UC DAVIS

TAHOE: STATE OF THE LAKE REPORT 2024

Tahoe Environmental Research Center

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INTRODUCTION

The University of California, Davis has conducted continuous monitoring of Lake Tahoe and its watershed 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 processes and human activity in the watershed and beyond are affecting the lake's clarity, physics, chemistry, and biology. We also present a portion of the data collected in 2023 — presenting all of it would be overwhelming. While Lake Tahoe is unique, the forces and processes that shape it are similar to 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 understand the lake's complexity and to use that knowledge 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 also need to account for and balance a host of other considerations.

This annual report is intended to inform non-scientists about the factors that affect lake health. One indicator of Lake Tahoe's health status, the annual clarity, is reported earlier each year. In this report, we publish many other environmental and water quality factors that serve as other indicators of the lake's condition and help explain the lake's changing clarity. This report sets the context for understanding the year-to-year changes as well as those that are observed over many decades.

Part of this report describes research and education taking place independently of the long-term monitoring. These updates highlight some of the most exciting and promising findings of work that is still in progress. The insights being gained through this research will help keep Lake Tahoe at the cutting edge of science for years to come. Many of the sections explore new ideas and approaches to address the ever-evolving challenges at Lake Tahoe.

The data we present are the result of efforts by a great many scientists, engineers, students, technicians, and educators who have worked at Lake Tahoe throughout the decades since monitoring commenced. I would, however, like to acknowledge (in alphabetical order) the contributions to this year's report by Brant Allen, Nick Bently, Brandon Berry, Mike Bruno, Tom Burt, Michael Cane, Luciana Cardoso, Bob Coats, Corrin Clemons, Troy Corliss, Alicia Cortés, Randy Dahlgren, MJ Farruggia, Helen Fillmore, Alex Forrest, Drew Friedrichs, Kendall Galvez, Fatima Garcia, Jenessa Gjeltema, Scott Hackley, Tina Hammell, Sarah Harry, Jade Hinson, Penelope Holland, Simon Hook, Camille Jensen, Jackelyn Lang, Kenneth Larrieu, Mui Lay, Anne Liston, Shannon Lynch, Patricia Maloney, Keeley Martinez, Jasmin McInerney, Antonina Myshyakova, Holly Oldroyd, Kanarat Pinkanjananavee (Job), Wesley Radford, Gerardo Rivera, Steven Sadro, S. Geoffrey Schladow, Heather Segale, Katie Senft, Oscar Sepúlveda Steiner, Steven Sesma, Samantha Sharp, Roland Shaw, David Smith, Adrianne Smits, Micah Swann, Lidia Tanaka, Misa Terrell, Ruth Thirkill, Raph Townsend, Alison Toy, Susan Ustin, Sergio Valbuena, Aaron Vanderpool, Rachel Vanette, Lindsay Vaughan, Shohei Watanabe, Michael Welsh, Logan Witt, and Erik Young to this year's report. In particular, Shohei Watanabe was responsible for the majority of the data analysis, Cara Hollis led the effort to write the State of the Lake overview, and Heather Segale and Alison Toy led the compilation, layout, and editing 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, Tahoe Regional Planning Agency, U.S. Geological Survey, and UC Davis.

Funders for current projects include the following: CalFire, California Delta Stewardship Council, California Natural Resources Agency, California Tahoe Conservancy, Incline Village General Improvement District, NASA Jet Propulsion Laboratory, the National Science Foundation, Nevada Department of Tourism and Cultural Affairs, Nevada Division of Environmental Protection, Nevada Division of State Lands, Parasol Tahoe Community Foundation, Santa Clara Valley Water District, the Tahoe Resource Conservation District, the Tahoe Truckee Community Foundation, the Tahoe Water Suppliers Association, the U.S. Bureau of Reclamation, and the U.S. Embassy, Chile.

Our monitoring is frequently done in collaboration with other research institutions and agencies. In particular, we would like to acknowledge our collaborators at UC Davis, California Conservation Corps (CCC), the Desert Research Institute (DRI), the National Aeronautics and Space Administration (NASA), the National Oceanographic and Atmospheric Administration (NOAA), the Tahoe Resource Conservation District (TRCD), the U.S. Forest Service, (USFS), the U.S. Geological Survey, the University of Miami at Ohio, and the University of Nevada, Reno (UNR).

We are very proud to recognize the funding support for actual production of this annual report from the following organizations: California Tahoe Conservancy, Incline Village Waste Not Program, Lahontan Regional Water Quality Control Board, Lake Tahoe Marina Association, Mountain Workspace, Parasol Tahoe Community Foundation, Tahoe Fund, Tahoe Lakefront Owners' Association, League to Save Lake Tahoe, Tahoe Regional Planning Agency, Tahoe Truckee Airport Community Partner, Tahoe Water Suppliers Association, and True Point Solutions. We sincerely thank these organizations for their dedication in supporting science to save the lake.

Sincerely,

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EXECUTIVE SUMMARY

The UC Davis Tahoe Environmental Research Center (TERC) and its collaborators are dedicated to the study of Lake Tahoe and its ecosystems. This dedication has produced an extensive long-term dataset that helps researchers understand ecosystem function and provides science-based evidence to elected officials and public agencies who are making policy decisions around the basin. As the impacts of climate change become more apparent in and around the lake, this comprehensive dataset is the foundation of understanding that allows researchers to monitor changes at all levels of the lake and for decisions to be made about new technologies, methodologies, and policies that need to be employed to continue to monitor and preserve the lake's health. This report is focused on how climate change will impact every level of the lake and the surrounding forest and how TERC researchers are documenting and responding to those changes.

The changes in question range from the things that are most apparent to residents and visitors, like observed seasonal shifts in lake clarity, algae growth, and the potential of Harmful Algal Blooms (HABS), to the least apparent to the casual observer, like changes in the population of the zooplankton that may be hard to see but can have an outsized impact on the health and clarity of the lake. Climate change is not only impacting species that are native to the lake but also making it easier for aquatic invasive species to gain a foothold in establishing themselves in the lake. These outside invaders have the potential to create very visible changes to the lake, and their presence needs to be studied and monitored to quantify their associated ecosystem impacts.

TERC research is not limited to how climate change is impacting life at and below the surface of Lake Tahoe. Researchers also look at the impacts on the surrounding forest health and across other lakes in the Sierras. From wildfires, drought, and parasitic invaders, TERC researchers are dedicated to understanding what pressures the forest is facing and working on strategies to make it more resilient to environmental change. Researchers are also studying the impact of wildfires, which are becoming more frequent and severe, and their associated smoke and ash-fall are having on the chemistry of Lake Tahoe and lakes beyond the basin. The impacts of climate change have no boundaries, and as such, research must go beyond Tahoe.

In order to adequately monitor Lake Tahoe, TERC has continued to develop and invest in new technologies to observe the lake in real-time. Lake Tahoe is monitored by 25 permanent

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"Previous year" for some parameters means data collated in terms of the water year, which runs from October 1 throught September 30; for other parameters, it means data for the calendar year, January 1 through December 31. Therefore, for this 2024 report, Water Year data are from October 1, 2022 through September 30, 2023. Calendar year data are from January 1, 2023 through December 31, 2023.

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monitoring stations in the lake and the use of remote sensing from autonomous underwater vehicles, satellites, aerial drones, and helicopters. This means that Lake Tahoe is a perfect laboratory to develop and test new monitoring technologies. As such, TERC is partnering with the Center for Information Technology Research in the Interest of Society (CITRIS) and created the Environmental Robotics Lab @ Tahoe. Through this partnership, TERC is continuing to develop and deploy glider technologies to not only study the inner workings of Lake Tahoe but also deploy them beyond the basin to study the impacts of climate change in critical climates such as the Arctic.

Finally, this report will cover reasons for hope and the importance of education and philanthropy in TERC's efforts to protect Lake Tahoe. It is the residents and visitors who love the lake who have the power to preserve it for future generations to enjoy. All this and more are covered in the following pages, and by reading this report and sharing the information you learned here with friends and family, you are taking the first step necessary to become a steward of Lake Tahoe.

This Tahoe: State of the Lake Report 2024 presents data from 2023 in the context of the long-term record. While we report on the data collected as part of our ongoing measurement programs, we also include sections summarizing some of the current research that is being driven by the important questions of the day and concerns for the future. These include:

- Climate change is a regional issue. From wildfire smoke blowing south last summer from Northern Canada to regional heat waves breaking new records this year to harmful algal blooms (HABs) affecting lakes and rivers across the country, the problems we face today cross state and national boundaries
- Another big winter brought cold air temperatures that impacted both winter water temperatures and the percentage of precipitation that fell as snow. Snow represented 63 percent of the 2023 total precipitation over the water year (WY).
- Because of these colder temperatures, the lake didn't warm as much, and annual average water temperatures came in below the long-term trend line. However, nearshore temperature monitoring shows that overall lake temperatures are still rising, with the last couple of years showing the warmest temperatures on record, especially in the nearshore.

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- On the meteorological front, extremes are the new normal. Looking at the monthly totals, precipitation was double the long-term (1910-2023) monthly average in December, February, and March due to a sequence of large storms last winter.

- The annual average water temperature was 41.9 °F (5.5 °C), which was well below the trend line. However, the surface water temperature was 52.7 °F (11.5 °C), which was right on the long-term trend line, showing continued summer warming.

- Clarity monitoring showed highs and lows in 2023. The clarity of Lake Tahoe's famed blue waters in 2023 continued its years-long trend of improving during the winter and deteriorating during the summer. In the winter of 2023, observations documented the 10th-best clarity measurement in the historical record. But the summer of 2023 contained the 5th-worst clarity measurement in the historical record.

- A deep mixing event on March 3, 2023, helped with winter clarity. Deep water mixing plays a critical role in winter clarity, as clearer bottom waters are mixed in with surface waters. The Lake mixed fully, and the duration of the 2023 mixing period was one of the longest recorded. This resulted because of the timing of a series of storms affecting the region.

- Deep mixing contributed to the disappearance of the high nitrate region in the bottom half of the lake. Nitrate was uniformly distributed until May, when the surface nitrate was being depleted, and a sharp "nitricline" was evident at a depth of 250 feet.

- Phosphorus mainly entered the lake in association with fine particles during runoff events in May through June. The relatively elevated values near the surface in May suggest that in 2023, nitrogen was the nutrient that limited algal growth, rather than phosphorus in the spring. Due to deep mixing in March, the preceding high phosphorus levels were rapidly diluted through the entire water column.

- Runoff from the heaviest winter snowfall in 70 years brought an influx of inorganic particles and a rapid drop in clarity in May.

- The dominant phytoplankton species, *Cyclotella*, has decreased since 2017, while another, slightly

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larger algae, *Synedra*, is increasing. Changes among the phytoplankton and zooplankton communities within the lake also have the potential to impact clarity. Nonnative Mysis shrimp are beginning to return, while zooplankton species are also experiencing changes in their populations.

- In 2023, diatoms comprised approximately 56 percent of the total abundance of algal cells, following a two-year period of major composition change with unusual dominance of cyanobacteria. This shift was likely associated with the smoke and ash deposition from the Caldor Fire.

- The lake level was below the natural rim until the end of 2022. By July 21st, it reached its highest at 6228.3 feet, which was less than one foot below the maximum legal limit. In late summer, normal evaporative loss took hold, and the lake level ended the year at 6227.2 feet above sea level.

- In 2023, TERC had 12,988 visitor contacts through tours, field trips, lectures, and community events, a 46 percent increase over the previous year. This trend is expected to continue with new UC Davis science exhibits in the Tahoe City Visitor Center, which opened in February 2024, and the Kings Beach Visitor Center, which opens on August 15, 2024.

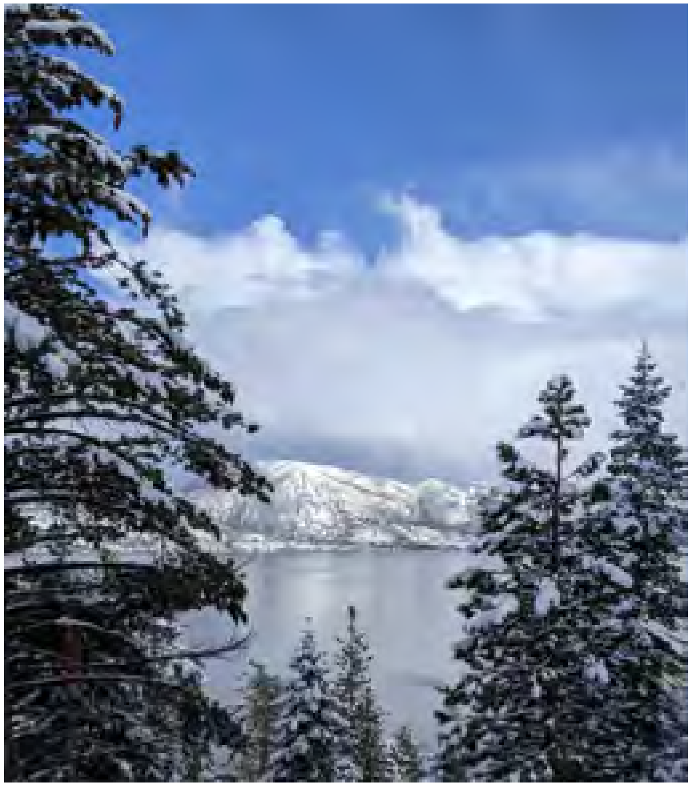
- Lake Tahoe is a laboratory. TERC researchers are advancing new technologies, using and refining equipment such as gliders and the new Wirewalker and analytical tools such as eDNA.

- Keeping hope. The data can seem bleak, but Lake Tahoe has the benefit of dedicated researchers, engaged citizens, and fantastic educational resources that are all working together to ensure its beauty and health for generations to come.

- UC Davis TERC recently joined the Association of Science and Technology Center's Seeding Action Network. Our new "Active Hope for Tahoe's Environmental Future" project aspires to cultivate a culture of environmental stewardship within the Tahoe Basin community. By harnessing existing research and data on Lake Tahoe's environmental health and forming partnerships with local schools, community organizations, and stakeholders, this initiative aims to forge a resilient and sustainable future for the region.

ABOUT LAKE TAHOE AND THE TAHOE BASIN

- Maximum depth: 1,645 feet (501 meters), making it one of the deepest lakes in the world and second deepest lake in the United States
- Average depth: 1,000 feet (305 meters)
- Lake surface area: 191 square miles (495 square kilometers)
- Watershed area: 312 square miles (800 square kilometers)
- Length: 22 miles (35 kilometers)
- Width: 12 miles (19 kilometers)
- Length of shoreline: approximately 75 miles (120 kilometers)
- Volume of water: 40 trillion gallons, plus or minus
- 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, within a few trillion or so
- A single *Daphnia* can consume 100,000 fine particles every hour
- In 2022, there were less than three billion *Mysis* shrimp, potentially setting the stage for the rebound of the cladoceran population and the continuation of clarity improvement in 2023
- 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 exits at Tahoe City, flows through Truckee and Reno, and terminates in Pyramid Lake, Nevada
- Number of monitoring stations TERC utilizes in the Tahoe Basin: 225
- 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



Alison Toy, UC Davis TERC

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 conducted continuous, year-round scientific monitoring of Lake Tahoe, creating the foundation on which restoration and stewardship efforts can be based.

TERC's activities are conducted out of permanent research facilities in the Tahoe Basin and at the University's main campus in Davis, California, about 100 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 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. The field station also houses the CITRIS Environmental Robotics Lab @ Tahoe. Tahoe City is the mooring site for our research vessels, the *R/V John LeConte* and the *R/V Bob Richards*. The *R/V Ted Frantz* operates out of Clear Lake, California and the *R/V Tom* and the *R/V Martini* are currently based in Davis, California. Malyj Manor, a 4-bedroom house in Tahoe City, provides short term housing for students and visiting researchers.

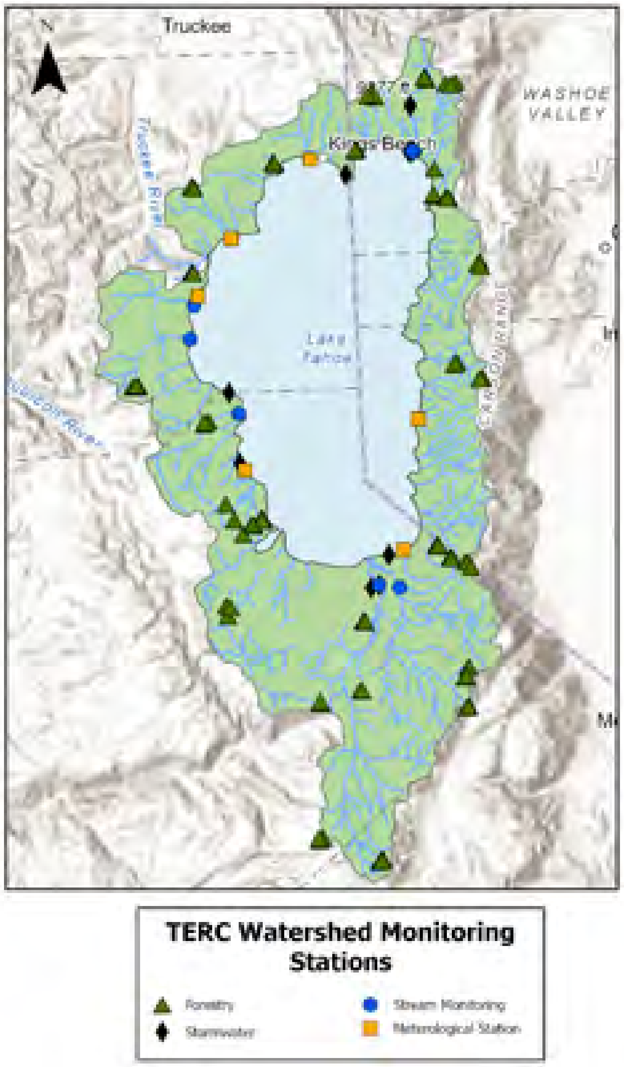
Additional laboratories and offices are located on the UC Davis campus at the Center for Watershed Sciences, Ghausi Hall and in Wickson Hall.

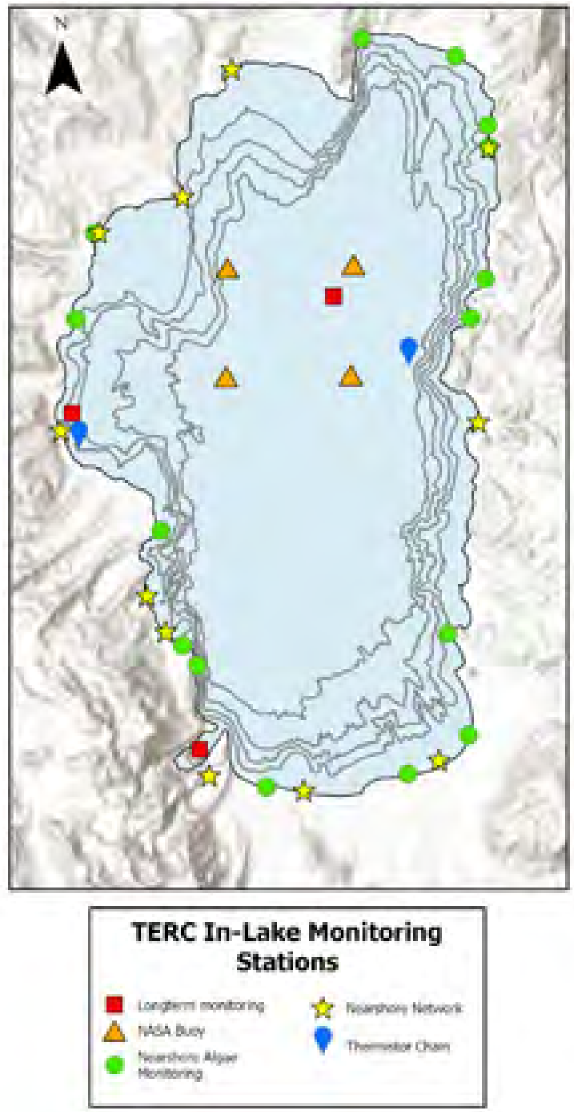
At locations throughout the basin, we have sensors continuously reporting on the health and well-being of the lake and its environs, all contributing to making Lake Tahoe the smartest lake in the world.

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

- Information for potential students, staff, faculty, research collaborators, and visitors;
- Access to near-real-time data sensors;
- TERC 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 2024

SCIENCE TO SAVE LAKES

UC DAVIS
Tahoe Environmental
Research Center

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Introduction

Lake Tahoe's iconic beauty and clarity are in danger. Challenges presented by aquatic invasive species, an increase in particle and nutrient introduction, changes in phytoplankton and zooplankton populations, and the overlying effects of climate change put the lake under constant shifting pressure. This report aims to explain how these factors affect the lake and to give hope that it is not too late. Everyone who loves the lake can take action to improve the outlook for Lake Tahoe and beyond.

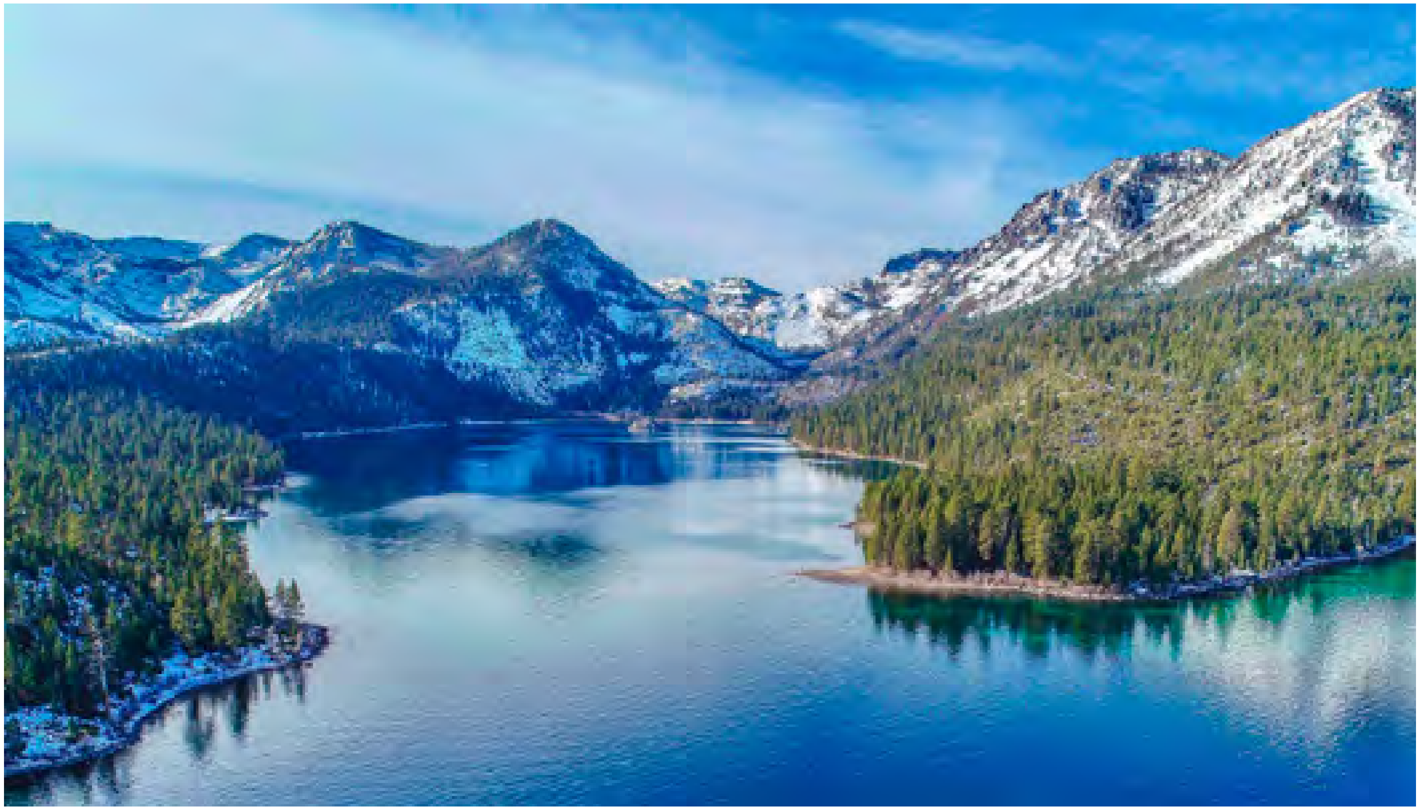
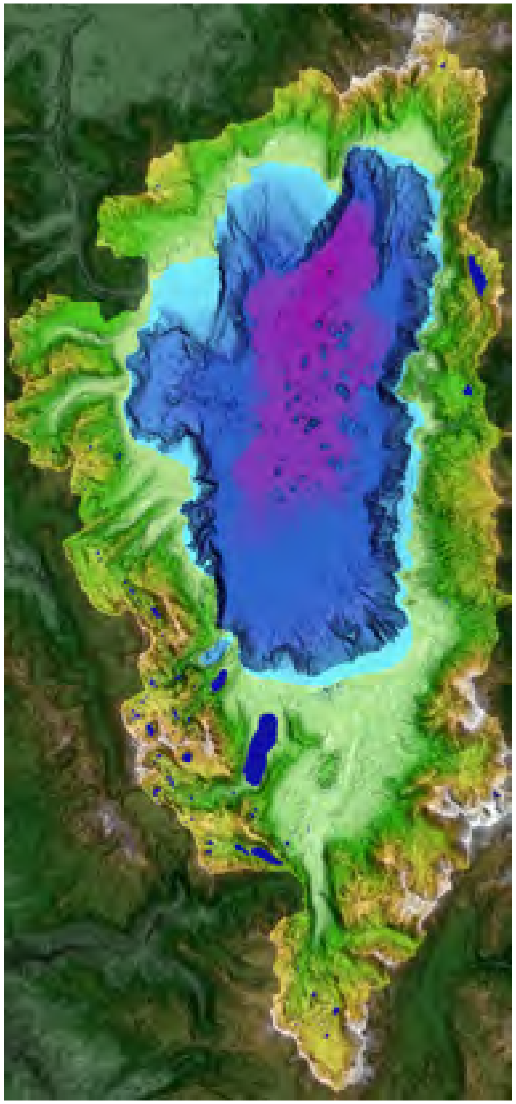


Figure 1. Emerald Bay and the surrounding peaks, the morning after a light dusting of snow (Brandon Berry, UC Davis TERC).

Climate Change has no Borders

Rachel Carson's classic book *Silent Spring* (1962) was a call to arms for a generation to protect our waterways. It led to better stewardship of our lakes and rivers by point source reduction of nutrients and contaminants. More than sixty years later, we continue to face similar challenges she described but are also faced with the ever-growing pressures that climate change presents. From wildfire smoke blowing south last summer from Northern Canada to regional heat waves breaking new records this year to harmful algal blooms (HABs) affecting lakes and rivers across the country, the problems we face today cross state and national boundaries.

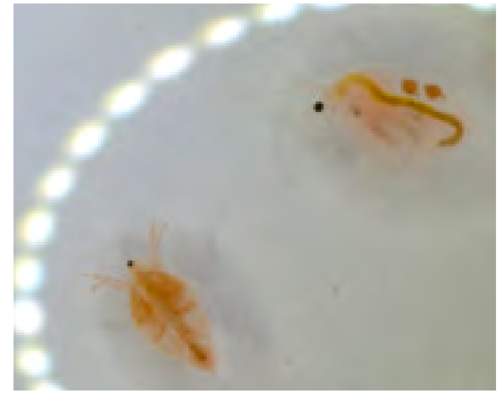
Lake Tahoe (Fig. 2-4) is subject to these same local, regional, and international climatic shifts, which researchers from Tahoe Environmental Research Center (TERC) see in the long-term records curated by TERC since 1968. These changes affect all aquatic, terrestrial, and atmospheric ecosystems, from warming waters to impacted forests to changing rain on snow events. However, people's passion and engagement for the lake and its watershed means it is also a flagship for stewardship and engagement. The lessons and tools we develop through our research at TERC can be widely applied to help protect freshwater across the Sierras, the State, nationally and internationally.



(Clockwise from Top Left) Figure 2. A bird's eye view of the Tahoe watershed and lake bathymetry (Steven McQuinn); Figure 3. Wildfire smoke causes a bright red sunset in Tahoe Vista (Alison Toy, UC Davis TERC); Figure 4. Thick layer of metaphyton washes up on a Lake Tahoe Beach (Katie Senft, UC Davis TERC).

How Does Climate Change Drive Ecosystem Shifts?

Warming water and air temperatures, changes to watershed hydrological patterns, and different chemical conditions are all examples of climate change-driven shifts happening within the lake and watershed. Every ecosystem is in balance, and these shifts will transition the ecosystem to a new balance. An example of this is the proliferation of harmful algal blooms (HABs) (Fig. 5) across California, with Lake Tahoe experiencing its first documented HAB in 2021. These shifts are occurring at all trophic levels in the lake, from the smaller cyanobacteria to the chlorophyll-producing algae (both considered as different forms of phytoplankton) to the zooplankton that include cladocerans (Fig. 6)and copepods (Fig. 7) that graze on the phytoplankton. As these tiny creatures sit at the base of the lake's food web, any significant shifts in population composition and diversity can have wide-ranging ripple effects on the rest of the lake's ecosystem.


Clockwise from Top Left: Figure 5. Surface expression of a HAB event in Clear Lake, CA (UC Davis TERC archives); Figure 6. Daphnia a native cladoceran (UC Davis Tahoe Science Center); Figure 7. Diaptomus a native copepod (UC Davis Tahoe Science Center).

How Does Climate Change Drive Ecosystem Shifts?

Cyanobacteria

Algae or phytoplankton are a naturally occurring simple plant that makes up the base of Tahoe's (and any lake's) aquatic food web. In 2021 and 2022, there was a shift in Tahoe's algae composition, with cyanobacteria dominating algae collected from sampling locations around the lake. Though cyanobacteria are a normal part of most lakes' algae, under some circumstances, some species form HABs that contain toxins that can harm humans and animals. Toxins that these blooms could produce include microcystins, neurotoxins, and hepatotoxins, which could produce reactions such as rashes, severe respiratory distress, or even decreased liver or brain function.

As HAB events are so rare in Lake Tahoe, they are not currently being studied locally by TERC. However, TERC is engaged in a multi-year research study at Clear Lake, CA where HAB events occur annually (Fig. 5, 8-9). This study is focused on understanding the dominant processes in the Clear Lake watershed and within the lake itself that are negatively impacting the rehabilitation of lake water quality and ecosystem health. Since December 2018, TERC researchers have collected monitoring data throughout the Clear Lake watershed to better understand the dominant physical, chemical, and biological processes controlling lake water quality. More information can be found at https://clearlakerehabilitation.ucdavis.edu/.

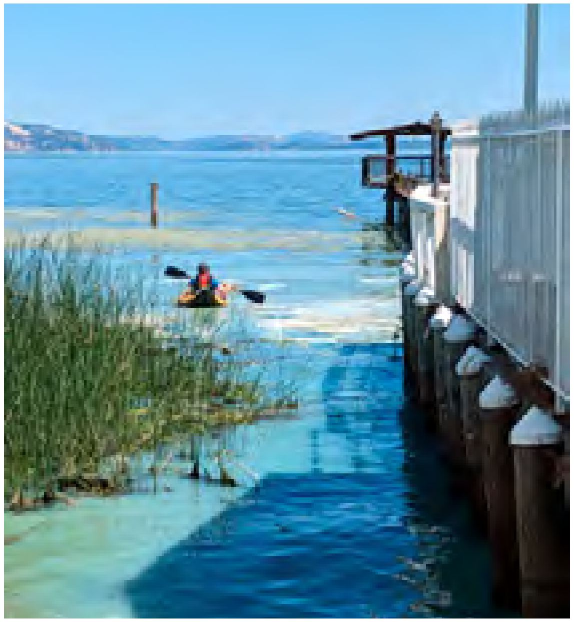


Figure 8. A TERC researcher samples a HAB event in Clear Lake, CA, with a kayak (UC Davis TERC).

Figure 9. Surface expression of a HAB event in Clear Lake, CA (UC Davis TERC).

How Does Climate Change Drive Ecosystem Shifts?

Phytoplankton

In addition to the infrequent occurrence of HABs, Lake Tahoe has also been witness to changes in the phytoplankton assemblage (the distribution of the dominant species). Since 2017, there has been a significant shift in the dominant phytoplankton species (Fig. 10). While *Cyclotella*, known to impact clarity, are still present, there has been a notable increase in the *Synedra* population. Researchers are trying to understand the drivers of these shifting population dynamics. While these diatoms are significantly larger (40 – 100 μm) than *Cyclotella* (5 – 7 μm), they may be playing a role in the continued reduction in clarity during the summer months by changing the optical properties of the water when they grow.

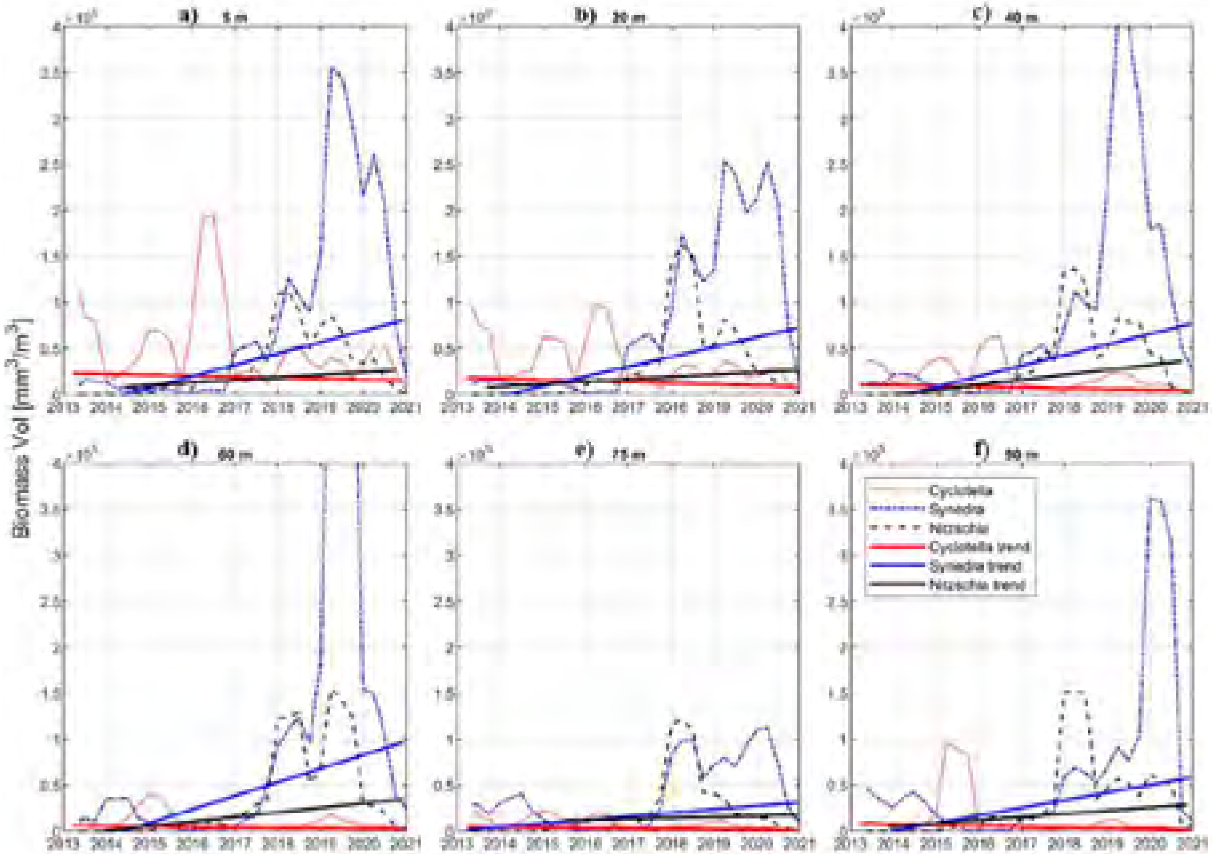


Figure 10. Biomass volume (from cell counts) of dominant genus Cyclotella (red), Synedra (blue), and Nitzschia (black), at a) 5 m, b) 20 m, c) 40 m, d) 60 m, e) 75 m, and f) 90 m. (McInerney, 2024).

How Does Climate Change Drive Ecosystem Shifts?

Nearshore Algae: Metaphyton and Periphyton

Nearshore algal blooms are increasing in freshwater bodies around the world, worsened by the impacts of climate change, nutrient pollution, and the introduction of non-native species. Warming waters enable algae to grow faster, and increased nutrient inputs from a lake's watershed can further fuel algae growth. Invasive species such as Asian clams, which will be discussed on page 6.13, are now established in sandy areas of Tahoe's shoreline and excrete nutrients that can also exacerbate algae growth. In recent years there has been concern that the growth of attached algae (periphyton) and floating algae (metaphyton) are increasing along Lake Tahoe's shoreline, but quantifying changes in nearshore algae is difficult due to its patchiness in space and time. Periphyton along Tahoe's nearshore has been monitored by TERC for decades by snorkeling or SCUBA diving at fixed locations (Fig. 11-12). Monitoring metaphyton has been challenging due to the mobility of the species. Current monitoring has not been sufficient to quantify the changes in metaphyton. TERC's new comprehensive nearshore algae monitoring plan seeks to fill this gap in knowledge.

Figure 11. TERC diver sampling metaphyton in Lake Tahoe (Brant Allen, UC Davis TERC).

Figure 12. Periphyton sampling in Lake Tahoe by TERC research divers (Katie Senft, UC Davis TERC).

How Does Climate Change Drive Ecosystem Shifts?

Nearshore Algae: Metaphyton and Periphyton

In 2023 and 2024, TERC researchers augmented the historical nearshore algae monitoring program by adding aerial monitoring techniques to identify where, when, and how much algae is growing along Tahoe's shoreline. Aerial imagery was collected approximately monthly from 15 shoreline areas using an aerial drone (UAV) and from the entire Tahoe shoreline via helicopter. Images were then used to estimate the spatial areas covered in algae using machine learning models (Fig. 13-14). When combined with ground-truthing and sample collection for algal species composition and biomass, this integrated approach improves monitoring nearshore algae in Tahoe and other clear-water lakes worldwide.

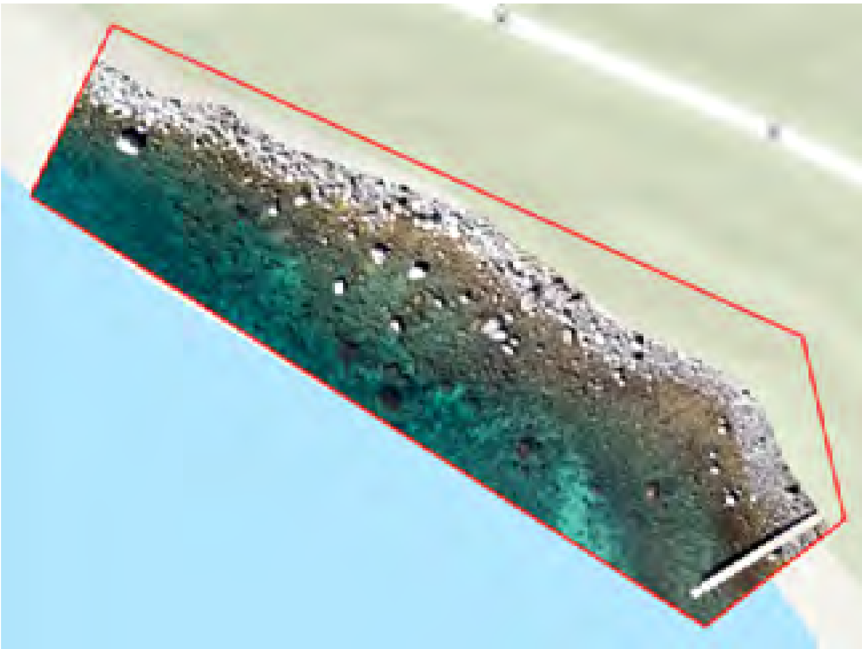


Figure 13. A sample of collected drone imagery of the Lake Tahoe nearshore (Brandon, Berry, UC Davis TERC).

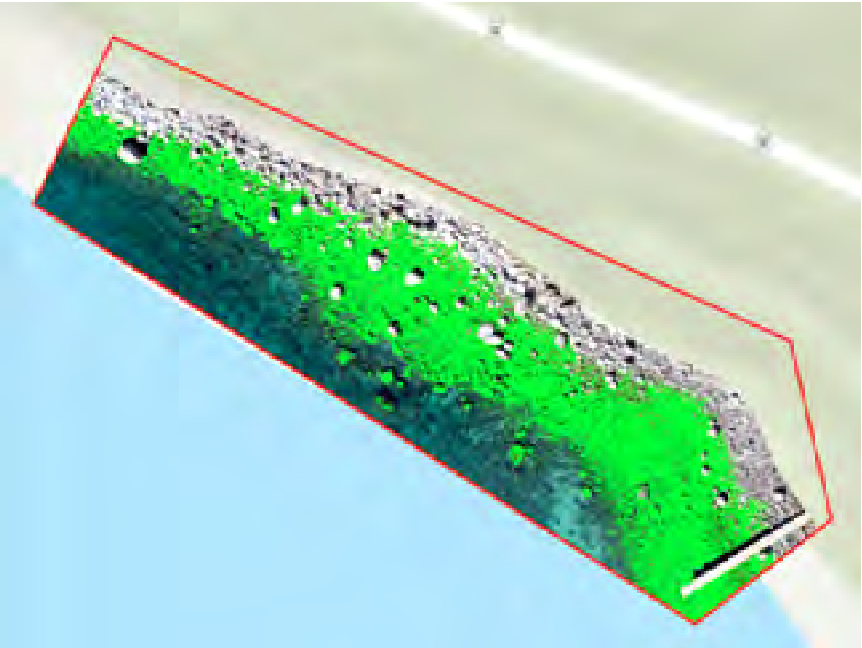


Figure 14. A sample of classified drone imagery of the Lake Tahoe nearshore delineating the presence of periphyton (Brandon, Berry, UC Davis TERC).

How Does Climate Change Drive Ecosystem Shifts?
Zooplankton

In recent years, much attention has been paid to the role of *Mysis* shrimp and their potential impact on the clarity of Lake Tahoe. The decline in the population numbers seen and reported in 2022 has since showed a slight recovery beginning in 2023. There also appears to be shifts in other zooplankton numbers. There have been spikes in the populations of native cladocerans (e.g. *Daphnia* or *Bosmina*) and copepods (e.g. *Diaptomus* or *Epischura*; Fig. 15) that have not been seen in the last decade. Similar to the shifts in phytoplankton numbers, the drivers of these dynamics, such as the reduction in *Mysis* numbers in 2022, are unclear, but each change has a ripple effect through the complex ecosystem of the lake. These changes to the central trophic levels of the ecosystem will require continued monitoring to quantify the long-term impacts on lake water quality.

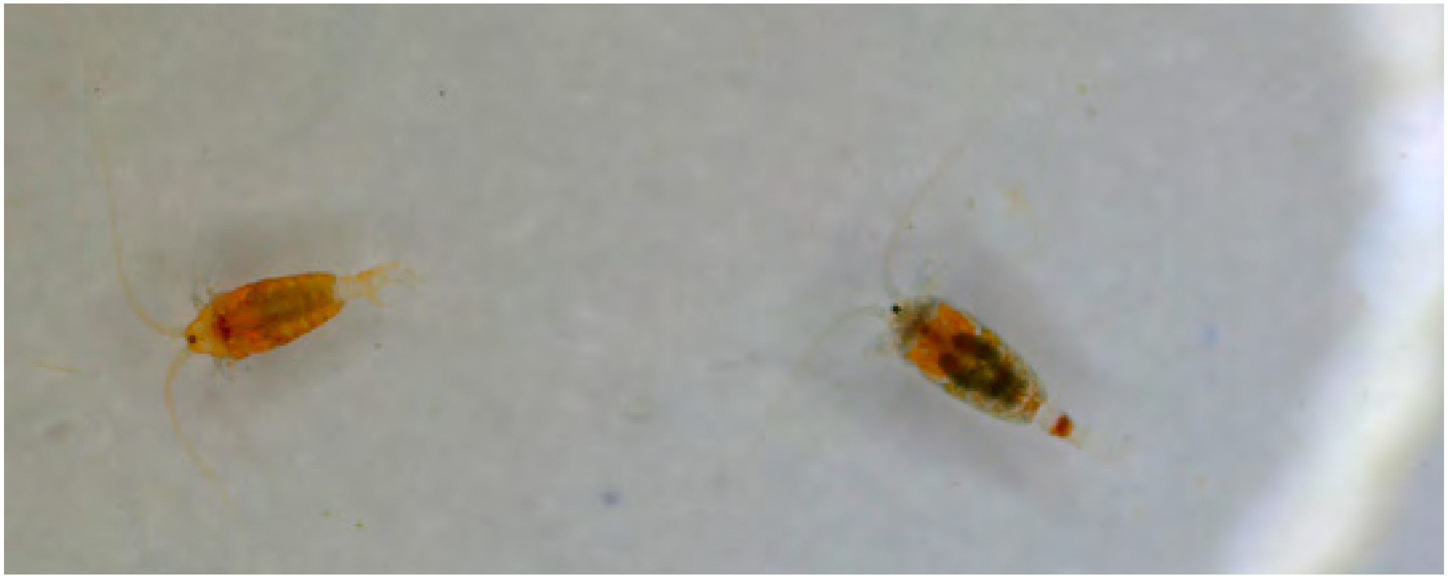


Figure 15. Two native copepods are found in Lake Tahoe, Diaptomus (left) are bright orange and Epischura (right) are opaque grey (UC Davis Tahoe Science Center).

How Does Climate Change Drive Ecosystem Shifts?

Zooplankton

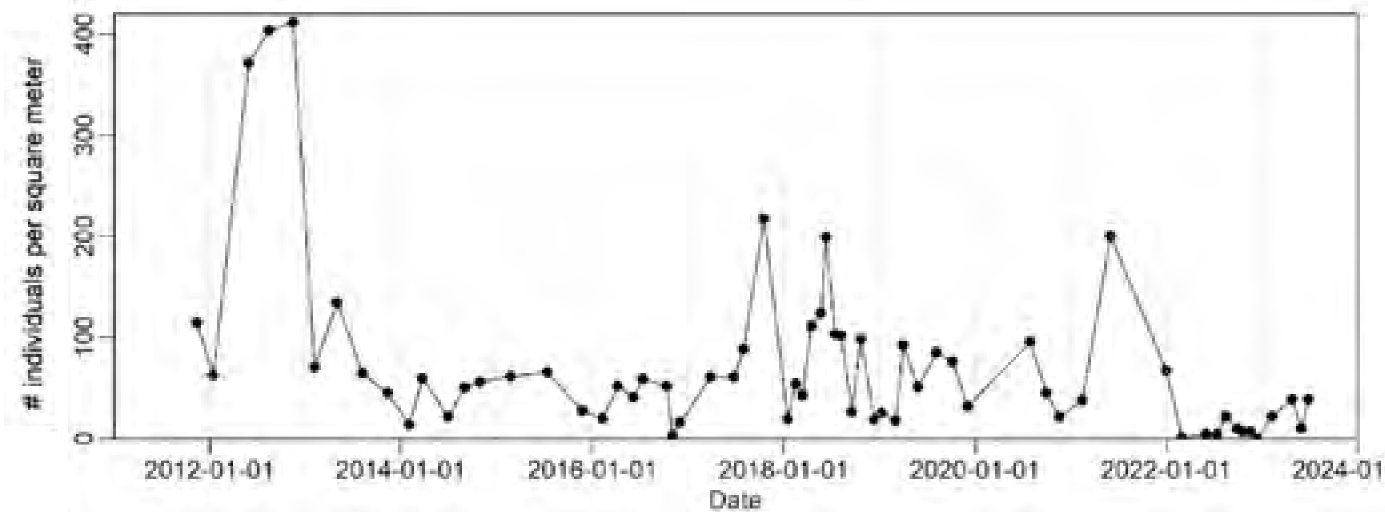


Figure 16. Mysis density in Lake Tahoe from December 2012 to June 2023. The presence of Mysis shrimp, which are a non-native species that were originally intentionally introduced to the lake in the 1960s, has been associated with a reduction in lake clarity due to their negative impact on the native food web.

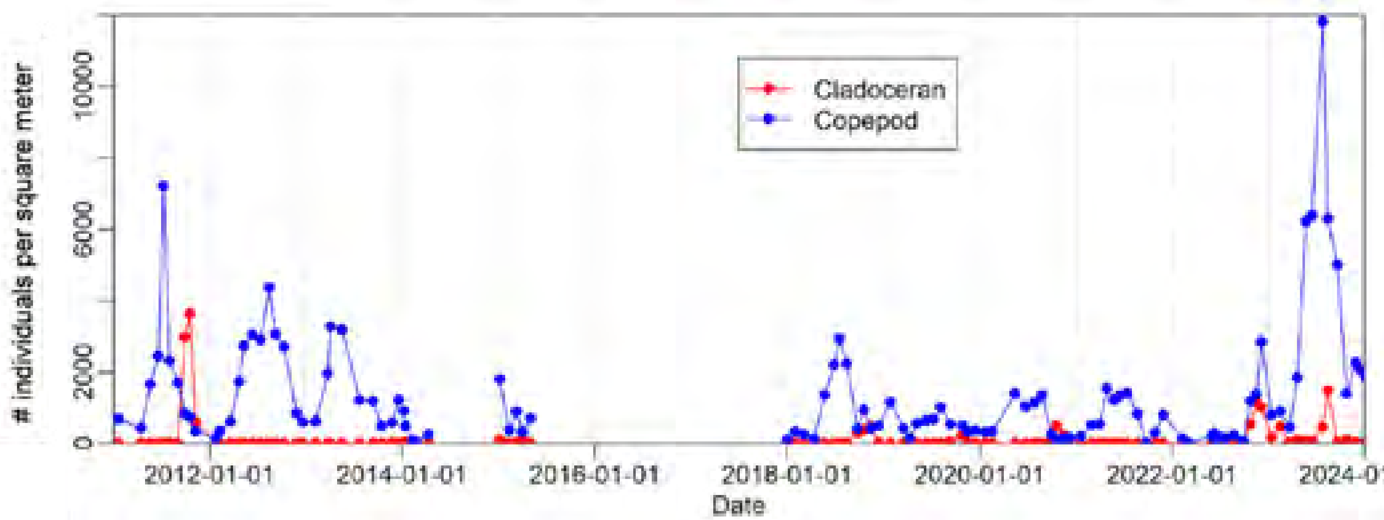


Figure 17. Cladoceran and copepod densities in Lake Tahoe from December 2012 to December 2023. The recent spike in populations indicates that fundamental changes are occurring in the lake, and more research is required to understand the cause and long-term implications.

2023 Lake Clarity

Clarity is measured as the depth to which a 10-inch white disk, called a Secchi disk (Fig.18), remains visible when lowered into the water. These measurements have occurred regularly since 1968, providing a long-term record of change. In 2023, UC Davis scientists took 25 readings at Lake Tahoe's long-term index station (LTP station) and 13 readings from the mid-lake index station (MLTP) that were deemed acceptable (See Appendix 11.1). View the historic clarity readings from 1968-2023 at https://portal.edirepository.org/nis/mapbrowse?scope=edi&identifier=1340.

More than 80 organizations, including government agencies, nonprofits, and research institutions, are working in collaboration with scientists to improve Lake Tahoe's water clarity and ecological health under the Lake Tahoe Environmental Improvement Program, or EIP, which is one of the most comprehensive, landscape-scale restoration programs in the nation. EIP partners are helping meet Total Maximum Daily Load (TMDL) reduction targets of fine-sediment particles and nutrients by reducing pollution through improved roadway maintenance and erosion control on roadways and private properties.

Observations of lake clarity for the 2023 calendar year show the continuing trends of improving clarity conditions during the winter (December through March) months (10th highest in the historical record and highest since 1983) and deteriorating conditions during the summer (June through September) months (5th lowest in the historical record). The annual average decreased from 71.8 ft. (21.9 m) in 2022 to 68.2 ft (20.8 m) in 2023, making it the 10th lowest observed annual average in the historical record. However, the value appears level as a long-term average.

Figure 18. The Secchi disk begins it's descent down the water column for a clarity reading (Brandon Berry, UC Davis TERC).

Figure 19. Winter months show an improving clarity of Lake Tahoe (Katie Senft, UC Davis TERC).

How Does Climate Change Affect Clarity?

Winter Clarity

The observed high winter clarity of 91.8 ft (28.0 m) in 2023 is partly the result of complete lake mixing (turnover). Deep water mixing plays a critical role in winter clarity as clearer bottom waters are mixed in with surface waters. The highest reading of 123 ft (37.5 m) on March 2, 2023, is the twelfth highest in the historical record and the second highest in the last 20 years. Full turnover occurred around February 26, 2023.

As the lake's ability to mix is a crucial component to the improved winter clarity measurements, this is one of the ways that climate change can negatively impact the long-term clarity of Lake Tahoe. Historical data shows that climate change is increasing air temperatures around Lake Tahoe. Increased air temperatures lead to increased temperatures in the lake's surface waters. The difference between the temperatures of the surface water and the deep water creates stratification in the lake. This means that the colder, clearer waters at the bottom of the lake cannot mix with the warmer, shallow waters. Climate change could make this stratification period longer every year, eventually preventing mixing altogether. This would have a devastating impact on the long-term clarity of Lake Tahoe's surface water.

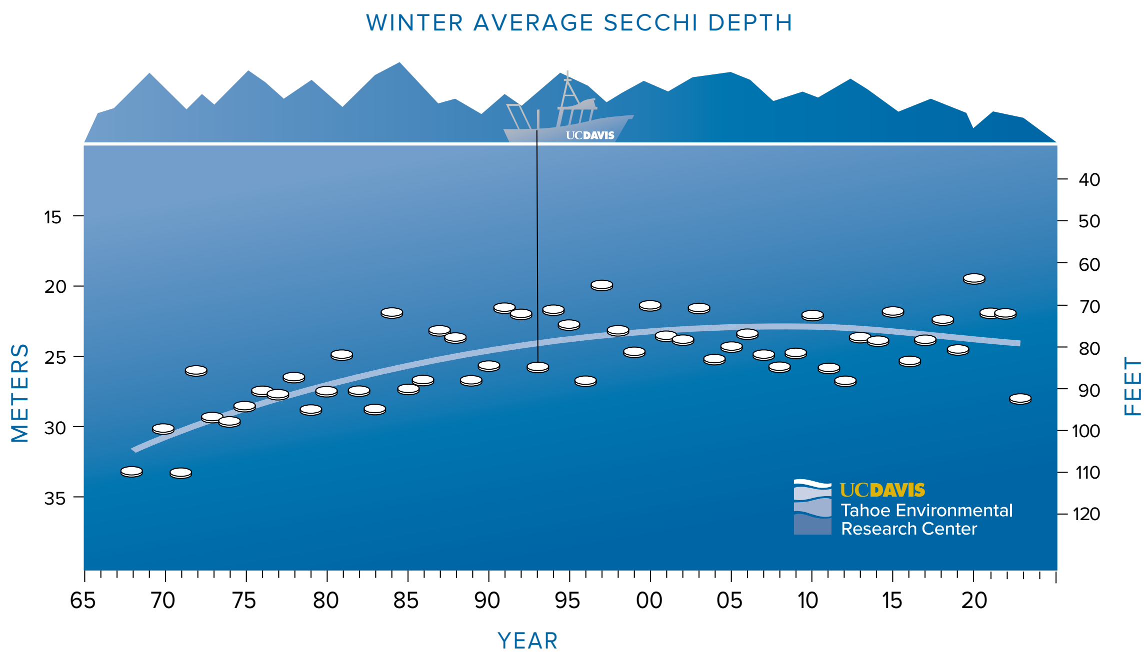


Figure 20. Winter (December – March) average Secchi depth as a measurement of lake clarity (UC Davis TERC).

How Does Climate Change Affect Clarity?
Summer Clarity

Low summer clarity of 53.5 ft (16.3 m) in 2023 primarily results from an increased number of particles in the surface waters. These particles are being discharged from the watershed following the melting of the large snowpack received in 2023. This is exemplified by the rapid decrease in clarity in May 2023, when stream discharge from the watershed neared the maximum. Fine particles (1-6.73 µm in size) in streams around the basin correlate with observed turbidity measurements.

There are factors outside of air and water temperature that are potentially impacting clarity. Future research on lake clarity should focus on understanding the processes associated with short- and long-term trends. Observed changes over the last decade in the zooplankton and phytoplankton communities (e.g. algal growth) are potentially playing a role in clarity. Particles resulting from microplastics may also result in changes in water optical properties but are poorly understood at small sizes (e.g., <5 µm) in Lake Tahoe. The relative contributions of each of these factors are the focus of ongoing research.

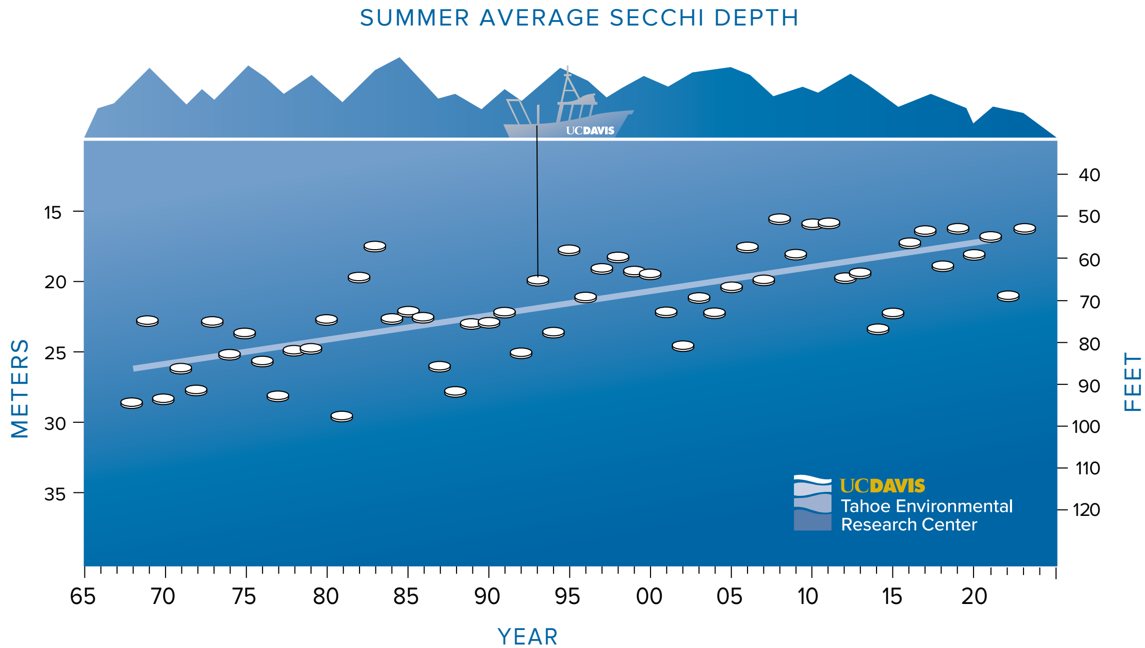


Figure 21. Summer (June – August) average Secchi depth as a measurement of lake clarity (UC Davis TERC).

What Role Does Climate Change Play with Aquatic Invasive Species?

Aquatic Invasive Species (AIS) are non-native species, plants, or animals, that can have devastating environmental, recreational, and economic impacts and potentially affect human health. AIS populations can result from accidental or intentional introduction and ecological shifts in aquatic ecosystems.

TERC is concerned with any invasive species in Lake Tahoe and the surrounding watershed, and examples of both animals and plants will be discussed below. However, before discussing any individual species, it is important to understand that changing lake conditions allow new species to establish themselves that might not have previously been able to. Warmer water makes it increasingly easier for AIS to establish themselves in Tahoe.

The best methodology to prevent the spread of AIS is thoroughly cleaning, draining, and drying all gear that touches the water, including boats, kayaks, inflatables, and fishing gear, before it is put into the lake. Boat inspection and vigilance are necessary to avoid AIS spreading around and between water bodies.

The Asian clam (*Corbicula fluminea*) is identified as an AIS that is well-established in Lake Tahoe. First recorded in Lake Tahoe in 2002, Asian clam densities of up to 5,000 individuals per square meter have since been reported, and its range has expanded substantially throughout much of the Lake's southeastern area. Asian clams have continued to spread to the north end of the lake, transported through currents in the lake and other vectors such as boat traffic. The Asian clam often dominates the benthos (aka life on the lake floor), where it occurs in Lake Tahoe. It is associated with, but not necessarily the cause of, filamentous algal blooms and the deposition of clam shells in the nearshore, which is considered a degradation of the aesthetic conditions in Lake Tahoe.

Figure 22. Examples of adult Asian Clams (Corbicula fluminea) (Marion Wittmann, UC Davis TERC, 2012).

Figure 23. Sediment in Marla Bay circa 1980 (Brant Allen, UC Davis TERC).

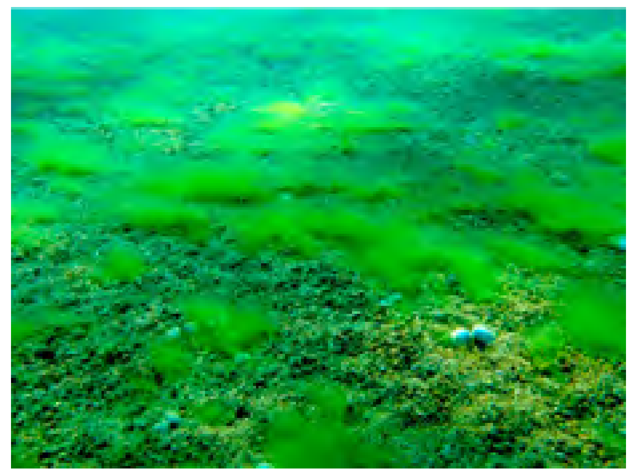


Figure 24. Sediment in Marla Bay circa 2010. Filamentous algae blooms often occur near established populations of Asian clams as a result of excreted nutrients from these animals (Brant Allen, UC Davis TERC).

What Role Does Climate Change Play with Aquatic Invasive Species?

The newest identified species in Lake Tahoe is the New Zealand mudsnail (*Potamopyrgus antipodarum*; NZMS), an AIS well-known for its ability to rapidly spread throughout water systems that were detected in Lake Tahoe in September 2023. In North America, the NZMS was likely introduced in the Great Lakes in the 1990s, and since then, it has rapidly expanded its range to cover most of the Great Lakes region and the American West. NZMS have multiple known ecosystem impacts that may threaten the Lake Tahoe basin. NZMS have the potential of directly affecting the water quality of Lake Tahoe. NZMS can increase nutrient (nitrogen) fixation rates by changing algae communities through grazing behaviors. This change in nutrient dynamics may eventually increase the likelihood of future filamentous algal blooms throughout the lake. Additionally, because of their high biomass (e.g. dense populations), NZMS can intake the majority of gross primary production in streams and dominate nitrogen and carbon cycling through grazing and excretion. NZMS can also be a threat to native macroinvertebrates, such as the native pea clam (Fig. 25) potentially altering the food web in Lake Tahoe.

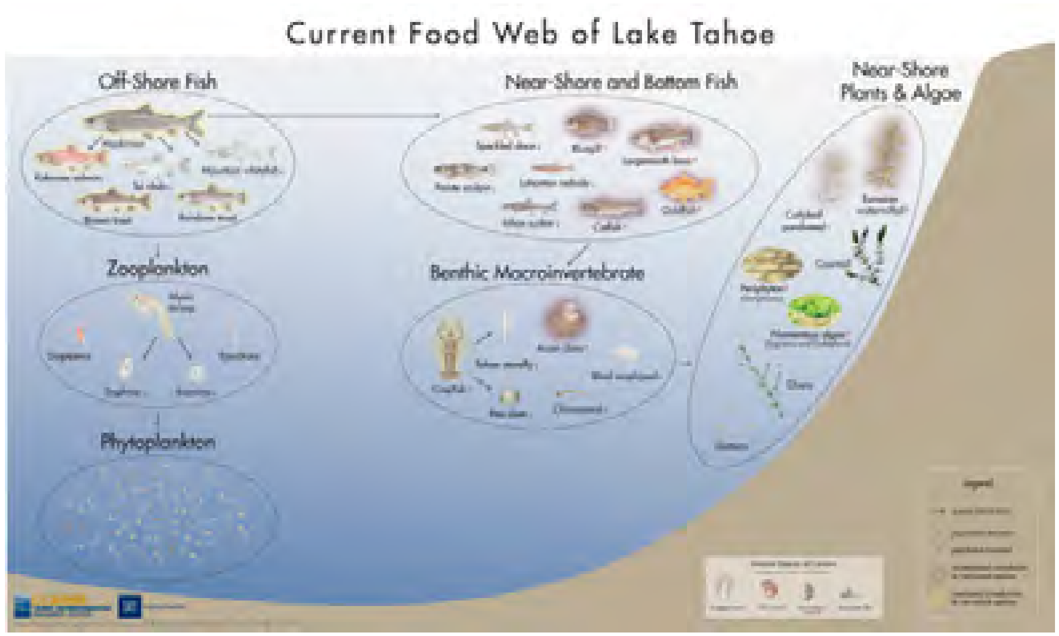


Figure 25. Ecological food web of Lake Tahoe (UC Davis TERC archive) The presence of the NZMS has the potential to disrupt the delicate balance of the established food web, potentially causing long-term and irreparable damage to the lake's ecosystems.

What Role Does Climate Change Play with Aquatic Invasive Species?

Advantageous reproductive cloning strategies allow for the secondary production of NZMS to be exceptionally high. Because they reproduce by cloning, it only takes one NZMS to establish a whole new population, so the species is easily spread and can easily monopolize resources in new waterbodies.

Early detection and monitoring of NZMS is vital for the effective management of populations by water managers (e.g. the Tahoe Regional Planning Agency; TRPA), but available sampling and analysis methods lack the resolution needed to reliably identify their presence in the water. Highly sensitive detection of NZMS environmental DNA (eDNA) from filtered water samples offers a potentially reliable means to detect the species' presence early and simultaneously monitor for other AIS. eDNA encompasses genetic material released into the environment through feces, skin, mucus, and gametes (reproductive cells). Studies utilizing eDNA have demonstrated lower false-negative detection rates compared to traditional survey methods, making it effective for detecting species present in low abundance, such as recently introduced AIS. eDNA is an emerging technique that TERC, in partnership with collaborators across campus, is working on developing the application of at Lake Tahoe.

Figure 26. Full-grown New Zealand mudsnails with a dime to scale, the newest invasive species in Tahoe, was found in the fall of 2023. The tiny species is easily spread on gear and equipment used in infected lakes. It can only take one NZMS to start a new population, so ensuring all equipment that touches the water is cleaned, drained, and dried before going to another water body is crucial to prevent their spread (U.S. Geological Survey).

What Role Does Climate Change Play with Aquatic Invasive Species?

Figure 27. A TERC research diver sampling Curlyleaf pondweed in Lake Tahoe (Brant Allen, UC Davis TERC).

Not all AIS are animals like the Asian clam or the NZMS; instead, they are plants or aquatic invasive weeds. The two most common in Lake Tahoe are Eurasian watermilfoil and Curlyleaf pondweed, which were initially introduced into the Tahoe Keys and have spread to many locations around the lake. Both plants produce dense growth that can crowd out native species, disrupt recreationalists, and increase algae growth. One of the challenges with trying to control these species is their manner of reproduction. For example, the Curlyleaf pondweed undergoes asexual reproduction by producing vegetative shoots called turions. When these turions are established in a new zone, they can seed new plant growth that will quickly colonize an area. Eurasian watermilfoil spreads easily because all it takes is a single fragment of the stem to start a new colony.

Monitoring and rapid response are critical for controlling the spread of these plants. In Emerald Bay, ongoing efforts by the TRPA and its partners are working to control Eurasian watermilfoil through annual diver surveys and rapid treatment and removal as soon as new plant growth is detected. This surveillance and treatment method is costly and labor intensive but necessary as boats can bring in fragments of these plants from other parts of the lake. In the Tahoe Keys, multiple methodologies are being tested to control the population of invasive plants and prevent their spread, including treatment with herbicides and ultraviolet light to kill the plants and deployment of bubble curtains to prevent the spread of turions and stem fragments outside of the marina area. Exploration of all these methods are part of ongoing research and management strategies around the Basin.

How does Climate Change Affect Atmospheric Deposition and Nutrient Levels?

Wildfire season in California and beyond is becoming longer and more intense due to the effects of climate change. As a result, Lake Tahoe is impacted by increased atmospheric deposition of ash and smoke from regional, national, and sometimes international fires. Scientists, including those from UC Davis studying the effects of wildfire on lakes, recently published a paper (https://doi.org/10.1111/gcb.17367) where they explored the effects of atmospheric deposition from wildfire smoke on the physical, chemical, and biological properties of lakes. In this work, they introduced the concept of the 'lake smoke-day,' or the number of days a given lake is exposed to smoke in a fire season, as a metric to evaluate the exposure of water bodies to changing conditions. It was discovered that 98.9% of lakes in North America experienced at least 10 lake smoke days per year during the study period (Fig. 28).

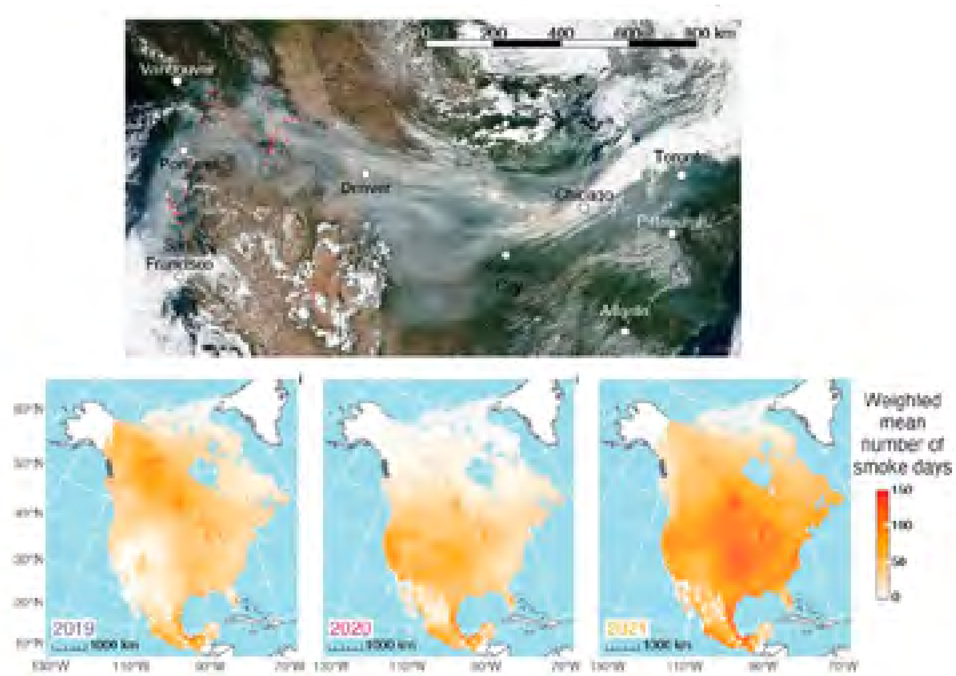


Figure 28. The weighted mean of the number of smoke days experienced across North America for 2019–2021 (Brahney et. al., 2024).

How does Climate Change Affect Atmospheric Deposition and Nutrient Levels?

Many of us recall the recent Caldor Fire (2021), Mosquito Fire (2023), or Royal Fire (2024). Wildfire is part of the reality within the Lake Tahoe watershed. Whether directly in the basin or brought in from afar, the deposition of this ash and smoke causes increases in both phosphorus and nitrogen levels. Research during 2021 and 2022 (Fig. 29), which were impacted by the Caldor and Mosquito fires, respectively, saw phosphorus and nitrogen levels spike at the time of the fires. It is well-established that increased phosphorus and nitrogen levels in Lake Tahoe lead to algae growth and decreased water clarity.

Figure 29. Sampling on Lake Tahoe during the Caldor wildfire event (Shohei Watanabe, UC Davis TERC)

How Does Climate Change Affect Forest Health?

Climate change impacts in the Tahoe Basin are not limited to the lake. The surrounding forest faces pressures from increased temperatures, wildfires, and drought, making the trees more susceptible to pine beetle infestations and fungal pathogens. To combat these trends TERC's Forest and Conservation Biology lab has conducted ecological and genetic studies to develop resilient reforestation strategies for the sugar pine and other 5-needled white pines endemic to the basin. TERC researchers have teamed up with GIS experts and specialists to develop restoration approaches steered by remote sensing technologies and advanced algorithms to develop models to select appropriate microsites for planting locally sourced and diverse seed material to give them the best chance of survival. These integrated approaches can equip land managers with effective adaptive ecosystem restoration tools to respond to extraordinary changes in forested landscapes resulting from climate change, amplify forest resiliency, and facilitate ecosystem recovery.

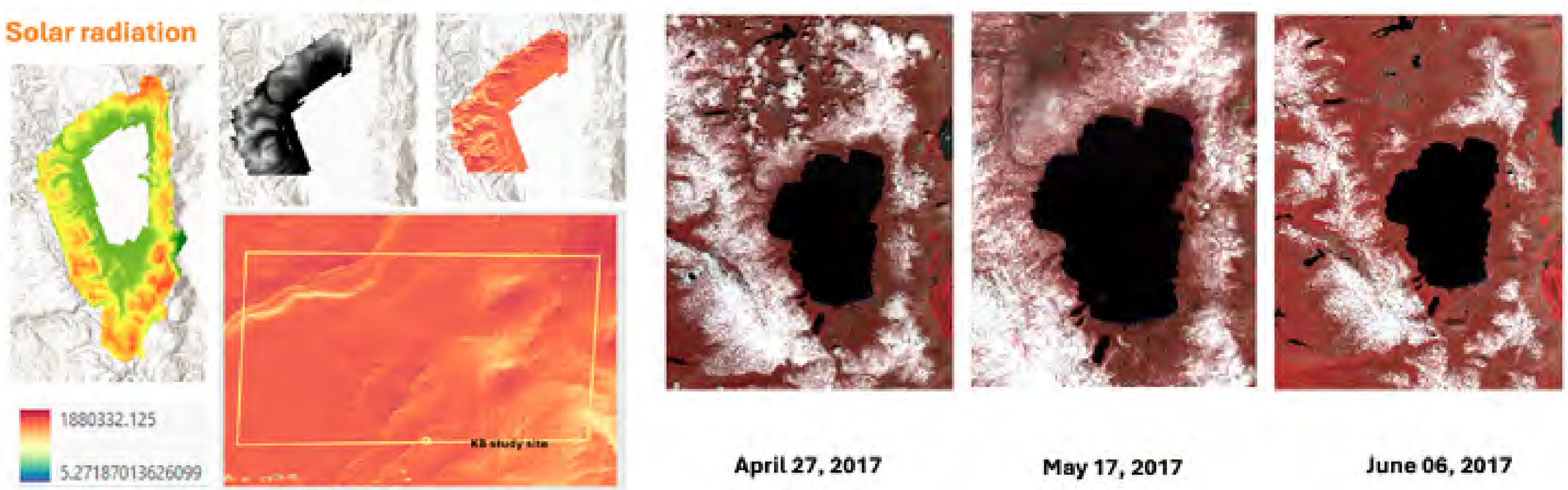


Figure 30. Remote sensing, geospatial data, and mapping products that include solar radiation (left) and late-lying snow (right) (Mui Lay, UC Davis).

How Does Climate Change Affect Forest Health?

This project also establishes a pipeline that recruits and integrates a diverse and equitable workforce into conservation and forest health-related careers by giving California Conservation Corps (CCC) members applied experience in STEM (e.g., restoration, geographic information systems science, plant sciences, and drone technology). Such pipelines are vital to improving our field and training the next generation of forest conservation experts. We will build upon past work and improve project outcomes by strengthening our existing partnership with the CCC, with the goal of fostering a diverse workforce around forestry, restoration, and climate change initiative as we improve restoration strategies. UC Davis and the California Conservation Corps (CCC) are planting trees at Colorado Hill (Monitor Pass area) and Kings Beach on the north shore of Lake Tahoe.

Figure 31. TERC field researcher oversees CCC members planting and watering seedlings at Colorado Hill in the Monitor Pass area (Camille Jensen, UC Davis TERC).

Figure 32. The CCC prepping a planting location in Kings Beach,CA on the north shore of Lake Tahoe (Aaron Vanderpool, UC Davis TERC).

How Does Climate Change Affect Pollinators?

Bees are important pollinators worldwide and in the ecosystems surrounding Lake Tahoe. Dr. Rachel Vannette is Chancellor's Fellow with the UC Davis Department of Entomology and Nematology researching solitary and social bees and their basic biology and life history. The common bees of the Tahoe Basin utilize adaptations to live in this climate including using local flowering plants and specific nesting requirements. Changing management and climate in the Tahoe basin may influence bee-flower interactions. Wildfire and other management practices influence bee communities and their effects on plants.

Dr. Vannette's lab is studying the bacteria and fungi that associate with developing stages of bees. They examine how these microbial communities change as bees develop, and their potential contributions to preservation of bee food (nectar + pollen), bee development, and pathogen protection. There is a great diversity of bee species and not all bee species are social (e.g. living in colonies). Native bees (not honey bees) are most important for maintaining wildflower diversity in Tahoe and some of the bacteria and fungi that live with bees can benefit them and be a source of novel chemistry.

Figure 33. A bumble bee (Bombus) on currant flowers (Rachel Vannette, UC Davis).

Figure 34. A ball of stored pollen that was constructed by a solitary bee (Diadasia) (Rachel Vannette, UC Davis)

Figure 35. A healthy developing larvae in its brood cell, with fungal hyphae lining the cell (S. Christensen, UC Davis).

What New Technologies Can Be Used to Study Climate Change?

One of the strengths of the research at Lake Tahoe is the long-term monitoring observations we've had since 1968. This is one of the longest continuous lake datasets in North America and is required to understand decadal-scale changes in the lake's chemical, biological, and physical conditions.

In an era of rapid technological development, TERC remains at the forefront of developing and applying new technologies to advance our understanding of Lake Tahoe and beyond. In 2020, the Center for Information Technology Research in the Interest of Society (CITRIS) Environmental Robotics Lab @ Tahoe was established. While this group is still relatively small, there is abundant growth potential for collaborations and travel. Core to this initiative has been the use of Autonomous Underwater Vehicles (AUVs) and underwater gliders (Fig. 36). These platforms have been used in Lake Tahoe to understand the dynamics of internal waves (i.e. waves propagating along the thermocline in the lake), aggregation processes of particles, and the horizontal and vertical variability of water quality properties within the lake.

One of the newest technologies funded through philanthropy for work on Lake Tahoe is a new 'wirewalker' system that is planned to be installed in the lake by the end of 2024 (Fig. 37). The principle of operation of this system is that an anchor is tethered to a surface buoy that moves as waves pass by. The resulting wave action causes the positively buoyant profiling platform to winch its way down the line to the specified depth before it releases from the line and profiles back to the surface. The use of wave energy in this way allows for continuous observations throughout the entire water column that will allow TERC researchers to better understand the dynamics of the lake.

Figure 36. TERC PhD student Kenneth Larrieu readying the underwater glider Storm Petrel to study particle dynamics (Sierra Phillips, UC Davis).

Figure 37. An underwater view of a wirewalker platform mid-profile (Del Mar Oceanographic).

What New Technologies Can Be Used to Study Climate Change?

From new observation platforms in the lake to new instruments in the lab, TERC must constantly innovate how we observe our world. Walter Munk was a physical oceanographer at the Scripps Research Institute who coined the phrase 'a century of undersampling' describing physical oceanography in the 20th century. He went on to say, "Advances in oceanography are dependent basically upon new kinds of instrumentation, the future of our science will be sterile unless we can continually find new things to observe and new ways to measure them." TERC and other scientific research organizations must follow this advice to advance the understanding of how systems, such as Lake Tahoe, are evolving in a changing climate.

Figure 38. TERC scientist Steven Sesma making measurements of water quality aboard the UC Davis research vessel (Steven Sesma, UC Davis TERC).

Figure 39. One of five buoys that calibrate NASA satellites and provide real-time data to the TERC Lake Conditions webpage (Alison Toy, UC Davis TERC).

How Can Lake Tahoe Be Used to Study Climate Change Outside of the Basin?

Studying Climate Change Across the Sierras

Although it is unique, Lake Tahoe is only one of tens of thousands of mountain lakes scattered across the mountains of California. While long term datasets like those collected on Lake Tahoe are vital to answering questions about environmental change through time, understanding how and why ecosystems are changing regionally requires a spatial network of lakes. Two smaller lakes within the Tahoe Basin are part of the California Mountain Lake Network (CaMoLaN), a network of 15 lakes scattered throughout the mountains of California established in 2017 by TERC scientist Dr. Adrianne Smits and Professor Steven Sadro. By selecting lakes that span gradients in size, depth, elevation, and latitude, the network provides a broad regional context in which to explore how climate change and other anthropogenic (human-created) processes affect lakes (Fig. 40).

Every year an undergraduate or graduate student field crew backpacks to each lake, spending 2-3 days sampling water chemistry and downloading data from instruments. Each lake contains a mooring anchored at the deepest location with instruments attached at intervals from the surface to the bottom, measuring temperature, dissolved oxygen, conductivity, light, and lake level. High-frequency monitoring data and short-term experiments from the CaMoLaN network lakes help scientists understand how the effects of climate warming, drought, and smoke from wildfires alter lake thermal dynamics, influence rates of lake productivity, cause algal or periphyton blooms, or affect lake food webs. Data from the network has provided vital information about fundamental lake function during the winter when most of these lakes are covered by 3 to 15 feet of ice and snow and how lake productivity is affected by smoke from wildfires, which can blanket the landscape for months at a time. The CaMoLaN network will help scientists understand the extent to which California's mountain lakes are sensitive to environmental change and help develop a predictive understanding that informs lake management.

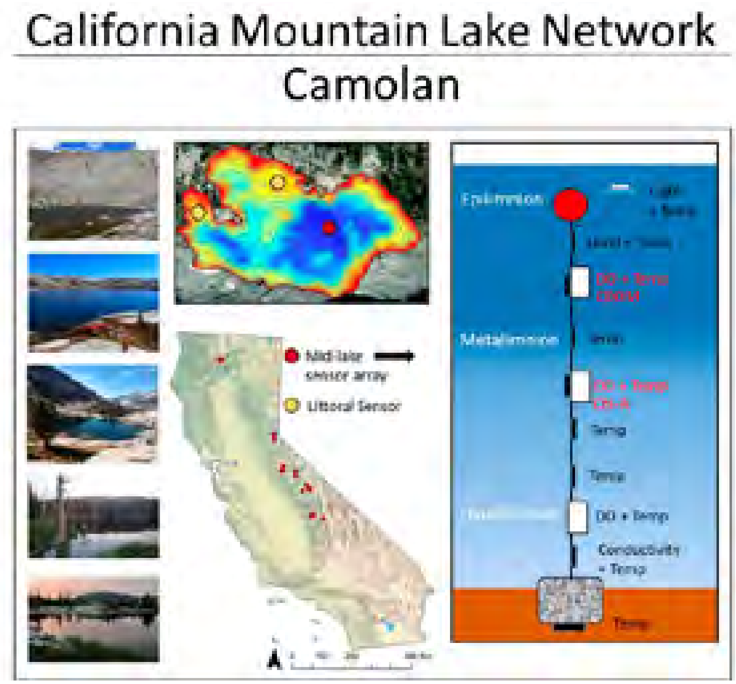


Figure 40. The California Mountain Lake Network provides high-frequency measurements of temperature, oxygen, conductivity, and lake level to characterize fundamental aspects of lake function (Steve Sadro, UC Davis TERC).

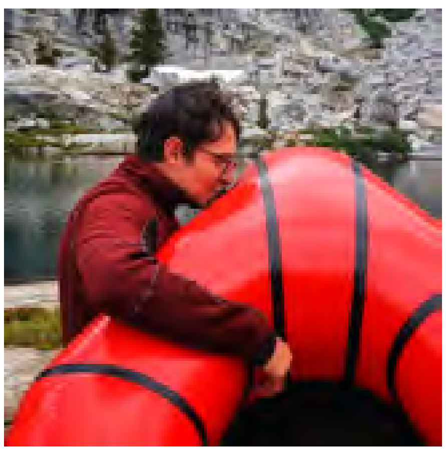


Figure 41. Field technician Mike Gomez inflates the research pack-raft before sampling (Steven Sadro, UC Davis TERC).

How Can Lake Tahoe Be Used to Study Climate Change Outside of the Basin?

Studying Climate Change in the Arctic

Lake Tahoe is an amazing natural laboratory to develop tools to study climate change outside of the Basin. Examples of this include collaborations with NASA for work on their Surface Biology and Geology (SBG) mission examining HABs in freshwater systems and the National Oceanic and Atmospheric Association (NOAA) for glider development for work in the Southern Ocean. Since 2016, TERC has been working with the Korean Polar Research Institute and other partners to develop underwater gliders to understand melting rates and stability of ice shelves (Fig. 42) in Antarctica, with several successful deployments in 2017, 2019, and 2022 in the Amundsen and Ross Seas.

Unfortunately, these environments are extremely high-risk. In 2024, after the previous year of preparation in Lake Tahoe, the glider was lost at sea during the deployment at the Thwaites Glacier (sometimes referred to as the Doomsday Glacier because of the potential impact of its melting on sea level rise). While this is a setback for ongoing work, this is the reality of these environments.

Tahoe as a natural laboratory, can be used to develop instrumentation in addition to observation platforms. In 2023, TERC welcomed a postdoctoral scientist from Switzerland who is using new sensors on gliders to understand the role of turbulence. Turbulence control how well things are mixed in the lake on the scale of the smallest organisms within the lake and the aggregation processes controlling the fate of particles. This work has direct application in Lake Tahoe but is also being used to study epishelf lakes (lakes dammed behind ice shelves) in the Canadian High Arctic (Fig. 43).

Figure 42. UC Davis PhD students participated in helicopter surveys of the Thwaites Glacier located in west Antarctica (Kenneth Larrieu, UC Davis TERC).

Figure 43. The frozen surface of the Milne epishelf lake and glacier on Ellesmere Island, Nunavut, Canadian High Arctic (Alex Forrest, UC Davis TERC).

Impacts Beyond Climate: Litter and Microplastics

Lake Tahoe's challenges are not limited to climate. With approximately 55,000 full-time residents and 15 million visitors annually, the lake also faces the impacts of human-generated litter and microplastics.

Since 2014, the nonprofit League to Save Lake Tahoe has been conducting beach cleanups and documenting the materials it collects. In just over 2,000 cleanups on beaches around the Tahoe basin, volunteers have removed 102,507 pounds of litter. Since 2020, the nonprofit Clean Up The Lake, which performs SCUBA-assisted litter cleanups along the shoreline, has removed over 40,000 pounds of litter from beneath Lake Tahoe's surface. In addition to creating a visual blight on the beautiful landscapes of the Tahoe basin, if left in the environment, the litter can breakdown and create negative impacts on the soils and water quality around the lake. While the impacts of litter breakdown on Lake Tahoe have not yet been studied or quantified, it is a cause for concern that needs to be addressed.

Another recently discovered concern for Lake Tahoe and other freshwater lakes around the world is microplastics. Plastic does not decompose. Instead, it breaks down into progressively smaller pieces. When these pieces become less than 5 mm in size, they are classified as microplastics. A recent study conducted by a coalition of researchers discovered that Lake Tahoe has the third-highest amount of microplastics among 38 freshwater reservoirs and lakes around the globe. Research is ongoing into the source and impacts of microplastics so that researchers can make science-informed recommendations to protect the lake in the long-term. Breaking down the composition of the plastic types sampled resulted in observations of three main classes (polyethylene, polypropylene, and polyesters; Fig. 44)

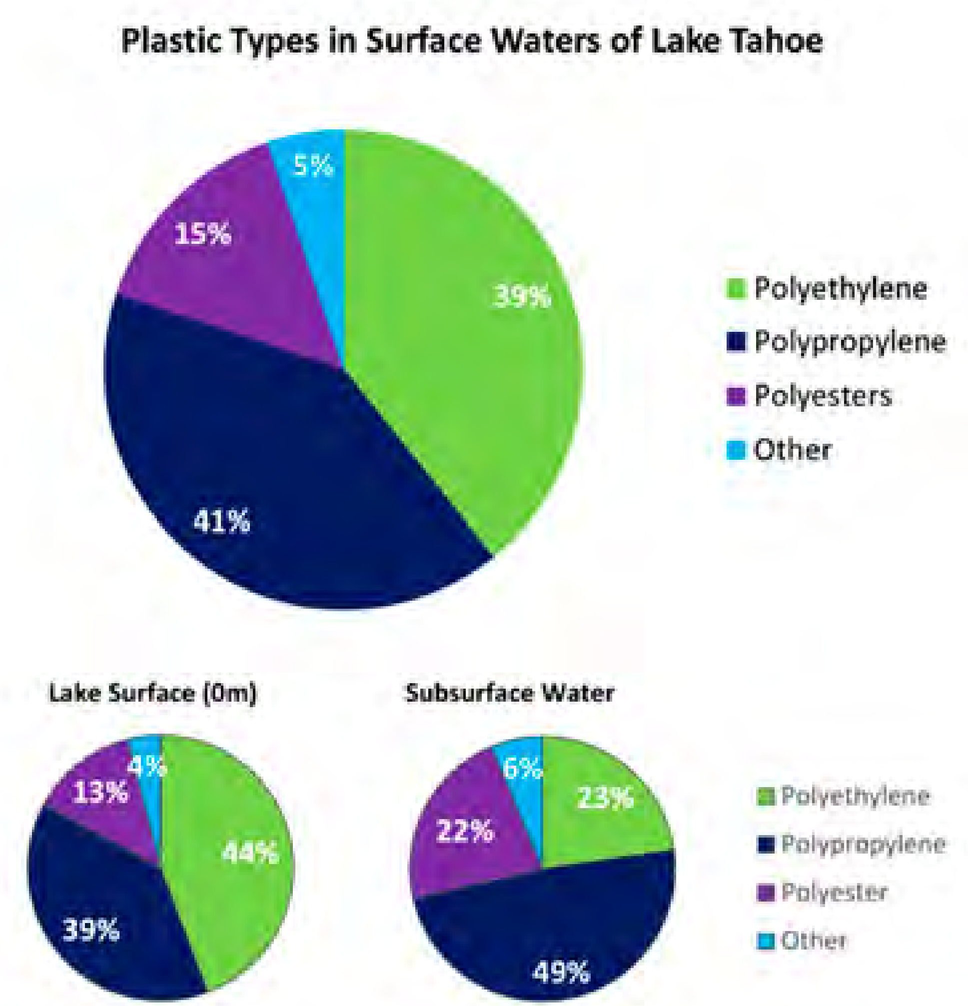


Figure 44. Synthetic polymer (plastic) types of confirmed microplastic particles collected from surface and subsurface waters of Lake Tahoe (Gjeltema et al., 2023).

How Can We Train the Next Generation to Help Mitigate the Impacts of Climate Change?

The Importance of Stewardship Education

Through our education and outreach programs, discussed in the next section, the goal is to provide science-based information about the Lake Tahoe region in order to foster responsible action and stewardship. We provide engaging exhibits, and interactive hands-on educational activities and conduct effective outreach to draw student groups, residents, and visitors to our facilities. Our education programs inspire an interest in environmental sciences, stimulate curiosity, and motivate active conservation and preservation of freshwater resources. We invite broad participation in planetary health solutions by providing evidence-based messaging, exhibits, programs, and other public engagement tools.

In 2023, the UC Davis TERC education team reached 12,988 total visitor contacts through tours, field trips, lectures, and community events. This represents a 46% increase in interactions, and this increasing trend of TERC education is expected to continue with the development of more innovative and exciting exhibits placed in new locations around the basin, including the Tahoe City Visitor Center and Kings Beach Visitor Center.

Science centers, museums, and other public engagement networks are institutions with expertise, community relationships, and platforms for conversations about climate change, biodiversity loss, and pollution. We work to share key messages to support informed, inclusive action that promotes community and planetary health. And our combined voices can be powerful. "Americans who hear others talk about global warming at least once a month have higher levels of perceived collective political efficacy than those who hear others talk about global warming less often – 54% versus 39%," found the Yale Program on Climate Change Communication. Together we can make a difference.

Figure 45. TERC Education team debuts a new extension of the Tahoe Science Center in Tahoe City (Madonna Dunbar, Incline Village General Improvement District).

Figure 46. Education and Outreach Director Heather Segale joins in the excitement of the 2024 Science Expo (Alison Toy, UC Davis TERC).

Figure 47. Summer Intern Meera Putz discusses summer project with TERC education associate Logan Witt (Alison Toy, UC Davis TERC).

There is Hope, and you can Help Mitigate the Impacts of Climate Change

After reading this report, it is easy to be concerned about Lake Tahoe's future. But despite the many challenges, Tahoe is actually in a good position, and TERC scientists are seeing some long-term negative trends begin to reverse.

Resources for Education

The number one thing that anyone who loves the lake and wants to protect it can do is get educated on all the challenges that the lake is facing. To facilitate this, TERC offers a variety of Lake Tahoe-focused education programs for the public, K-12 students, teachers, and other groups. TERC's education programs include:

- Exhibits: Engaging exhibits at the Tahoe Science Center in Incline Village, NV, and Eriksson Education Center in Tahoe City, CA, let individuals get a hands-on understanding of what makes Lake Tahoe unique and highlights the challenges it is facing.
- Outreach: Programs specially designed for student groups, residents, and visitors to the UC Davis Tahoe Science Center
- Tours: Public tours at the UC Davis Tahoe Science Center
- Community events: Lectures and presentations on ongoing research and vital information about the lake and other events like gardening and composting in the basin.
- Field Trips and Workshops: Programs for K-12 students and educators
- Summer Tahoe Teacher Institute: A STEM education program for teachers in partnership with school districts

No time for a visit to TERC? No problem. Sign up to receive TERC newsletters by visiting: https://tahoe.ucdavis.edu/newsletters. These newsletters contain information on TERC research and staff and share the schedule for our TERC talks, which are another great way to find out what is going on with Lake Tahoe.

When residents and visitors educate themselves on the challenges facing Lake Tahoe, they can then educate their friends and neighbors, advocate for the lake in their town, and become protectors of the lake. If all the residents of the Tahoe Basin had the information they needed to become dedicated stewards of the lake, the future would indeed be bright.

Monitored and Studied

TERC's mission is to communicate science-informed solutions to help preserve Lake Tahoe's ecological health and beauty for future generations. As such, TERC has been monitoring Lake Tahoe's health since 1968. This long-term dataset helps researchers understand how the lake's ecosystems function and how they have changed over time. This has allowed TERC researchers to recommend policy changes around the basin and in two states that protect the lake's long-term health. Currently, TERC is adding to this long-term data set by actively monitoring the lake with multiple sensor networks, including:

- Nearshore monitoring networks to track turbidity, algal concentration, and dissolved organic matter concentrations;
- Remote sensing from satellites, aerial drones, and helicopters;
- Autonomous underwater vehicles to collect real-time measurements from around the entire lake; and,
- Installed instrumentation to understand deep lake oxygen dynamics year-round.

All of this work is executed with the purpose of understanding Lake Tahoe so that its beauty can be sustained for future generations to enjoy.

There is Hope, and you can Help Mitigate the Impacts of Climate Change

Collaborations with Scientists and Policy Makers

TERC is not the only group of researchers working to understand and protect the lake. UC Davis works with researchers from other scientific organizations, such as the University of Nevada at Reno and the Desert Research Institute, in part through the Tahoe Science Advisory Council (TSAC).

The Tahoe Science Advisory Council was established in 2015 by a memorandum of understanding (MOU) between the States of California and Nevada. The Council is an independent group of scientists who work collaboratively to advise policymakers to promote, enhance, and maintain the ecological integrity of Lake Tahoe and its watershed. The Council utilizes the best available scientific information on matters of interest to both the states to preserve Lake Tahoe. By bringing together representatives from academic institutions and government agencies tasked with protecting the environment, the Council aims to leverage efforts and maximize resources, streamline and bridge research and restoration activities from watershed to lake.

Collaborations with Citizen Scientists

The Tahoe Basin is a large geographic area with diverse and complex ecosystems that need to be monitored. Even the largest research teams have difficulty covering the entire area and certainly can't do it 24-7. This is why contributions from Citizen Scientists are so valuable. It might seem intimidating but all you need to do is visit citizensciencetahoe.org and select the survey you wish to complete, and you will be guided on how to submit your observations straight to TERC. Citizen Scientists can report observations on algae, invasive species, litter, water quality, and ashfall from wildfires. By increasing the number of observations of these issues all around the lake, residents and visitors can play an active role in protecting the lake.

Citizen Science Tahoe was developed by the UC Davis Tahoe Environmental Research Center (TERC) in collaboration with the Desert Research Institute (DRI) and League to Save Lake Tahoe (Keep Tahoe Blue).

If that is not enough for our engaged residents, TERC welcomes you to become a volunteer docent at the Tahoe Environmental Research Center's Education Center in Incline Village. Volunteer docents are trained to share information about what makes Lake Tahoe unique, environmental issues, how science and research are used to better understand them, and what can be done to protect and preserve our beautiful lake.

Reversing Negative Trends

Though the clarity story is complicated, the fact that water clarity in the winter is improving shows that actions taken to limit the input of fine sediment particles and nutrients are working. The investments made in roadway improvements, erosion controls, and watershed restoration are having a positive effect on the lake. This shows that policies informed by science and research can protect the lake in the long-term.

Actions you can take from anywhere - Donate to Fund our Research

TERC's advancements and achievements are possible because a community of philanthropically minded individuals is committed to making a difference in Lake Tahoe's future. Their vision and generosity support a world-class center for research and education. Private support is essential to continuing TERC's groundbreaking work to restore and sustain Lake Tahoe for future generations. Donations support TERC's research and monitoring efforts, education and outreach programs, undergraduate and graduate students, and the capital projects that make real-time monitoring of the lake possible.

On climate, our goal isn't to have the world paralyzed by anxiety but rather galvanized for action. And for that, we need hope; not false hope that all will be well (it won't be, if we don't act) but hope based on the conviction that if we do something, it WILL make a difference.

- Katharine Hayhoe, Nature Conservancy

Figure 48. Sunrise from Cascade Falls over Emerald Bay (Brant Allen, UC Davis TERC).

TAHOE:
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2024

METEOROLOGY

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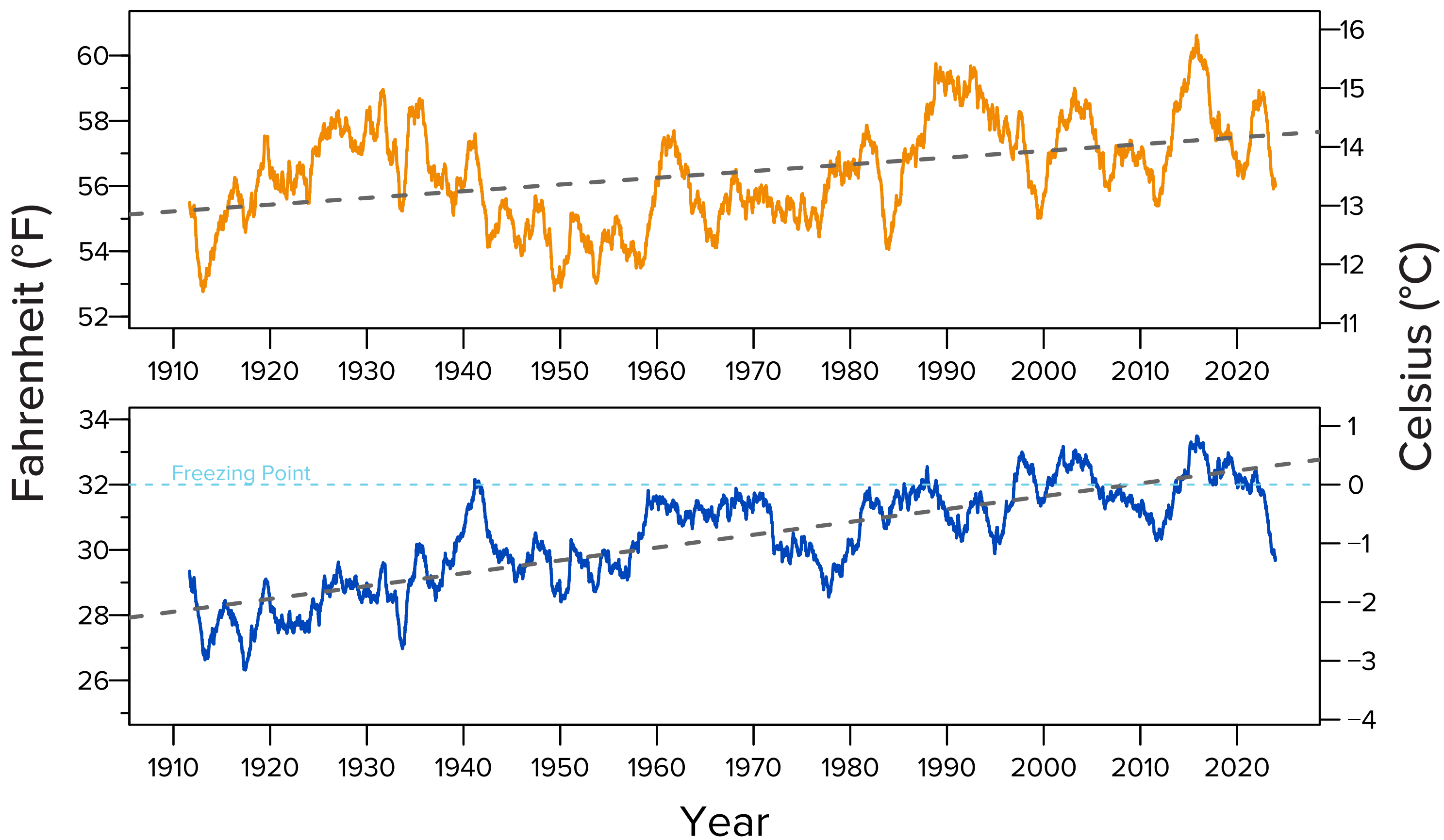
Air temperature - smoothed daily maximum and minimum

Daily since 1911

Over the last 112 years, daily air temperatures measured at Tahoe City have increased. The long-term trend in average daily minimum temperature (bottom figure) has increased by 4.42 °F (2.45 °C) and the long-term trend in average daily maximum temperature (upper figure) has risen by 2.45 °F (1.28 °C). The trend line for the minimum air temperature has exceeded the freezing temperature of water for the last 15 years, contributing to generally more rain and less snow as well as earlier snowmelt at Lake Tahoe. These data are smoothed using a two-year running average to remove daily and seasonal fluctuations.

Data source: Long-term NOAA daily maximum and minimum temperatures data set.

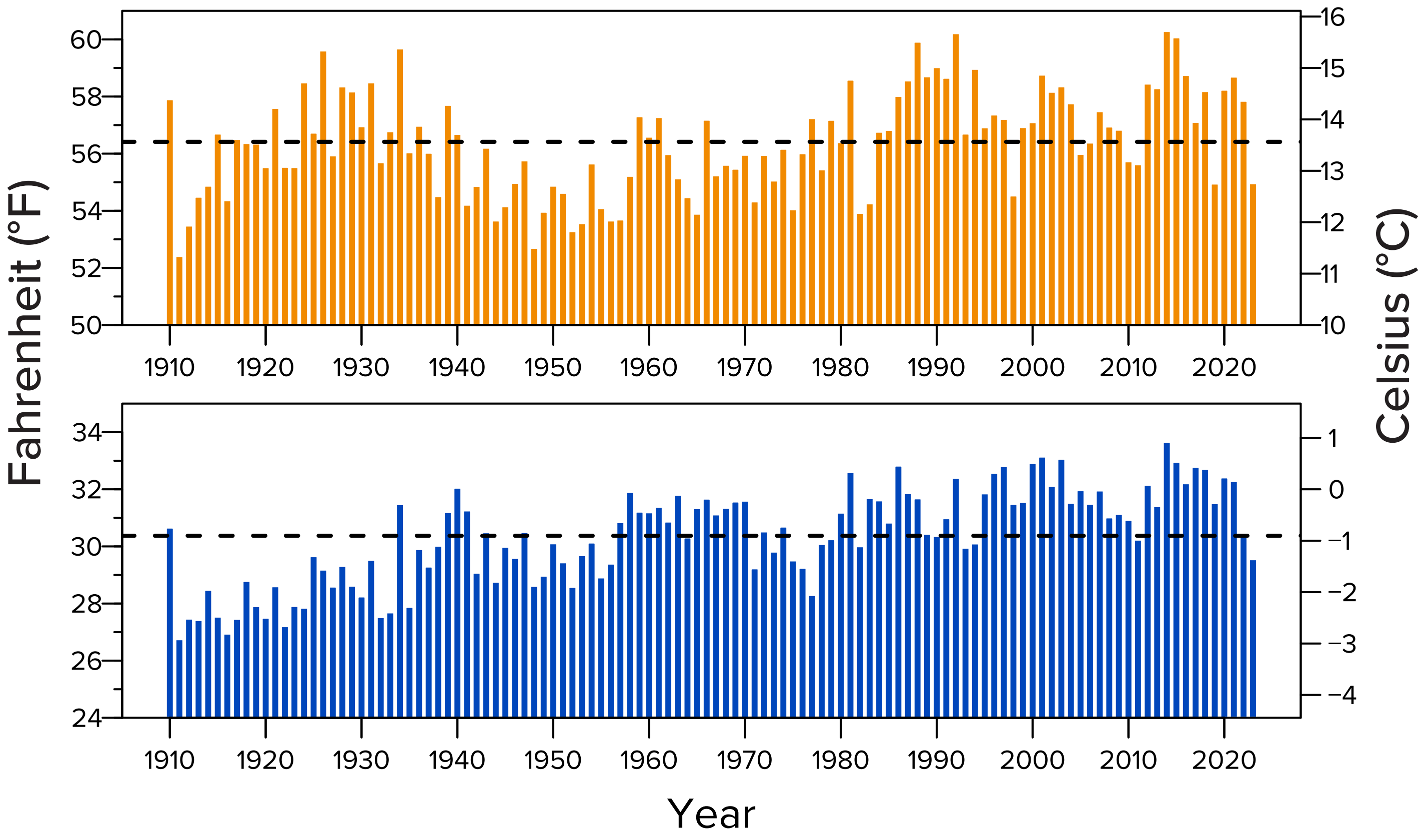


Air temperature - annual average maximum and minimum

Since 1910

Annual average maximum (upper figure) air temperatures in 2023 was lower than the previous year and below the long-term average (dashed line) air temperature. Annual average minimum (lower figure) air temperatures in 2022 was slightly lower than the previous year and lower than the long-term average (dashed line) air temperature. The annual average maximum temperature was 55.0 °F (12.8 °C), which was 2.9 °F cooler than the previous year. The 2023 annual average minimum was 29.6 °F (-1.4 °C), which was 0.8 °F (0.5 °C) cooler than the previous year. The long-term averages for the maximum and the minimum are 56.4 °F (13.6 °C) and 30.4 °F (-0.9 °C), respectively.

Data source: Long-term NOAA daily maximum and minimum temperatures data set measured at Tahoe City.



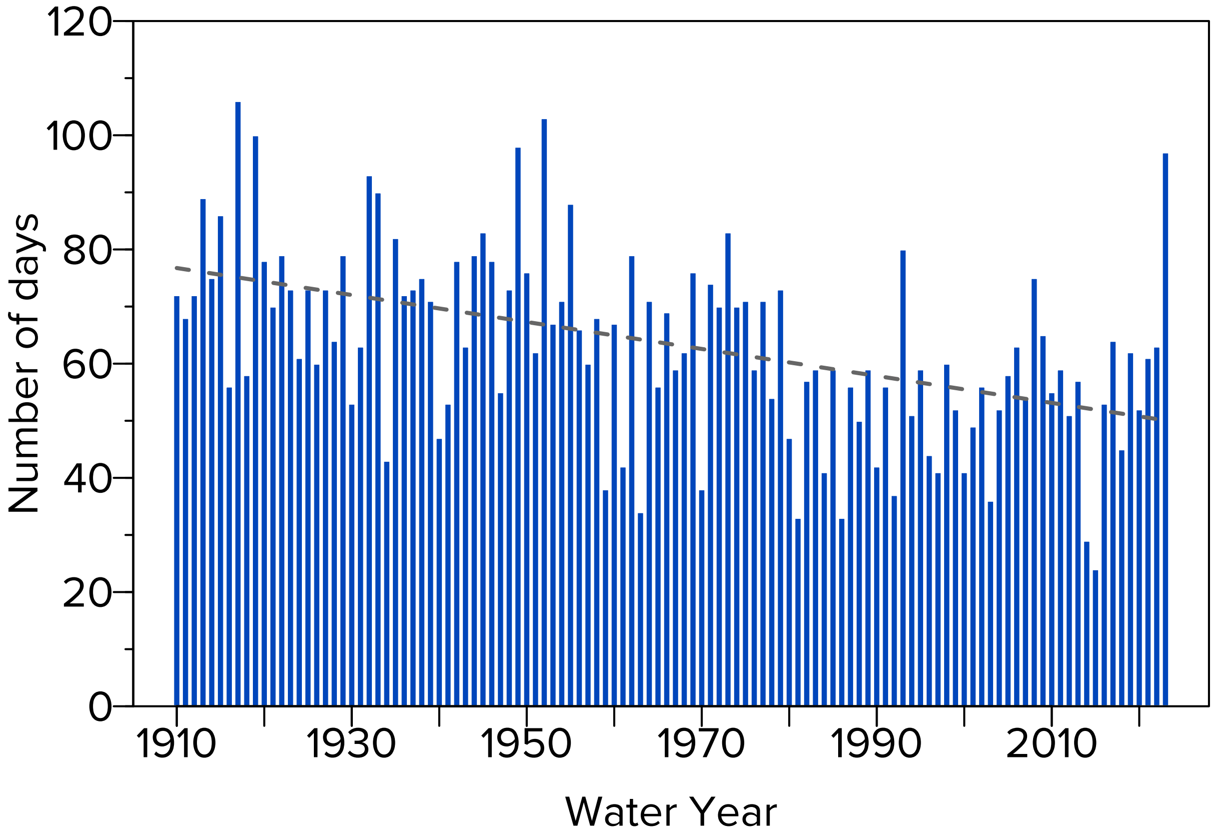
Below-freezing air temperatures

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 over 27 days since 1911. In WY 2023, the number of freezing days was 97, well above the declining long-term trend line. This amount, which is nearly double the number of days above the trendline, is consistent with the measured air temperatures for 2023.

Data source: Long-term NOAA daily maximum and minimum temperatures data set measured at Tahoe City.

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

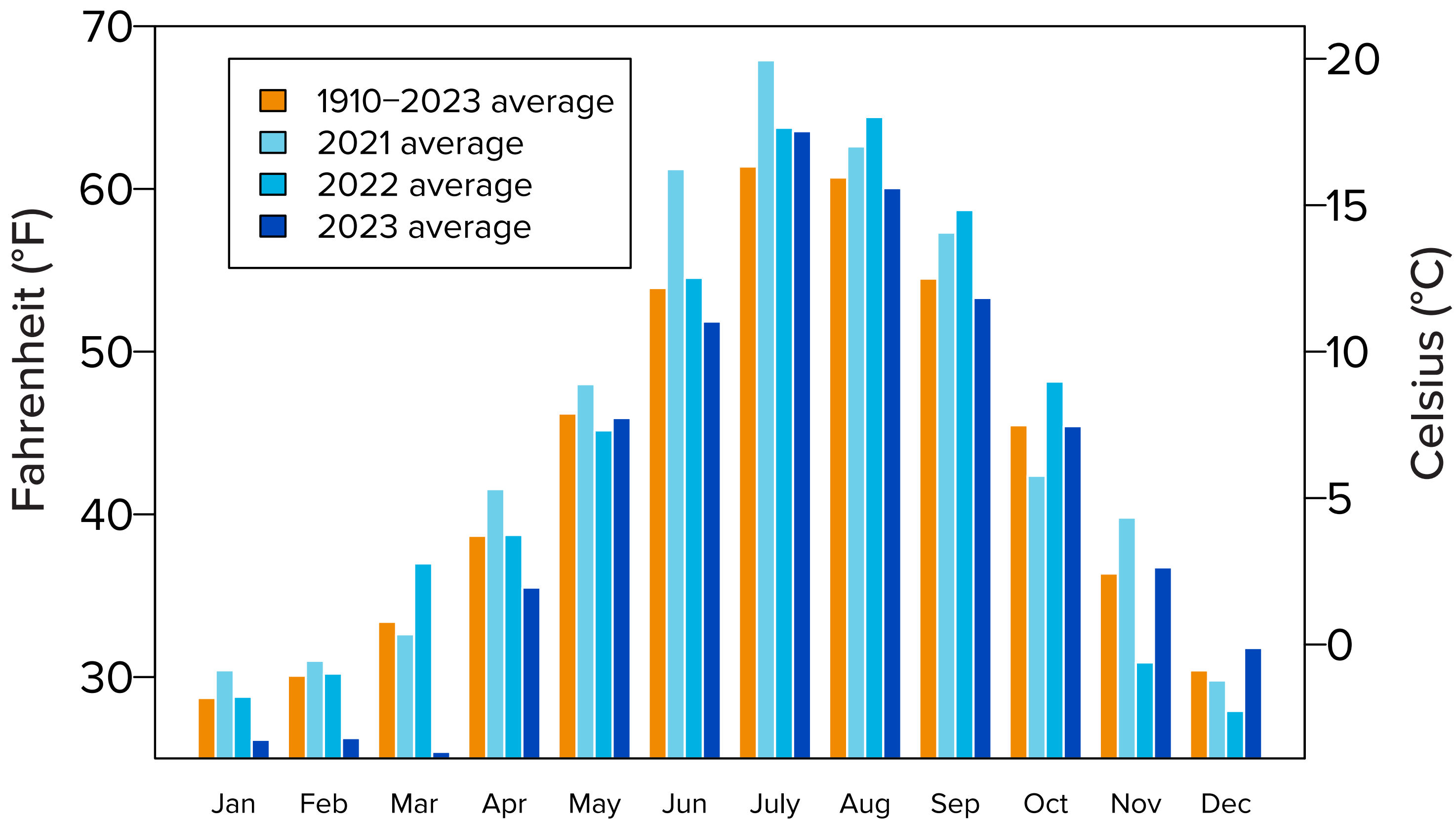


Monthly air temperature

2021, 2022, 2023 and 1910 to 2023

In 2023, monthly daily average air temperatures were lower than the long-term average for 8 of the months of the year and distinctly colder during the winter months of January through March. However, July was warmer than the average.

Data source: Long-term NOAA daily maximum and minimum temperatures data set.

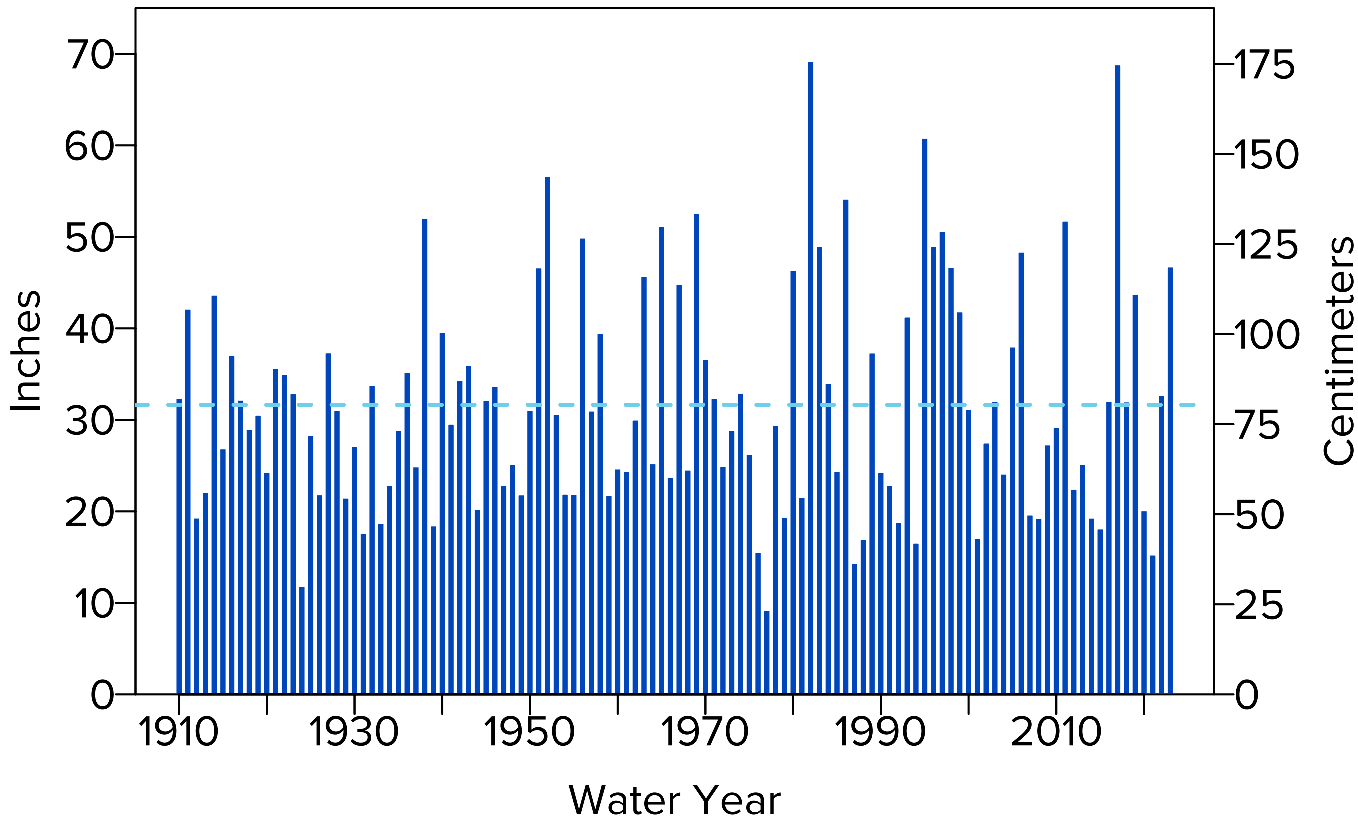


Annual precipitation

Yearly since 1910

From 1910 to 2023, average annual precipitation (water equivalent of rain and snow) measured at Tahoe City was 31.6 inches. The maximum recorded was 69.2 inches in 1982. The minimum recorded was 9.2 inches in 1977. At 46.8 inches, 2023 was 15.1 inches above the long-term average (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. There is also an increase in precipitation with elevation in the Tahoe basin. Precipitation is summed over the Water Year, which extends from October 1 through September 30.

Data source: Long-term NOAA daily precipitation data set.

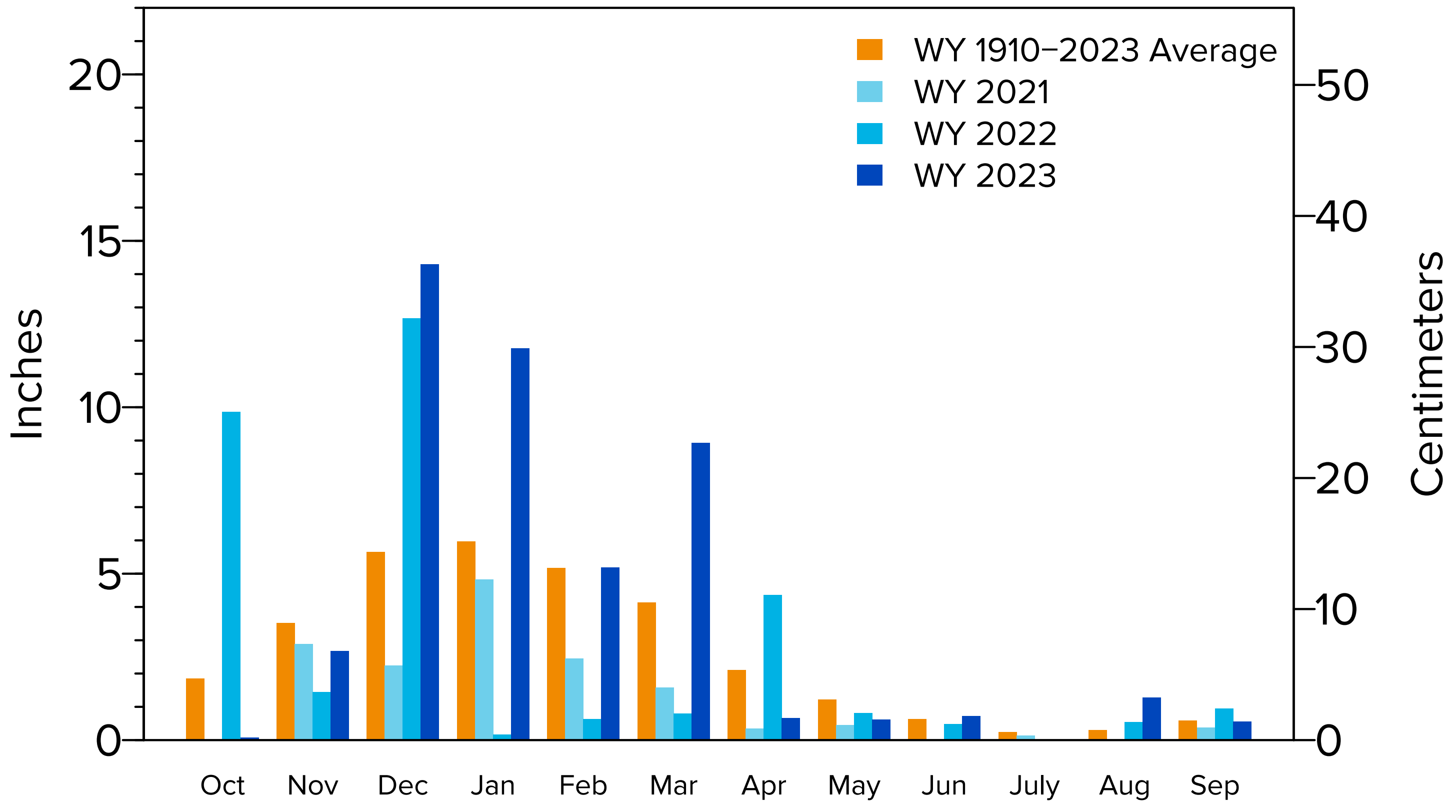


Monthly precipitation

2021, 2022, 2023 and 1910 to 2023

The 2023 Water Year had an annual average of 46.8 inches of precipitation, slightly above the long-term average of annual precipitation of 31.6 inches at Tahoe City. Precipitation in December, January, March and August of the 2023 Water Year was well above the long-term averages for those months. In all other months it was generally lower than the long-term average. The 2023 Water Year extends from October 1, 2022, through September 30, 2023.

Data source: Long-term NOAA daily precipitation data set.

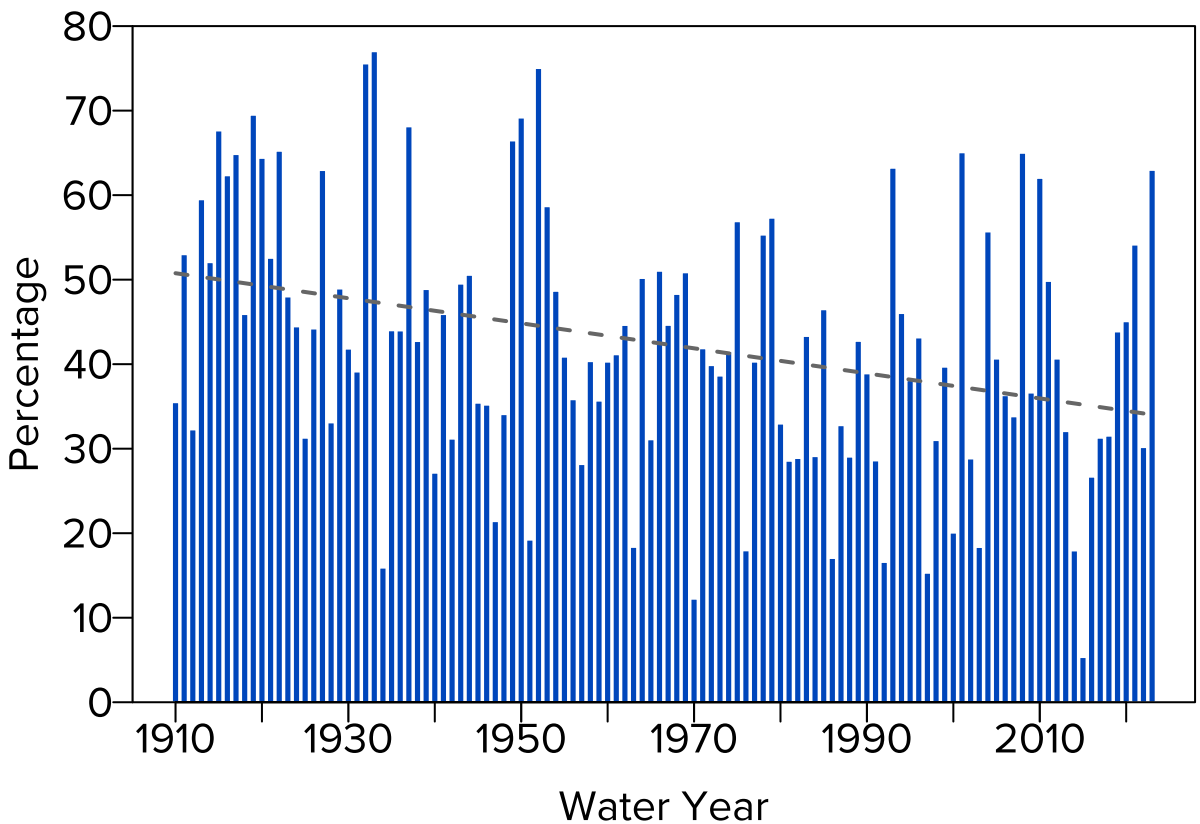


Snow as a fraction of annual precipitation

Yearly since 1910

Snow has declined as a fraction of total precipitation from an average of 51 percent in 1910 to 34 percent in 2023. In Tahoe City, snow represented 63 percent of the 2023 total precipitation, far above the trendline and more than double the 2022 percentage. These data are calculated based on the assumption that precipitation falls as snow whenever the average daily temperature (the average of the daily maximum and minimum temperatures) is below freezing. Precipitation is summed over the Water Year, which extends from October 1 through September 30.

Data source: Long-term NOAA daily air temperature and precipitation data sets.



April snowpack

Since 1916

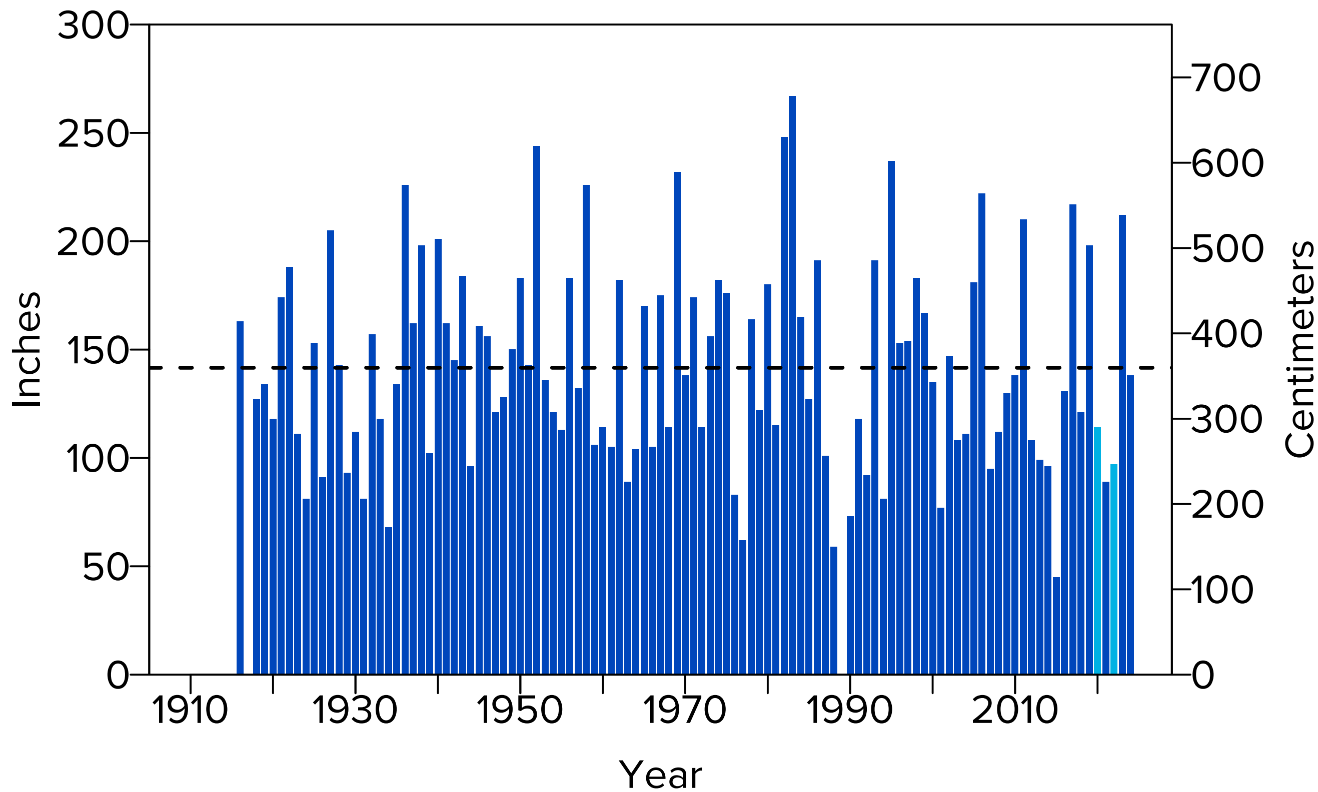
The depth of the snowpack is measured over the year at multiple locations throughout the Sierra. Shown here are the readings taken on approximately April 1 since 1916 at the Lake Lucille Snow Course Station (located in Desolation Wilderness, elevation 8,188 feet (Lat. 38.86 deg. Long. -120.11 deg.).

In 2020 and in 2022, the April snowpack readings at Lake Lucille were not made due to storm conditions. Instead, the values were estimated by correlation with values made at the Rubicon #1 snow course. The correlation estimates are shown with the lighter blue columns.

For April 1, 2024, the value was 138 inches, just below the long-term average. The largest amount on record was 267 inches on April 5, 1983. The average snow depth (shown by the dotted line) over the period 1916-2023 was 142.3 inches.

Note: April snow depth data are not available for 1917 and 1989.

Data source: USDA Natural Resources Conservation Service, California Monthly Snow Data.

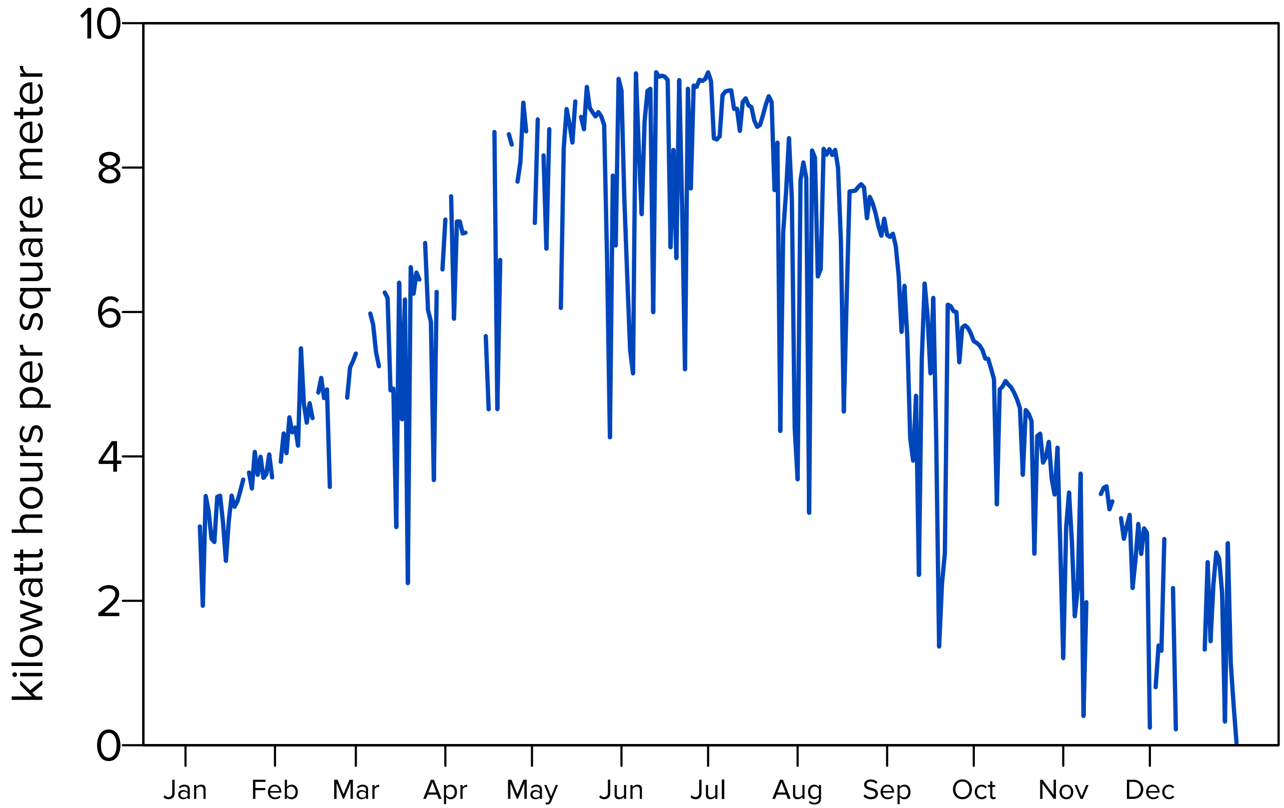


Daily solar radiation

In 2023

Solar radiation showed the typical annual pattern of sunlight, peaking at the summer solstice on June 21 or 22. Dips in daily solar radiation are primarily due to cloud coverage. Smoke and other atmospheric constituents play a smaller role. It is worth noting that solar radiation on a clear day in mid-winter can exceed that of a cloudy or smokey day in mid-summer.

The TERC meteorological station where these data are collected is located on the U.S. Coast Guard dock at Tahoe City.



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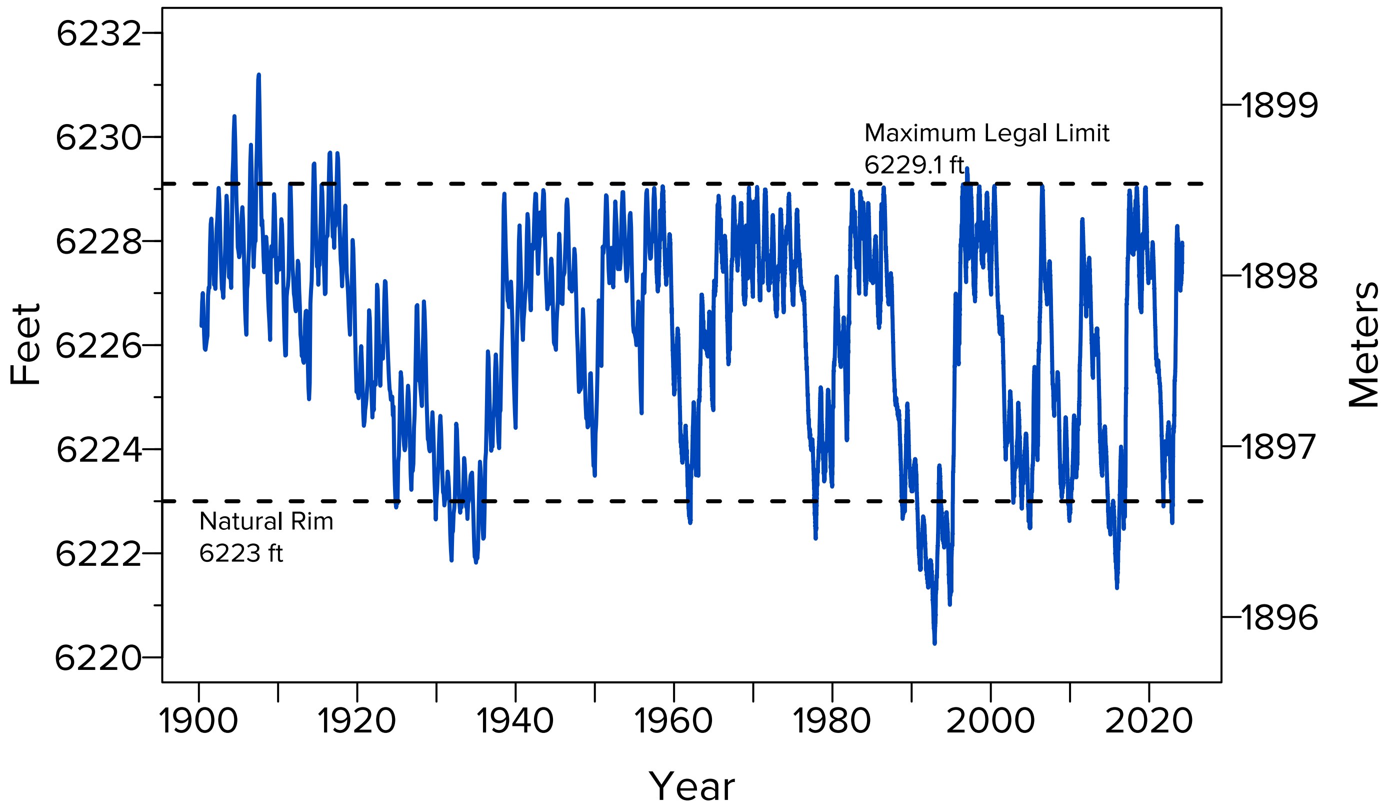
PHYSICAL PROPERTIES

Lake surface level

Daily since 1900

Lake surface level varies throughout the year. Lake levels rise due to high stream inflow, groundwater inflow, and precipitation of rain and snow directly onto the lake surface. It falls due to evaporation, in-basin water withdrawals, groundwater outflows, and outflows via the Truckee River at Tahoe City. In 2023, the highest lake level was 6,228.29 feet on July 21, and the lowest was 6,223.72 feet on January 1, 2023, just above the natural rim of the lake. The natural rim of the lake is at an elevation of 6,223 feet. Lake Tahoe fell below its rim on October 24, 2022, but rose back above it on December 27, 2022. When the lake was below its rim, outflows via the Truckee River ceased. Several episodes of lake level falling below the natural rim are evident in the last 114 years. The frequency of low water episodes appears to be increasing. The lowest lake level on record is 6,220.26 feet on November 30, 1992, 2.74 feet below the natural rim.

Data source: US Geological Survey level recorder in Tahoe City.

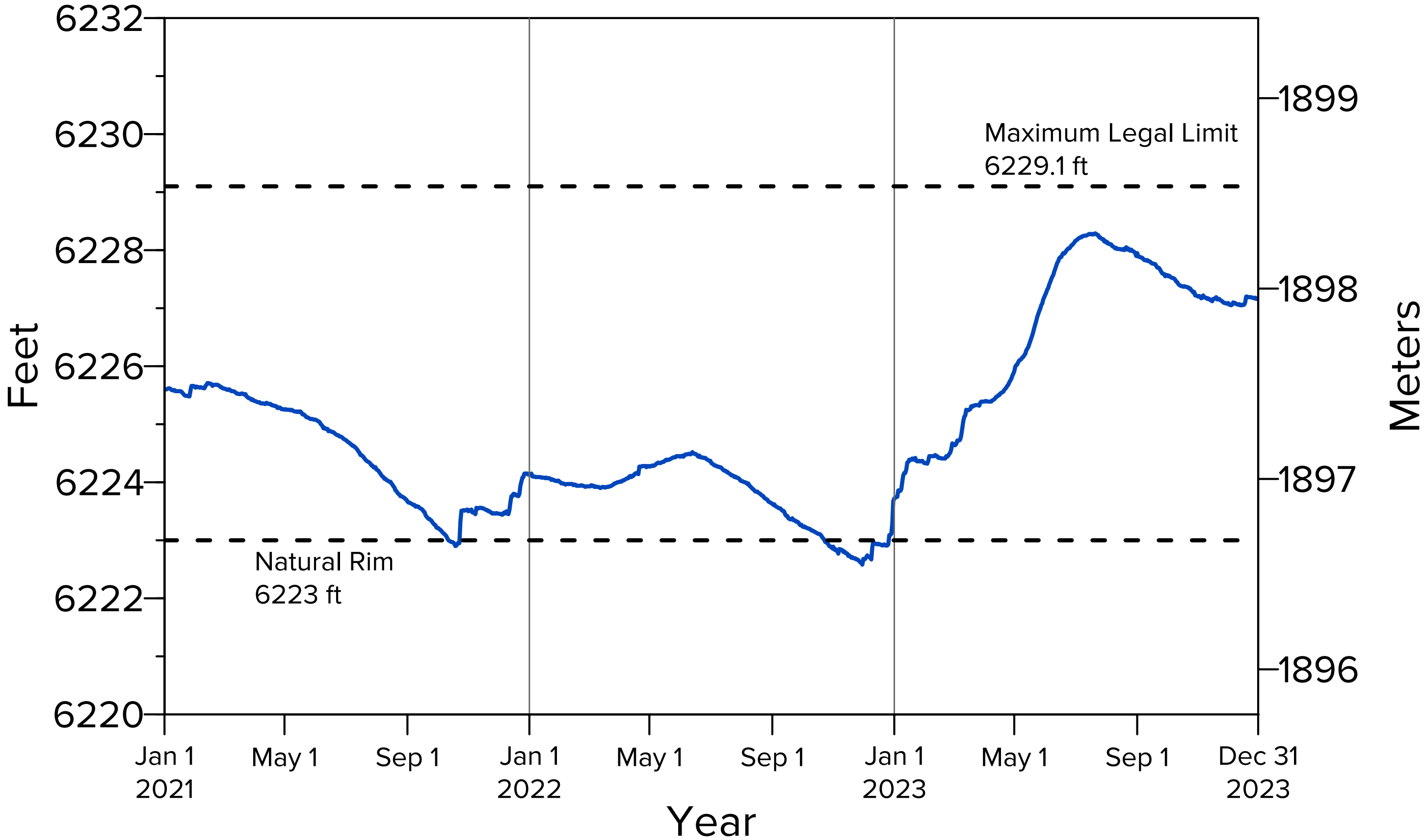


Lake surface level

Daily in 2021, 2022, and 2023

The subset of lake surface data is extracted from the same data as in Fig. 8.1 for the most recent three years from 2021–2023. This more time-restricted presentation of recent lake level data better displays the annual patterns of rising and falling lake level in greater detail. In 2023, on account of the higher-than-average precipitation, the winter and spring rises in lake level are evident. Precipitation in December 2022, January and March 2023 produced sudden jumps in lake level. Snowmelt in spring continued the rise in lake level, but after July 21 the water level slowly fell.

Data source: US Geological Survey level recorder in Tahoe City.

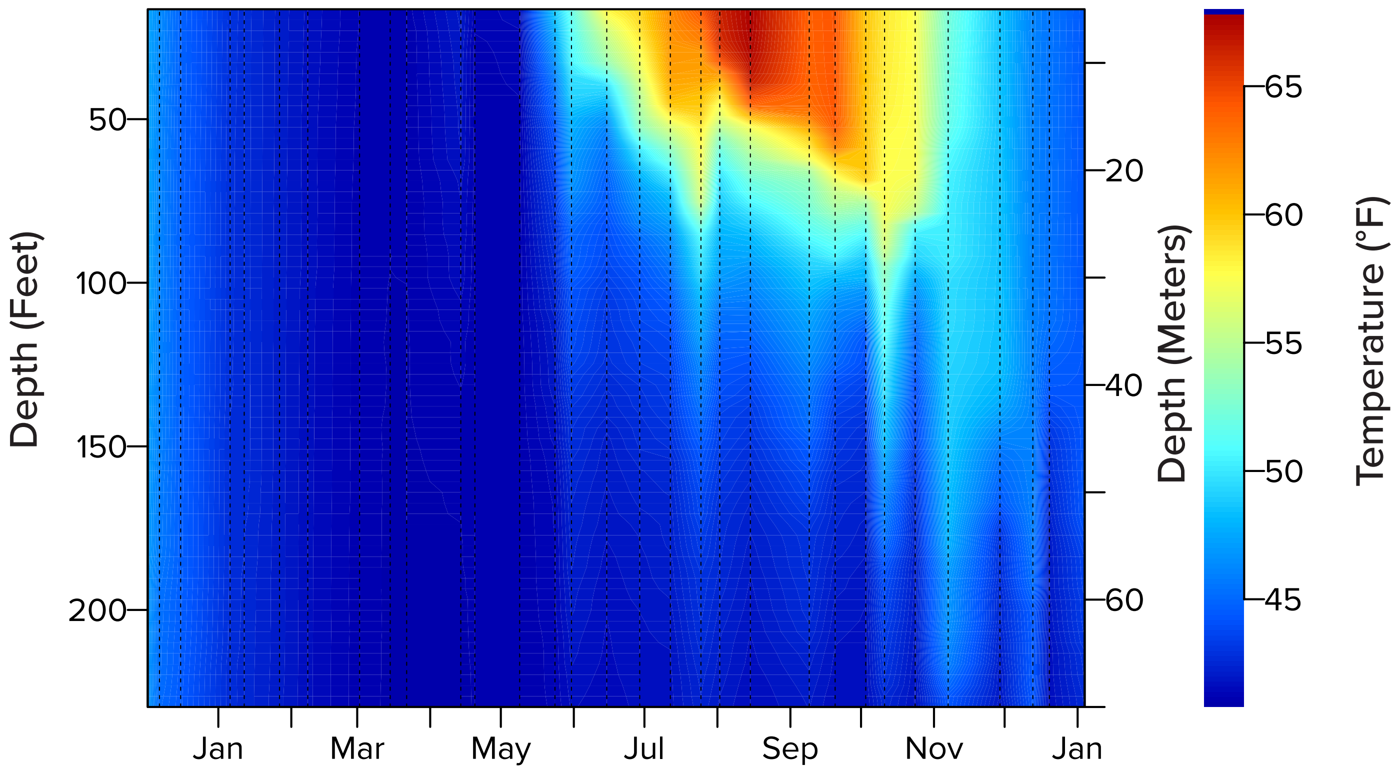


Water temperature profile

In 2023

Water temperature profiles are measured in the lake using a CTD (conductivity, temperature, depth) profiler on the days indicated by the dashed vertical lines. The measured temperature is accurate to within 0.005 °F. The vertical distribution of water temperature is a very important lake attribute as it represents lake density. During the summer months, the warmer, lighter water remain suspended at the lake surface in the region above the thermocline known as the epilimnion. The temperature in the upper 230 feet (70 m) of Lake Tahoe is displayed as a color contour plot. In the early part of 2023, the lake temperature followed the typical seasonal pattern. In February and March, the lake surface was at its coldest, while it was at its warmest in August before fall cooling took place.

Data source: TERC lake monitoring.

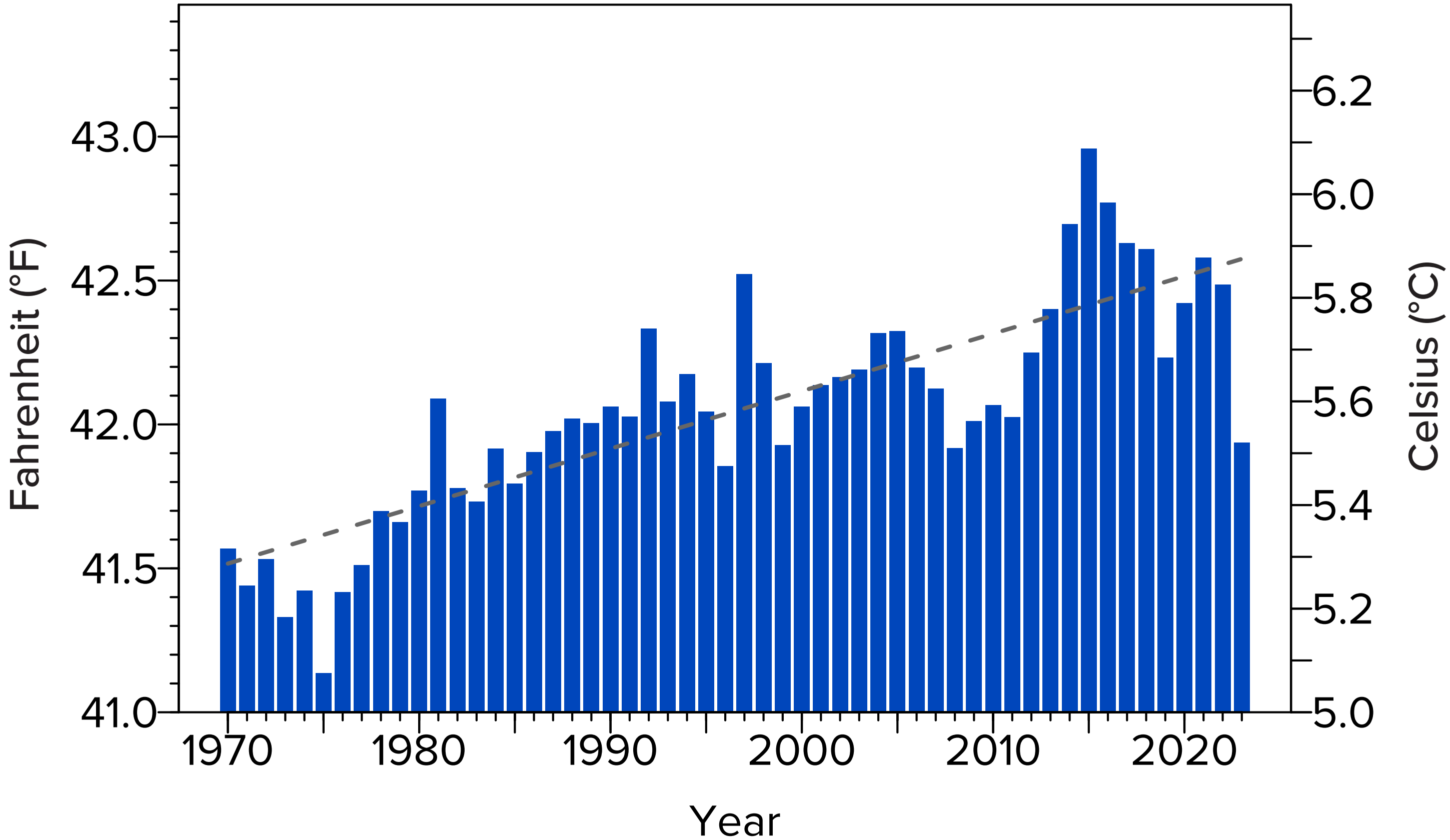


Annual average water temperature

Since 1970

The volume-averaged temperature of the lake for each year since 1970 is shown. The trend line indicates that water temperature has increased by approximately 1.1 °F (0.6°C) since 1970. The annual rate of warming is 0.21 °F/decade (0.12 °C/decade). The monthly temperature profile data from the top to the bottom of the lake has been smoothed, and any seasonal influences were removed to best show the long-term trend. The 2023 annual average water temperature of 41.9 °F (5.5°C) was below the trendline.

Data source: TERC lake monitoring.

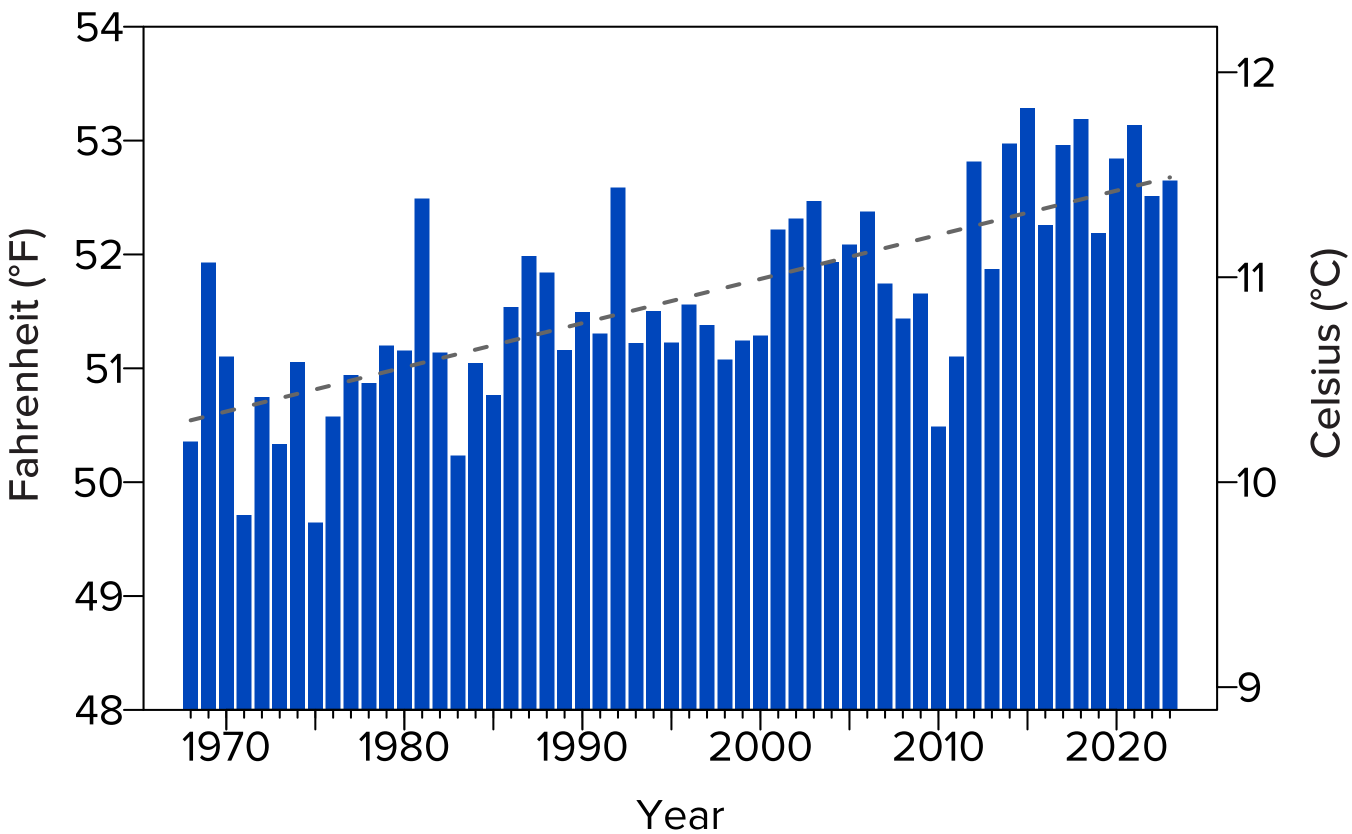


Annual surface water temperature

Yearly since 1968

Surface water temperatures (measured at a depth of 5 feet) have been recorded monthly at the Mid-lake and Index stations from TERC's research vessels since 1968 and from four research buoys since 2007. Despite year-to-year and longer cyclical variability, the annual average surface water temperatures show an increasing trend. The average temperature in 1968 was 50.4 °F (10.2 °C). For 2023, the average surface water temperature was 52.7 °F (11.5 °C), right around the long-term trend line. The overall rate of warming of the lake surface is 0.39 °F (0.22 °C) per decade.

Data source: TERC lake monitoring.



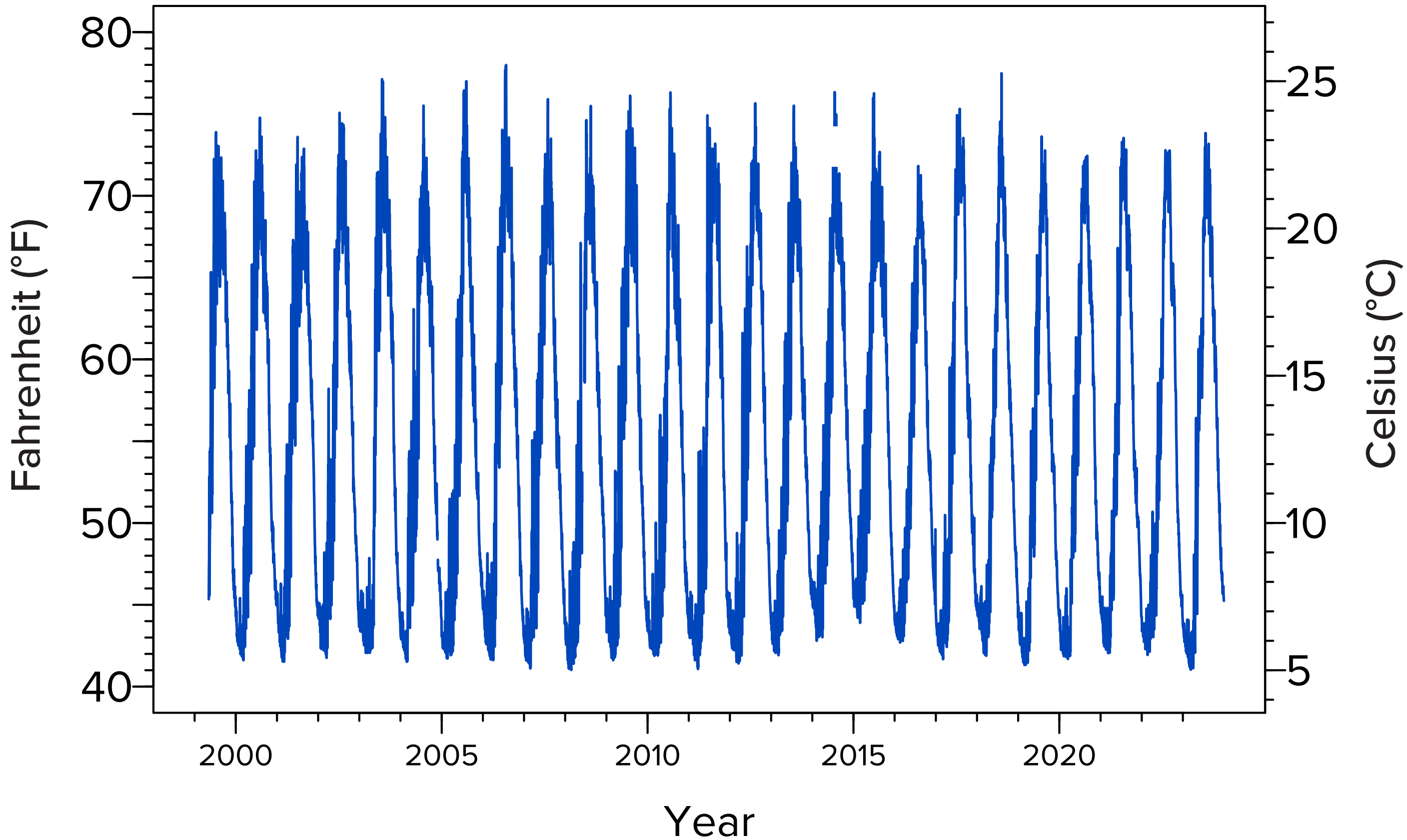
Maximum daily surface water temperature

Surface temperature measured since 1999 every 2 minutes

The maximum daily surface water temperature follows a sinusoidal pattern, with the temperature being in equilibrium with the air temperature and other meteorological variables. In 2023, the highest maximum daily surface water temperature (summer) was 73.8 °F (23.2 °C), recorded on July 21. The lowest maximum daily surface water temperature (winter) was 41.0 °F (5.0 °C), which was recorded on March 13. This was relatively warm, due in part to the absence of deep mixing.

These data are collected from thermistors at a depth of 5 feet (1.5 m) that are attached to four research buoys located over the deepest parts of the lake. The highest daily value from among the four buoys is considered as the daily maximum.

Data source: TERC lake monitoring.



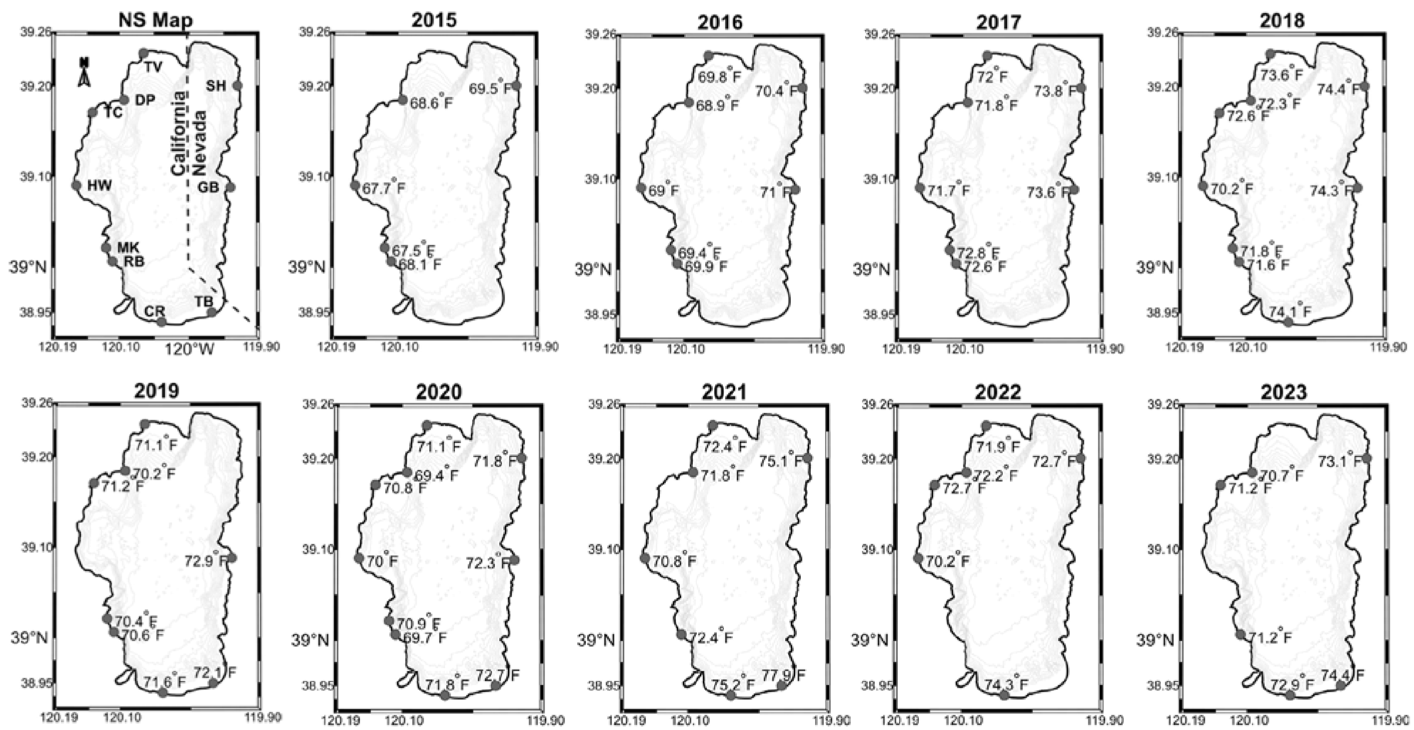
Maximum annual nearshore water temperature

Surface temperature measured by nearshore sensors

In 2014, TERC began installing a network of nearshore water quality monitoring stations around the perimeter of Lake Tahoe. The monitoring program aims to improve understanding of water quality variability in the nearshore zone. In 2023 there were 10 active stations installed around Lake Tahoe, including one station on Cascade Lake, which feeds into Lake Tahoe. Each station consists of an optical instrument measuring turbidity (clarity), algal concentration, and dissolved organic matter concentrations, dissolved oxygen, along with a Conductivity Temperature Depth (CTD) sensor, measuring conductivity, water temperature, water depth, and wave height. An underwater cable connected to shore power and internet enables a real-time data feed with high resolution data every 30 seconds.

Nearshore Sensor Stations (clockwise from top): Tahoe Vista (TV), Sand Harbor (SH), Glenbrook (GB), Timbercove (TB), Camp Richardson (CR), Rubicon Bay (RB), Meeks Bay (MK), Homewood (HW), Tahoe City (TC), and Dollar Point (DP)

Data source: TERC lake monitoring.

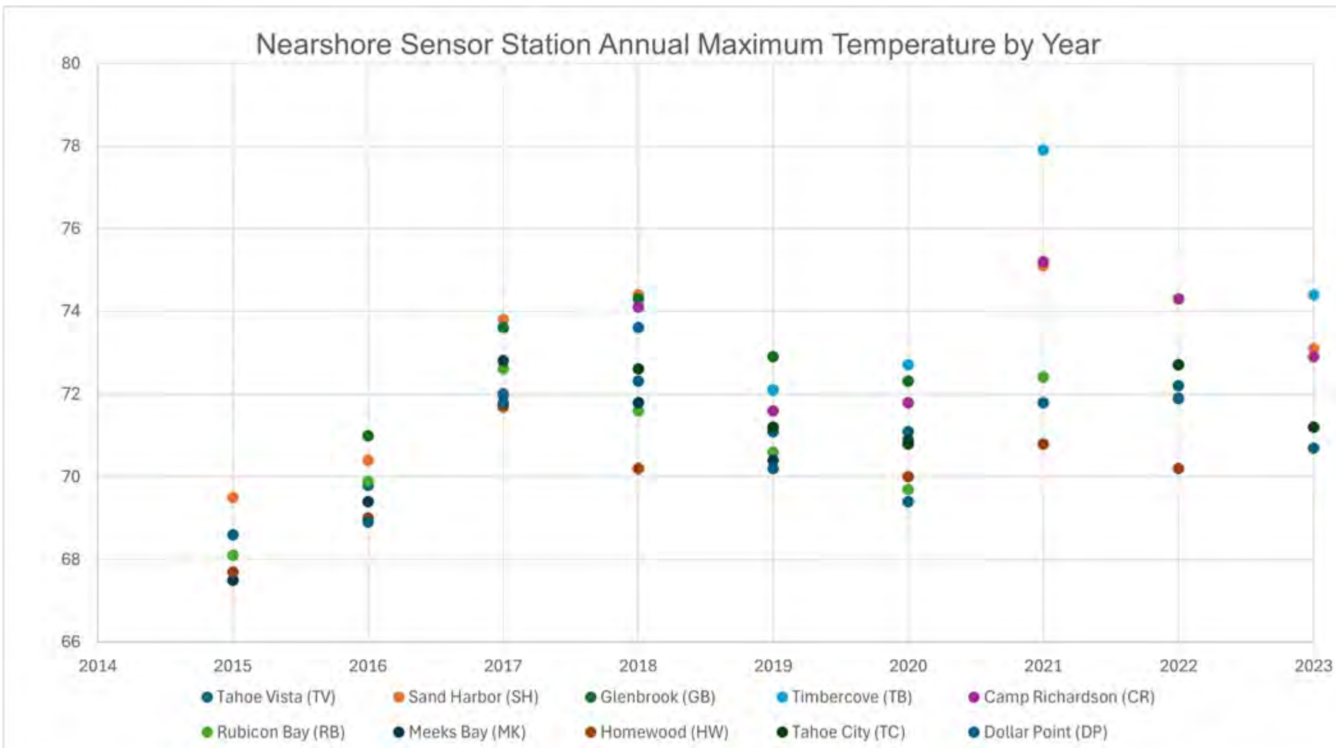


Maximum annual nearshore water temperature, continued

Surface temperature measured by nearshore sensors

The strategic locations of the nearshore sensor network allow us to characterize the spatial heterogeneity of Lake Tahoe's nearshore while identifying the lake locations that tend to exhibit warmer temperatures as well as the locations with the most striking impact from the wind. The figure shows an evident increase in the water temperature at all sites since 2015. The eastern shore tends to be warmer than the western shore because of the usual southwestern winds (the wind pushes the warmer surface water towards the east). The southern shore is exhibiting a rapid increase in temperature, likely due to the broad sediment shelf and shallow water column.

Data source: TERC lake monitoring.

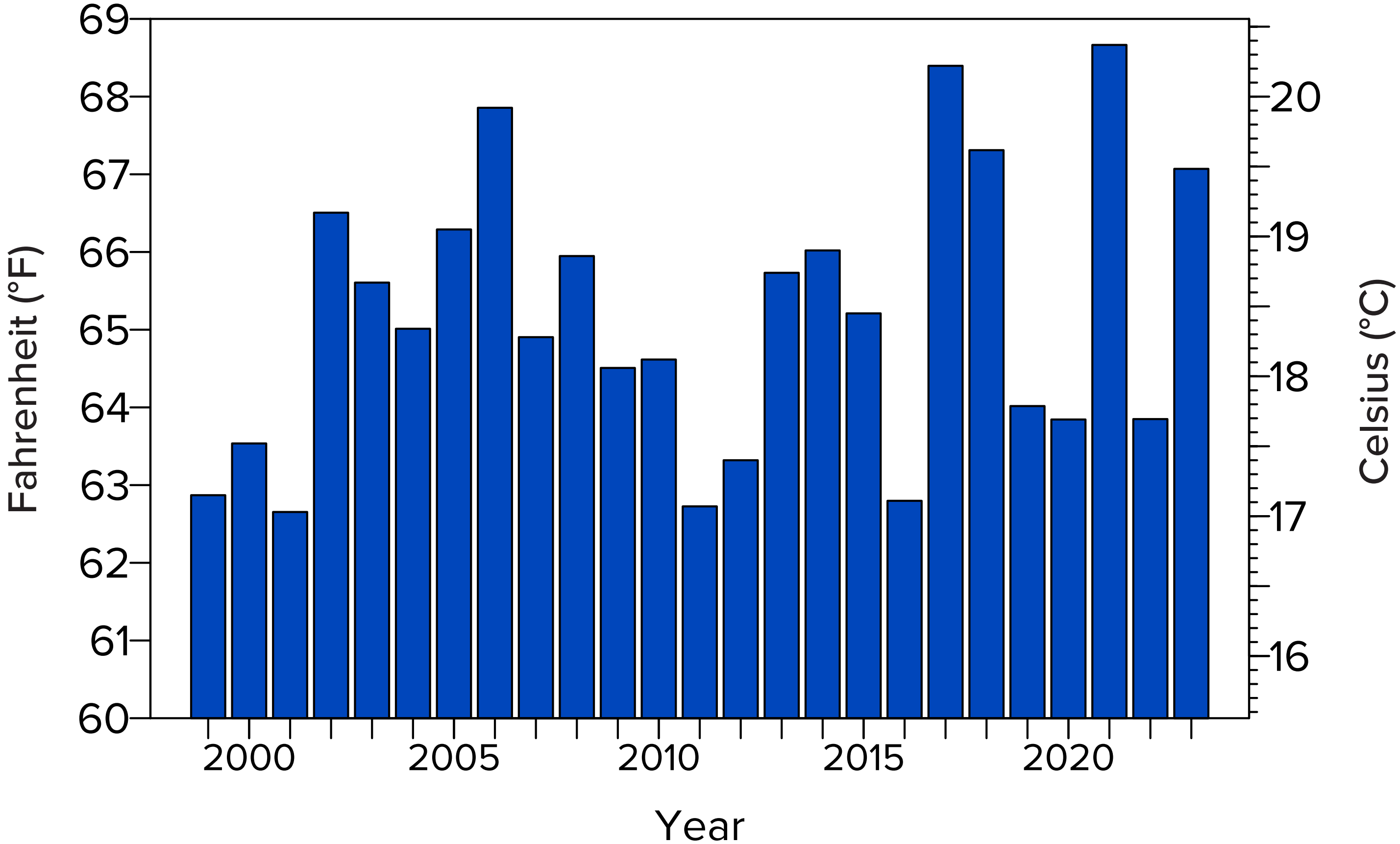


July average surface water temperature

Measured since 1999 every 2 minutes

Surface water temperature has been continuously recorded since 1999 from four NASA/UC Davis buoys in the center of the lake. Shown here are 25 years of average surface water temperatures in the month of July when water temperatures are typically at their warmest and the greatest number of people are recreating on the lake. In 2023, July surface water temperature was relatively warm. It averaged 67.1 °F (19.5 °C). This was increase over the previous year. The long-term average is 65.2°F (18.4°C) for the 25-year period of record. These data are collected from thermistors at a depth of 5 feet (1.52 m) that are attached to four buoys located over the deepest portions of the lake.

Data source: TERC lake monitoring.



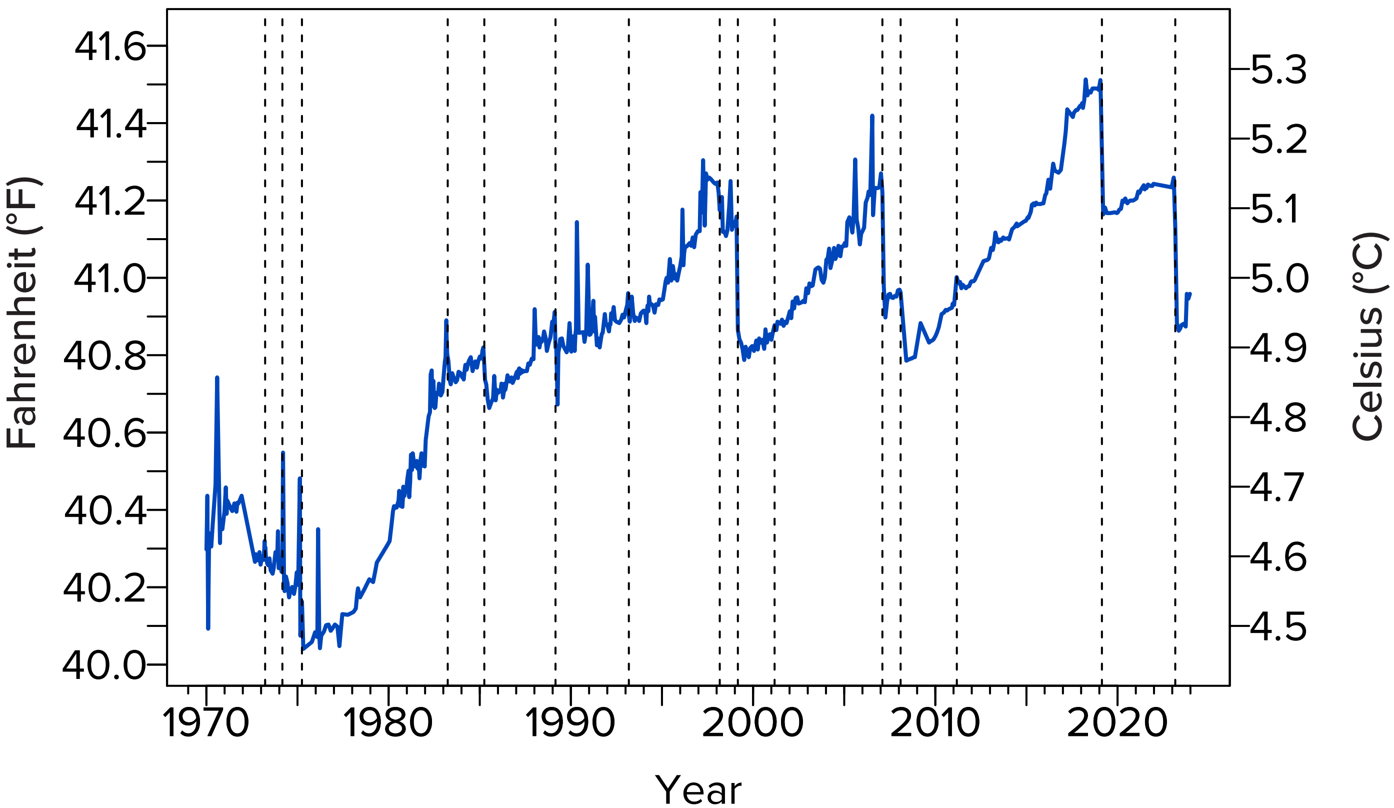
Deep water temperature

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. The deep-water temperatures show a complex pattern of warming and sudden cooling. During deep mixing events (the dashed vertical lines), the temperature can drop "precipitously" over a short period of time, although these drops are generally less than 0.3 °F. The heating of the bottom water along with the fluctuations when deep mixing does not occur is an area of current research.

In general, bottom temperatures are warming. Complete vertical mixing is an event that allows a large amount of heat to escape from the lake. In 2023, there was deep mixing (see Fig. 8.9) and water temperatures dropped by 0.4 °F from 41.26 °F to 40.86 °F. Between the last two deep mixing events in 2011 and 2019, the rate of water warming was 0.07 °F/yr.

Data source: TERC lake monitoring.



Depth of mixing

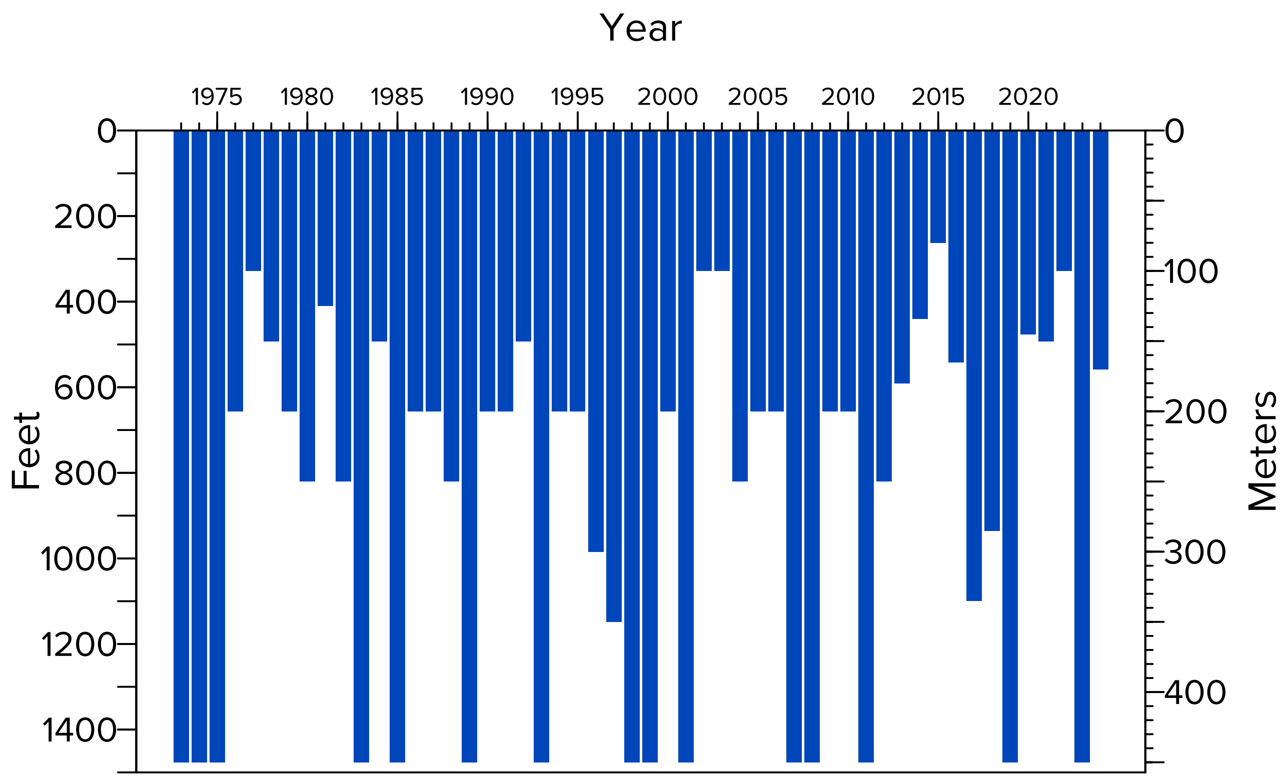
Yearly since 1973

The water of Lake Tahoe vertically mixes each winter as surface waters cool and sink downward. In a lake as deep as Tahoe, the intensity of cooling in winter determines how deep the lake mixes vertically. Mixing depth has profound impacts on lake ecology and water quality. Deep mixing brings nutrients to the surface, which promote algal growth. It also carries oxygen downward to deep waters, promoting aquatic life throughout the water column.

The deepest mixing typically occurs between February and March. On March 3, 2023, Lake Tahoe was observed to have mixed fully to a depth of 1476 feet (450 m). The duration of the 2023 mixing period is one of the longest recorded. This resulted because of the timing of a series of storms affecting the region.

Since 2013, the depth of mixing has been determined with high-resolution temperature profiles rather than nitrate concentration sampled at discrete depths. Continuous temperature measurements off Glenbrook provided additional confirmation data.

Data source: TERC lake monitoring.

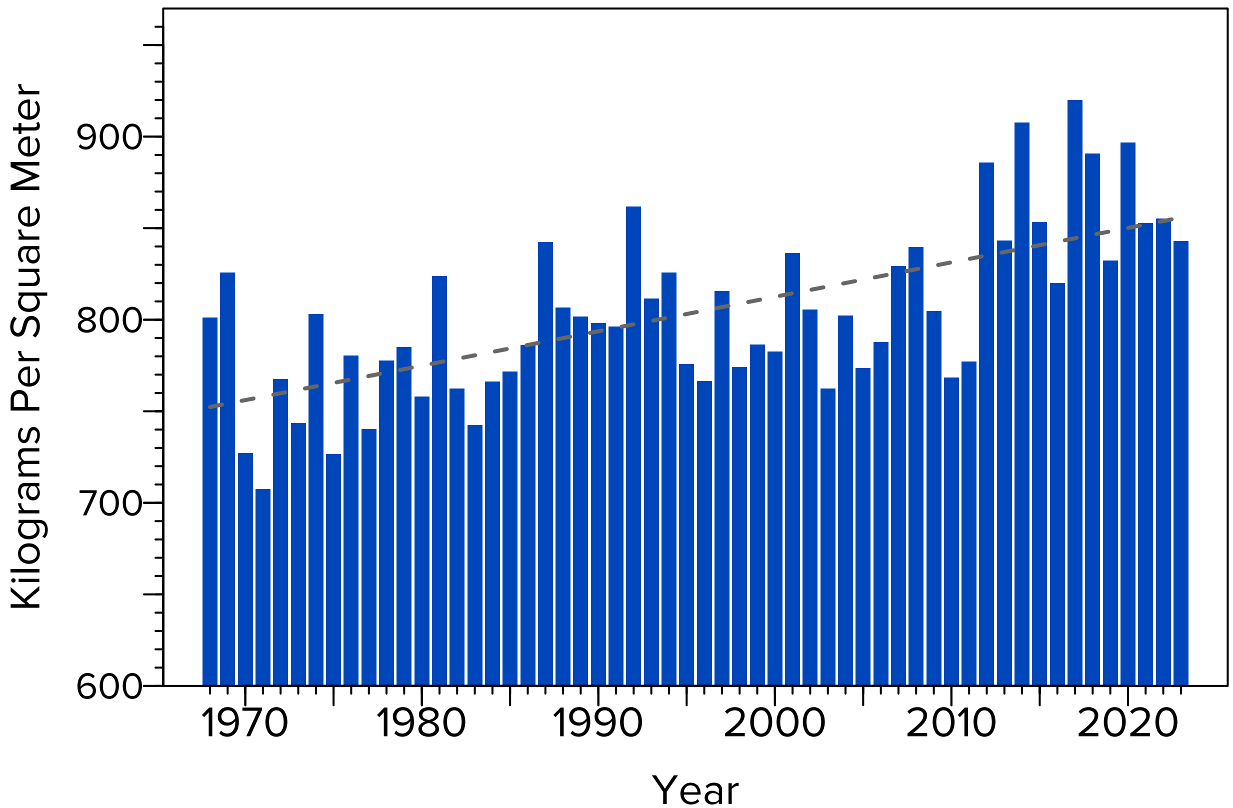


Lake stability index

Since 1968

Increasing stability poses a potential threat to all lakes. When the lake has a vertical distribution of temperature, it has a corresponding distribution of density. Warmer and lighter water remains at the surface above the colder and denser water below. As the temperature difference between top and bottom increases, the lake is said to become more stable. The stability index is a measure of the energy required to vertically mix the lake when it is density 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- to 20-day intervals. There has been an overall increase in lake stability by 13.8 percent in the last 55 years.

Data source: TERC lake monitoring.

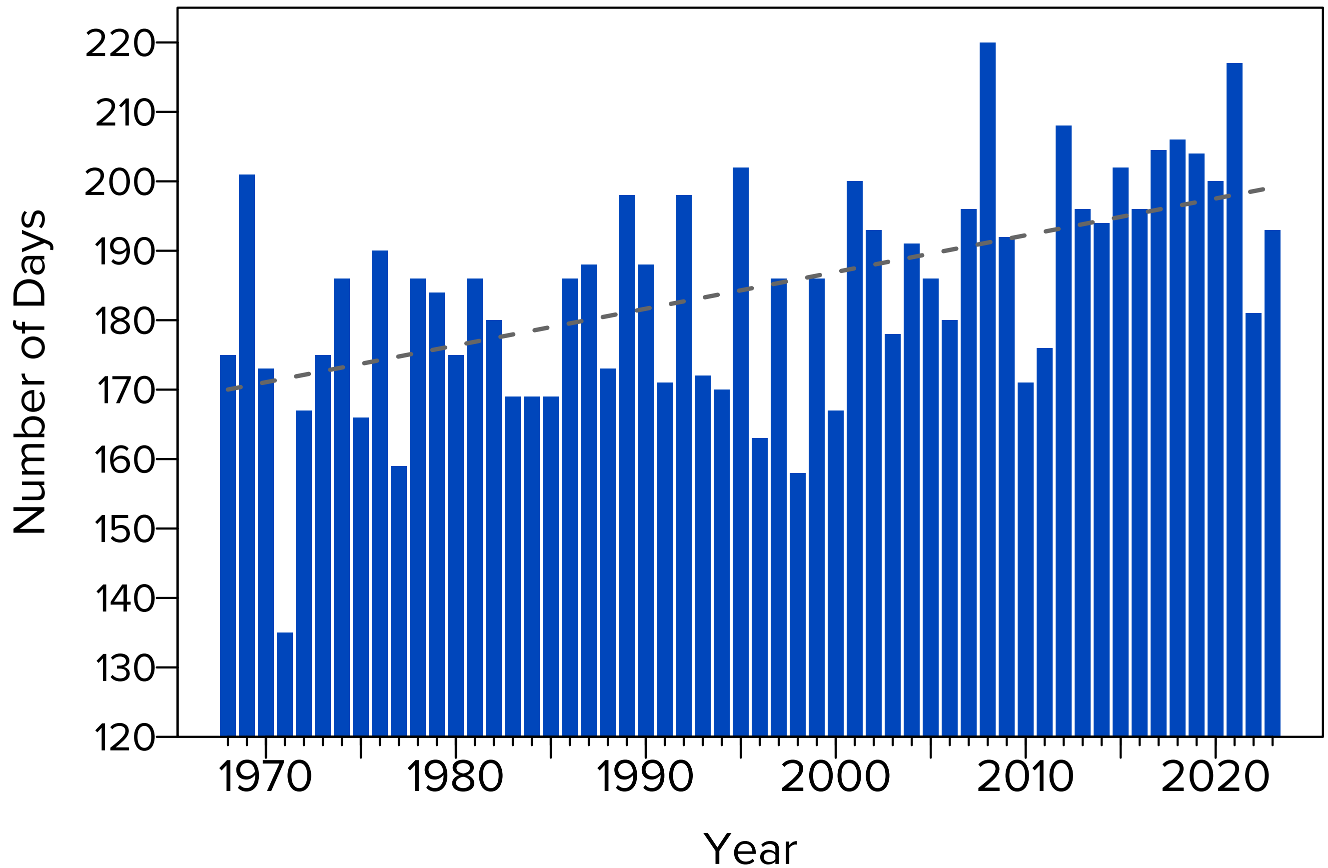


Stratified season length

Since 1968

The stability index is a measure of the energy required to vertically mix the lake that can be evaluated for every day of the year. We define the stratification season as the number of days when the stratification index exceeds a value of 600 kilograms per square meter. Since 1968, the length of the stratification season has increased by 29 days, albeit with considerable year-to-year variation. In 2023, the length of the stratified season was 193 days.

Data source: TERC lake monitoring.



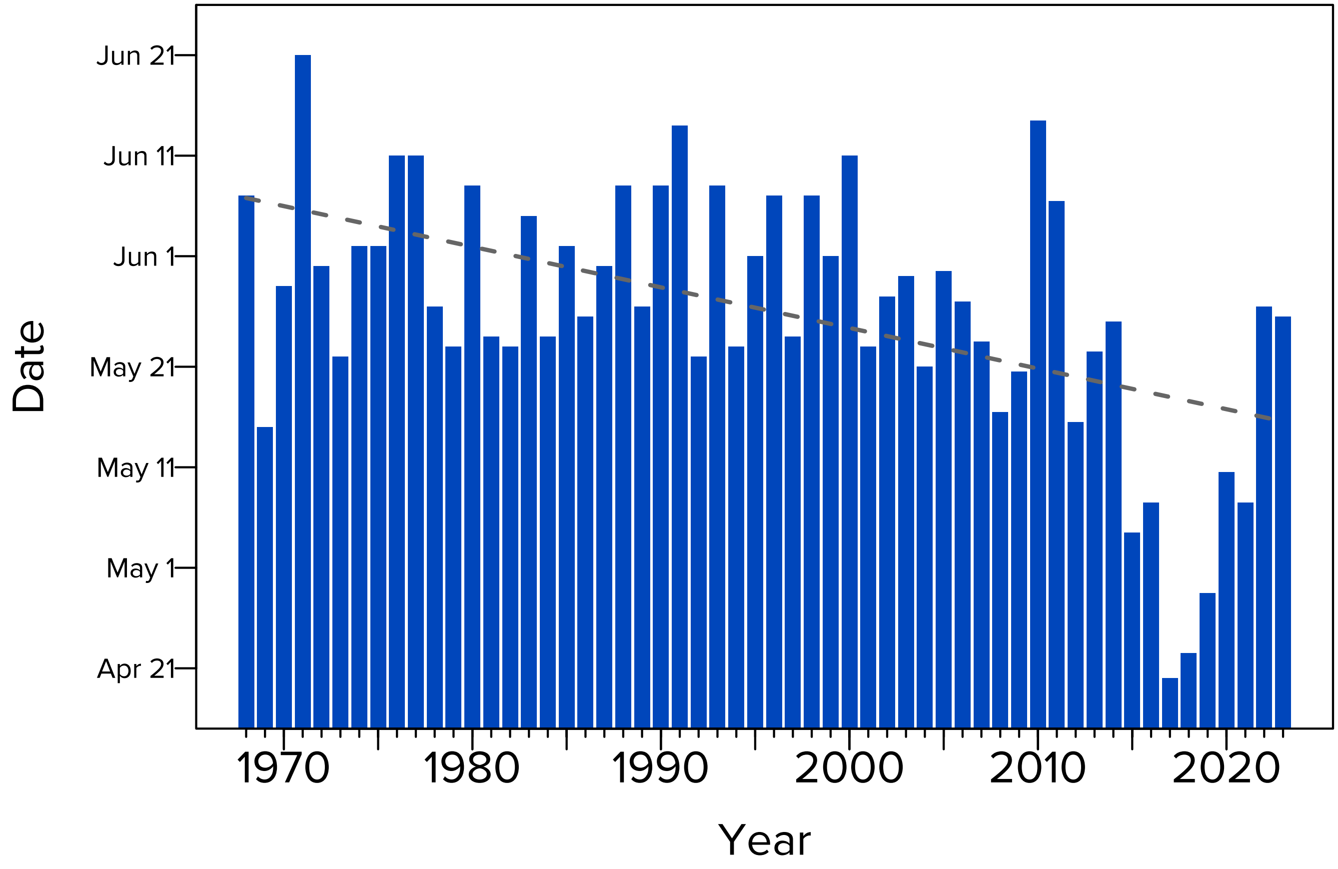
Beginning of the stratification season

Since 1968

The amount of time that Lake Tahoe is stratified has been increasing since 1968. One reason for this is the increasingly early arrival of spring as evidenced by the earlier commencement of stratification.

In 2023, the stratification commenced relatively late, on May 26 (Day 146). This was almost two weeks later than the long-term trend line would have suggested.

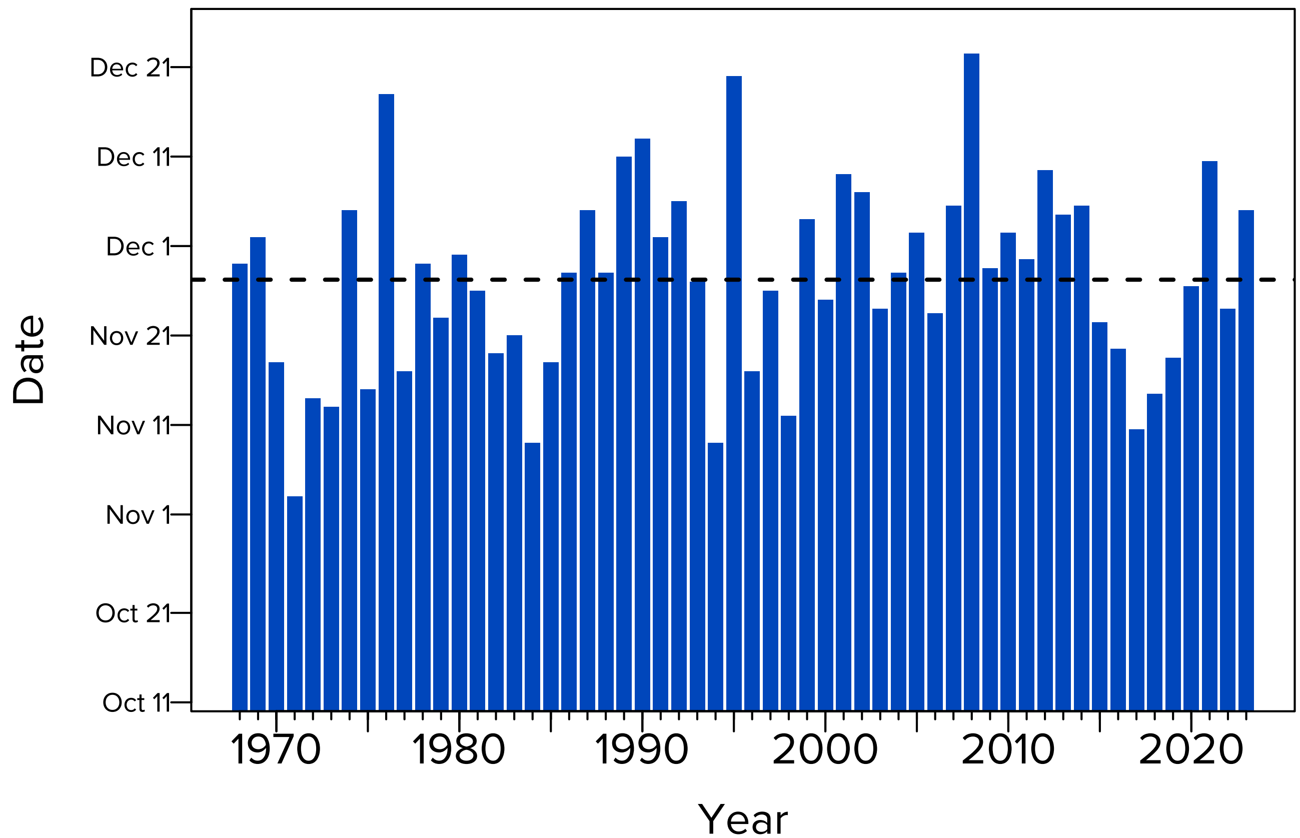
Data source: TERC lake monitoring.



End of stratification season

Since 1968

The amount of time that Lake Tahoe is stratified appears to have increased by almost a month since 1968. The end of the stratification season has been extended, but not as much as the onset of stratification (See Fig. 8.12). Over the 55-year record, the end of stratification appears to have been extended by approximately one week. Although the trend is not statistically significant, extended duration of stratification can have important implications for lake mixing and water quality, such as the buildup of nitrate at the bottom of the lake and the timing of deep-water mixing events. The dashed black line indicates the long-term mean for the end of stratification date. In 2023, the end of stratification was five days later than the long-term mean.
Data source: TERC lake monitoring.

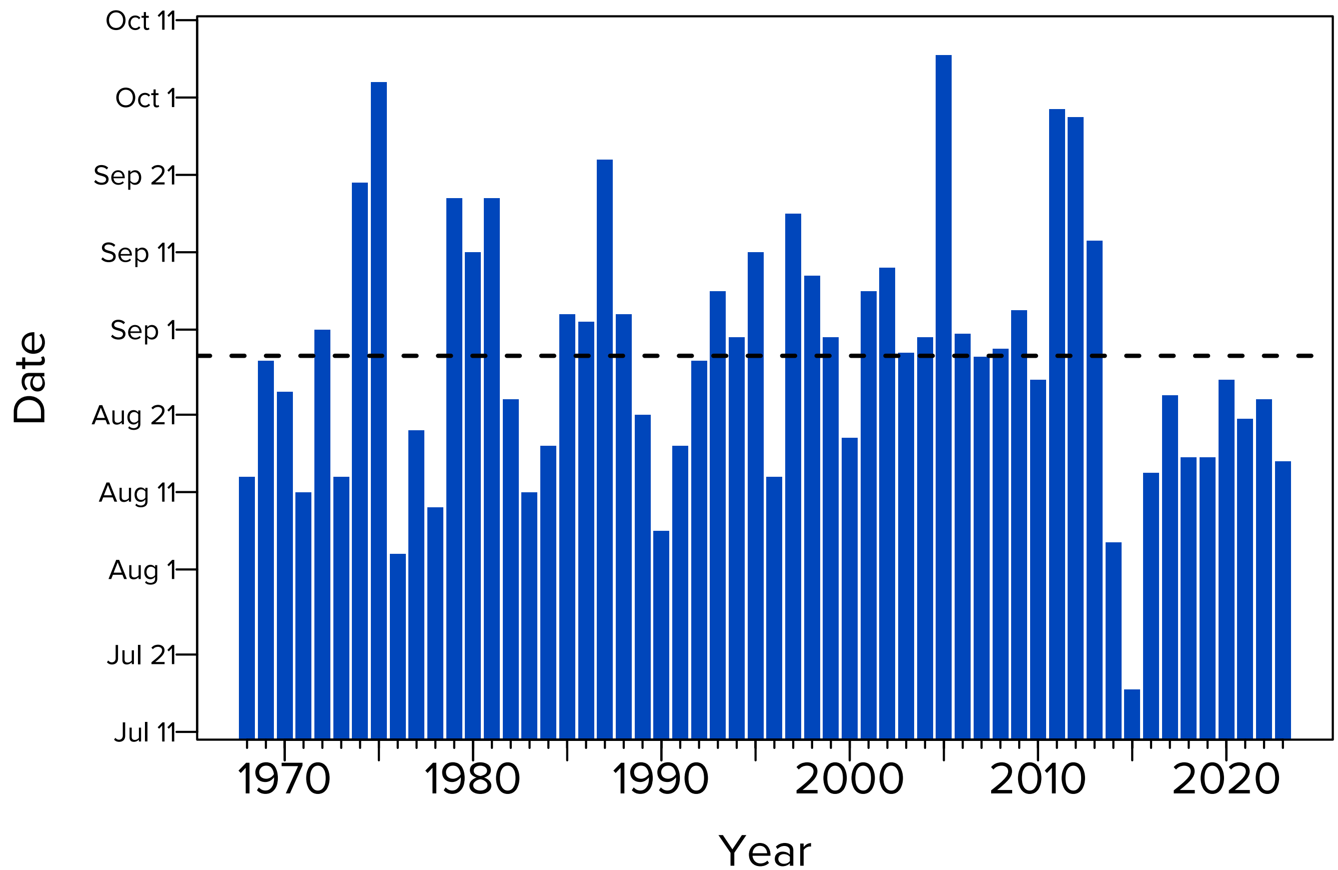


Peak of stratification season

Since 1968

Over the last ten years the occurrence of the peak of stratification has been earlier than the long term mean date. The day of the year when lake stratification reaches its maximum value is the peak of stratification season. There is considerable year-to-year variation, but over time there has been no statistically significant change in when the peak occurs. The dashed line shows the long-term mean. In 2023, the peak occurred on August 15.

Data source: TERC lake monitoring.

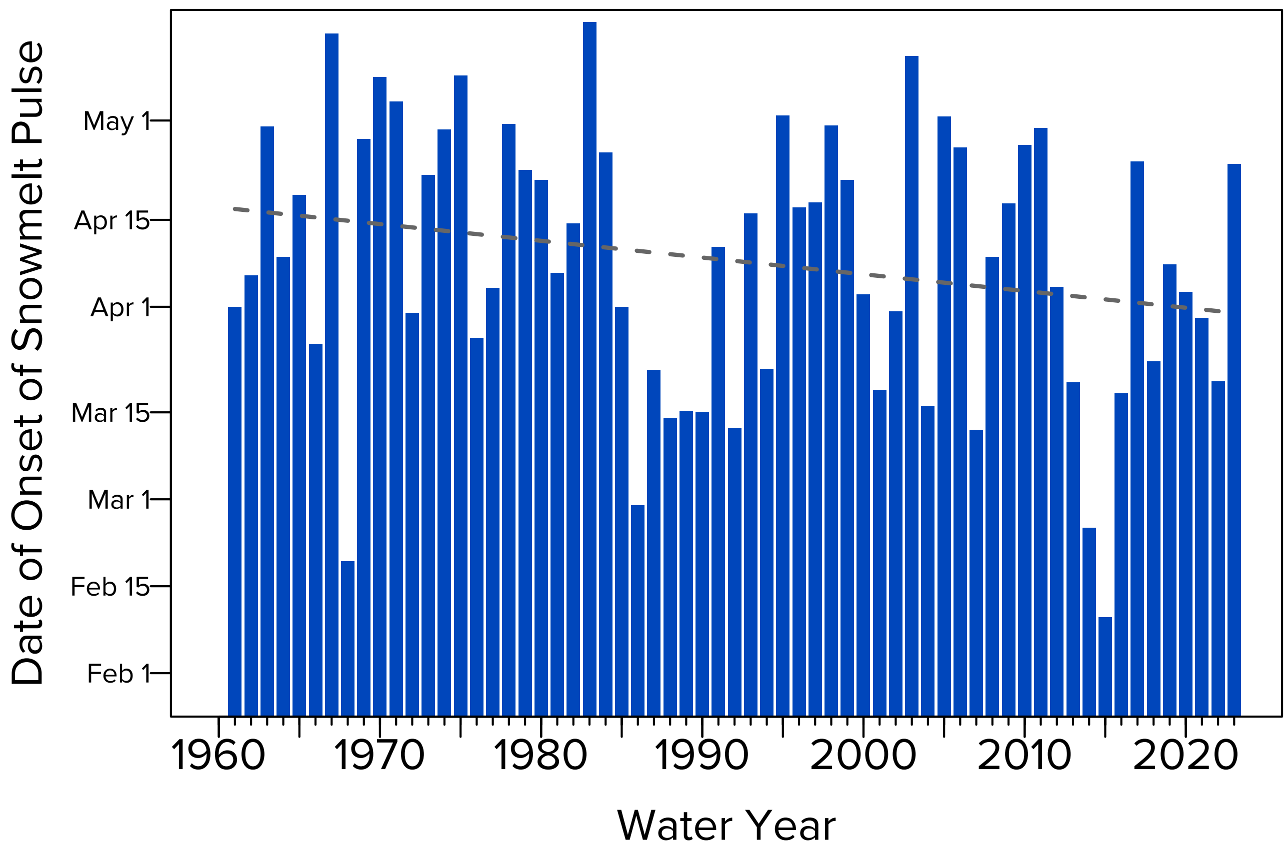


Onset of snowmelt pulse

Yearly since 1961

Although the date on which the onset of snowmelt commences varies from year to year, since 1961 it has shifted earlier by an average of over 16 days. The snowmelt pulse is calculated and averaged for five streams—the Upper Truckee River, Trout Creek, Ward Creek, Blackwood Creek, and Third Creek. This shift is statistically significant and is one effect of climate change at Lake Tahoe. In 2023, the onset occurred on April 24, thirty-five days later than the previous year. According to the regression line, since 1961, the onset of the snowmelt pulse has occurred earlier by 17 days than it did in 1961. The onset of the pulse is calculated as the day when flow exceeds the mean flow for the period January 1 to July 15. In the past, the peak of the stream hydrograph was used to estimate this metric.

Data source: US Geological Survey stream monitoring.



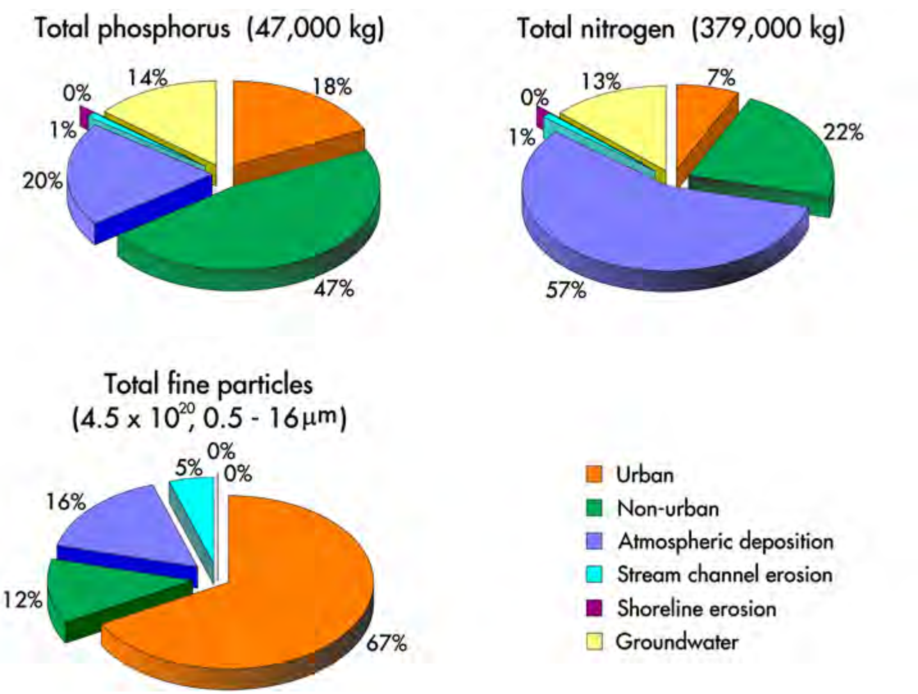
TAHOE: STATE OF THE LAKE REPORT 2024

NUTRIENTS AND PARTICLES

UC DAVIS
Tahoe Environmental Research Center

Sources of clarity-reducing and blueness-reducing pollutants

Research has quantified the primary sources of nutrients (nitrogen and phosphorus) and fine particulate material that are causing Lake Tahoe to lose clarity and blueness in its upper waters. One of the primary contributors to clarity decline is extremely fine particles (in the size range of approximately 1–6 µm) in stormwater that originate from both the urbanized watersheds and the streams that drain the majority of the basin's land area. For nitrogen, atmospheric deposition is the major source (57%). Phosphorus is primarily introduced by the urban (18%) and non-urban (47%) watersheds. These categories of pollutant sources form the basis of a strategy to restore Lake Tahoe's open-water clarity by management agencies, known as the Lake Tahoe Total Maximum Daily Load (TMDL) Program.



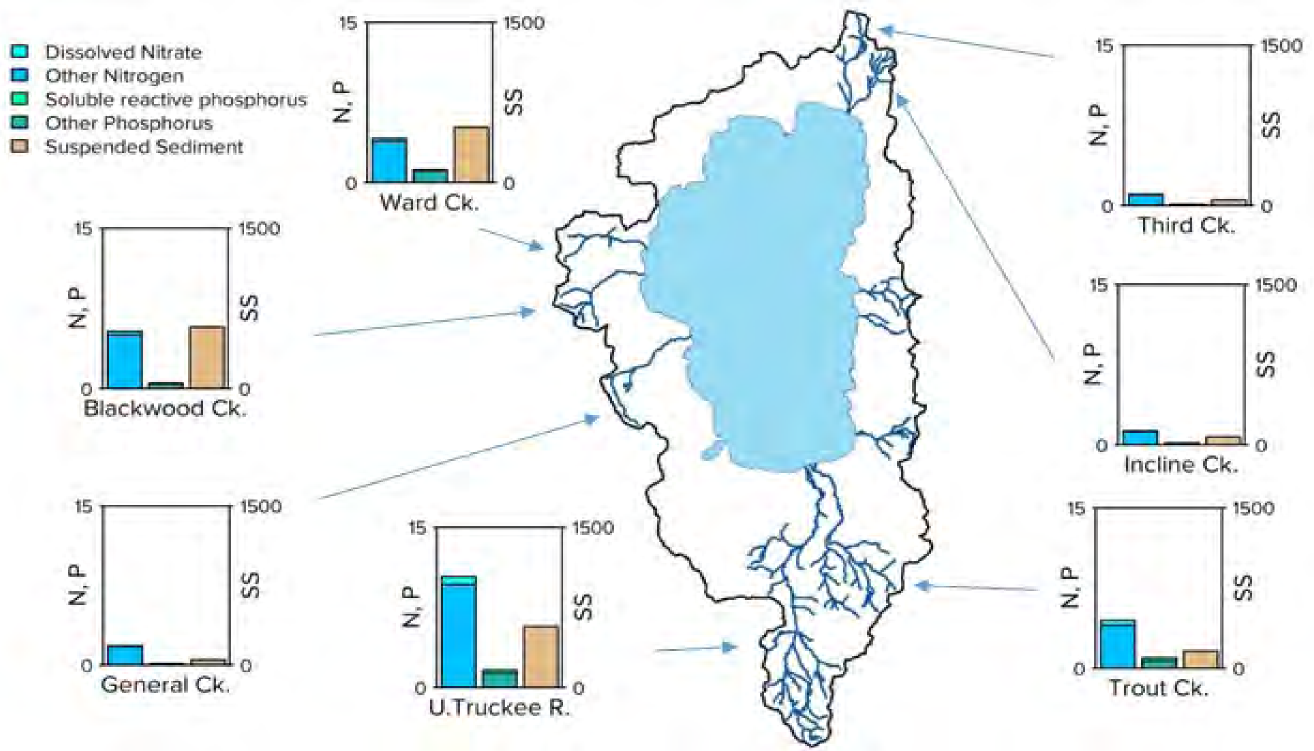
Pollutant loads from seven watersheds

In 2023

The Lake Tahoe Interagency Monitoring Program (LTIMP) measures nutrient and sediment input from seven of the 63 watershed streams. The streams are the Upper Truckee River, Trout Creek, Incline Creek, Third Creek, Ward Creek, Blackwood Creek, and General Creek. In 2023, the majority of stream phosphorus and nitrogen, as well as suspended sediments, came from the Upper Truckee River. This is often the case, but in some years, smaller streams, such as Ward Creek and Blackwood Creek, can also be significant contributors.

It should be noted that suspended sediments as represented in these data include all sediment sizes and is measured by weight. For clarity, it is the number of fine particles (in the range of 1–6 µm) that is important. These particles make up a very small fraction of the suspended sediment, but largely control lake clarity.

The LTIMP stream water quality program is supported by the Lahontan Regional Water Quality Control Board, the Tahoe Regional Planning Agency, the U.S. Geological Survey, and UC Davis TERC. TERC and the U.S. Geological Survey jointly collect and analyze the stream data.

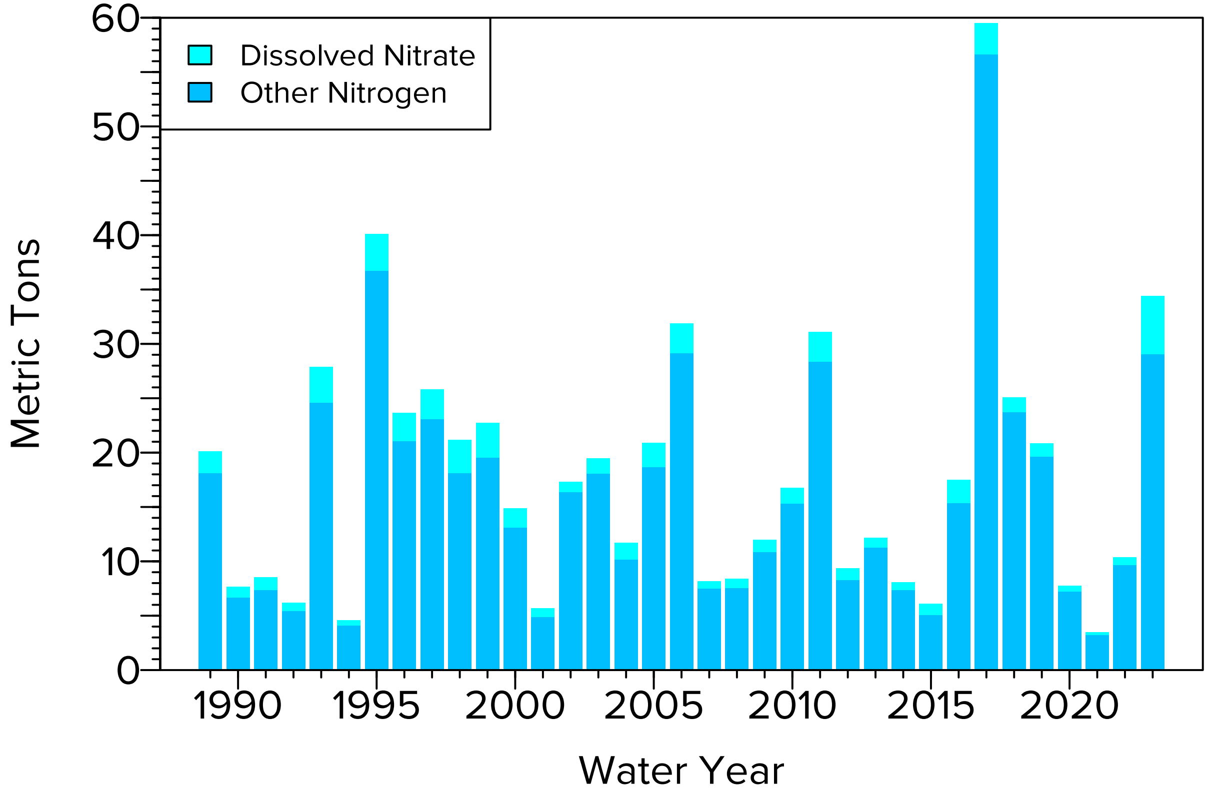


Nitrogen contribution by Upper Truckee River

Yearly since 1989

Nitrogen (N) is important because it, along with phosphorus (P), stimulates algal growth. The Upper Truckee River is the largest of 63 streams that flow into Lake Tahoe, contributing about 25 percent of the inflowing water. The river's estimated contribution of dissolved nitrate and the remainder of the total nitrogen load are shown here. Over the 34 years of record, the percentage of nitrate to total nitrogen has been in the range of 5–14 percent. The year-to-year variations primarily reflect changes in precipitation. For example, 1994 had 16.6 inches of precipitation and a low total nitrogen load of 4.6 MT, while 2017 had 68.9 inches of precipitation and a record high total nitrogen load of 59.5 MT.
In 2023, there were 46.8 inches of precipitation and the total nitrogen load from the Upper Truckee River of 34.4 MT. Nitrate load was a record high of 5.4 MT. The long-term mean annual total nitrogen load is 17.8 MT/yr while for nitrate it is 1.7 MT. (One metric ton (MT) = 2,205 pounds.).

Data source: TERC and US Geological Survey stream monitoring.

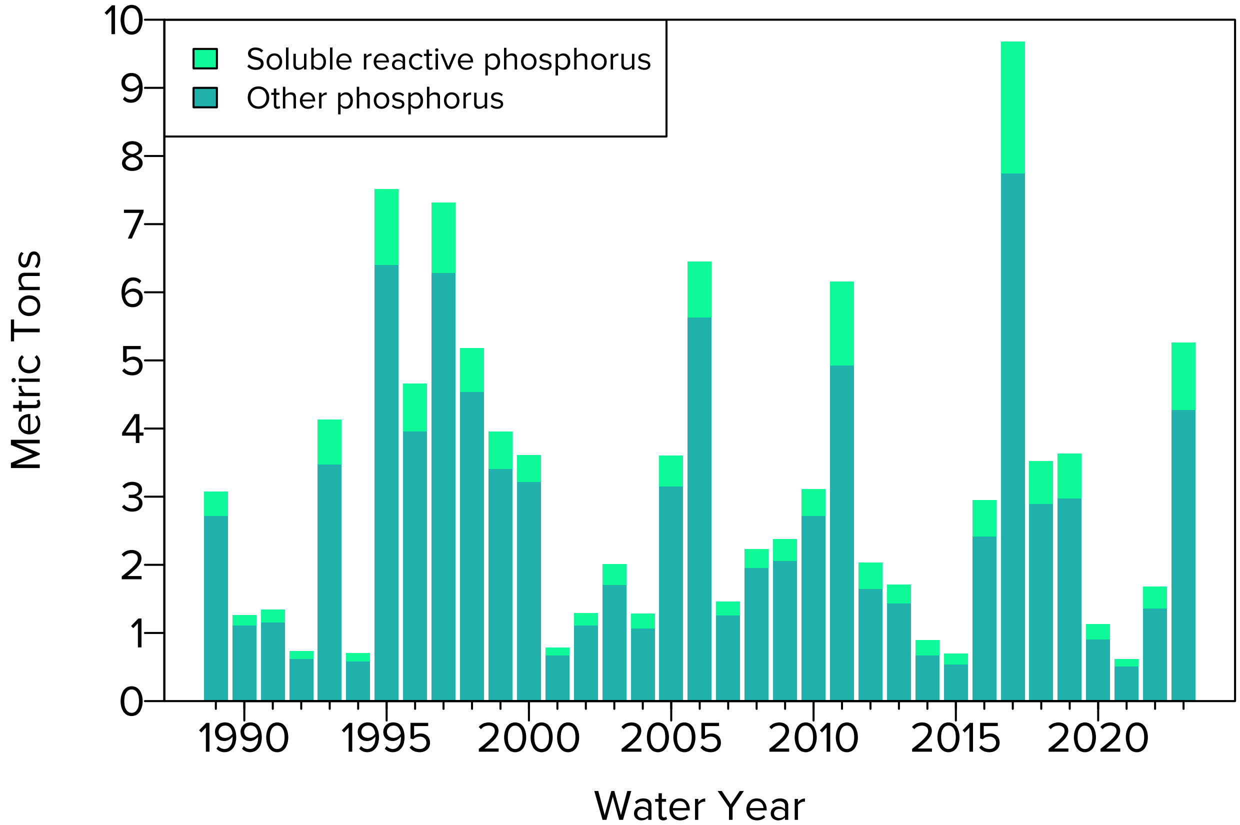


Phosphorus contribution by Upper Truckee River

Yearly since 1989

Soluble reactive phosphorus (SRP) is the fraction of total phosphorus immediately available for algal growth. As with nitrogen (Fig. 9.3), the year-to-year variation in estimated loads largely reflects the changes in precipitation. Above-average precipitation in 2023 resulted in above-average values for total phosphorus load of 5.26 MT and an SRP load of 0.99 MT. These compare with the long-term averages of 3.09 and 0.48 MT respectively. Over the 33 years of record, the percentage of SRP to total phosphorus load has been in the range of 11–25 percent. Decreasing nutrient inputs are 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.).

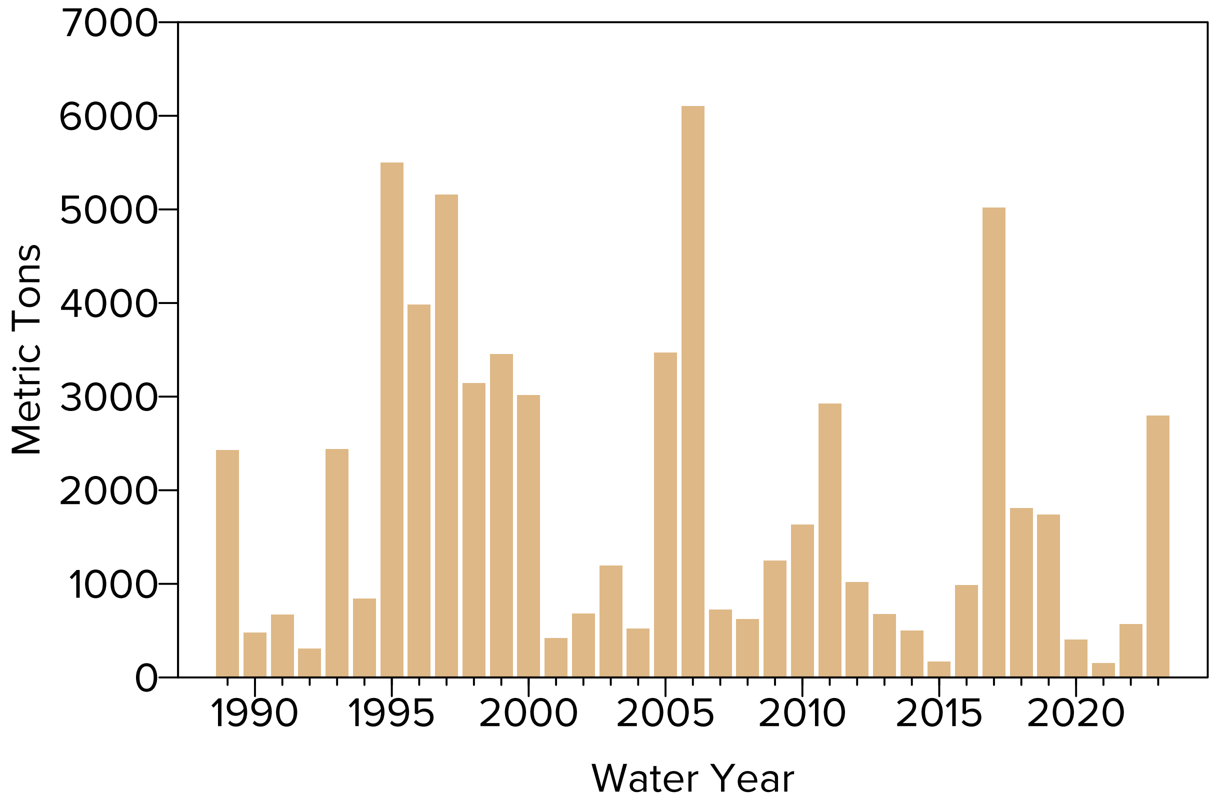
Data source: TERC and U.S. Geological Survey stream monitoring.



Suspended sediment contribution by Upper Truckee River

Yearly since 1989

The load of total 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 (in the size range of 1–6 microns in diameter) from urbanized areas. By contrast, efforts to restore natural stream function, watershed condition, and restoration of habitat for plants and wildlife, focus on reducing loads of total sediment regardless of size. In 2023, the estimated suspended sediment load from the Upper Truckee River was 2,799 MT. The highest load ever recorded was 6,100 MT in 2006. The average annual load is 1,909 MT. (One metric ton (MT) = 2,205 pounds.). Data source: TERC and U.S. Geological Survey stream monitoring.

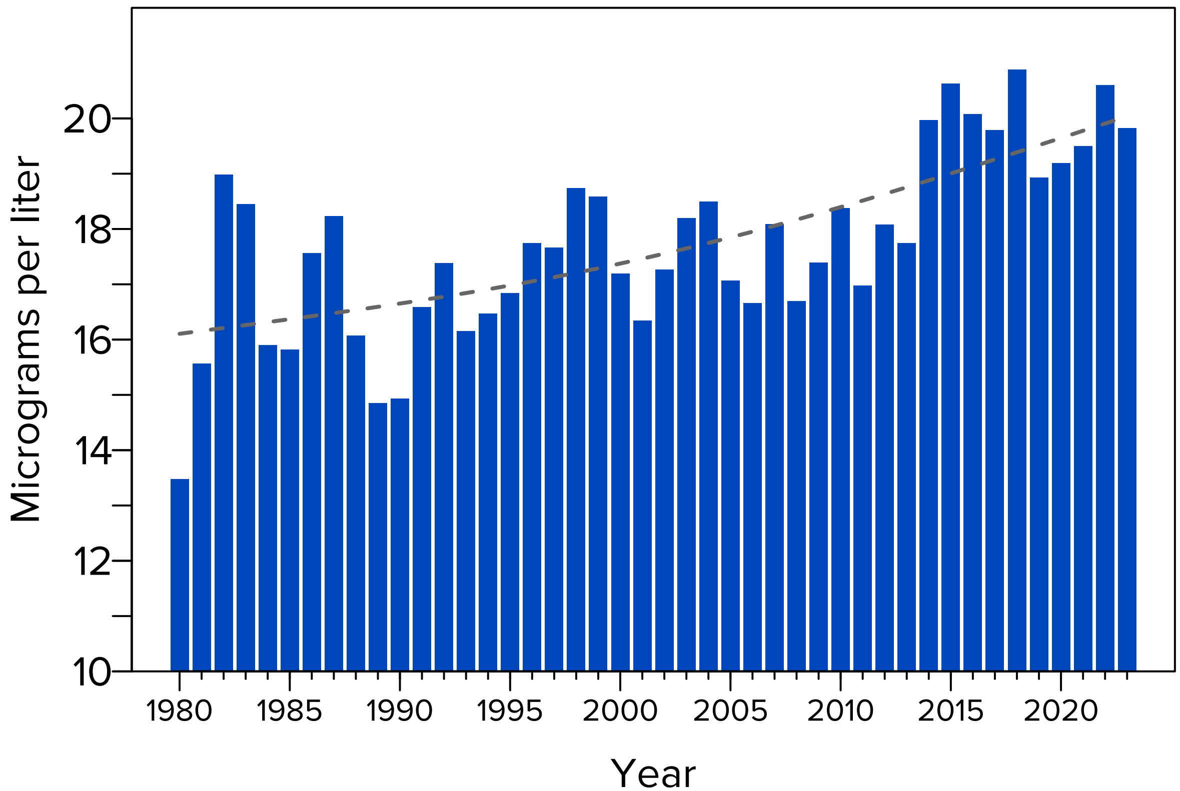


Lake nitrate concentration

Yearly since 1980

Until 2012, the volume-weighted annual average concentration of nitrate-nitrogen had remained relatively constant year-to-year, ranging between 13–19 micrograms per liter. Since that time, however, the lake's nitrate concentration has been increasing, as evident in the trend line produced with a Generalized Additive Model. In 2023, the volume-weighted annual average concentration of nitrate-nitrogen was 19.8 micrograms per liter. In 2023, lake nitrate concentration declined due to the deep mixing that redistributed the nitrate built up at the bottom of lake for the previous two years and made it available for algal uptake. In years with only shallow mixing, nitrate recommences accumulating and results in the increasing in-lake nitrate concentration. Another factor in the last several years is the additional atmospheric nutrient loading due to wildfire smoke engulfing the region. The impact of the 2021 wildfires is the subject of a continuing analysis.

Data source: TERC lake monitoring. Water samples are taken at the Mid-lake station at 13 depths from the surface to 1,480 feet.



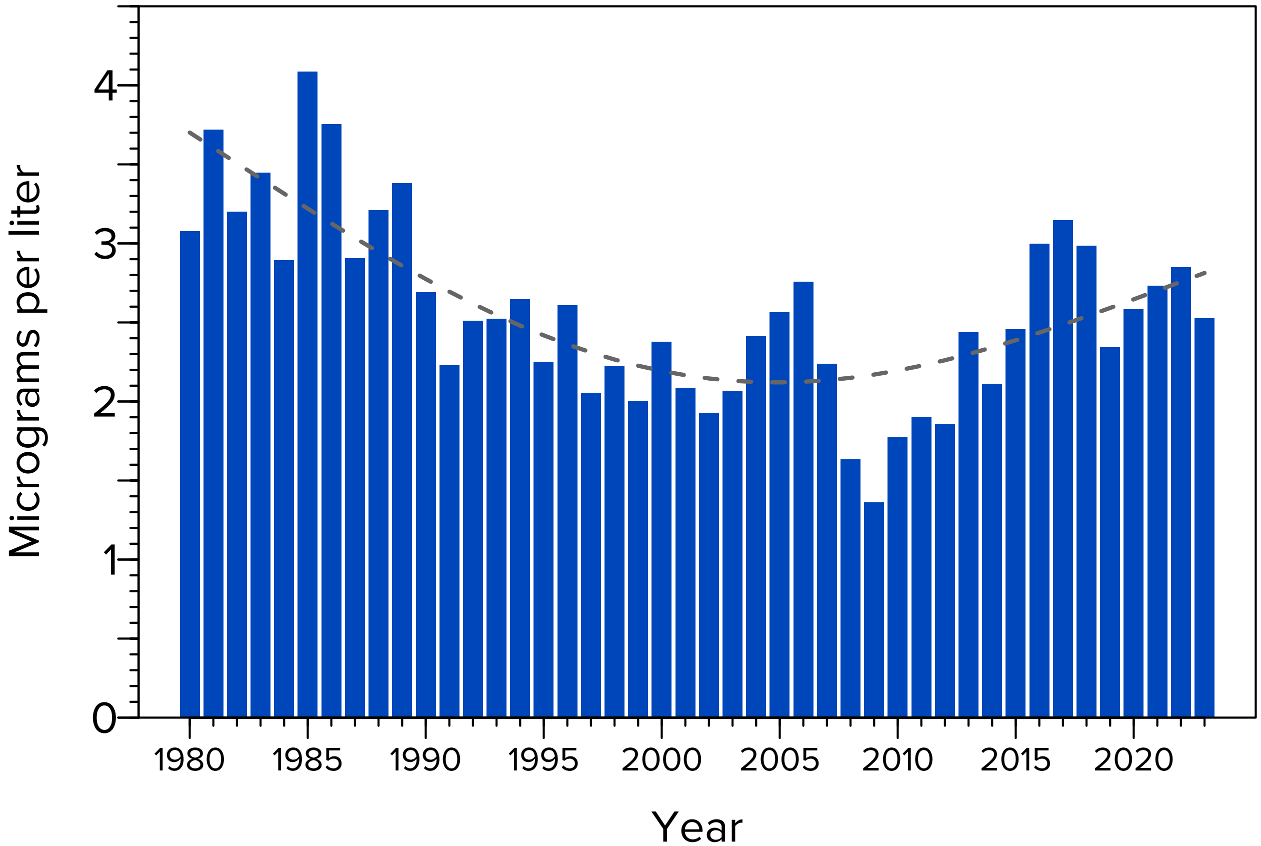
Lake total hydrolyzable phosphorus concentration

Yearly since 1980

Phosphorus naturally occurs in Tahoe Basin soils and enters the lake from soil disturbance and erosion. Total hydrolysable phosphorus (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 declined, although in the last 18 years the values have been increasing.

In 2023, the volume-weighted annual average concentration of THP was 2.53 micrograms per liter. Another factor in the last several years is the additional atmospheric nutrient loading due to wildfire smoke engulfing the region. The impact of the 2021 wildfires is the subject of a continuing analysis.

Data source: TERC lake monitoring. Water samples are taken at the Mid-lake station at 13 depths from the surface to 1,480 feet.



Lake fine particle concentration

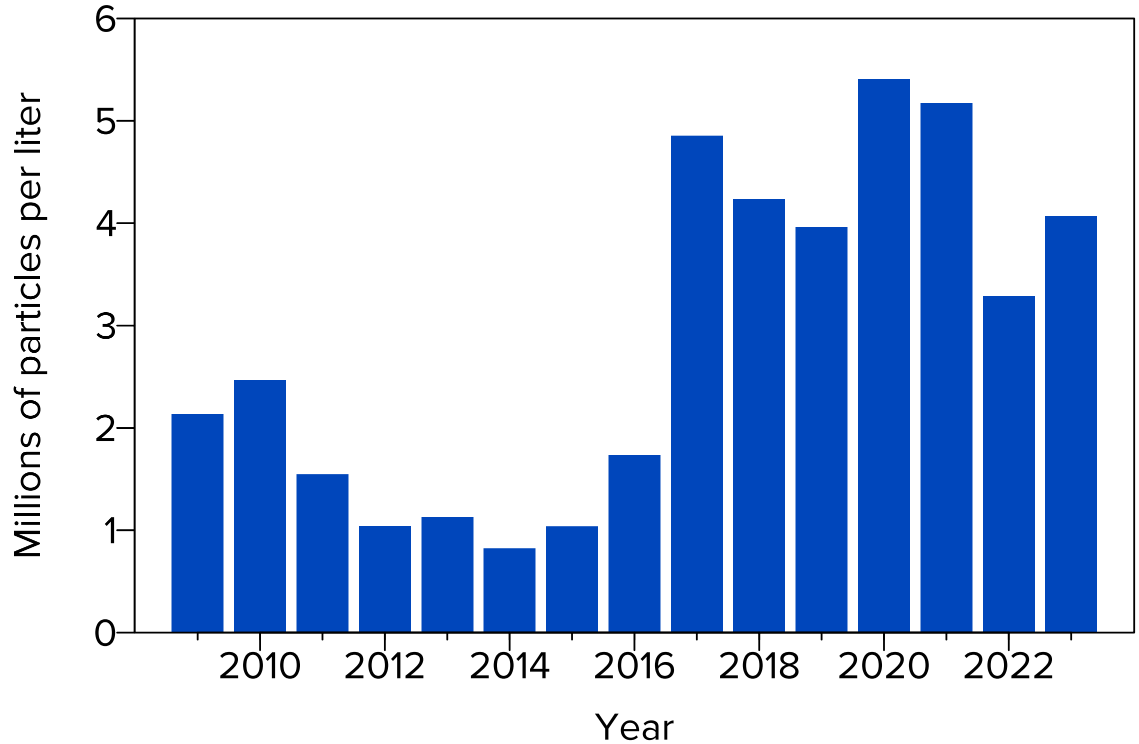
Yearly since 2009

Fine particles in the size range of approximately 1–6 microns in the upper 50 m are principally responsible for the attenuation of visible light and the consequent loss of lake clarity. These particles can be inorganic (clay and silt) or organic (phytoplankton). As particles in this size range settle slowly, their removal from the lake depends in large part on their aggregation into larger particles. The settling rate of a particle depends on the square of its diameter. Larger, aggregated particles will settle disproportionately faster.

`2017 was an extremely wet year, there was a large increase in fine particles delivered to Lake Tahoe from the streams in the watershed. This would account for the step change in concentration evident between 2016 and 2017. The continued high average concentration since that time is difficult to explain. 2020 and 2021, both of which were low precipitation years, displayed an increase in particle concentration beyond the 2017 level. In 2023, an increase in particle concentration coincided with an increase in precipitation

Loading of particles from wildfires and streams were lower in 2023. A preliminary analysis comparing rates of aggregation of lake particles, suggests that aggregation rates have not changed significantly over the period of the record.

Data source: TERC lake monitoring. Water samples are taken monthly at the MLTP (mid-lake) station at 13 depths from the surface to 1,480 feet.



Lake fine particle concentration

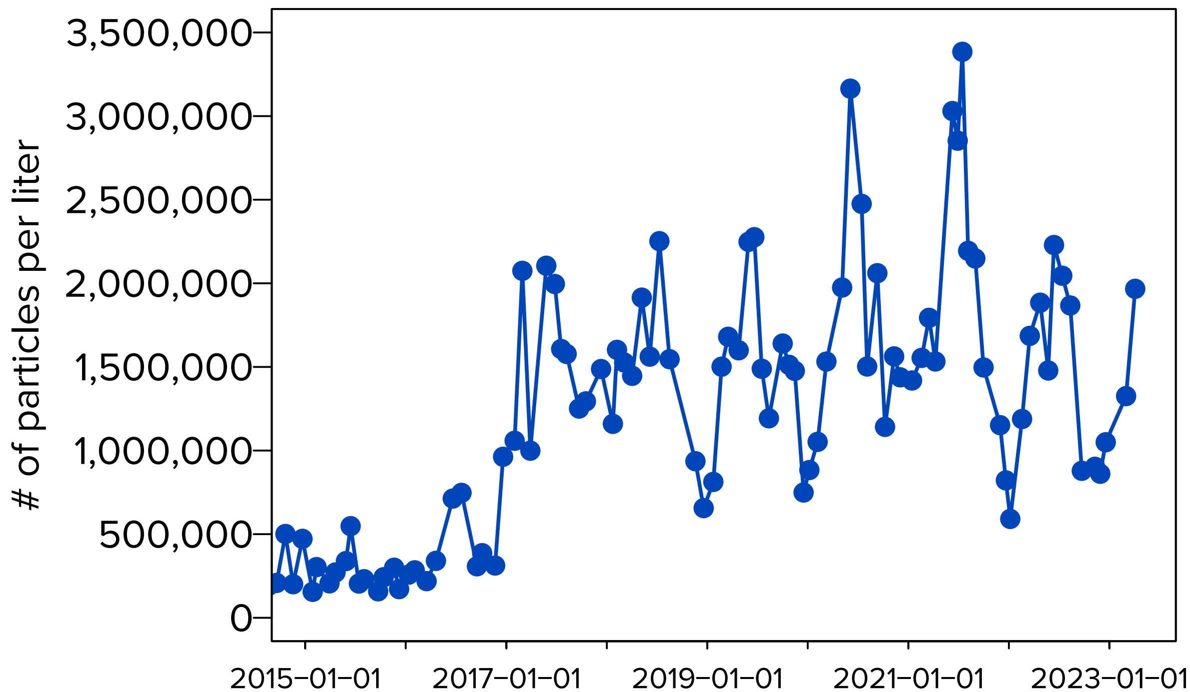
Monthly since 2015

Fine particles in the size range of approximately 1–6 microns in the upper 50 meters are principally responsible for the attenuation of visible light and the consequent loss of lake clarity. These particles can be inorganic (clay and silt) or organic (phytoplankton).

The data indicate the annual increase of fine particles at mid-year were due to a combination of particle influx from spring snowmelt and a consequent algal bloom. In 2017, an extremely wet year, there was a large increase in fine particles delivered to Lake Tahoe from the streams in the watershed. This would account for the step change in concentration evident between 2016 and 2017. The continued high average concentration since that time is difficult to explain. According to the UC Berkeley Central Sierra Snow Lab, 2022-23 had the second greatest amount of snowfall that was recorded since 1946. This large amount of snow potentially resulted in an astonishing large particle concentration that is twice the amount that has ever been since 2009.

Water samples are taken monthly at the MLTP (mid-lake) station at 13 depths from the surface to 1,480 feet. Here, data from 0 m, 10 m and 50 m were utilized.

Data source: TERC lake monitoring.



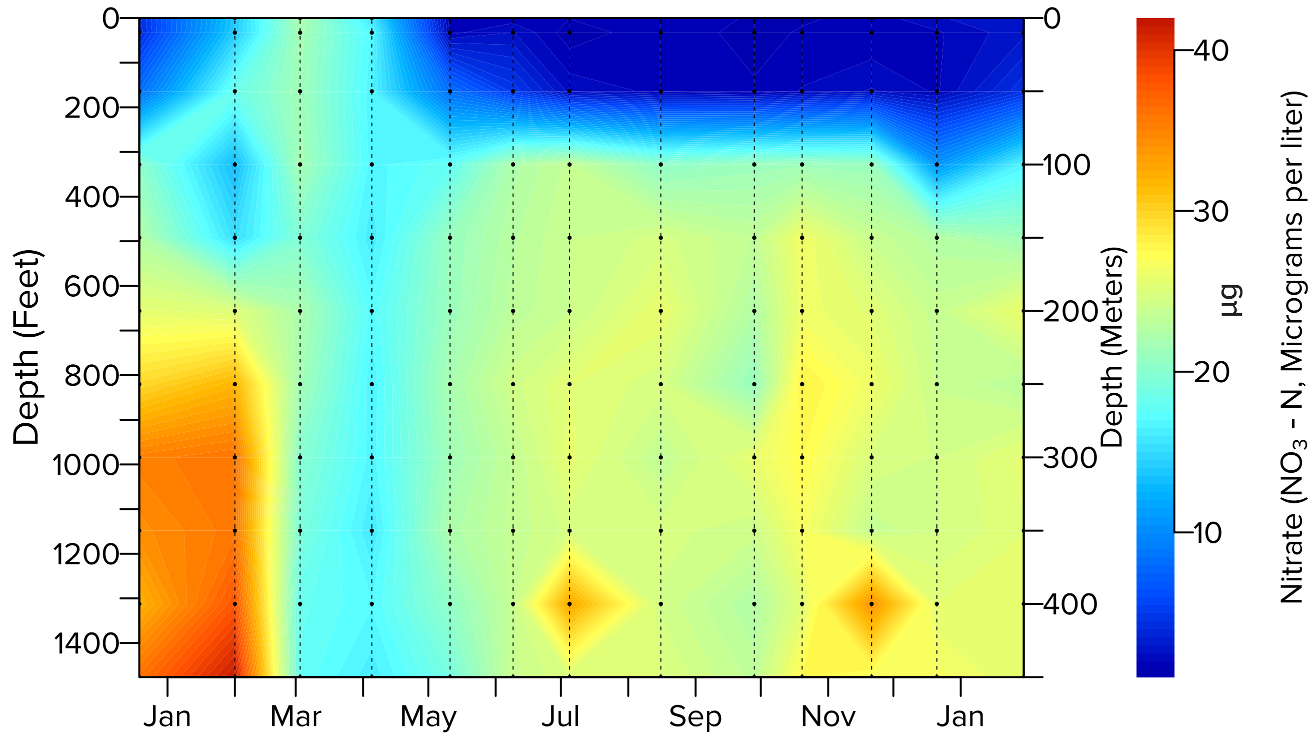
Nitrate distribution

In 2023

Water samples are collected approximately every month (on dates indicated by the dashed lines) at 13 depths (indicated by the dots) at the MLTP station in the middle of the lake. These samples are then processed 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 disappearance of the high nitrate region in the bottom half of the lake with deep mixing in March. Nitrate was uniformly distributed until May when the surface nitrate was being depleted and a sharp "nitricline" is evident at a depth of 250 feet. Although most of the "new" nitrate enters at the surface through atmospheric deposition, it is rapidly taken up by the algae and surface concentrations remain 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.

Data source: TERC lake monitoring.



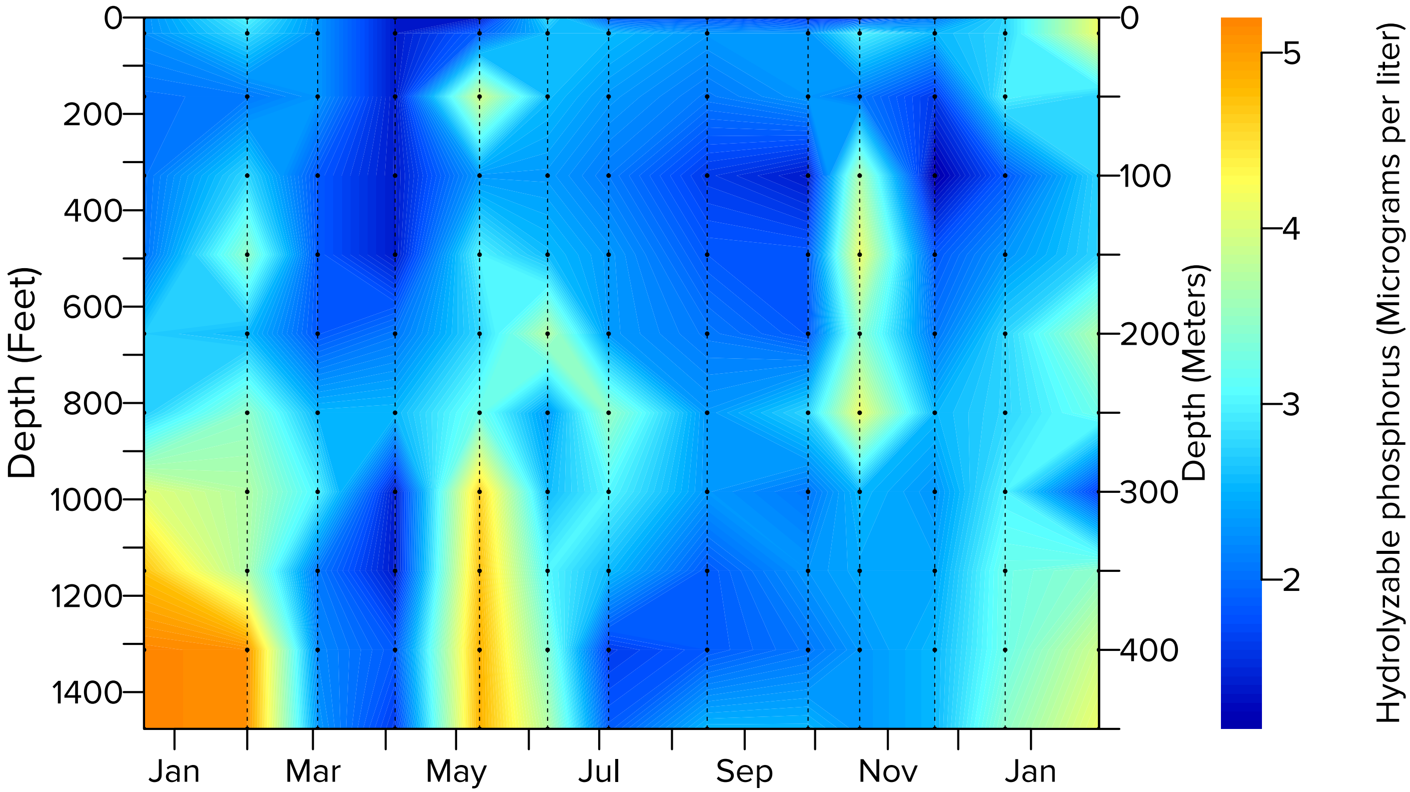
Total hydrolyzable phosphorus distribution

In 2023

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

Phosphorus mainly entered the lake in association with fine particles during runoff events in May through June. The relatively elevated values near the surface in May suggest that in 2023, nitrogen was the nutrient that limited algal growth, rather than phosphorus in the spring. Due to deep mixing in March, the preceding high phosphorus levels were rapidly diluted through the entire water column.

Data source: TERC lake monitoring.



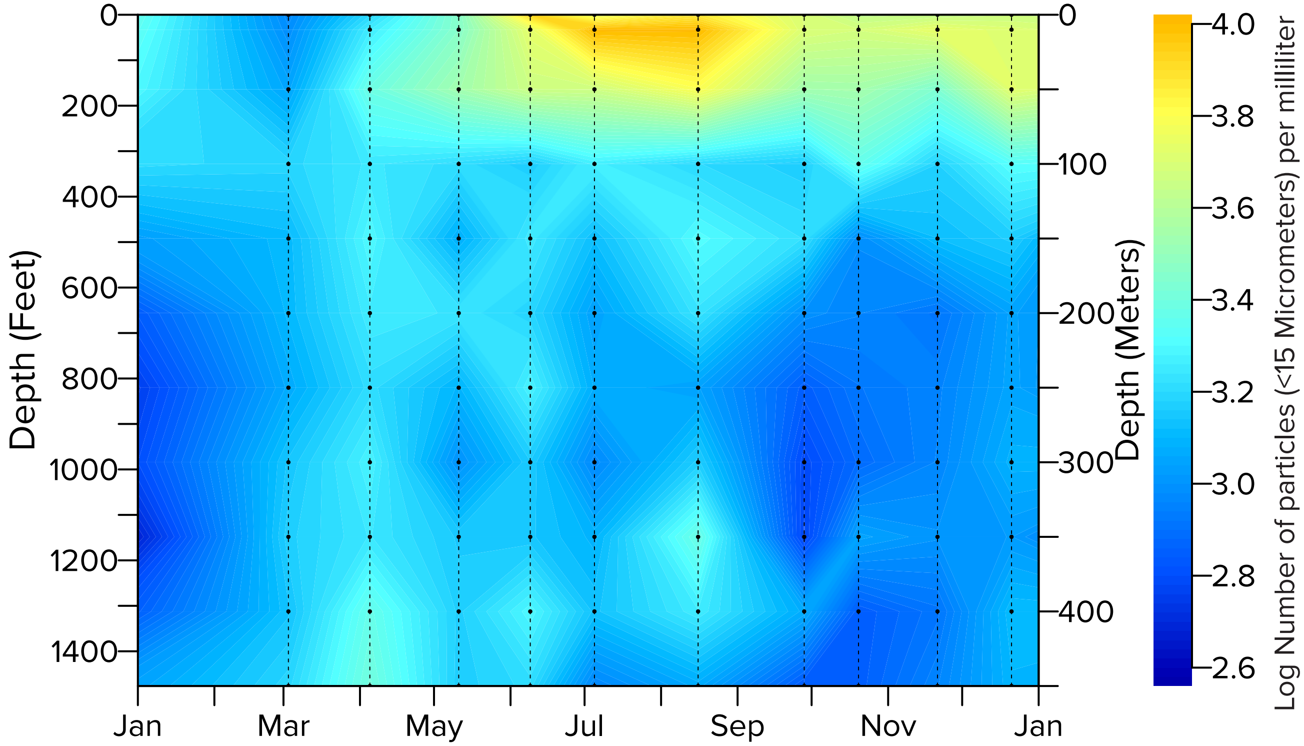
Fine particle distribution

In 2023

Water samples are collected approximately monthly (on dates indicated by the dashed lines) at 13 depths (indicated by the dots) at the MLTP station. These samples are analyzed in the TERC laboratory for concentrations of fine particles in 15 different bin sizes. The distributions of fine particles (in the size range of 1–6 microns) are shown in the form of color contours. Particles can be inorganic particles such as clay or silt or organic particles such as very small algal diatom particles.

Unlike the nutrients in Figures 9.9 and 9.10, fine particles are in low concentrations deep in the lake throughout the year. The entry of particles in the upper part of the lake (above 300 ft) associated with spring snowmelt is evident in late May through August. In 2023, there was a continued trend of a large decline in the particle concentration in the upper 300 ft of the lake to levels below which have been observed in the recent years. This is consistent with the very high Secchi depths that were recorded in the beginning of 2023 (See Fig. 11.4). The particles do not decrease in the upper layer in the same way as nitrogen or phosphorus, as they are not taken up by algal growth. Instead, fine inorganic particles gradually clump together (aggregate) which allows them to settle to the lake bottom more rapidly. Additionally, they can be removed by zooplankton grazing.

Data source: TERC lake monitoring.



TAHOE:
STATE OF THE LAKE
REPORT
2024

BIOLOGY

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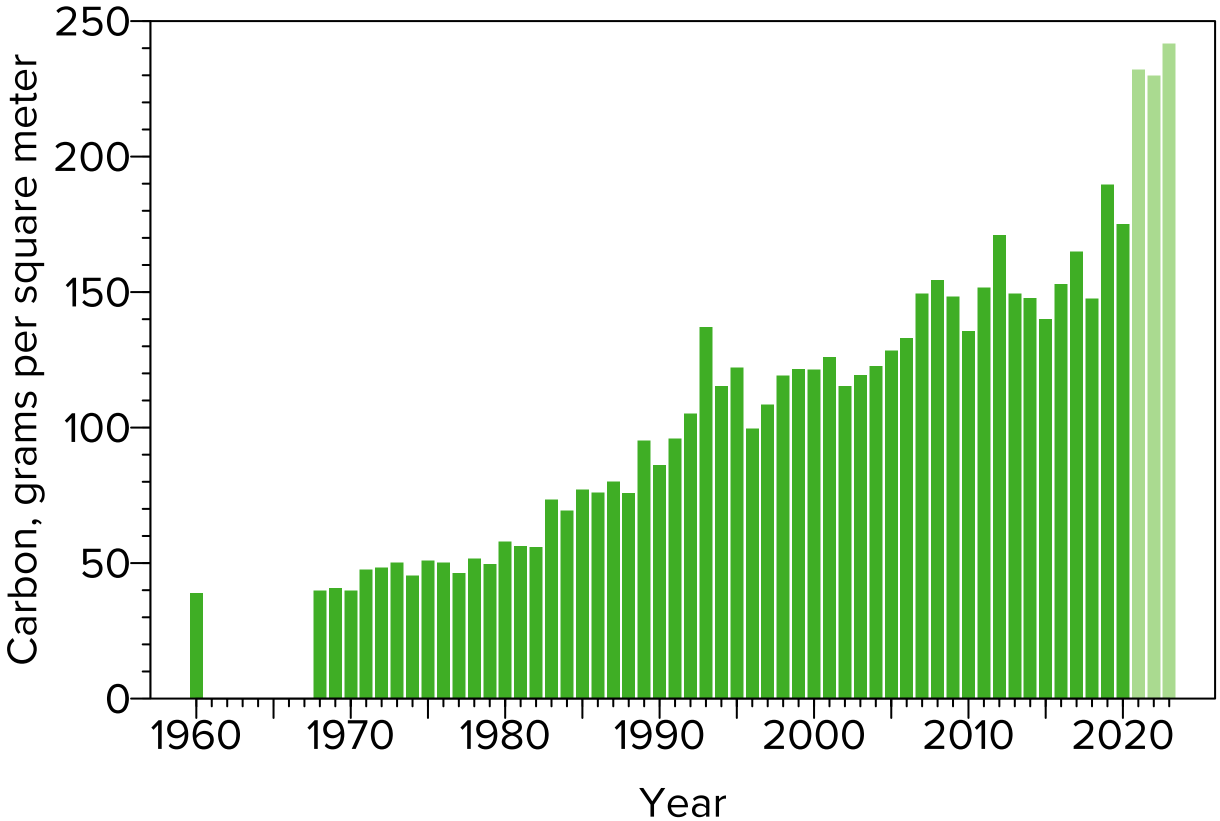
Algae growth (primary productivity)

Yearly since 1959

Primary productivity is a measure of the rate at which algae incorporate inorganic carbon through photosynthesis to produce organic matter or biomass. It was first measured at Lake Tahoe in 1959 and has been measured continuously since 1968. Regulated by a complex interplay of nutrient availability, light levels, temperature, composition and physiological state of algae, and many other factors, the long-term trend shows that primary productivity has increased over time, particularly in the last few years.

The long-term dataset was recently reviewed and corrected data show that over the last 55 years, there was a 480% increase in the annual average primary productivity. Since 2021, there have been extremely high standard deviations indicative of highly fluctuating month-to-month values. In 2023, the annual average primary productivity attained a record high value of 240 mg of carbon per m^2.

Data source: TERC lake monitoring.

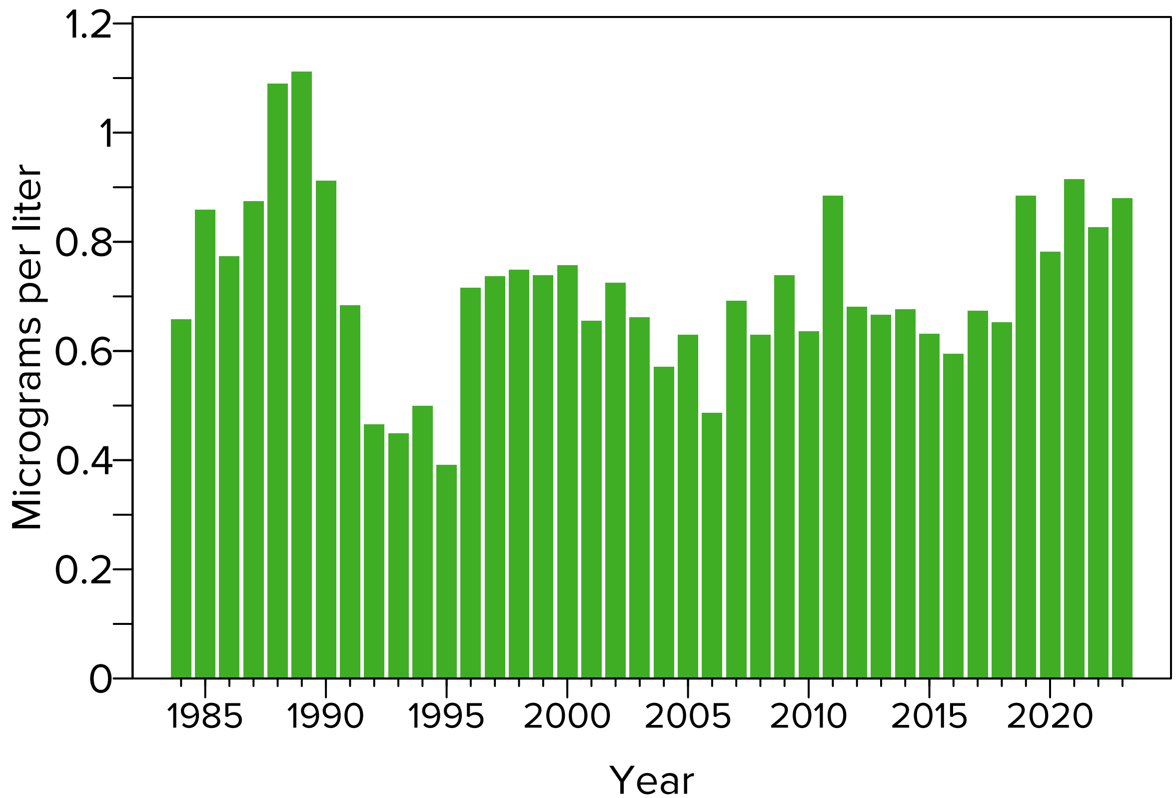


Phytoplankton chlorophyll annually

Yearly since 1984

Phytoplankton (algae) are the base of the Lake Tahoe food web and essential for lake health and the well-being of the entire ecosystem. Like land plants, all phytoplankton have chlorophyll-a which is a photosynthetic pigment that allows them to absorb and covert light energy into biomass. Therefore, measurements of the concentration of chlorophyll-a of phytoplankton can be used to estimate the algal biomass in the lake water. Though the value varies annually and at different depths throughout the lake, for the last 26 years the average concentration has shown remarkable consistency and 2023 continued along this pattern. The average annual concentration for the year was 0.88 micrograms per liter, a slight increase from the previous year. For the period of 1984–2023 the average annual chlorophyll-a concentration in Lake Tahoe was 0.72 micrograms per liter.

Data source: TERC lake monitoring.

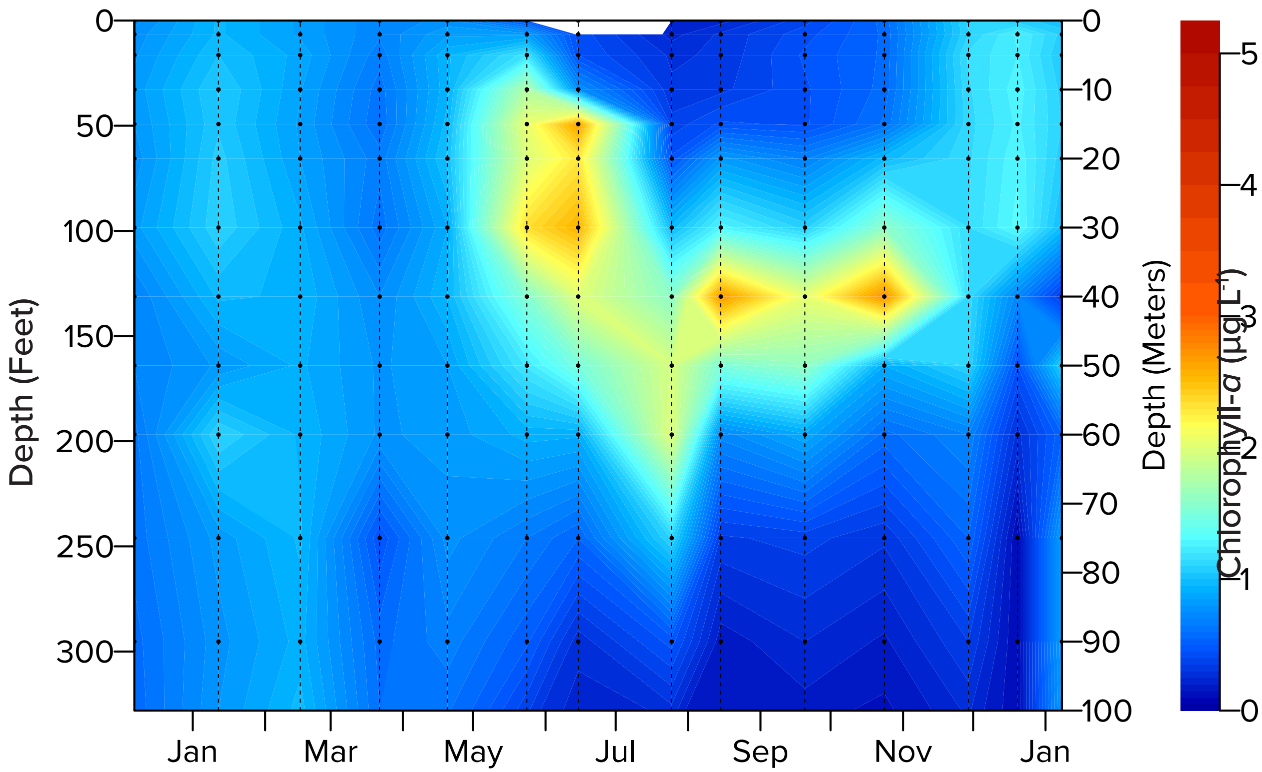


Chlorophyll-*a* spatial distribution

In 2023

The spatial and temporal distribution of chlorophyll-a at the euphotic zone (to a depth of 350 feet.) Below this depth, chlorophyll-a concentrations are near zero due to the absence of light. Lake Tahoe typically has a distinct deep chlorophyll maximum (DCM) in the summer that occupies the range of 150–300 feet (45-90 m) in the water column, well below the thermocline.

In 2023, however, DCM was present in a much shallower range mostly between 30-160 feet (9-49 m) in the water column. The full mixing of the lake and redistribution of nutrients in the water column in March and April may have contributed to the development of a chlorophyll peak at shallow depths during late May and June. During a short period in late-July the warmer surface water extended in depth, and elevated levels of chlorophyll-a were similarly observed reaching 250 feet (76 m). On two occasions, secondary chlorophyll-a peaks occurred after the onset of thermal stratification. Later in December, then again, with the commencement of mixing, the algae were redistributed in the water column.

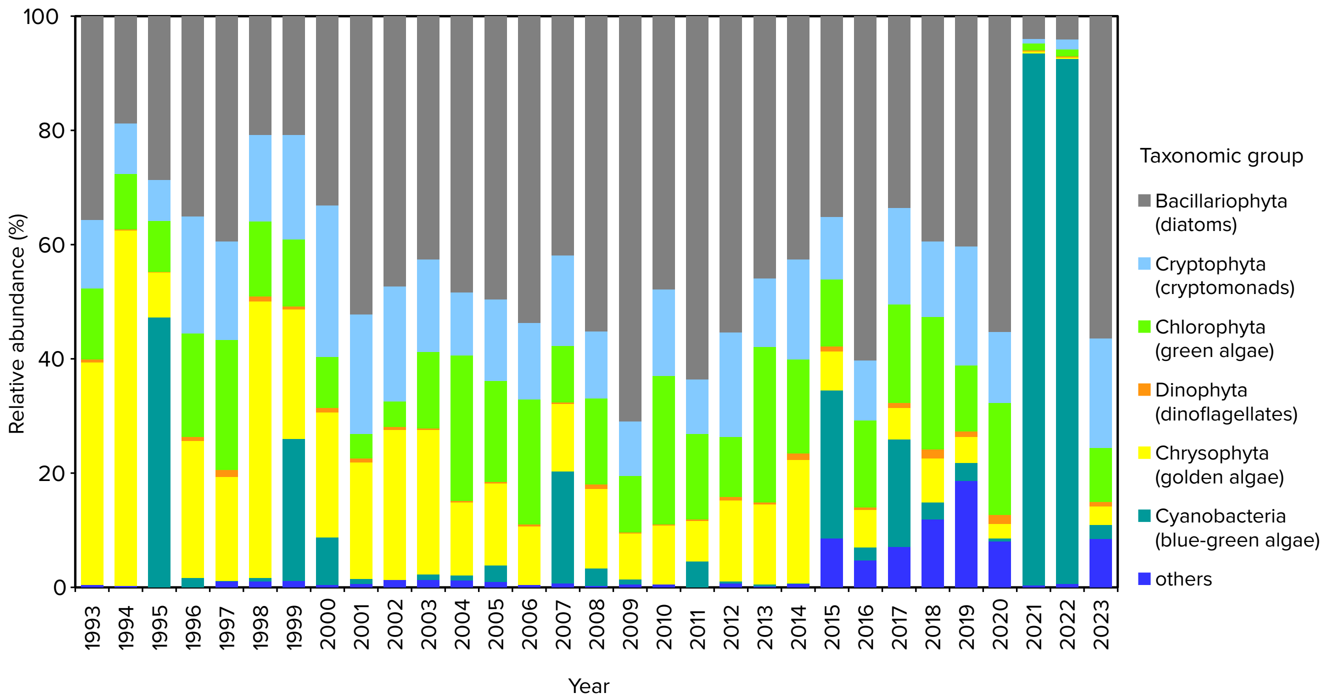


Distribution of algal groups

Yearly since 1993

There are six major taxonomic groups represented in the pelagic phytoplankton from Lake Tahoe. The relative abundance of different groups varies from year to year, but diatoms are generally the most common type of algae. In 2021 and 2022, cyanobacteria dominated the phytoplankton assemblage part of a single, contiguous event resulting from nutrient inputs from the Caldor Fire. In 2023, diatoms comprised approximately 56 percent of the total abundance of algal cells, following a two-year period of major composition change with unusual dominance of cyanobacteria. This shift was likely associated to contiguous event resulting from the Caldor Fire. Cryptomonads, green-algae and golden-algae comprised respectively 19, 9.5 and 3 percent of the total cell counts in 2023, while cyanobacteria accounted for 2.5 percent of 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 climate and changing conditions.

Data source: TERC lake monitoring.

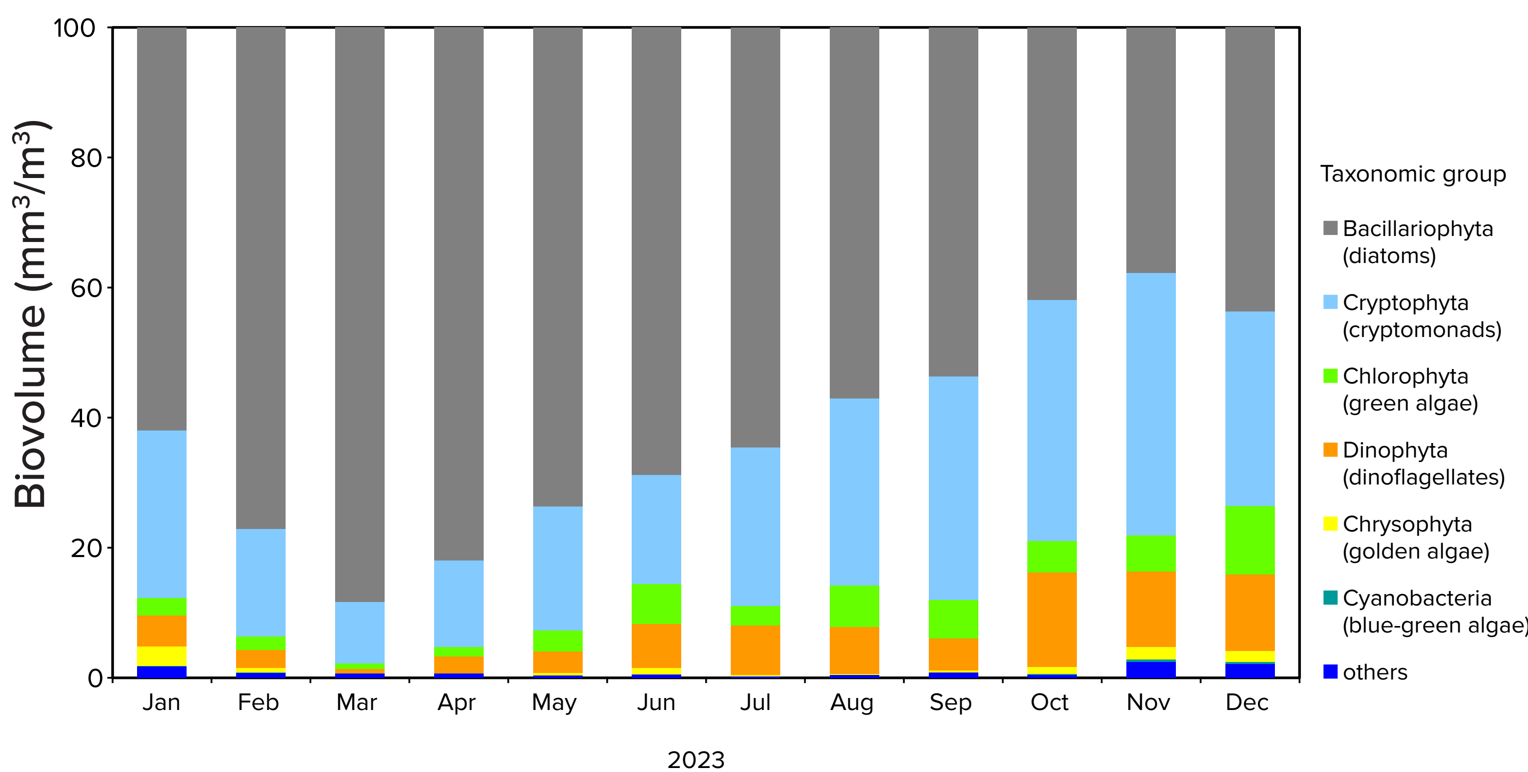


Algal groups as a fraction of total biovolume

Monthly in 2023

The biovolume of algal populations usually vary seasonally as well as year to year. In 2023, the total biovolume was largely dominated by diatoms. The highest biovolume was recorded between March and May with the occurrence of a peak of 320 cubic millimeters per cubic meter in April. This "spring bloom" is a typical occurrence in Lake Tahoe and many other temperate lakes. Annual minima occurred between late-fall and early-winter. While the proportion of the major algal groups have shown a degree of consistency from year-to-year. TERC data show how extreme events can easily disrupt balance of these groups in Lake Tahoe for multiple years before returning to baseline conditions.

Data source: TERC lake monitoring.



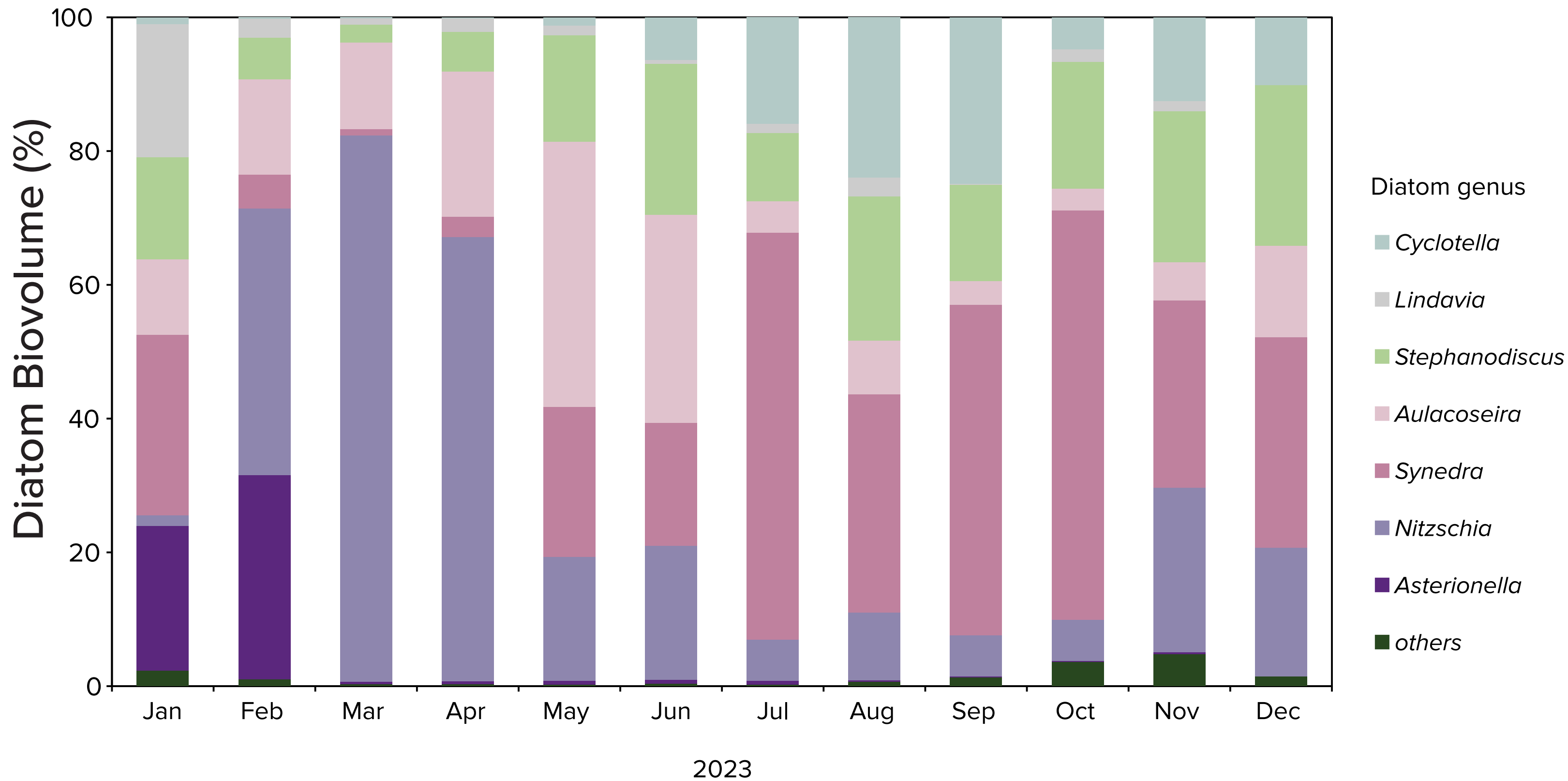
Abundance of dominant diatom species

Monthly in 2023

Since 1982, diatoms have been the dominant algal group at Lake Tahoe for all but a few years. Diatoms are unique among algae in that they have a rigid cell wall made of silica, called a frustule. The relative abundance of dominant diatoms in terms of depth-integrated biovolume at Lake Tahoe in 2023 are shown below.

There were large variations in the relative composition with the succession of seven major genera throughout the year. The genera *Asterionella*, *Lindavia*, *Stephanodiscus*, *Synedra*, *Nitzschia*, and *Aulacoseira* are all relatively large diatoms, while Cyclotella is in a smaller size range. It is worth noting that in terms of cell counts, larger forms may be less abundant than smaller ones, but their biovolume may have higher contribution to the total biomass.

Data source: TERC lake monitoring.



Mysis population

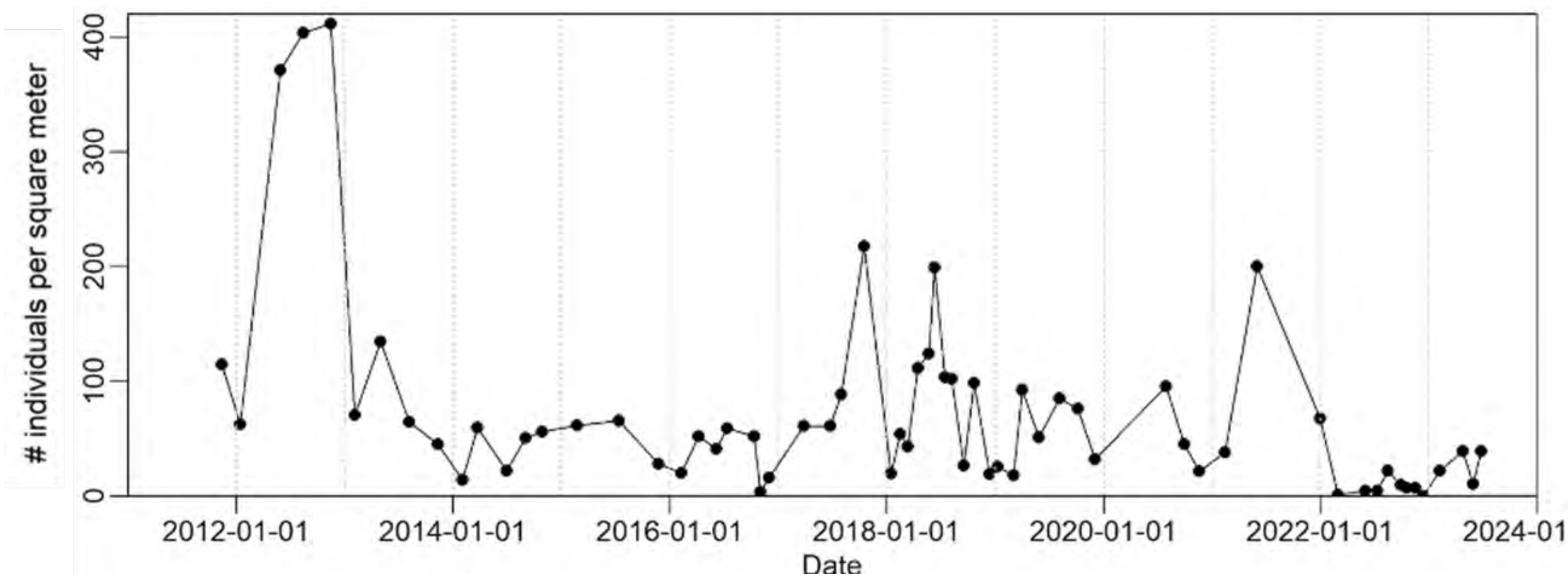
Since 2012

Mysis shrimp were introduced to Lake Tahoe in the 1960s in an attempt to improve the size of game fish in the lake. The intended result did not occur and instead the *Mysis* upset the existing lake food web. Within four years of their introduction, they had decimated the populations of the native cladocerans (*Daphnia* and *Bosmina*) and since that time, these zooplankton are rarely observed. *Daphnia* and *Bosmina* were once an important food source for native minnows, which in turn provided food for kokanee salmon and rainbow trout.

In the 1980s, research on *Mysis* essentially stopped. However, since 2012, TERC has recommenced regular surveys of Lake Tahoe and Emerald Bay. The sampling net is pulled vertically in Lake Tahoe at 3-month intervals from three sites: South Shore Deep (200 m), LTP Index (100 m), and MLTP (200 m). Since early 2022, sampling has increased to monthly intervals.

The *Mysis* densities (number of individuals collected divided by the net opening area) in Lake Tahoe show considerable variability. It is estimated that a *Mysis* population of 27 individuals per square meter represents the threshold at which cladocerans can reestablish. In early 2022, *Mysis* numbers fell below that threshold and remained low through the end of the year. In 2023, the *Mysis* population in Lake Tahoe has started to recover.

Data source: TERC lake monitoring.



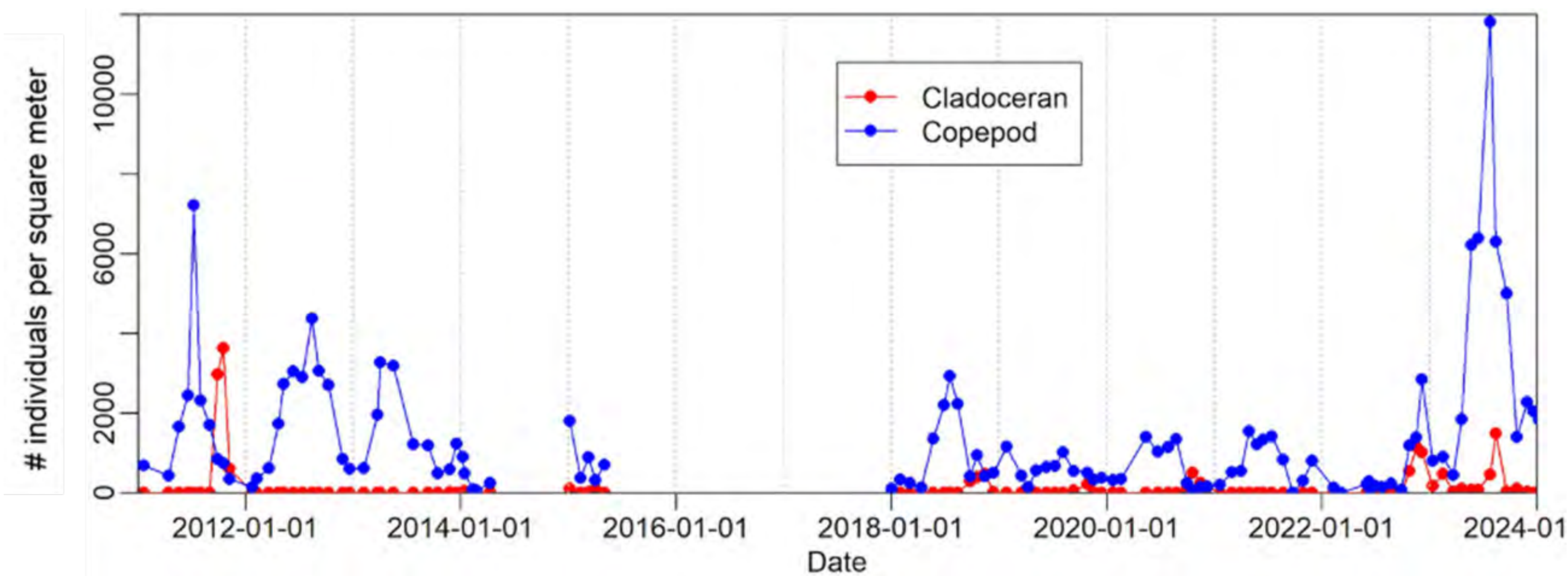
Zooplankton populations

Since 2012

The zooplankton populations in Lake Tahoe have been monitored episodically since the 1960s, but due to a lack of funding there are many data gaps. Since 2012, TERC has sought to re-establish monitoring. The data shown below are from the LTP site, where zooplankton were collected with replicate vertical trawls from a depth of 330 feet to the surface during the middle of the day.

The figure shows the abundance of three groups of zooplankton — cladocerans (*Daphnia* and *Bosmina*) and copepods (*Epischura* and *Diaptomus*). The cladocerans are typically at very low values, a feature that first occurred after the introduction of *Mysis* shrimp in the 1960s. Notably at the end of the record, in September 2022, their numbers increase. The copepods are generally variable, but in late 2021 their numbers collapsed possibly due to a fungal infection.

Data source: TERC lake monitoring.



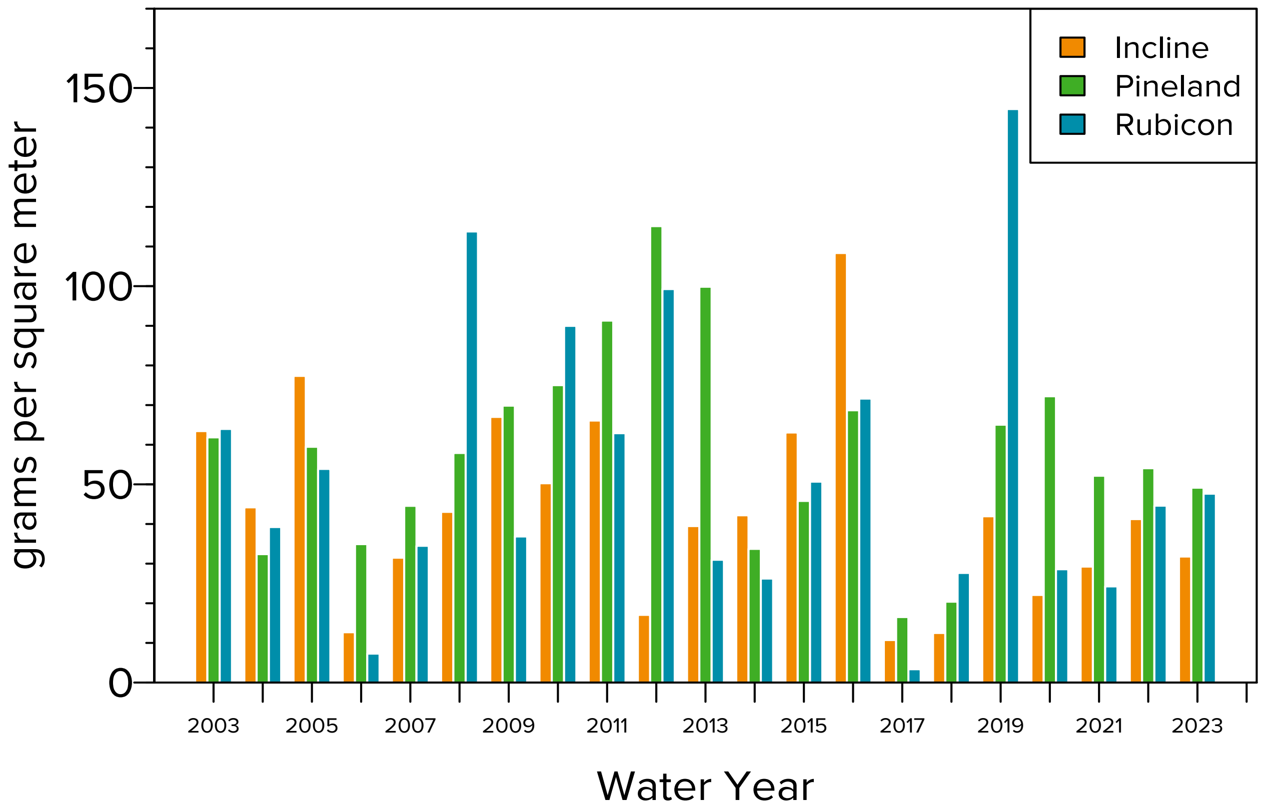
Peak shoreline algae concentrations

Yearly since 2003

Periphyton, or attached algae, makes rocks around the shoreline of Lake Tahoe green and slimy, or they sometimes form a very plush white carpet after being sun-bleached. This graph shows the maximum biomass measured at 1.5 feet (0.5 m) below the surface at three sites from January to June. In 2023, concentrations at the Incline, Pineland, and Rubicon sites were all below their long-term average.

This data is a part of the newest whole-lake aerial approach to better represent the spatial extent of periphyton blooms. This site-specific measuring does not capture the critically important spatial extent of periphyton blooms but does maintain a long-term record for comparison with the much larger dataset currently being collected.

Data source: TERC lake monitoring.



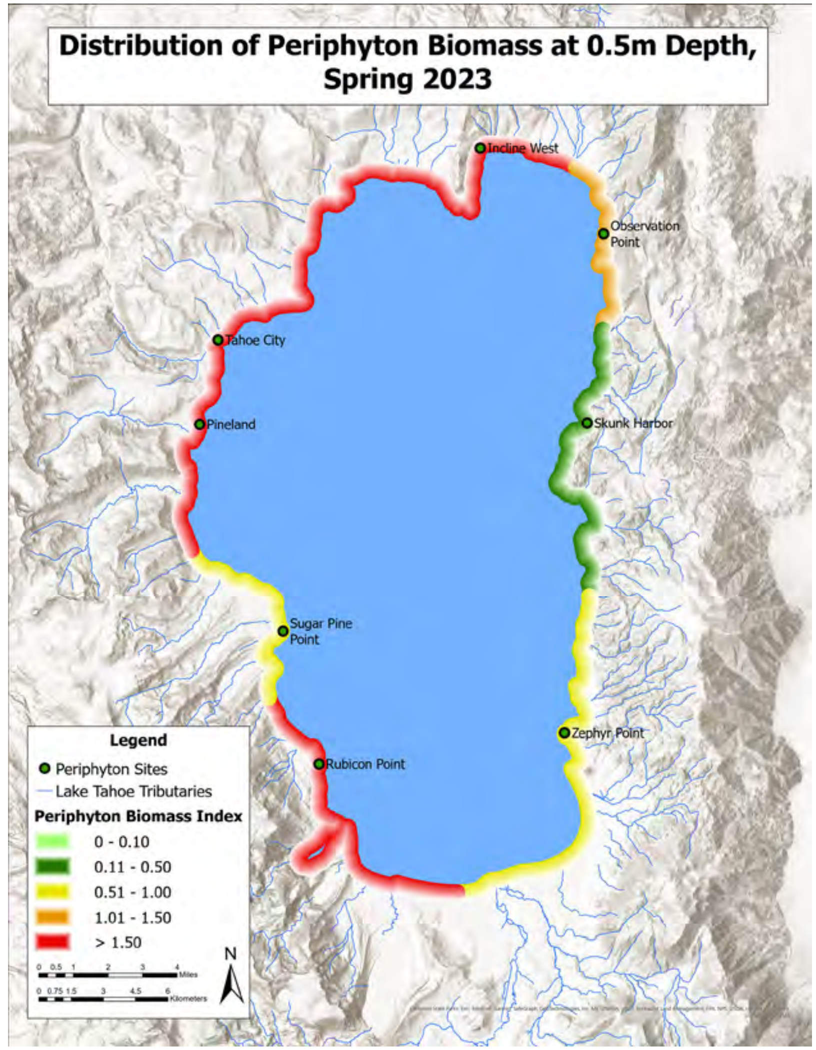
Shoreline algae distribution

In 2023

Periphyton biomass was surveyed in 1.5 feet (0.5 m) of water around the lake over a three-week period during the spring when periphyton is usually at its annual maximum. In 2023, periphyton growth peaked in April. A Periphyton Biomass Index (PBI) is used as an indicator to assess the amount of periphyton algae growth. The PBI is used to indicate the amount of periphyton growth, the higher the ranking, the more algal growth. TERC monitors eight periphyton sites, strategically located around the nearshore of Tahoe. At each site, divers take in-situ PBI measurements and cover approximately 200m of shoreline. The measurements are averaged to provide one PBI measure per site. This PBI ranking is then extrapolated to the length of shoreline adjacent to each site, providing an estimate of periphyton growth around the entire nearshore. While divers are unable to take measurements continuously around the entire 72-mile shoreline of Lake Tahoe, these interpolated rankings are a good estimate of algae growth, but there may be areas of variability within each section of shoreline. The goal of this monitoring is to track periphyton growth both spatially and temporally throughout the year.

Most of the east shore had relatively low growth. This is in part a reflection of the high wave activity that causes the periphyton to slough, as well as generally lower amounts of precipitation and runoff along the east shore.

Data source: TERC lake monitoring.



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.

TAHOE: STATE OF THE LAKE REPORT 2024

CLARITY

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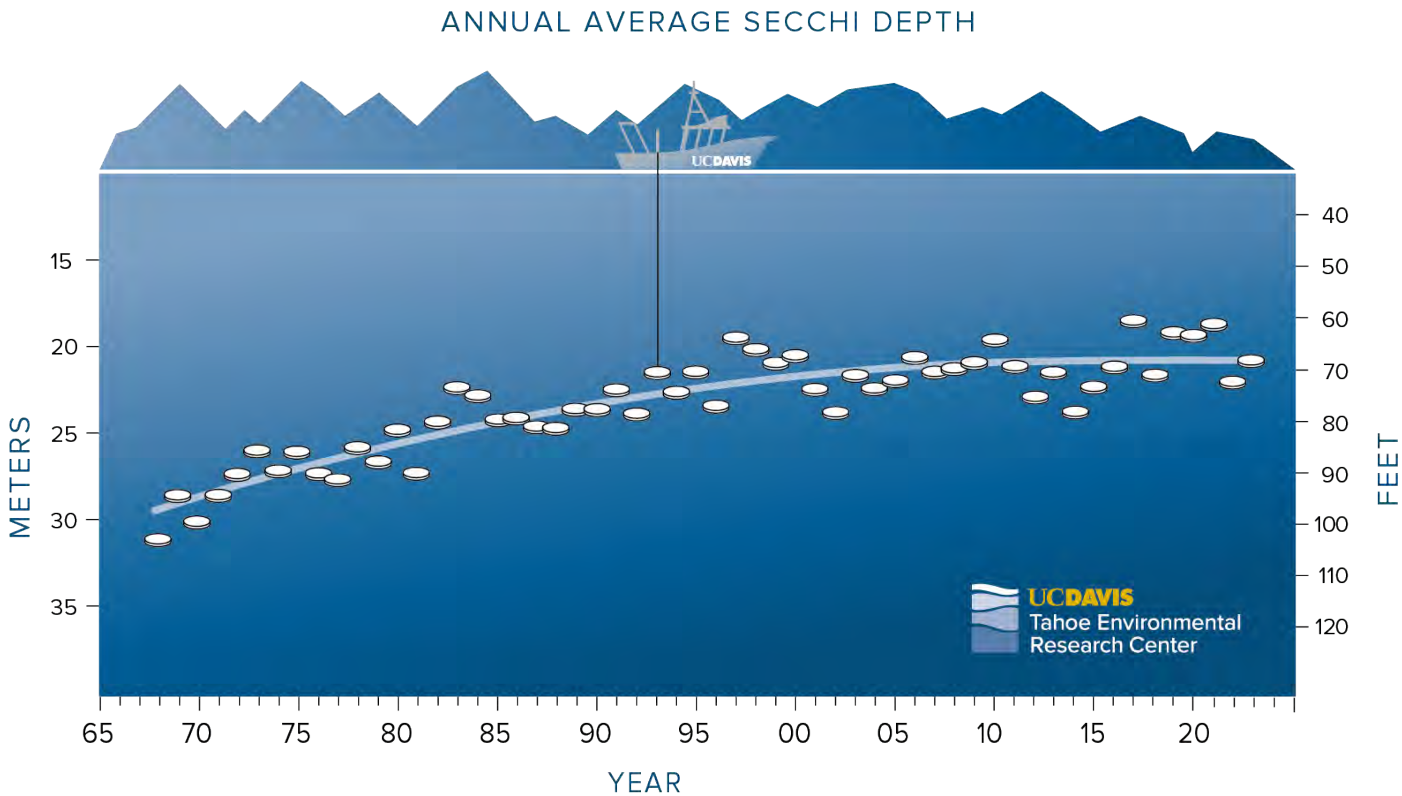
Annual average Secchi depth

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 2023, the annual average Secchi depth dropped to 68.2 feet (20.8 m) based on 27 readings from its 2022 value of 71.9 feet. The greatest individual value recorded in 2023 was 123 feet (37.5 m) on March 2. This was the result of an ephemeral lake "upwelling." Upwellings are episodic events produced by strong winds and are not reflective of the overall lake clarity and health. The lowest clarity reading was 26.2 feet (8 m) on May 24.

The clarity restoration target of an annual Secchi depth of 97.4 feet (29.7 m) set by federal and state regulators, is a goal that agencies and the Tahoe Basin community continue to work toward.

Data source: TERC lake monitoring.

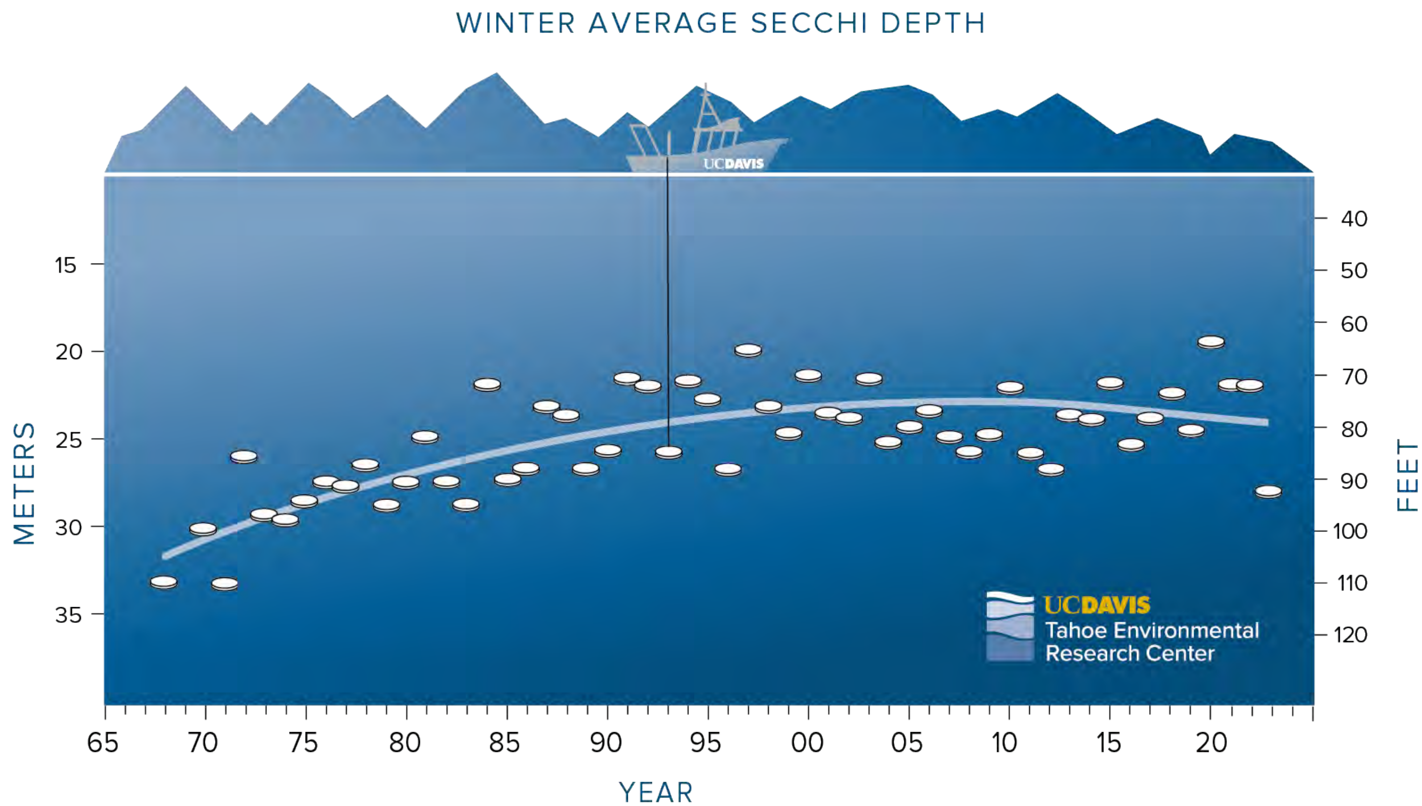


Winter Secchi depth

Yearly since 1968

Average winter lake conditions were the clearest observed since 1983 and the 10th best on record, with visibility of 91.9 feet (28 m) under the surface, compared with 72.2 feet (22 m) in 2022, based on ten readings between December 2022 and March 2023. During the winter months this clarity is attributed to deep mixing events that brought clear water to the surface from the bottom of Lake Tahoe.

Data source: TERC lake monitoring.



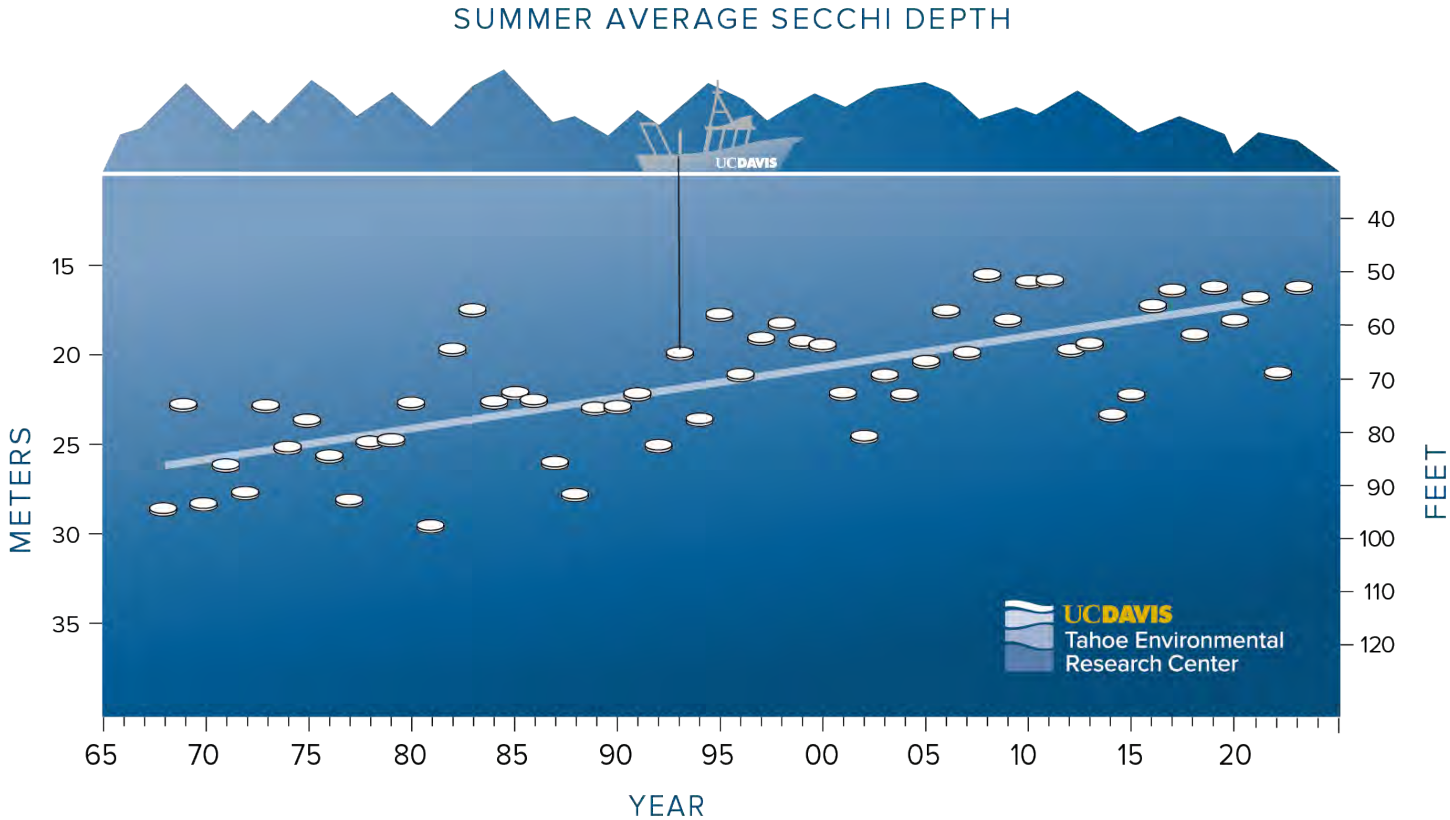
Summer Secchi depth

Yearly since 1968

Summer (June–September) clarity in Lake Tahoe in 2023 was 53.5 feet (m), a decrease of over 15.4 feet from the previous year. Runoff from the heaviest winter snowfall in 70 years brought an influx of inorganic particles and a rapid drop in clarity in May. Summer is typically the season of poorest clarity. The long-term summer trend is dominated by a consistent degradation.

As is shown in Figure 11.4, the month of June was the commencement of improving clarity.

Data source: TERC lake monitoring.

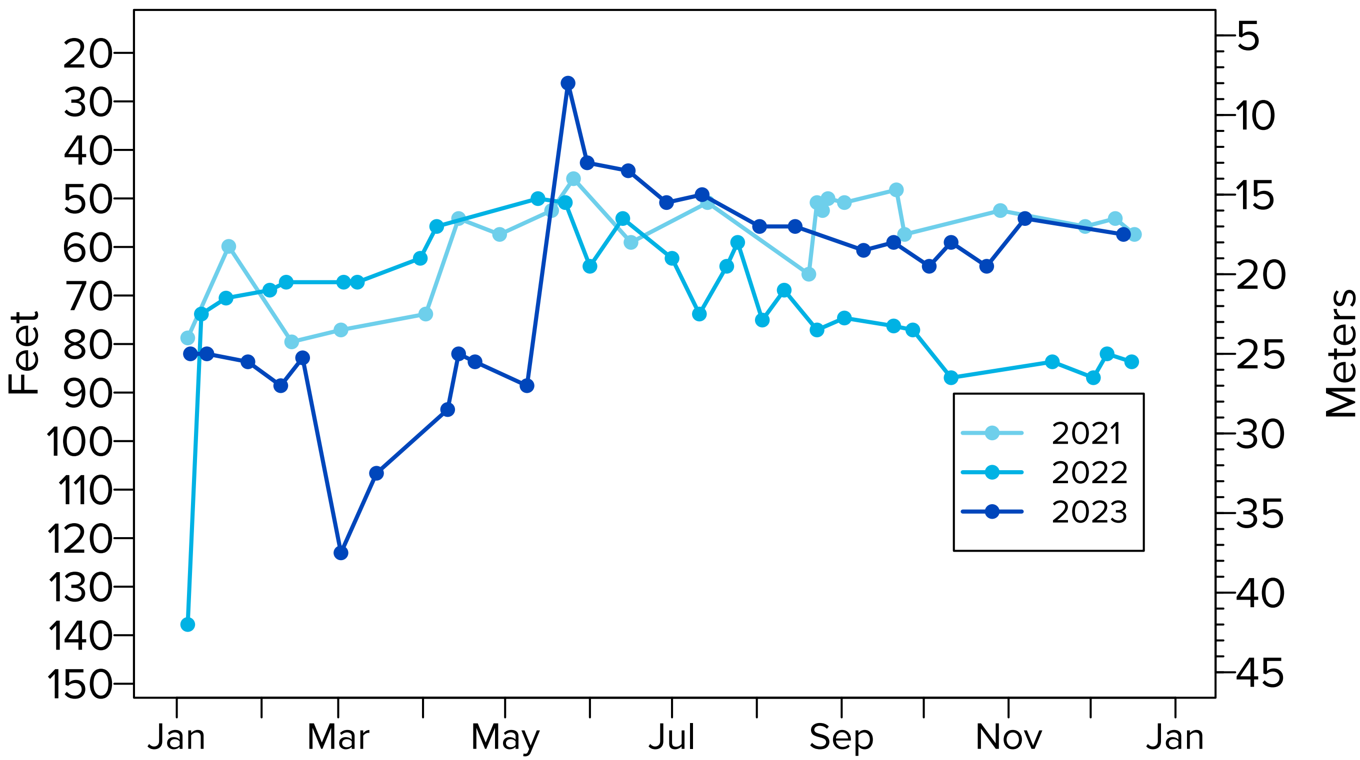


Individual Secchi depths

2021, 2022, and 2023

The individual Secchi depth readings from the Index station on the west side of the lake for 2021, 2022, and 2023 are plotted. Secchi values can be seen to sometimes vary considerably over short time intervals. It is worth nothing that on March 2, 2023, when a Secchi depth of 123 feet (37.5 m) was observed. This is the 12th best Secchi depth ever recorded at Lake Tahoe and was the result of a wind-driven upwelling, a temporary phenomenon that brings very clear hypolimnetic (bottom) water up to the surface. Conversely, on May 24, 2023, a reading of only 26.2 feet (8 m) was taken.

Data source: TERC lake monitoring.



TAHOE:
STATE
OF THE
LAKE
REPORT
2024

EDUCATION AND OUTREACH

UC DAVIS
Tahoe Environmental
Research Center

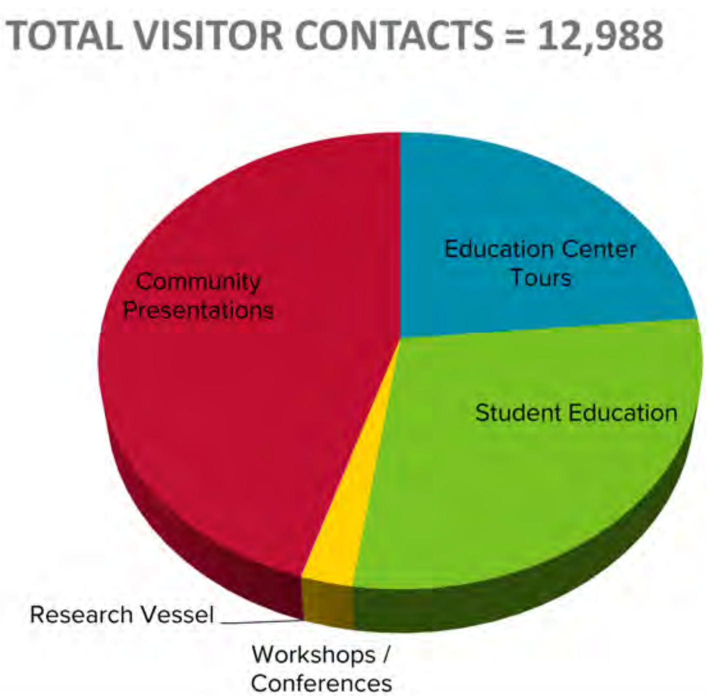
Education and outreach

In 2023

Education and outreach play a complementary role with TERC science and research providing access to educational content developed from technical reports, publications, and data, as well as discussion with TERC researchers. This material is designed for tours, school field trips, programs, exhibits, outreach events, and more. Increasing public accessibility to science fosters a more educated local and visiting population and empowers people to take action.

In 2023, TERC interacted with 12,988 visitors through tours, field trips, lectures, and community events. This represents a 46% increase of interactions for the advancement of TERC and UC Davis. The increasing trend of TERC education is expected to continue with the development of more innovative and exciting exhibits placed in new locations around the basin.

The TERC Education Team conducted 74 field trips for 3,731 students with themes focused on the lake's aquatic ecosystem, climate change, forest health, geology, microplastics, and misinformation. TERC continued educating the public through lectures, community presentations, and outdoor programming. The monthly lecture series brought science-rich content to 791 community members through 12 lectures. The TERC Education Team participated in community outreach events that reached 5,855 people. This was twice as many people compared to outreach efforts in 2022.



Educational exhibits

2024

UC Davis TERC continues to expand offerings with exhibits and video content now available at the Tahoe City Visitor Center and Kings Beach Visitor Center. Our team is also contributing exhibit ideas for the League to Save Lake Tahoe's Education Center in South Lake Tahoe. One of our newest exhibits utilizes digital signage players to provide an interactive touchscreen in the Underwater Lake Tahoe lounge and the Tahoe City Visitor Center.

This year, TERC partnered with Truckee Roundhouse and joined their annual Maker Show outreach event. Expanding the popular Robot Rumble event, TERC educators worked with the TERC CITRIS Robotics Group to help repurpose an older Remotely Operated Vehicle (ROV) as an education tool. Using a darkened trough filled with water, TERC educators created a controlled environment to allow participants at the Maker Show to operate the ROV and hunt for treasures hidden under the water. This latest teaching tool provides a hands-on engaging way to educate the public about how TERC researchers can collect data in the frigid waters of the Antarctic or less pleasant conditions such as Clear Lake during a harmful algal bloom.

During a preview event, education program manager Alison Toy gives a young visitor a boost to check out the newest Augmented Reality Sandbox installed at the Tahoe City Visitor Center as an extension of the UC Davis Tahoe Science Center.
Photo: North Tahoe Community Alliance

At the Truckee Roundhouse Maker Show, education program associate Penelope Holland explains how to use a TERC Remotely Operated Vehicle (ROV) that has been retired from research and has found a new role as the latest traveling exhibit used for outreach events.
Photo: S. Harry

Visitors to the Tahoe Science Center Underwater Lounge and the Tahoe City Visitor Center can now view the latest TERC videos showcasing UC Davis Underwater Research at Lake Tahoe through a new touchscreen exhibit.
Photo: P. Holland

Educational programs

2024

TERC programs aim to highlight the research excellence of UC Davis through a variety of educational opportunities for the Tahoe audience. Topics and themes are chosen for their ability to expand public awareness and knowledge of environmental issues at Lake Tahoe.

In 2024, TERC hosted the 2nd Grow Your Own Community Garden Festival and saw the number of participants double from the previous year. This event is an offshoot of our popular workshops that capitalize on people's love of gardening to get them involved in a long-term varietal phenology project while disseminating information about watershed-friendly gardening practices. On the same day as the festival, TERC brought together faculty, staff, post-doctoral scholars, and graduate students for a TERC-wide staff meeting. This meeting provided the opportunity to showcase TERC's reach beyond Tahoe.

For 16 years, TERC has hosted a monthly lecture series at the Tahoe Science Center in Incline Village. Starting in 2023, TERC brought this lecture series to the California side of the lake, hosting world-class researchers at Granlibakken Tahoe and Sunnyside Restaurant and Lodge in Tahoe City, CA. Occasionally, TERC still hosts a special event at the Tahoe Science Center. At the start of 2024, in collaboration with the Tahoe Regional Planning Agency, and the University of Nevada, Reno at Lake Tahoe, TERC presented internationally renowned climate scientist Dr. Katharine Hayhoe to the Tahoe Science Center for an exclusive North Shore presentation. This sold-out event was an extension of Operation Sierra Storm Television Meteorologists' Conference, organized by the Lake Tahoe Visitors Authority. Her inspiring presentation was about how to address climate change by simply talking about it.

In collaboration with the UCCE Lake Tahoe Master Gardeners and Slow Food Lake Tahoe, TERC hosted the second annual Grow Your Own Community Garden Festival bringing over 1,000 participants in three days. Photo: A. Toy

An all staff meeting highlighted TERC's multi-disciplinary fields of study. The Tahoe Basin acts as a living laboratory for aquatic and terrestrial research that TERC can then extend to lakes globally. Photo: Tahoe Yacht Club

Tahoe Regional Planning Agency director Julie Regan, climate scientist Dr. Katharine Hayhoe, and TERC education and outreach director Heather Segale tour the Tahoe Science Center before Hayhoe's sold-out presentation. Photo: A. Toy

UC Davis Tahoe Environmental Research Center is dedicated to interdisciplinary research and education to advance the knowledge of aquatic and terrestrial ecosystems and their interactions within natural and developed Earth systems, and to communicate science-informed solutions worldwide.

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