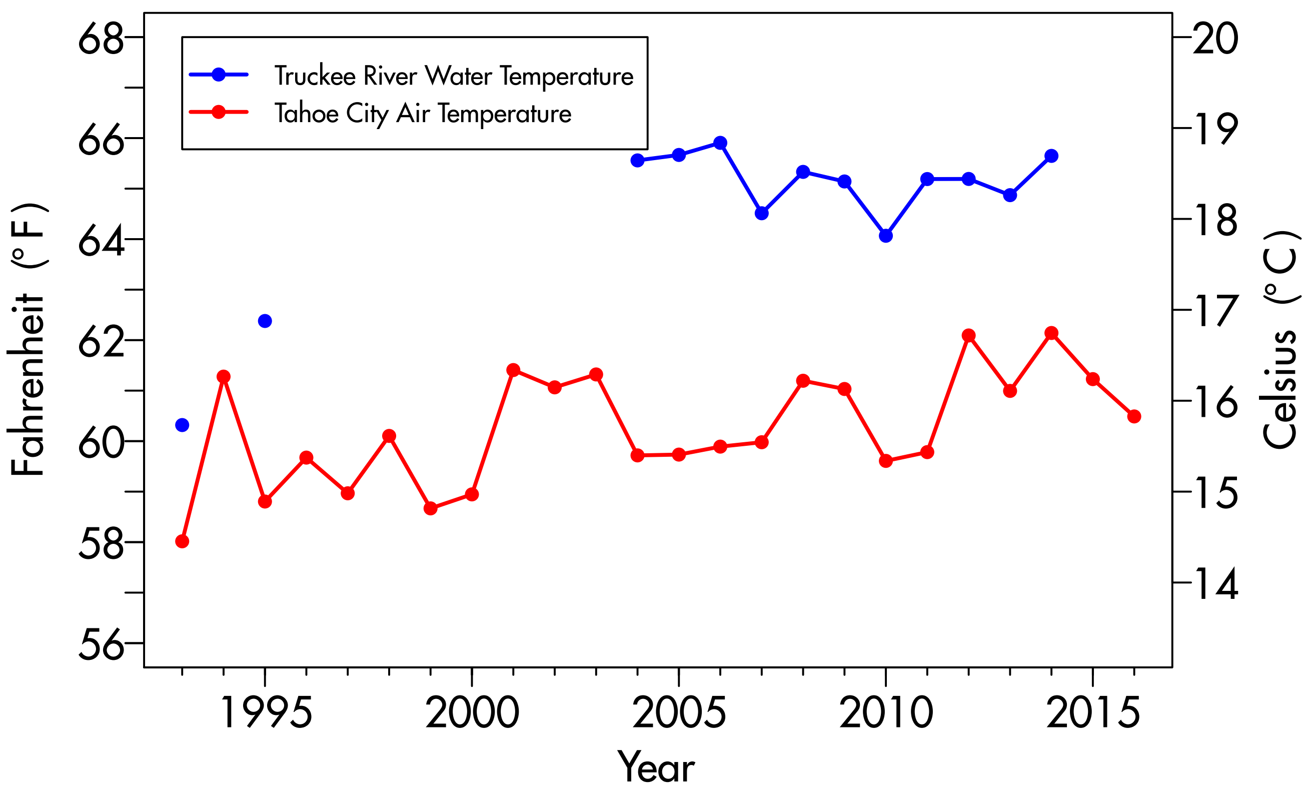


PHYSICAL PROPERTIES

Truckee River July-September water temperatures

Since 1993

Water temperature of the Truckee River as it departs Lake Tahoe in the summer months (July-September) is measured by the U.S. Geological Survey. Data gaps prevent a complete pattern, but the measurements suggest that a 4-5 °F (2.2-2.8 °C) rise in the average temperature may have occurred since 1993. Average air temperatures from Tahoe City for the same period also suggest a temperature rise but at a lower rate. Elevated river temperatures can also negatively impact fish spawning and fish rearing. In 2016, there was flow from the Truckee River from Lake Tahoe for only part of the year, so an average water temperature could not be calculated.

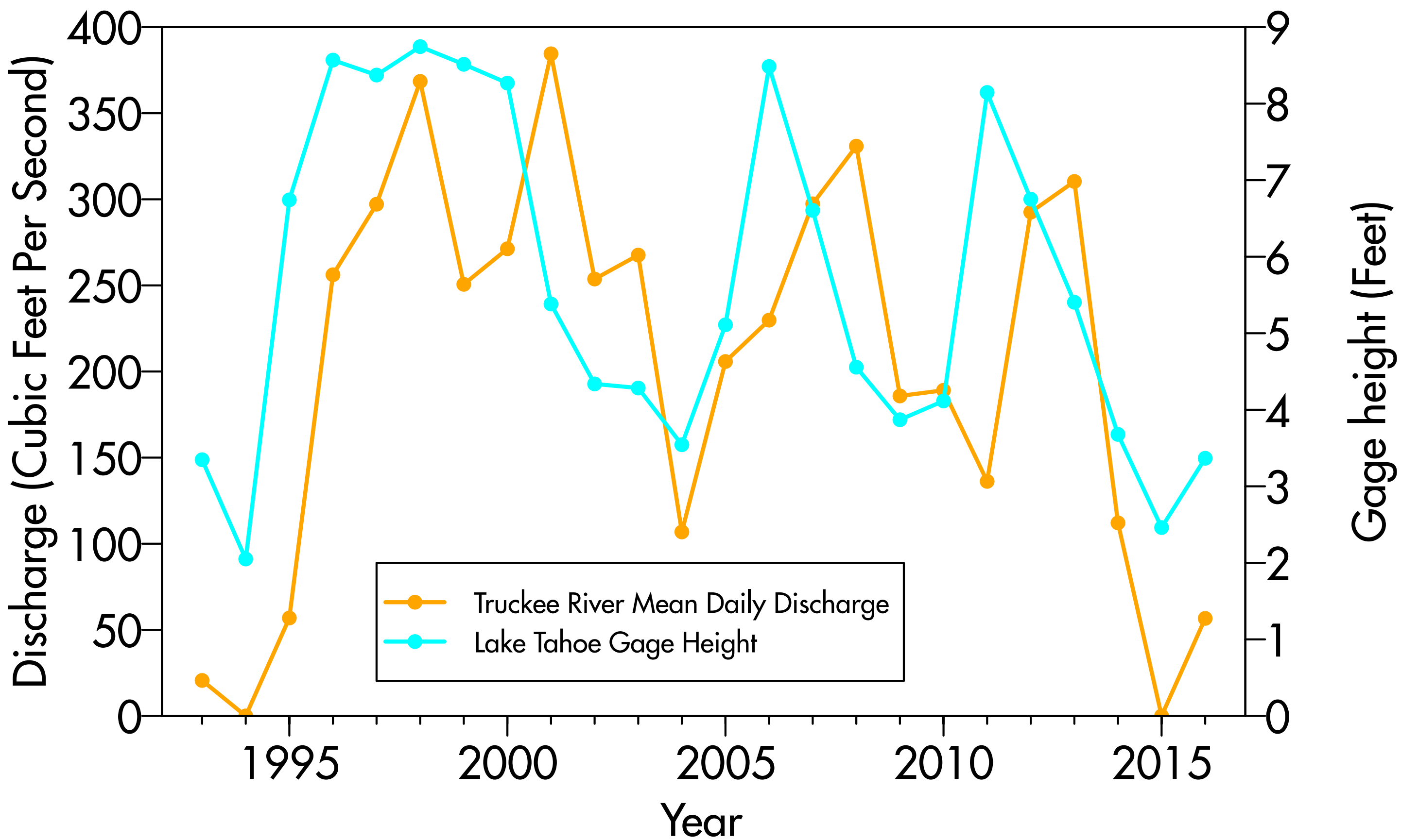


PHYSICAL PROPERTIES

Truckee River summer discharge and lake elevation

Since 1993

Flow rate of the Truckee River as it departs Lake Tahoe in the summer months (July-September) and lake level for the same period is measured by the U.S. Geological Survey. Here the relationship between these two variables is evident, with mean daily river discharge typically showing a one- to two-year lag from the lake elevation. Gage height is measured relative to a datum of 6,220 feet. Release of water from Lake Tahoe is controlled by the Federal Water Master.



TAHOE: STATE OF THE LAKE REPORT 2017

NUTRIENTS AND PARTICLES

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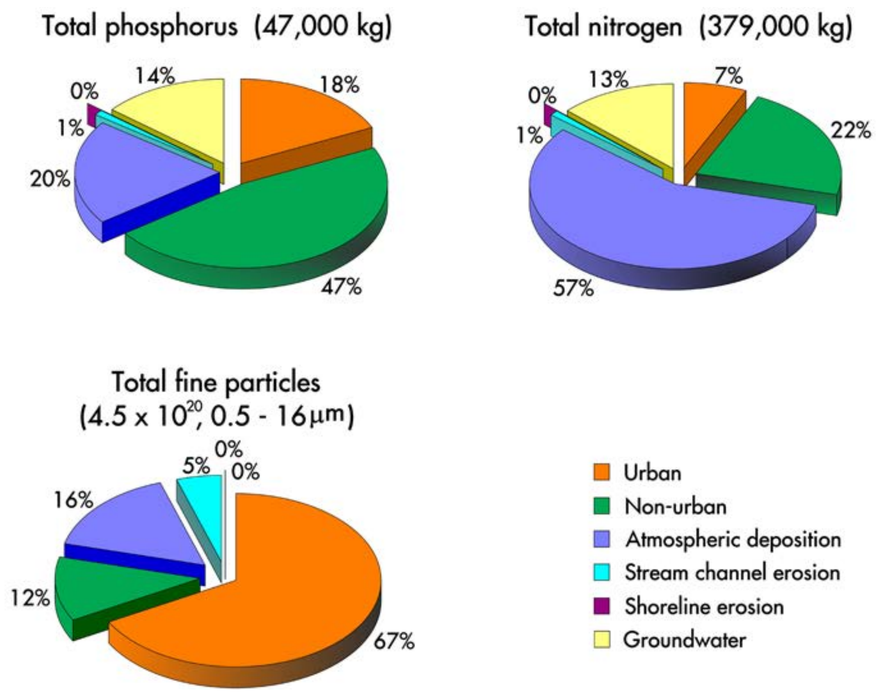
NUTRIENTS AND PARTICLES

Sources of clarity-reducing and blueness-reducing pollutants

In 2016

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.



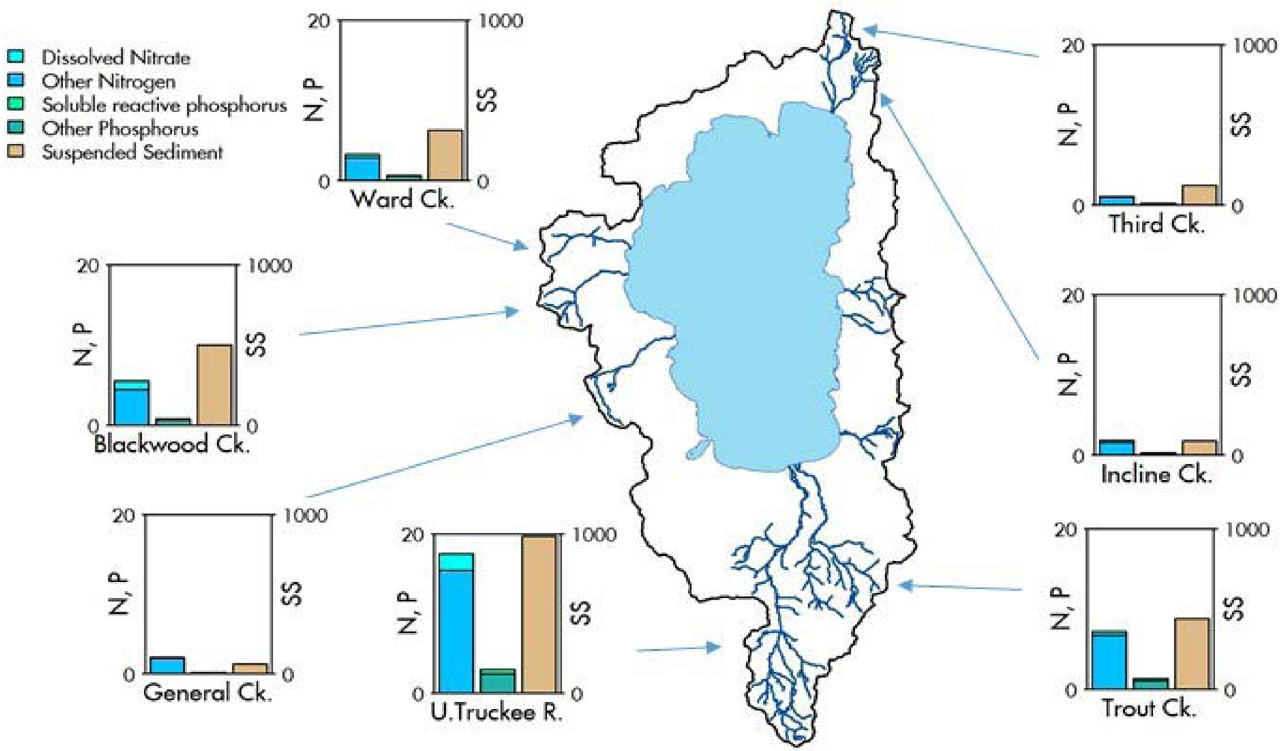
NUTRIENTS AND PARTICLES

Pollutant loads from seven watersheds

In 2016

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 vast majority of stream phosphorus and nitrogen comes from the Upper Truckee River, Trout Creek, Blackwood Creek and Ward Creek.

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 and the Tahoe Regional Planning Agency.

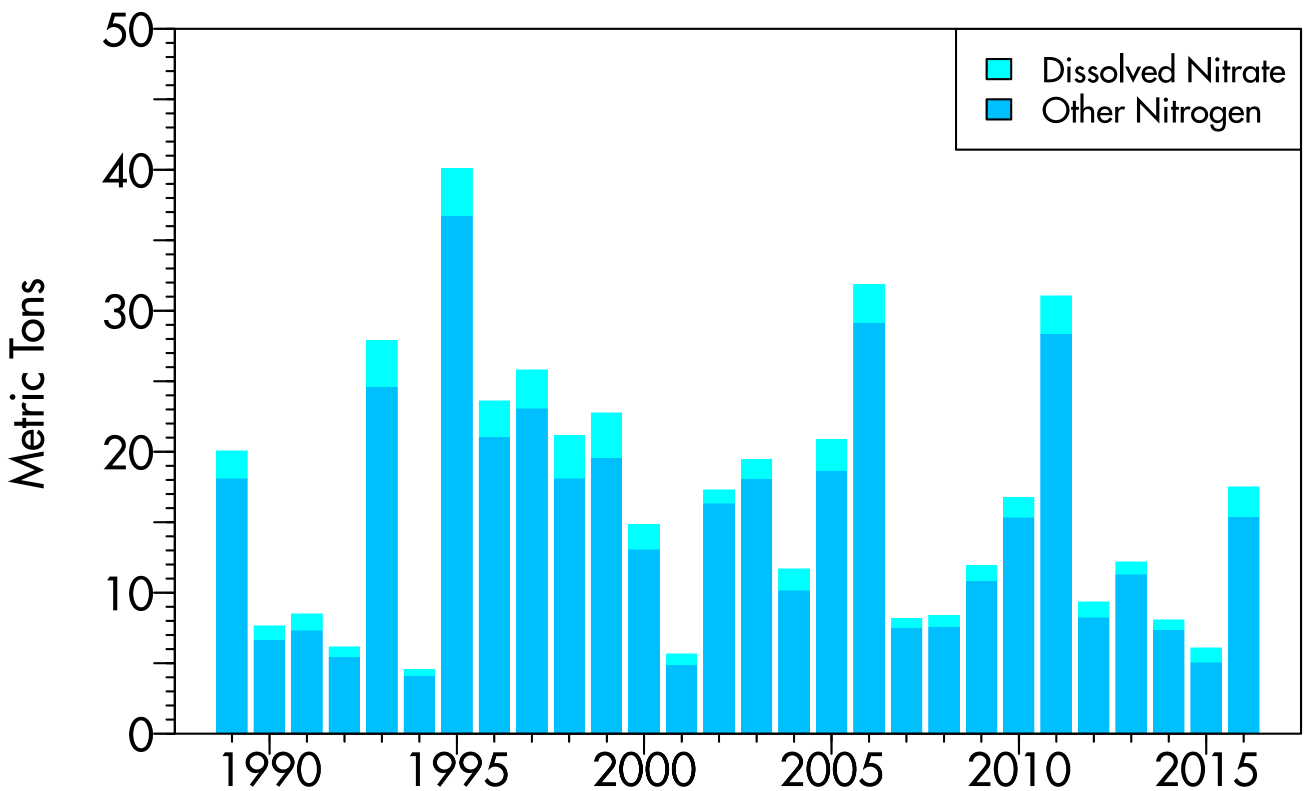


NUTRIENTS AND PARTICLES

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. For example, 1994 had 16.59 inches of precipitation and a low nitrogen load, while 1995 had 60.84 inches of precipitation and a very high nitrogen load. 2016 had 32.1 inches of precipitation, This was considerably higher than the previous four drought years.   (One metric ton = 2,205 pounds.)

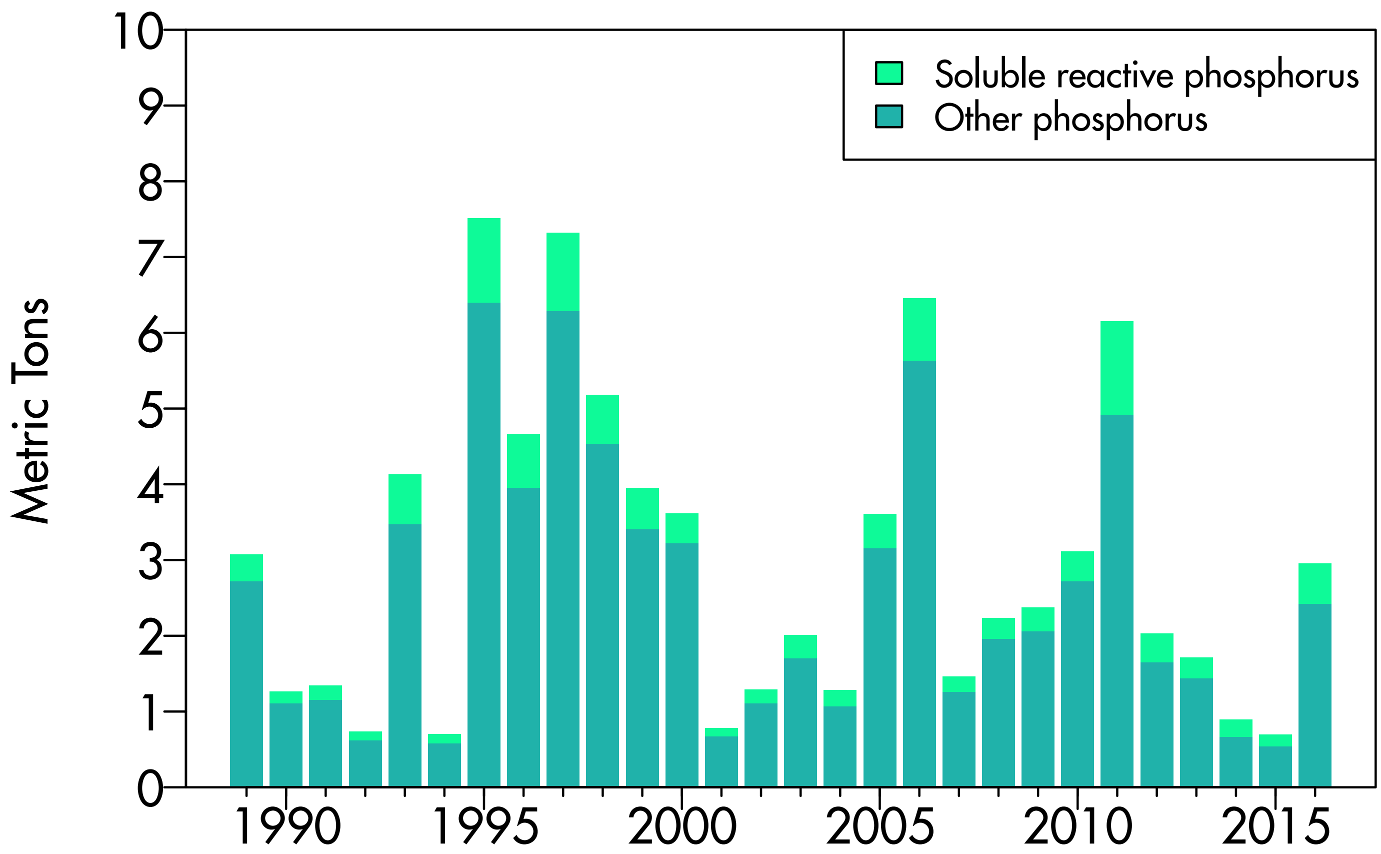


NUTRIENTS AND PARTICLES

Phosphorus contribution by Upper Truckee River

Yearly since 1989

Soluble reactive phosphorus (SRP) is that fraction of phosphorus immediately available for algal growth. As with nitrogen (Fig. 9.3), the year-to-year variation in load largely reflects the changes in precipitation. Average precipitation in 2016 resulted in a Total Phosphorus level of 2.95 MT and a SRP load of 0.53 MT. These compare with the long-term averages of 3.07 and 0.35 MT respectively.. Decreasing nutrient inputs is fundamental to restoring Lake Tahoe's iconic blueness. 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.)

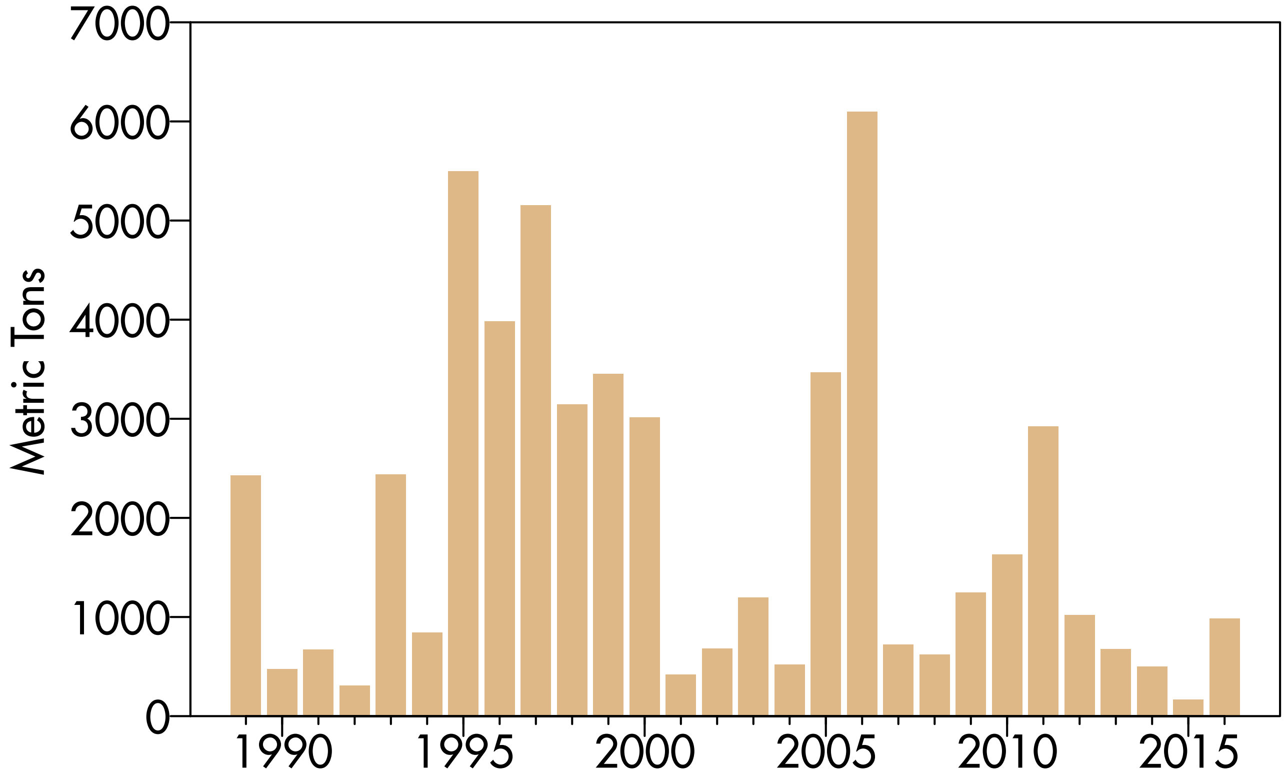


NUTRIENTS AND PARTICLES

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 2016, the suspended sediment load from the Upper Truckee River was 986 MT. The highest load ever recorded was 6100 MT in 2006. The average annual load is 1940 MT.

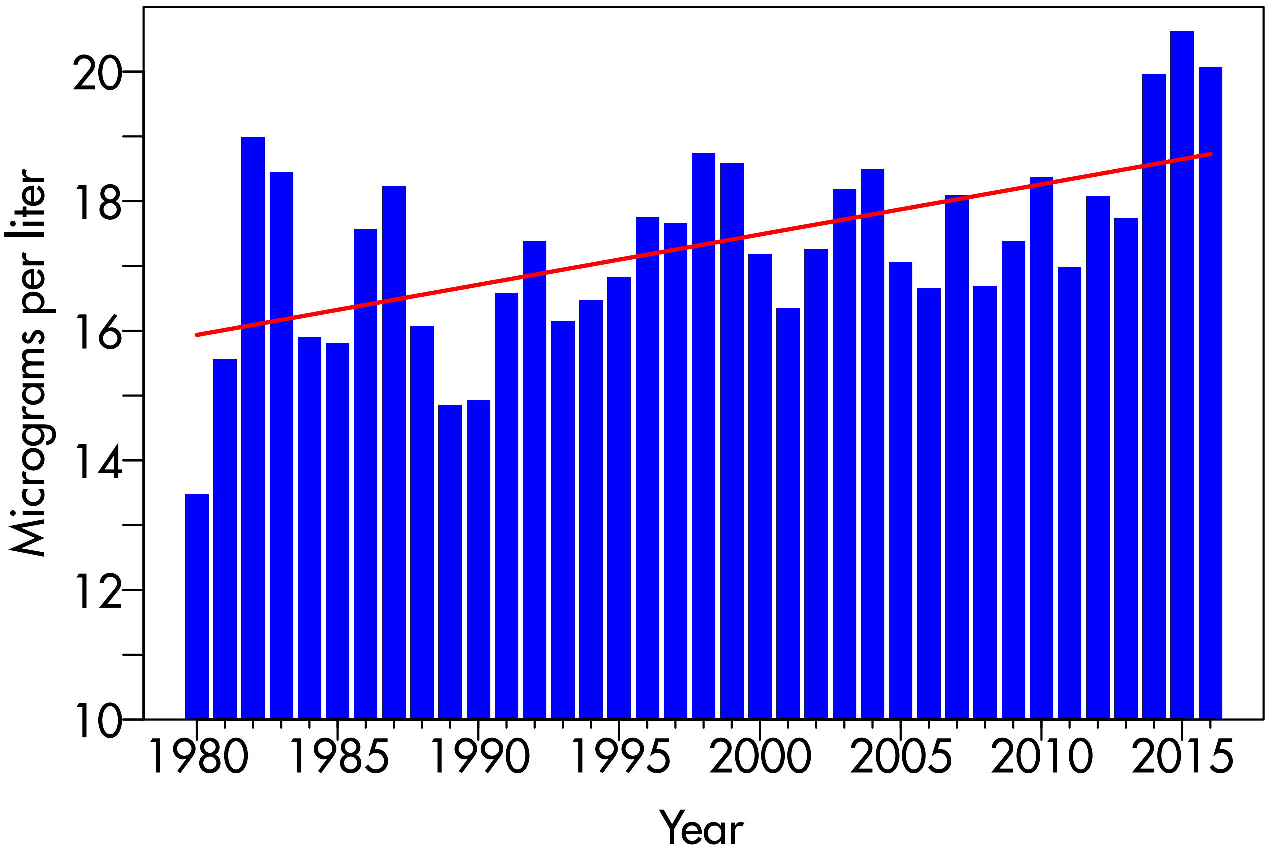


NUTRIENTS AND PARTICLES

Lake nitrate concentration

Yearly since 1980

Since 1980, the volume-weighted annual average concentration of nitrate-nitrogen has remained relatively constant, ranging between 13 and 19 micrograms per liter. In 2016, the volume-weighted annual average concentration of nitrate-nitrogen was 20.1 micrograms per liter. This high value is in part due to the fifth 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 17.3 micrograms per liter. Water samples are taken at the MLTP (mid-lake) station at 13 depths from the surface to 450 meters.

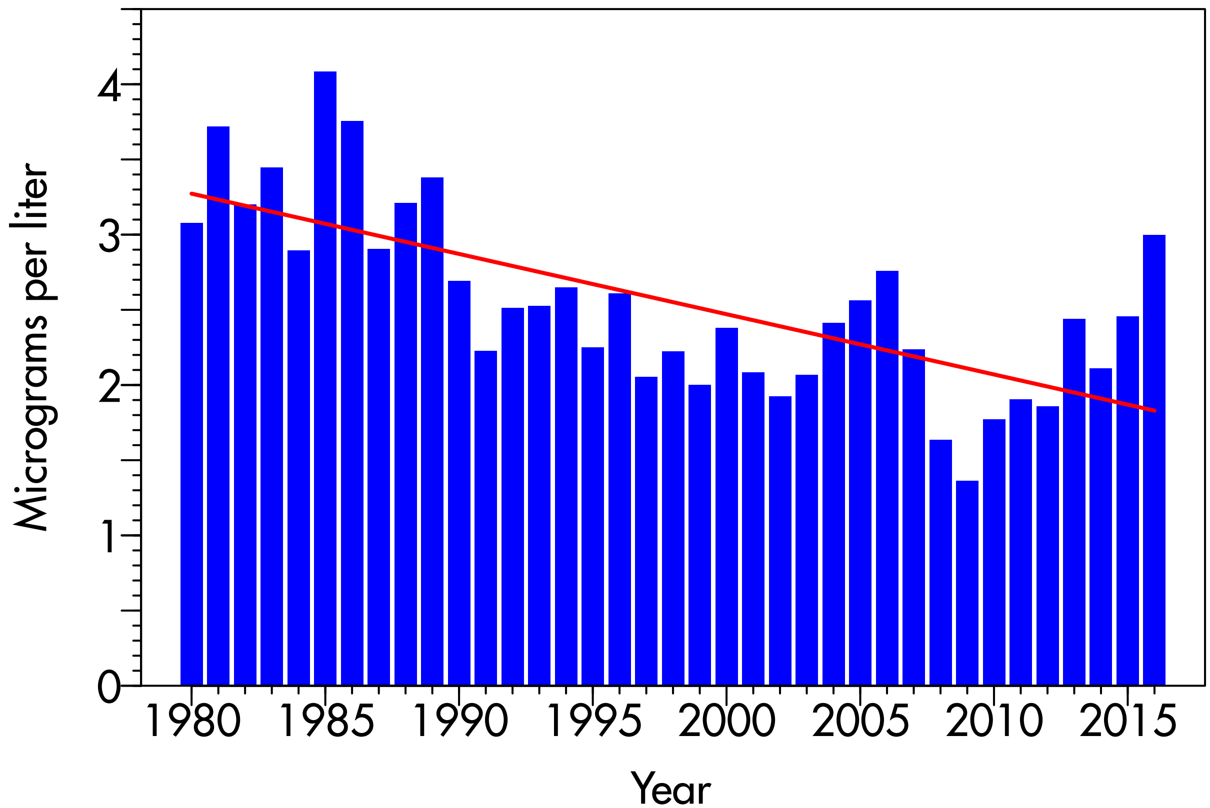


NUTRIENTS AND PARTICLES

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 tended to decline, although in the last seven years the values have been increasing toward levels that were present in the 1980s. In 2016, the volume-weighted annual average concentration of THP was 3.00 micrograms per liter, the highest level since 1989. The average annual value is 2.55 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

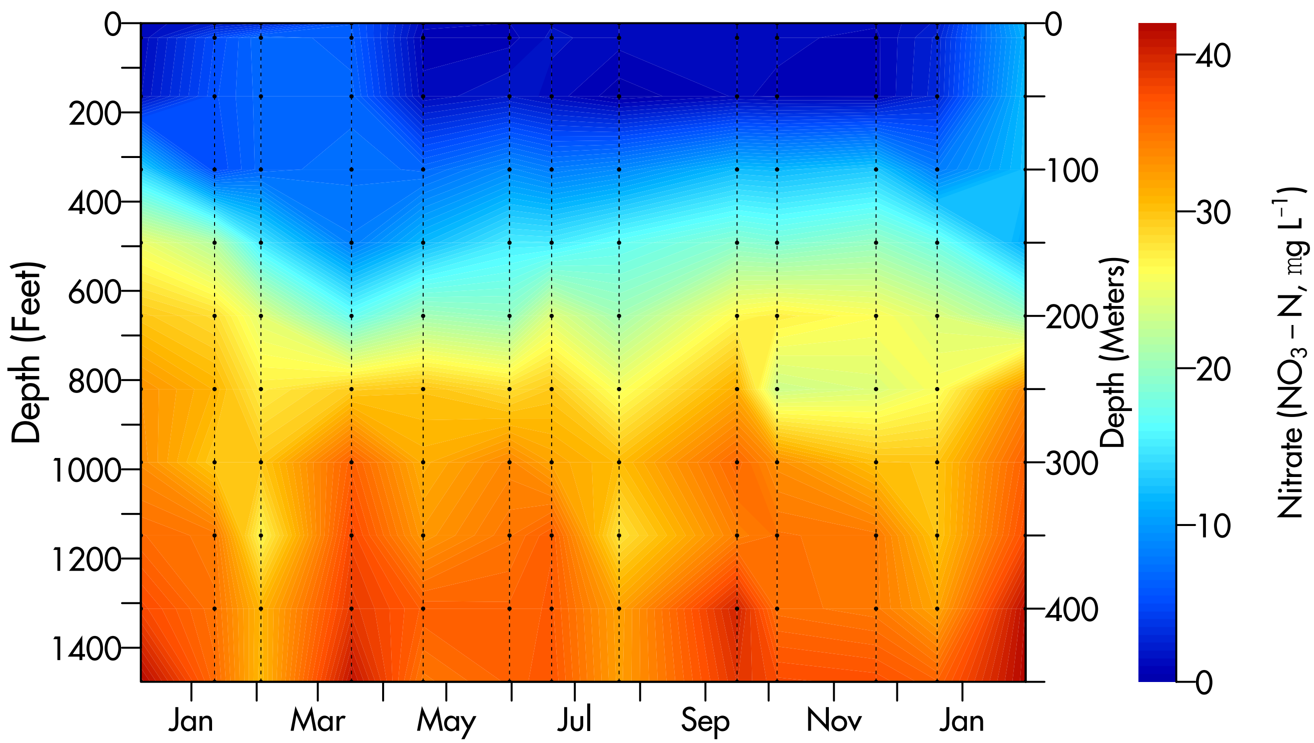
Nitrate distribution

In 2016

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 350 feet are generally high. The surface waters, where there is sunlight to enable algae to 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, however, 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. 2016 was a year with low mixing, extending to only 540 feet, and so most of the nitrate remained trapped in the deep water. The annual nitrate concentration at a depth of 1485 feet was 37.0 micrograms per liter.



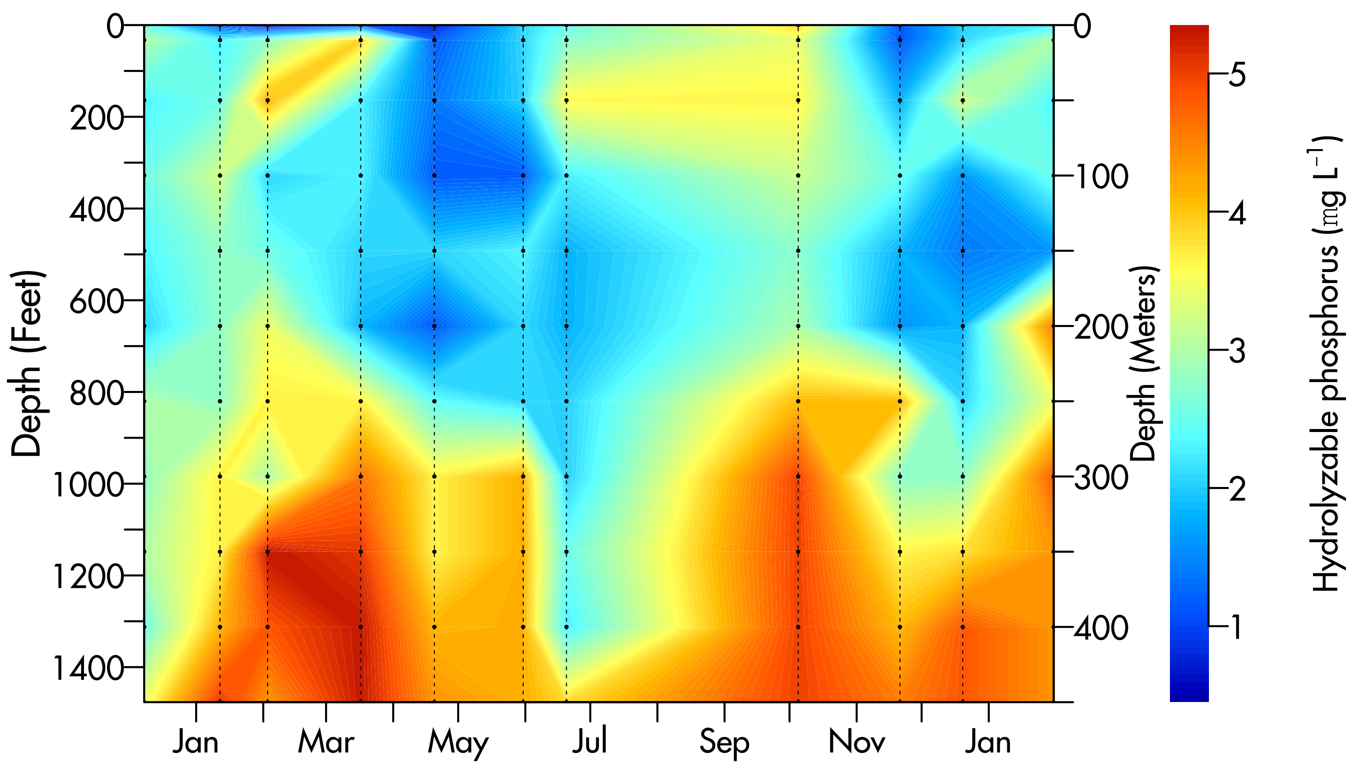
NUTRIENTS AND PARTICLES

Phosphorus distribution

In 2016

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 in winter and summer suggest that in 2016 nitrogen was the nutrient that limited algal growth. 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 1485 feet was 3.8 micrograms per liter.



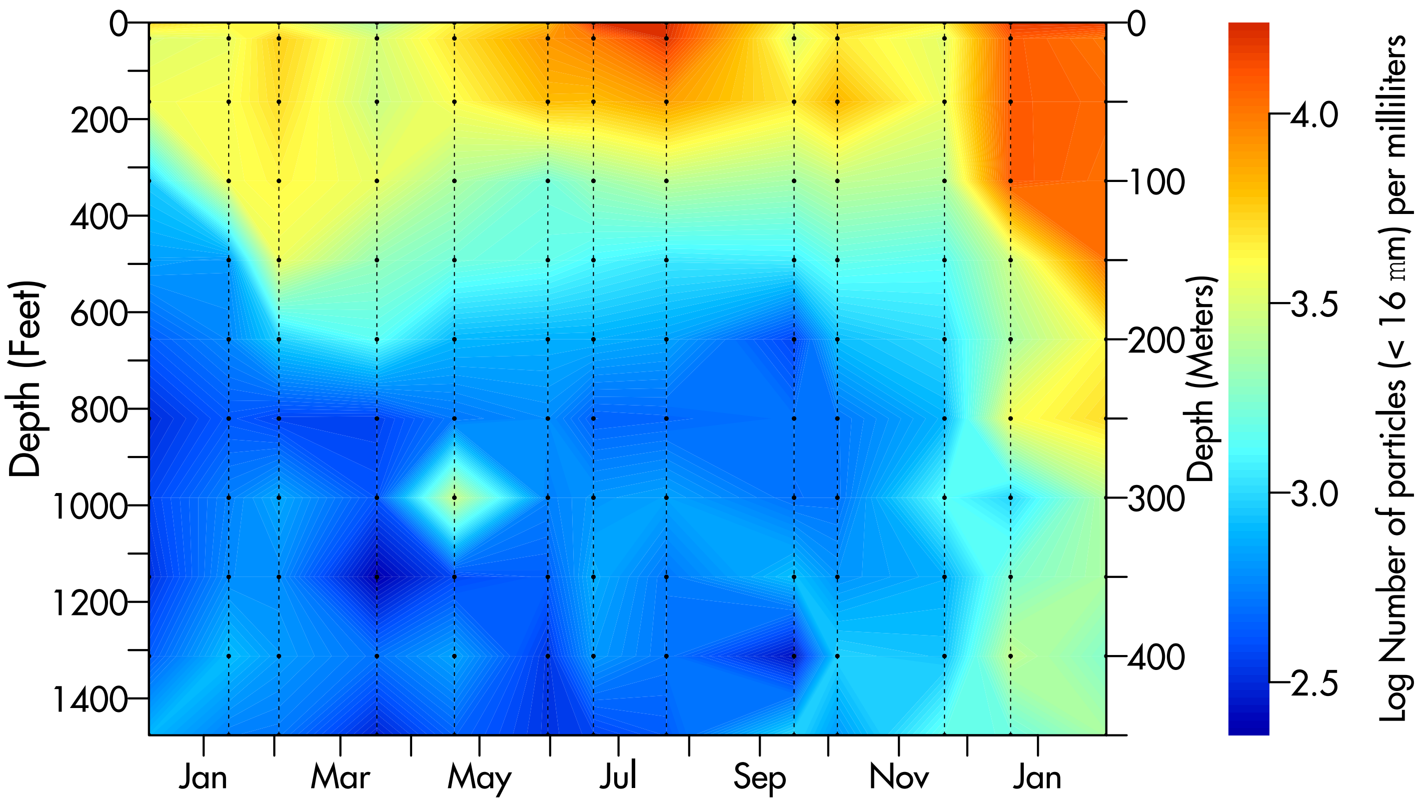
NUTRIENTS AND PARTICLES

Fine particle distribution

In 2016

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. In the early part of the year (winter), when clarity is generally greatest, surface concentration of particles is the lowest. The particle concentration is highest after July, which coincides with the annual variation in Secchi depth this year. The fine particles gradually clump together (aggregate) and allows them to more rapidly settle to the lake sediments at the bottom.



TAHOE: STATE OF THE LAKE REPORT 2017

BIOLOGY

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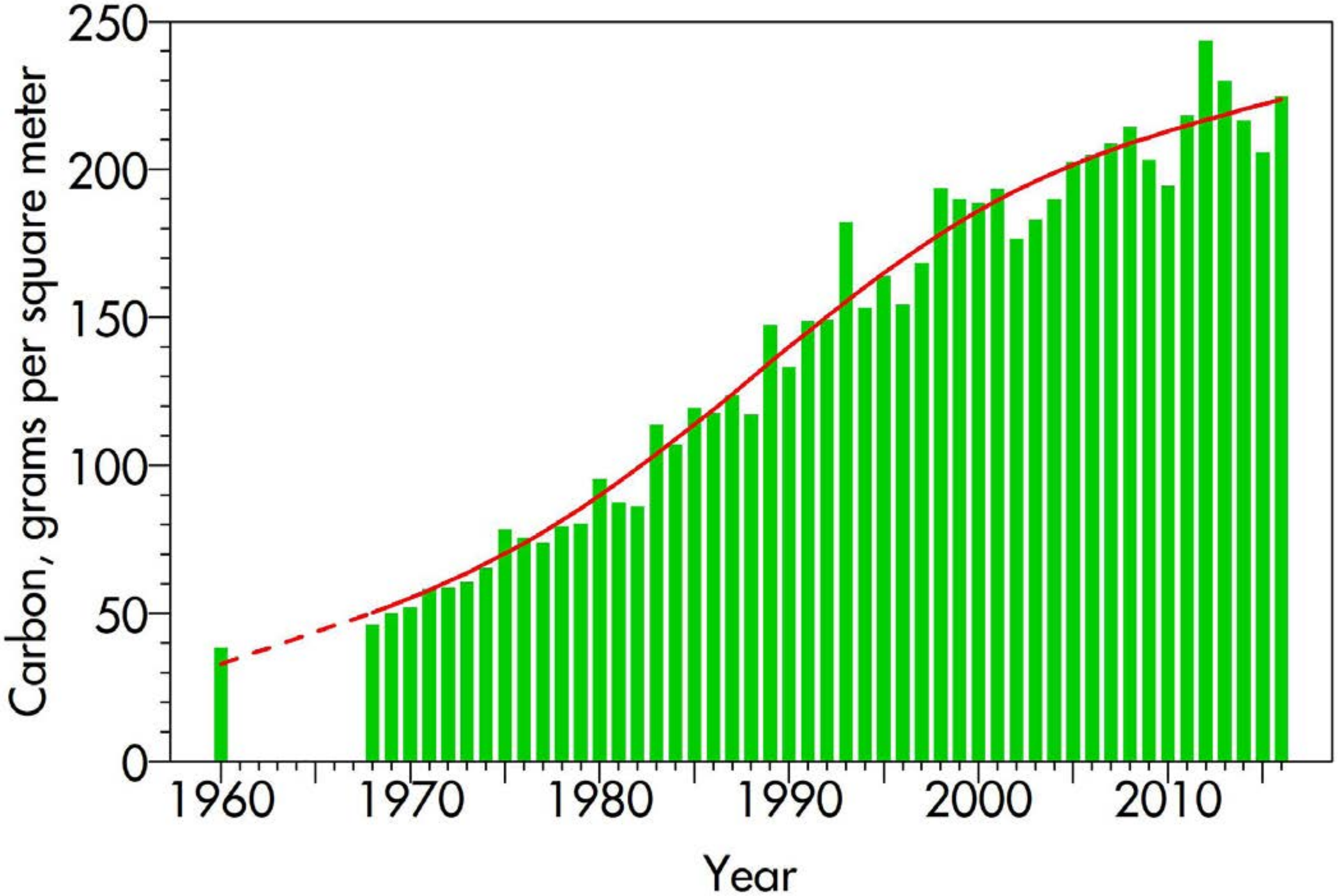
BIOLOGY

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 2016, there was a slight increase in primary productivity to 225.1 grams of carbon per square meter.

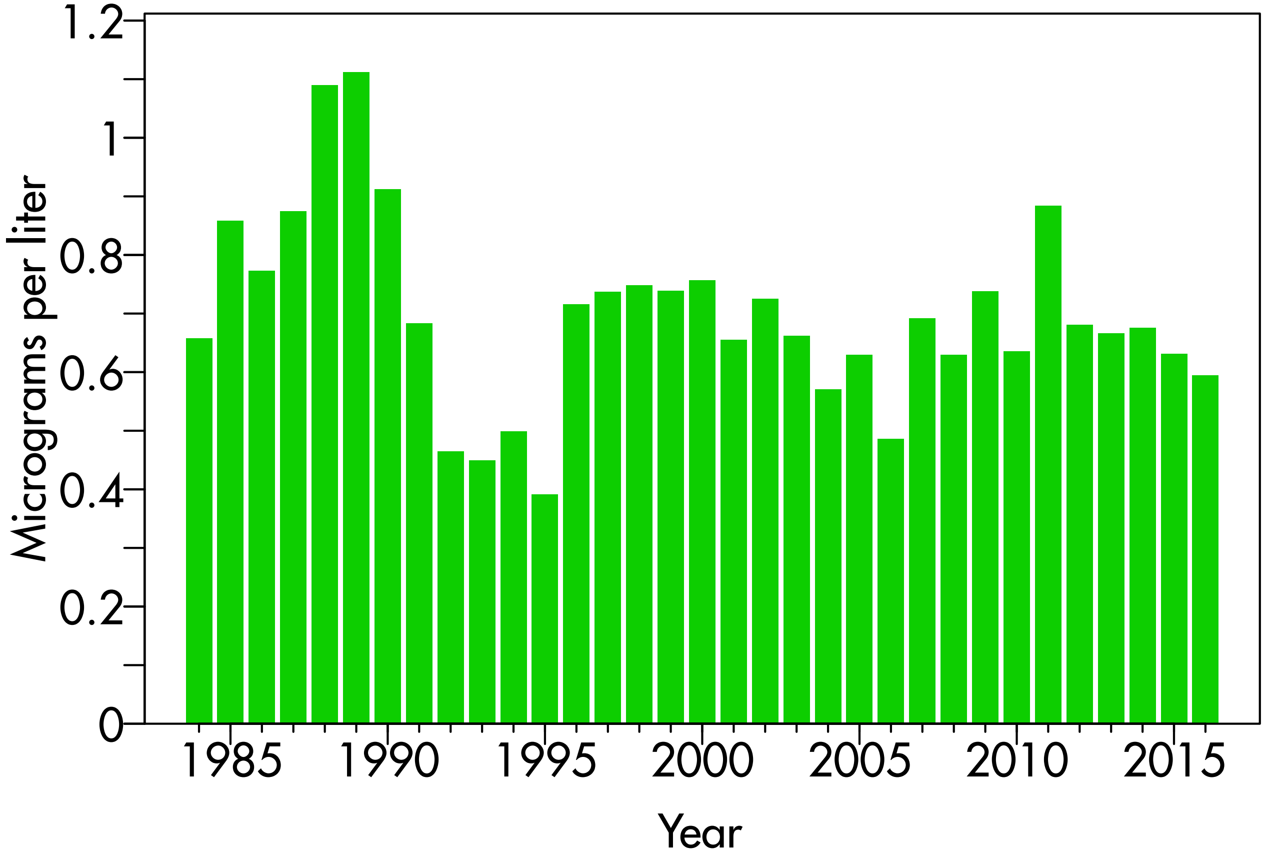


BIOLOGY

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, it has shown a significant increase since measurements began in 1984. The average annual concentration for 2016 was 0.59 micrograms per liter, lower than the previous nine years. For the period of 1984-2016 the average annual chlorophyll-a concentration in Lake Tahoe was 0.70 micrograms per liter.



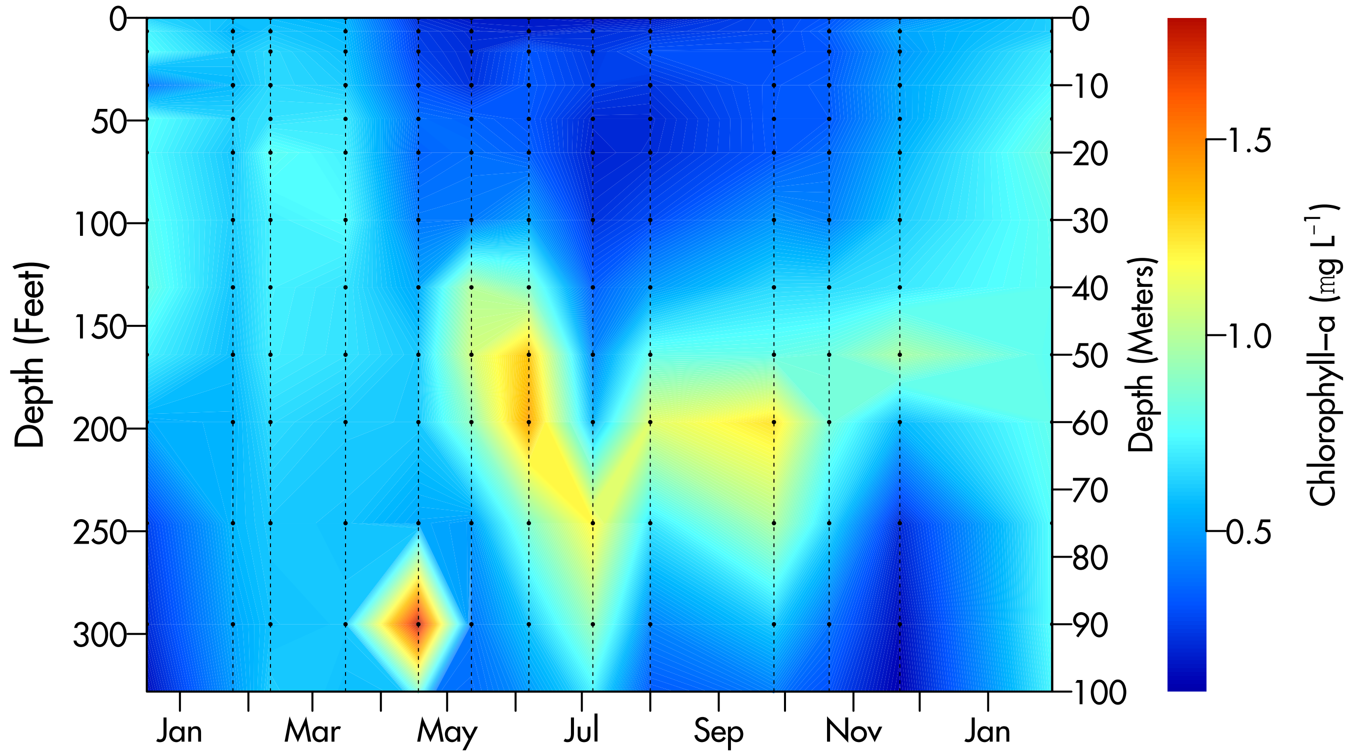
BIOLOGY

Chlorophyll-*a* distribution

In 2016

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 ft. 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 year concentrations decreased as nutrients were depleted. In November and December, the commencement of mixing again redistributed the algae over a broader depth range. Note that the *Cyclotella gordonesis* at the surface have a very small chlorophyll expression. However, the large number of these tiny cells are what matters.

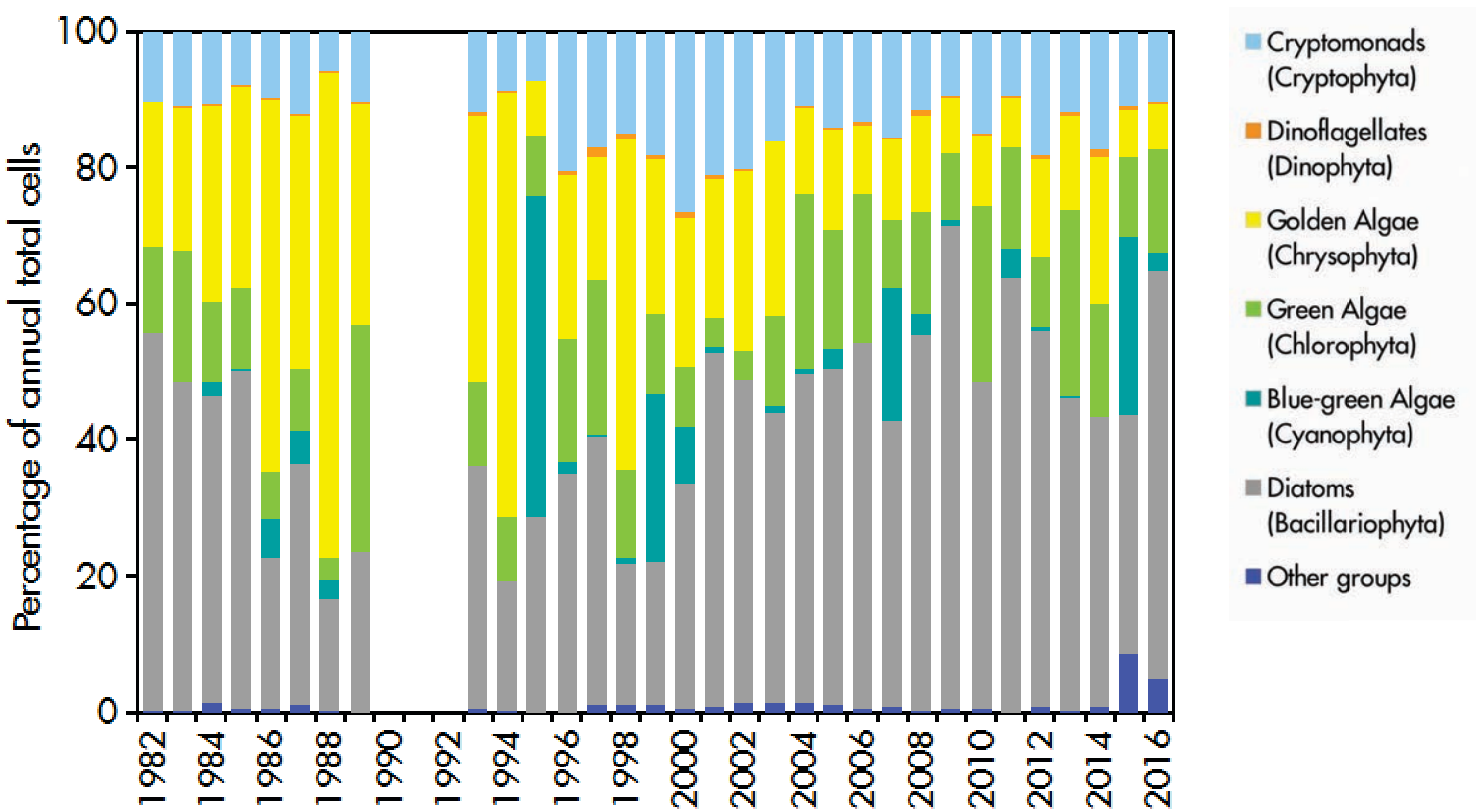


BIOLOGY

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 approximately 60 percent of the total abundance of algal cells in 2016. Chrysophytes, cryptomonads, and green algae are next, each comprising less than 15 percent of the total. 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.



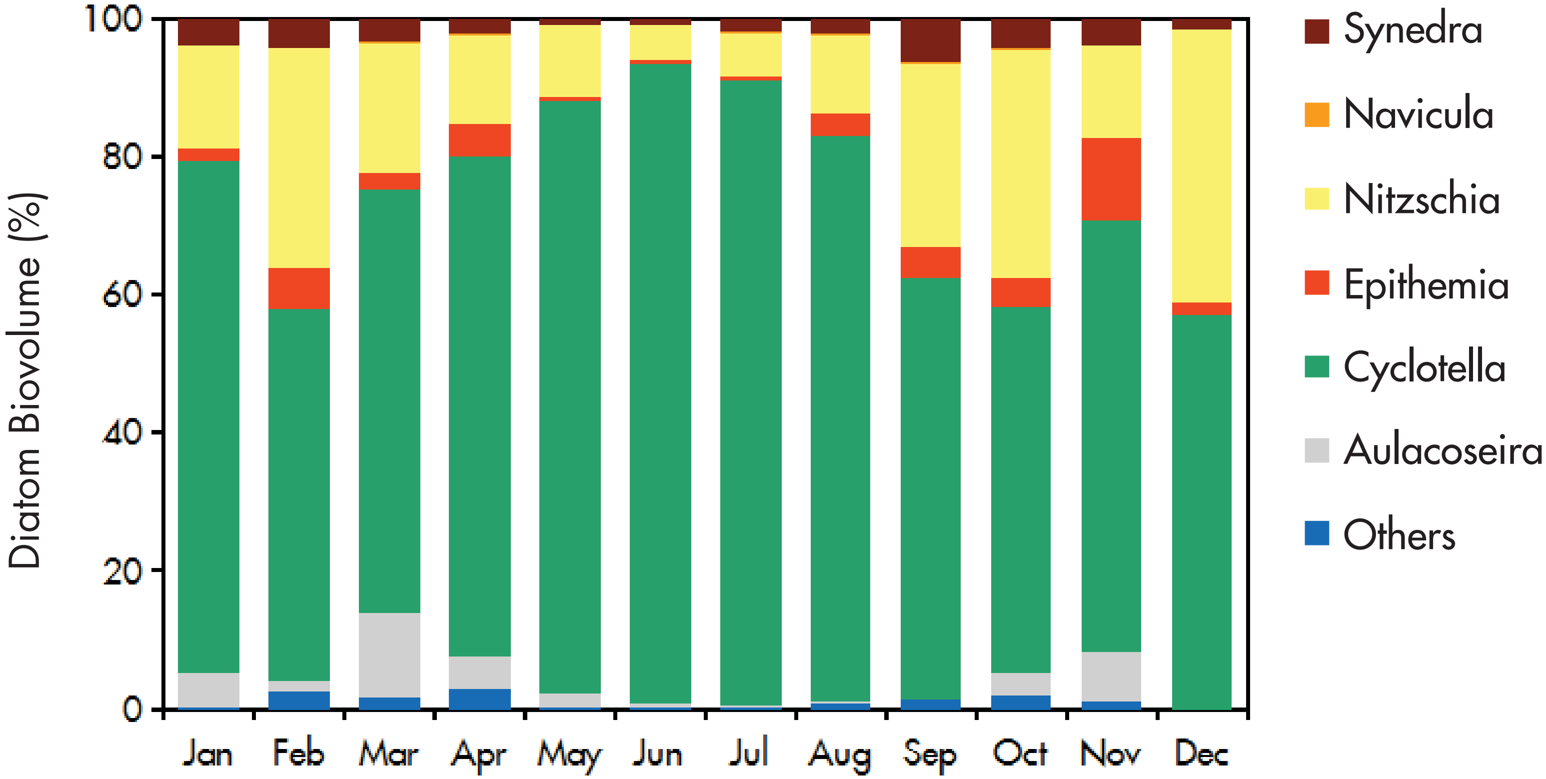
BIOLOGY

Abundance of dominant diatom species

Monthly in 2016

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 2016 are shown. Large variations are evident by month in the relative composition. Generally, *Cyclotella gordonensis* is the dominant diatom species during every month of the year. This recent increase in *Cyclotella gordonensis* reduced clarity in 2016.

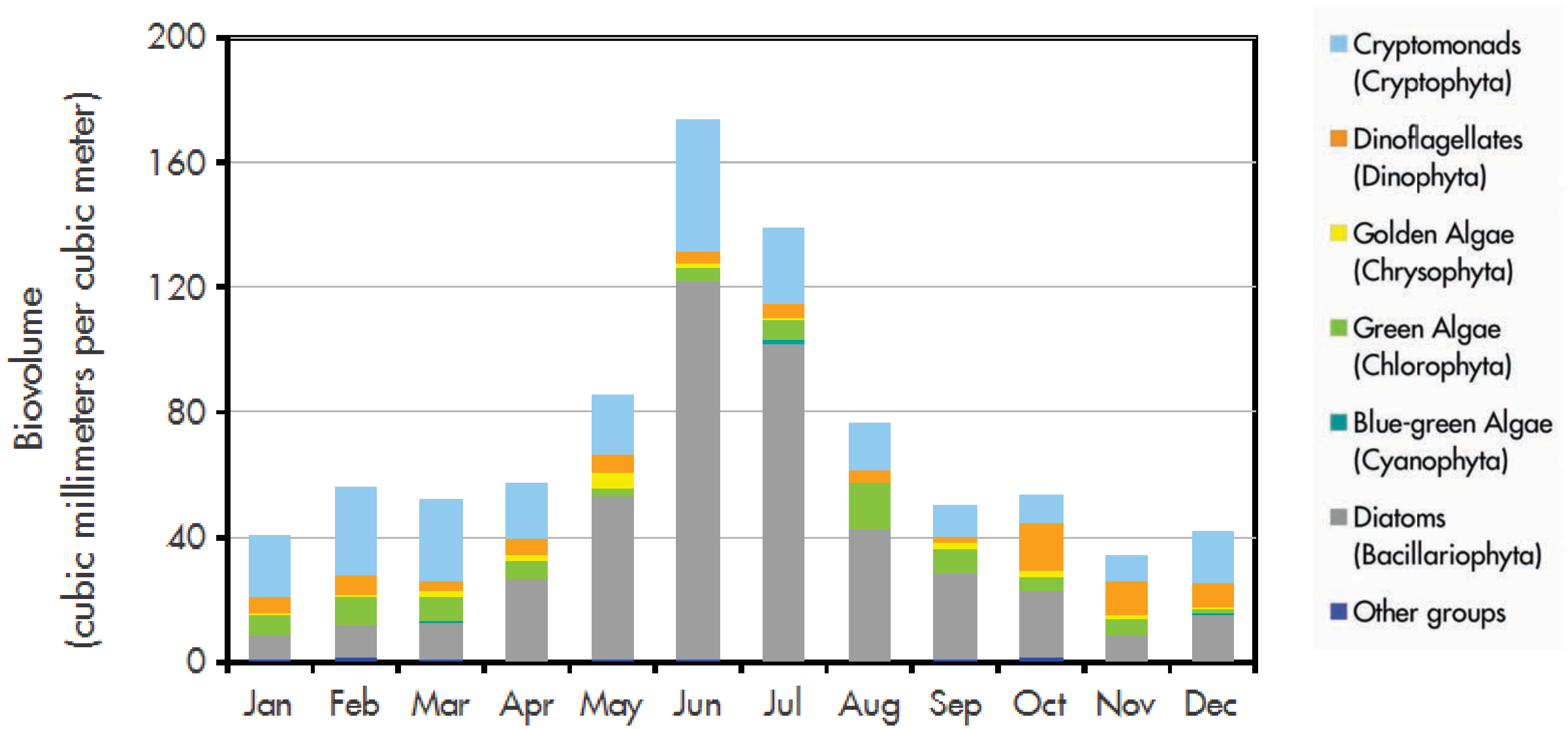


BIOLOGY

Algal groups as a fraction of total biovolume

Monthly in 2016

The biovolume of algal populations vary month to month, as well as year to year. In 2016, diatoms again dominated the biovolume of the phytoplankton community, especially in the summer. The peak in the biovolume occurred later in 2016, occurring from May to July (the "spring bloom"). Even at the peak of the bloom, algal cells occupied only one ten-millionth of the water in the lake. The peak biovolume in 2016 (170 cubic millimeters per cubic meter) was almost double the biovolume in 2015, a reflection of the increase in *Cyclotella gordonensis*.

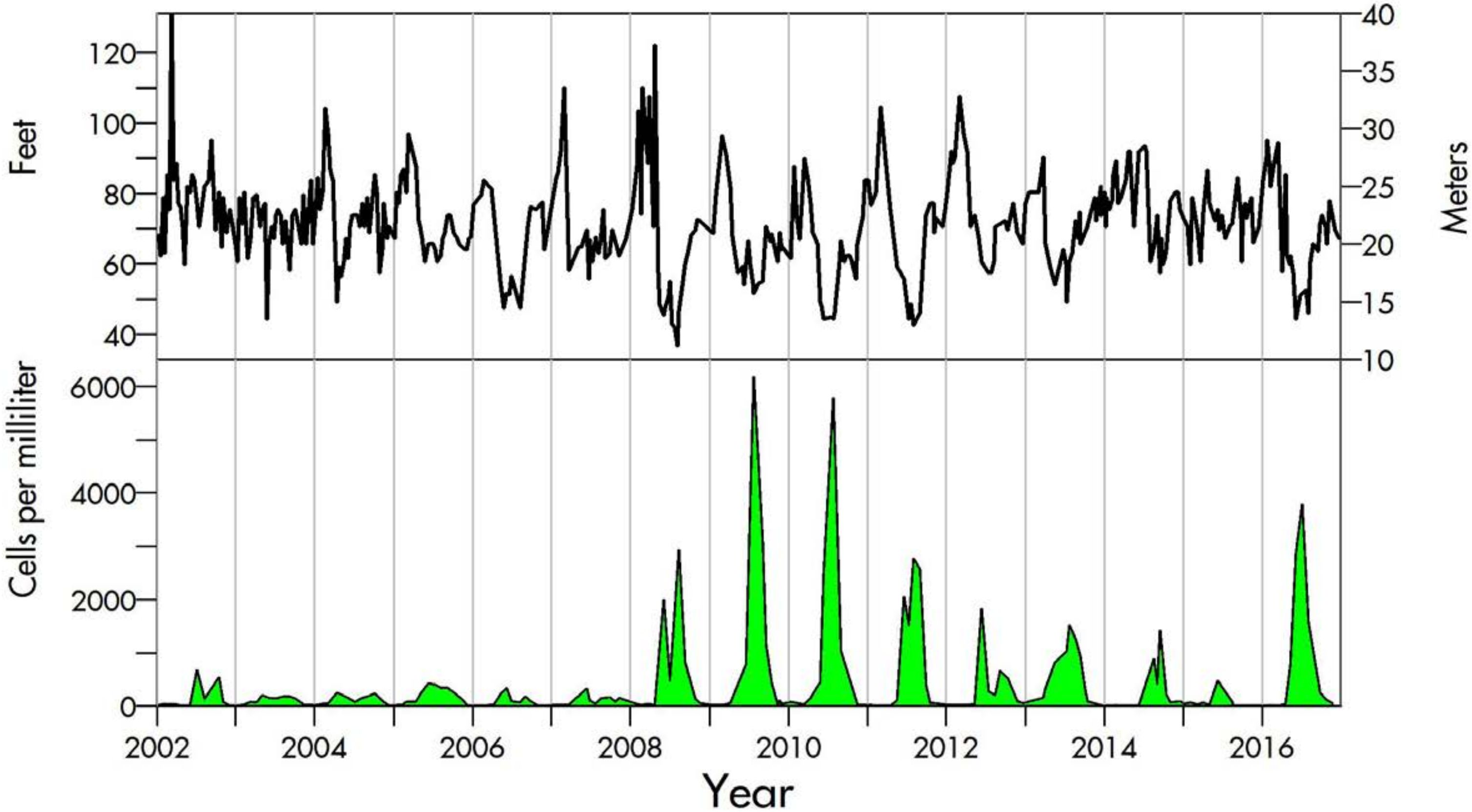


BIOLOGY

Predominance of *Cyclotella gordonensis*

From 2002 through 2016

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 2016, the high concentration of *Cyclotella* cells returned. 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. The summer decrease of Secchi depth coincides perfectly with the increase in *Cyclotella* concentration.

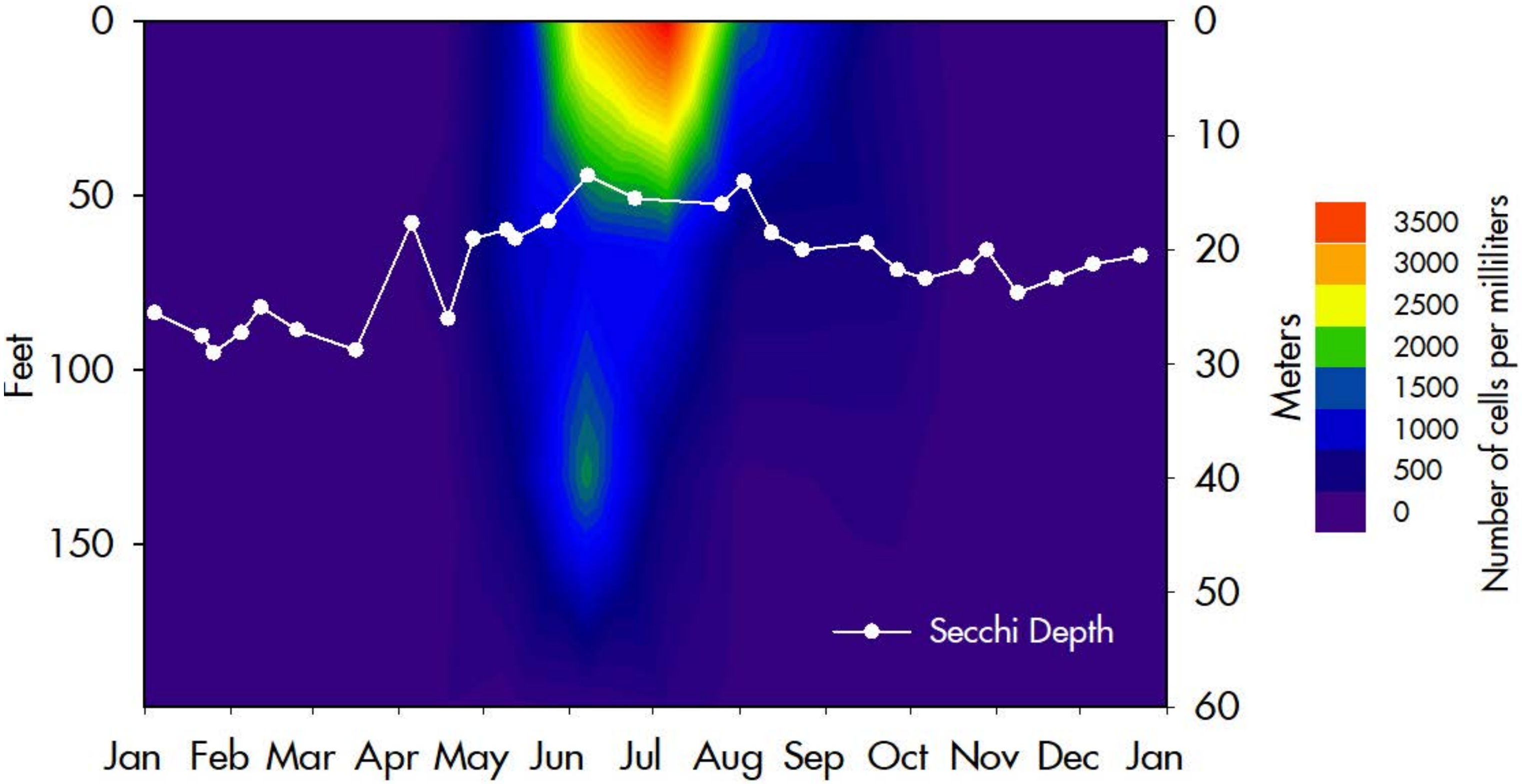


BIOLOGY

Distribution of *Cyclotella gordonensis*

In 2016

This year *Cyclotella gordonensis* returned to Lake Tahoe in high numbers. The color contours of the number of cells per milliliter are shown along with the individual Secchi depth measurements. The very high concentration of cells during June, July, and August, together with their location in the upper 50 feet of the water column produced low summer clarity readings.

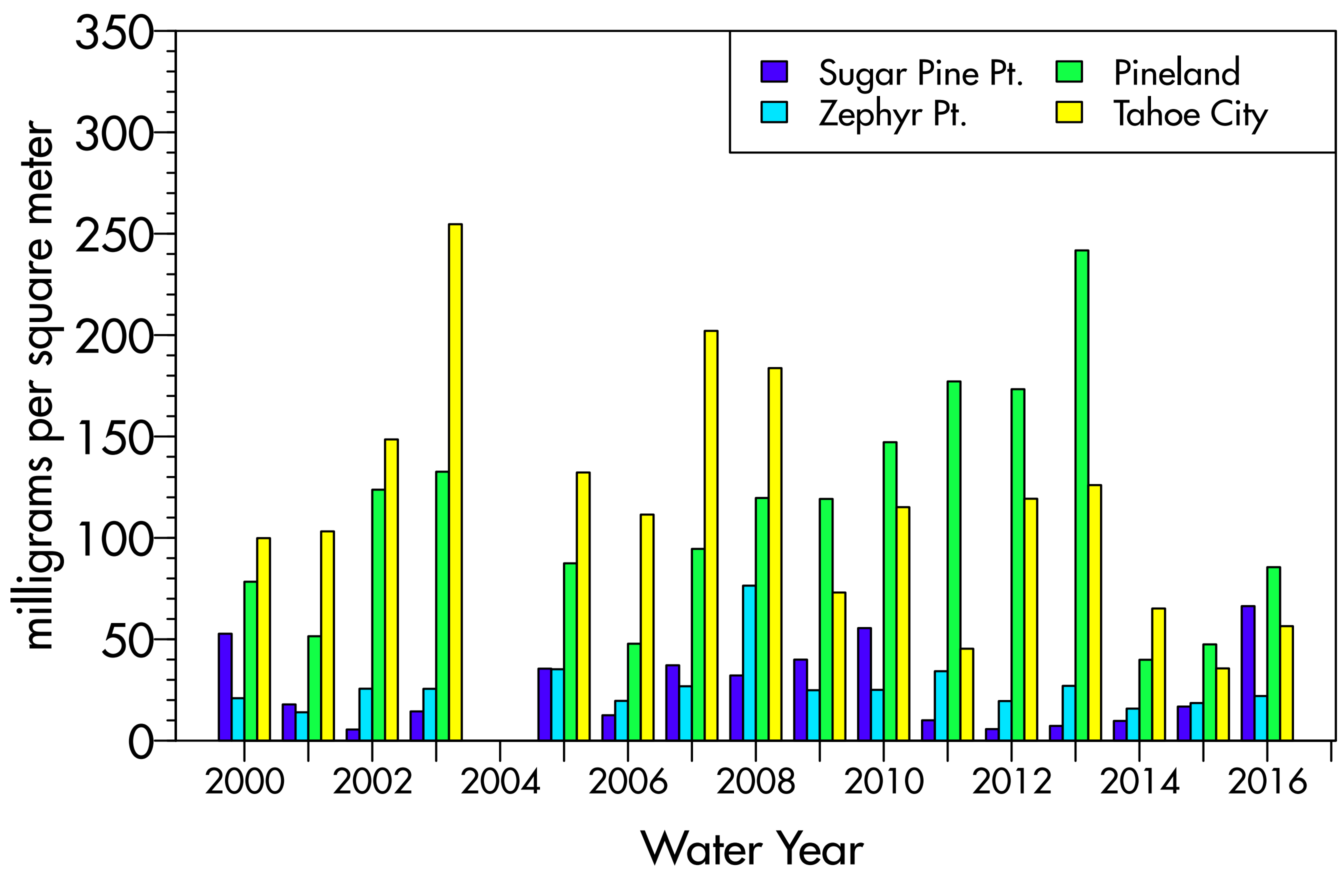


BIOLOGY

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 2016, concentrations at the four sites shown were close to their historic lows. The two most urbanized sites, Tahoe City and Pineland, were less than half of their values in comparison with 2013. While monitoring periphyton is an important indicator of near-shore health, these data do not shed information on what is controlling year-to-year changes.



BIOLOGY

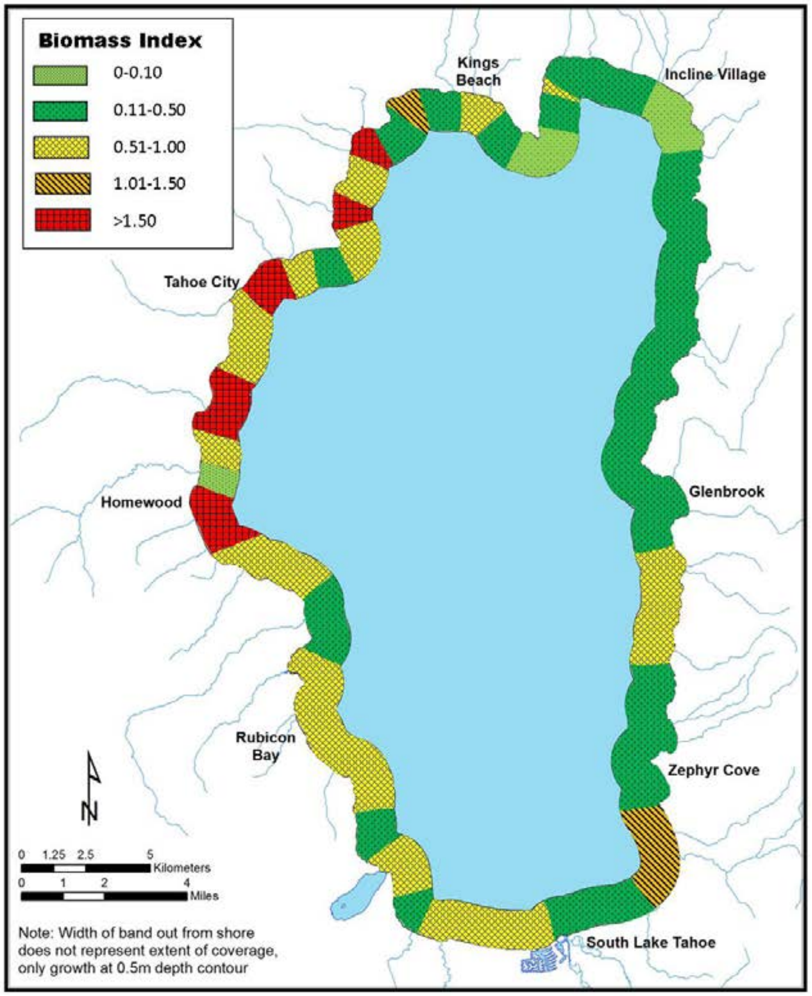
Shoreline algae distribution

In 2016

Periphyton biomass was surveyed around the lake during the spring of 2015, when it was at its annual maximum. Nearly 45 locations were inspected by snorkel survey in 1.5 feet (0.5 m) of water. A Periphyton Biomass Index (PBI) is used as an indicator to reflect what the casual observer would visually detect looking into the lake from the shoreline. The PBI is defined as the fraction of the local bottom area covered by periphyton multiplied by the average length (cm) of the algal filaments. The PBI had fewer very high occurrences (PBI > 1.5) in 2015, possibly due to the low lake levels that prevailed. Instead there was a greater number of moderate areas (PBI = 0.51 -1.0), especially on the east shore. As lake level falls during low lake level years, the 1.5 ft. measurement depth is increasingly dominated by blue-greens at many sites including the east shore sites resulting in moderate biomass index values (in contrast, the east shore often has relatively low growth of algae at higher lake levels).

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 0.5m Depth, Spring 2016



TAHOE: STATE OF THE LAKE REPORT 2017

CLARITY

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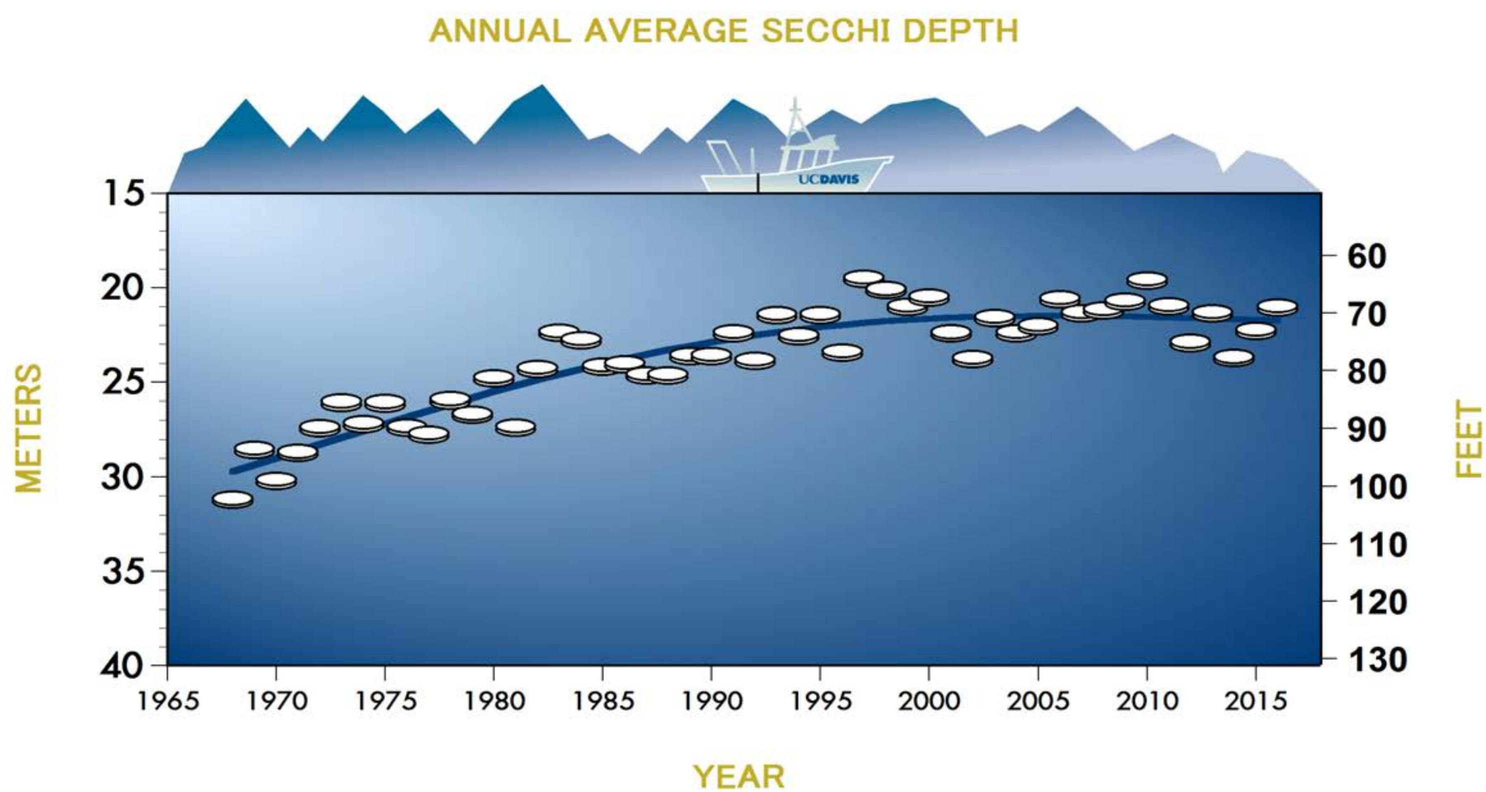
CLARITY

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 2016, the annual average Secchi depth was 69.2 feet (21.1 m), a 3.9 foot decrease from the previous year but still over 5 feet greater than the lowest average of 64.1 feet (19.5 m) recorded in 1997. The annual average clarity in the past decade has been better than the prior decade. The highest individual value recorded in 2016 was 95.1 feet on January 25, and the lowest was 44.3 feet on June 7. The decline this year is largely attributable to high concentrations of the diatom *Cyclotella gordonesis*. While the average annual clarity is now better than in preceding decades, it is still short of the clarity restoration target of 97.4 feet set by federal and state regulators, a goal agencies and the Tahoe Basin community continue to work toward.

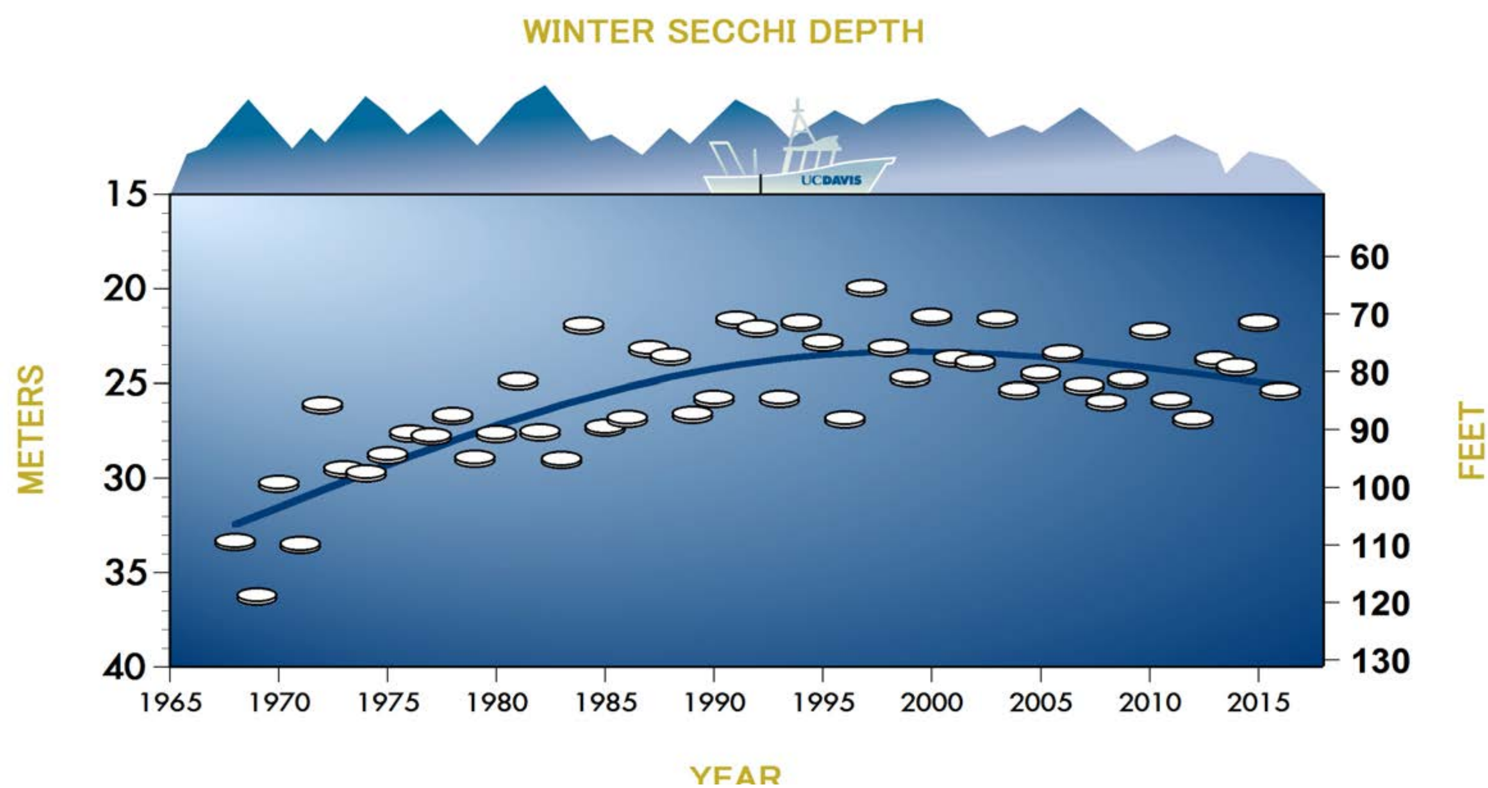


CLARITY

Winter Secchi depth

Yearly since 1968

Annual winter (December-March) Secchi depth measurements from 1968 to the present indicate that winter clarity at Lake Tahoe is showing definite improvement. In 2016, winter clarity increased by 11.7 feet. The winter average of 83.3 feet (25.4 m) was still well above the worst winter average, 65.6 feet (20.0 m), seen in 1997. Winter precipitation (which was close to the long-term average) had little effect on clarity, due to stormwater control and watershed restoration projects.

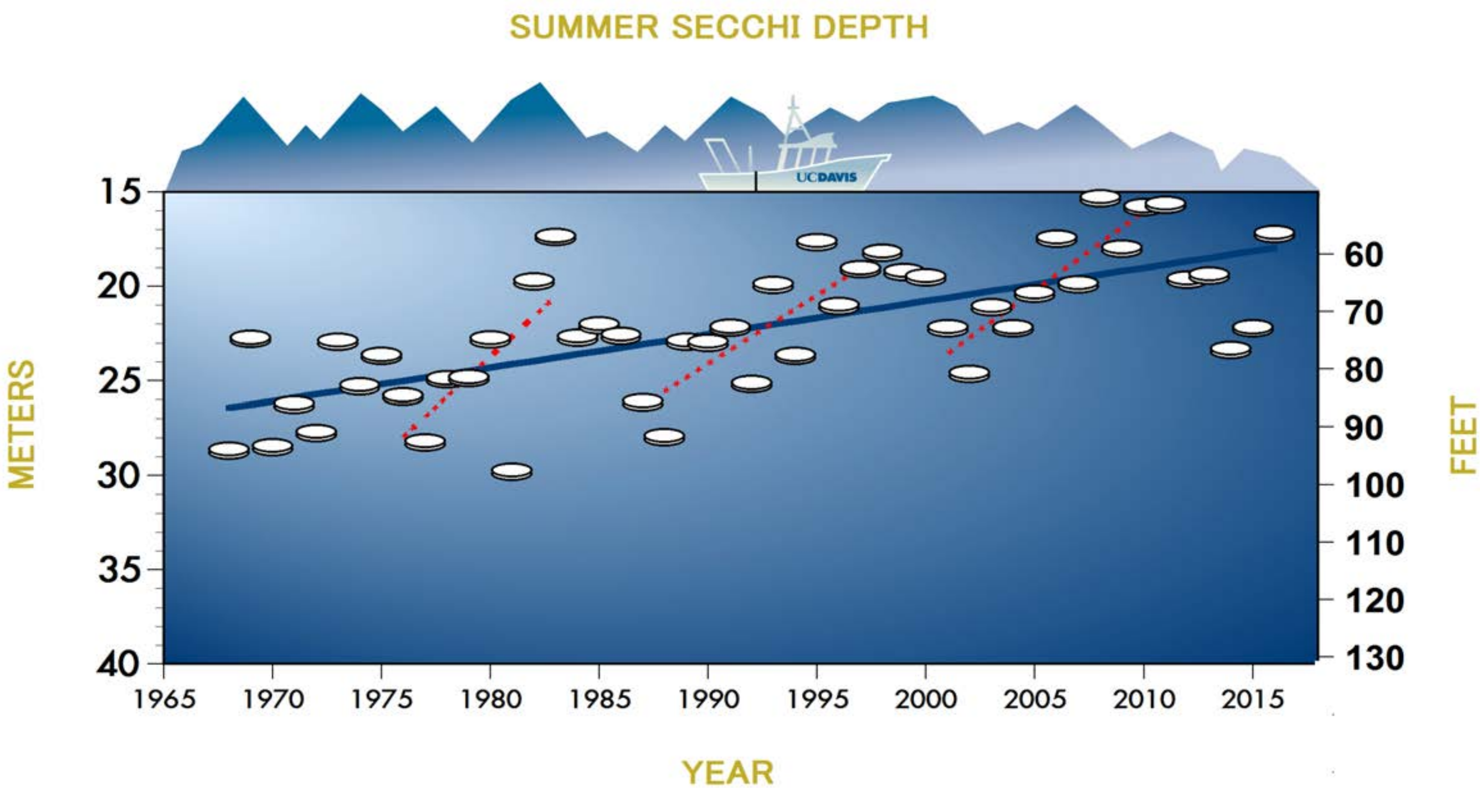


CLARITY

Summer Secchi depth

Yearly since 1968

Summer (June-September) clarity in Lake Tahoe in 2016 was 56.4 feet (17.2 m), a 16.7 foot decline from 2015. The cause of the decline was a large increase in the concentration of Cyclotella gordonesis, a small diatom (5 microns). The summer trend is dominated by a consistent long-term degradation but with a noticeable 10-15 year cyclic pattern. The red dashed lines are linear regressions for the periods: a) 1976 to 1983, b) 1987-1998, and c) 2001 to 2011.



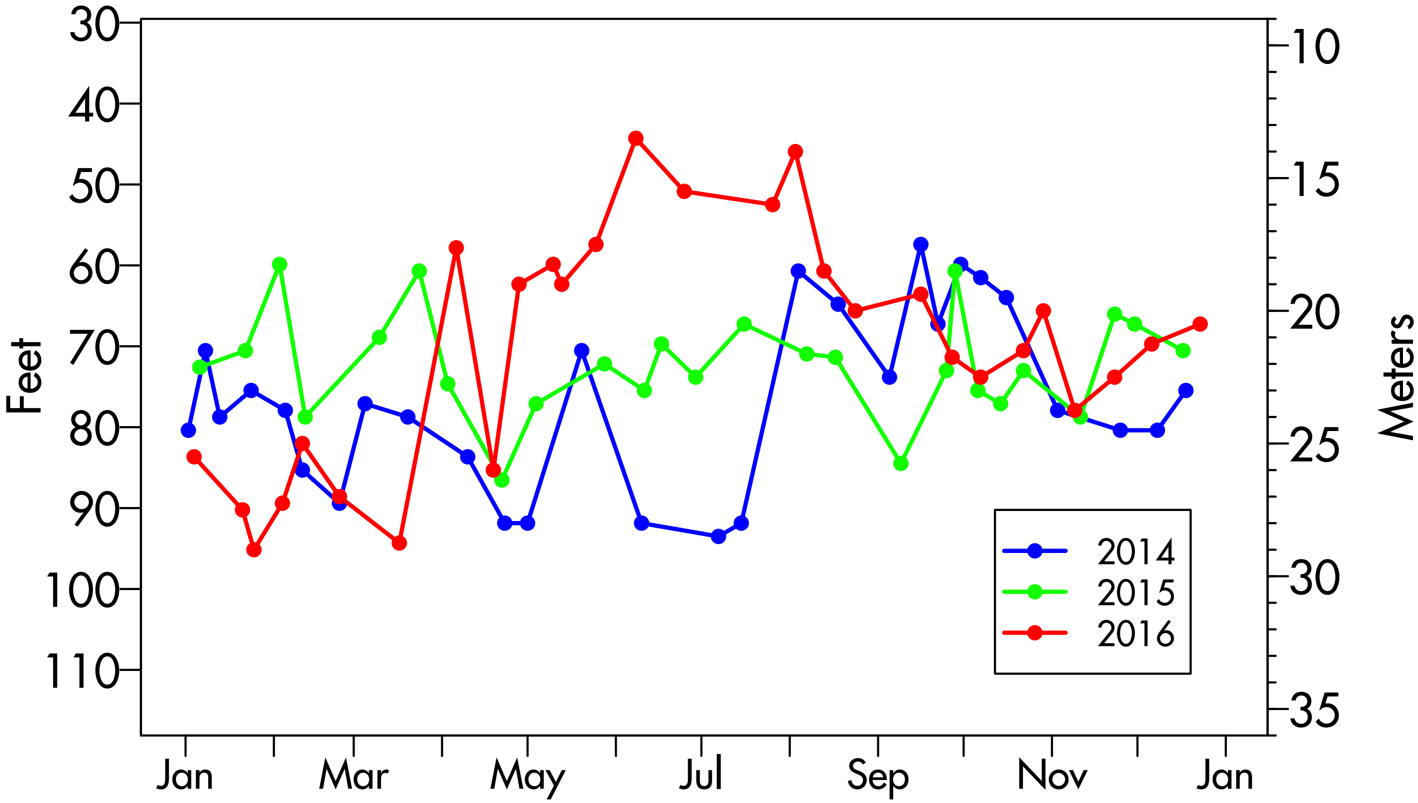
CLARITY

Individual Secchi depths

2014, 2015, 2016

Here, the individual Secchi depth reading from the Index station on the west side of the lake for 2014, 2015 and 2016 are plotted.

Secchi values can be seen to sometimes vary considerably over short time intervals. This is evident on April 5 and April 16, 2016 where the Secchi depth changed from 58 feet to 85 feet respectively. Such short-term variability is common in lakes. In these cases the sudden change is due to episodes of strong wind.



TAHOE: STATE OF THE LAKE REPORT 2017

EDUCATION AND OUTREACH

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EDUCATION AND OUTREACH

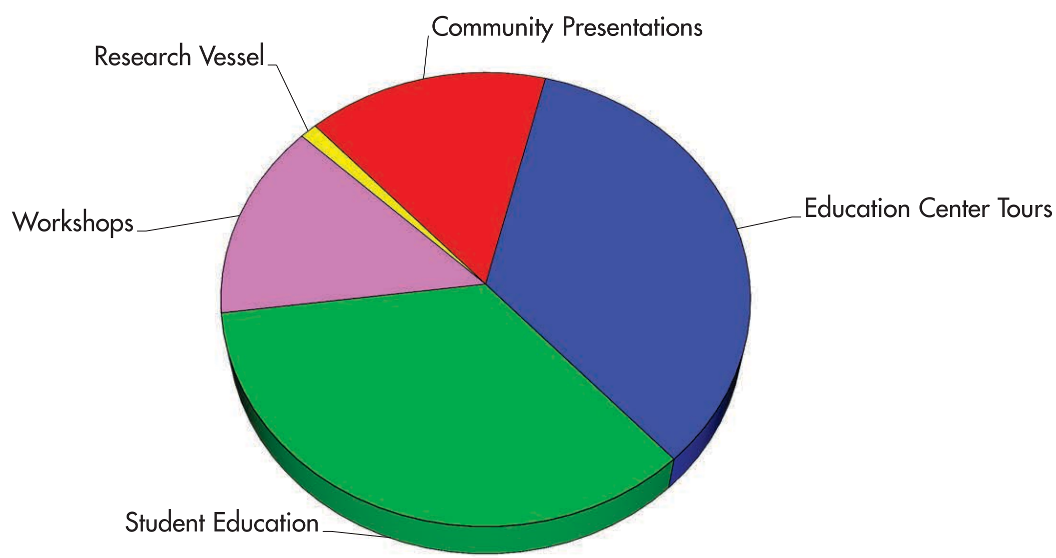
TERC education and outreach

In 2016

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 2016, TERC recorded 15,997 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, Project WET workshops, and a volunteer docent training program.

TERC also partners with numerous groups to deliver environmental science education in the Tahoe basin. In 2016, these included AmeriCorps, Lake Tahoe Outreach Committee, North Tahoe Environmental Education Coalition, Sierra Nevada College, Sierra Watershed Education Partnerships (SWEP), South Tahoe Environmental Education Coalition, UC Davis Young Scholars, and many others.



Total Number of Contacts: 15,997

EDUCATION AND OUTREACH

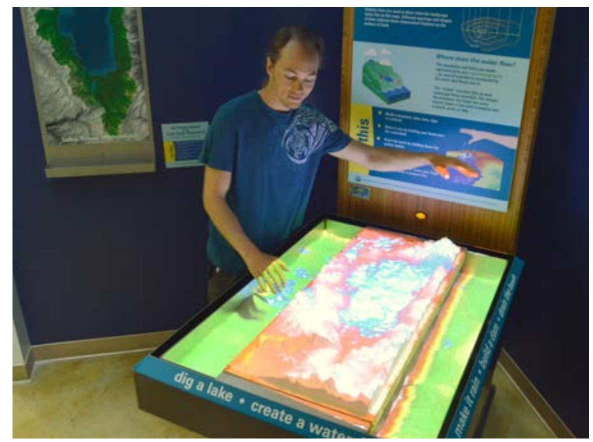
TERC educational exhibits

In 2016

Each year, TERC works to enhance our exhibits and increase the offerings available in the UC Davis Tahoe Science Center. During 2016, we continued work on the Lake Tahoe in Depth touchscreen exhibit, contributed to the Take Care™ stewardship campaign by designing a mural wall with interactive flip-panels, added hands-on activities related to Lake Tahoe's geology, added exhibit signage, and updated our Citizen Science Tahoe mobile app. These activities all aid in our mission to provide engaging exhibits and interactive hands-on educational activities.

The Lake Tahoe in Depth exhibit wall has new wall signage and content describing both real-time and historical lake water quality conditions. By viewing data from around the shores of Lake Tahoe, visitors will be able to explore how conditions are changing over time and at different locations around the lake. Photo: A. Toy

Utilizing the Take Care™ (TakeCareTahoe.org) stewardship messages, TERC staff created a flip-panel mural which provides a fun and engaging way to teach visitors about local stewardship and actions to take care of Tahoe.
Photo: A. Toy



A new 3D Printed Model of the Lake Tahoe Watershed is available for the Augmented Reality Sandbox. This model took over 150 hours of 3D print time and was completed by Aaron Vanderpool and Andy Rost of Sierra Nevada College. Fill the lake with virtual water to see the evolving shape of Lake Tahoe at different lake levels. Photo: A. Toy

EDUCATION AND OUTREACH

TERC educational exhibits, continued

In 2016

TERC and our partners have launched an updated version 2.0.7 of the smartphone app, "Citizen Science Tahoe," that encourages beach-goers of all ages to submit what they see at Lake Tahoe. This observational data will be used by scientists to better understand conditions around the lake.

Citizen scientists can help lake researchers by taking a few minutes to enter what they see at the beach, from algae to wildlife to litter. Share all of your observations on our mobile app. Join Tahoe's largest community-powered science project and become part of our citizen scientist community to help us understand conditions around the lake.

New hands-on exhibits: *Rocks of Tahoe* and *Erosion* were added to the growing number of science activities at the Tahoe Science Center.

TERC's native and non-native aquariums at both science centers have new and growing occupants.

Download the new Citizen Science Tahoe mobile app (CitizenScienceTahoe.com) and add a splash of science to your family's beach day. Share what you observe whenever you visit the beach. Photo: A. Toy

New hands-on exhibits on the *Rocks of Tahoe* and *Erosion* were added. TERC continues to seek ways to provide more engaging hands-on activities for visitors. Funding was provided by the Nevada Department of Tourism and Cultural Affairs. Photo: A. Toy

TERC provides information about Lake Tahoe's aquatic food web by showcasing various native and non-native species in our aquariums at the Tahoe Science Center and Tahoe City Field Station. Our largest trout "Lahnie," a Lahontan cutthroat trout grown from the Trout in the Classroom project, is now 2.5 years old and nearly 10 inches. Photo: A. Toy

EDUCATION AND OUTREACH

TERC educational programs

In 2016

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.

K-12 programs include school field trips, Trout in the Classroom, Youth Science Institute, and Science Expo. The TERC Education Team provided informal science education to more than 5,450 third- through eleventh-grade students by hosting over 74 field trips during the year.

Each year we train new volunteer docents at our annual Docent Training. Volunteer docents become local experts and lead public tours at our two science centers. Volunteers also participate in garden work each year to make the Tahoe City Field Station's native plant demonstration garden a beautiful community and ecological resource.

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 share their love of Lake Tahoe with others. Photo: A. Toy

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: Kings Beach Elementary School

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: H. Segale

EDUCATION AND OUTREACH

TERC educational programs, continued

In 2016

During the summer months, we offer programs at the Tahoe City Field Station. In 2016, volunteer docent and Lake Tahoe Master Gardener Dave Long provided the first annual high altitude gardening workshop series which provided guidance on how to grow vegetables and fruit in our unique climate.

Another new program from TERC's education and outreach programs was the first annual Nevada STEM Underwater and Aerial Vehicle Computer Science Institute for teachers hosted by TERC faculty member Alex Forrest with the Northern Nevada Regional Professional Development Program.

We continued to update and modify available science activities and thematic field trips. Landforms and Topography are pre-existing activities that have been updated. Climate Change and Cabon Cycling are the newest activities to join the selection of programs available to academici nstitutions of all forms.

Volunteer docent Dave Long describes the varietals of vegetable seedlings for attendees to take home from the gardening workshops held at the Tahoe City Field Station. Photo: A. Toy

Alex Forrest (far left) oversees the "OpenROV" first underwater mission in Pyramid Lake as part of the Nevada STEM Underwater and Aerial Vehicle Computer Science Institute for teachers. Photo: B. Crosby

TERC creates new science activities to enhance student interest in science. In the "What Contains Carbon Activity" students investigate every day items that contain carbon and model how carbon cycles through the environment. Photo: A. Toy

EDUCATION AND OUTREACH

TERC special events

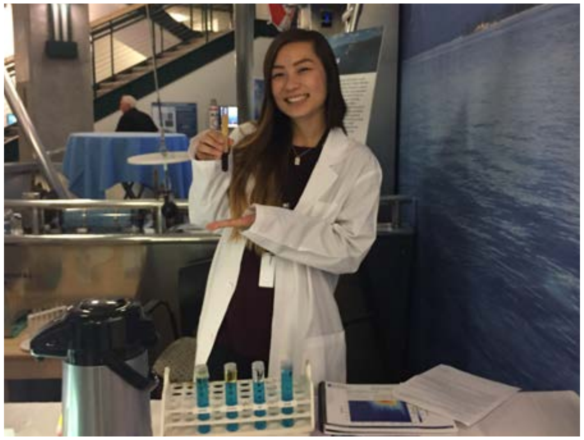
In 2016

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 2016 included “Exploring Mars”, “Physics of Snow”, “Tree Mortality”, “A Gut-Feeling: How Intestinal Microbes Modulate Mood and Behavior”, “Science of Beer”, “Science of Wine”, “Imperiled Fishes”, and “Climate Change Models Using Ocean Species.”

Special events hosted annually include North Tahoe Science Expo (March), South Tahoe Science Expo (April), Garden workshops (June - August), Summer Teacher Institute (July), and the new Science of Cocktails event (October).

At the 12th annual North Tahoe Science Expo students learned about Earth science, weather, climate, and space science. Students use dry ice to explore how different volcanoes erupt. Photo: A. Toy

At the second annual South Lake Science Expo, held on the Lake Tahoe Community College campus, students learn about weather and cloud formation with the “Cloud in a Bottle” experiment. Photo: A. Toy



At the first annual Science of Cocktails event, themed beverages taught about density (shown here), pH, fluorescence, sublimation, polymers, latent heat, fermentation, and alcohol science. Photo: T. Dolan

The UC Davis Tahoe Environmental Research Center is a global leader in research, education, and public outreach on lakes that provides critical scientific information to help understand, restore, and sustain the Lake Tahoe Basin and other systems worldwide.

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