

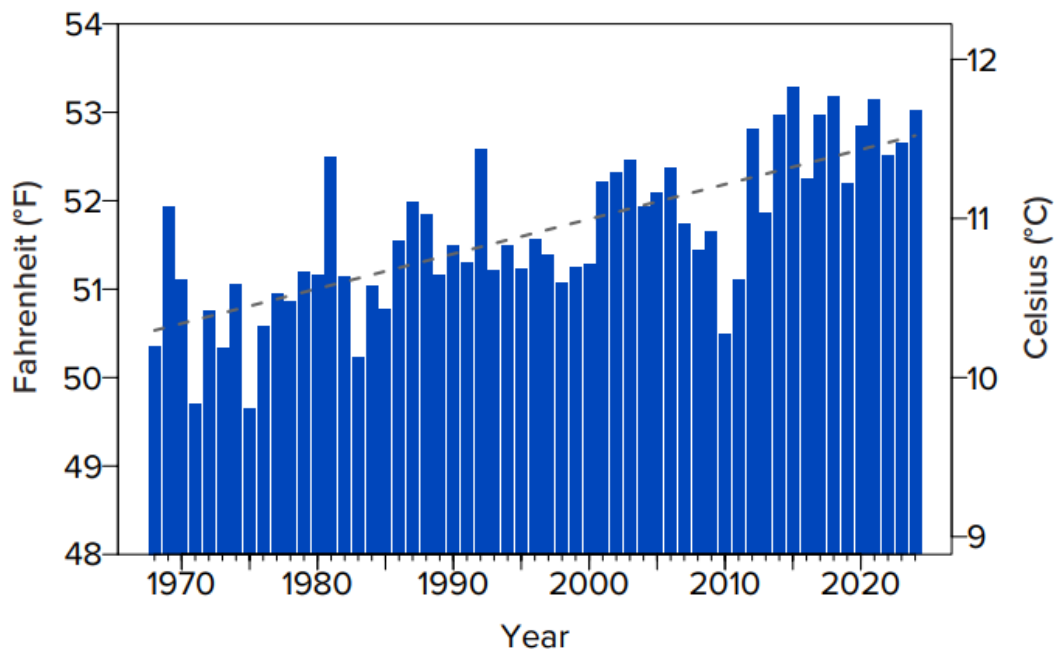
3.15 Lake Water Temperature

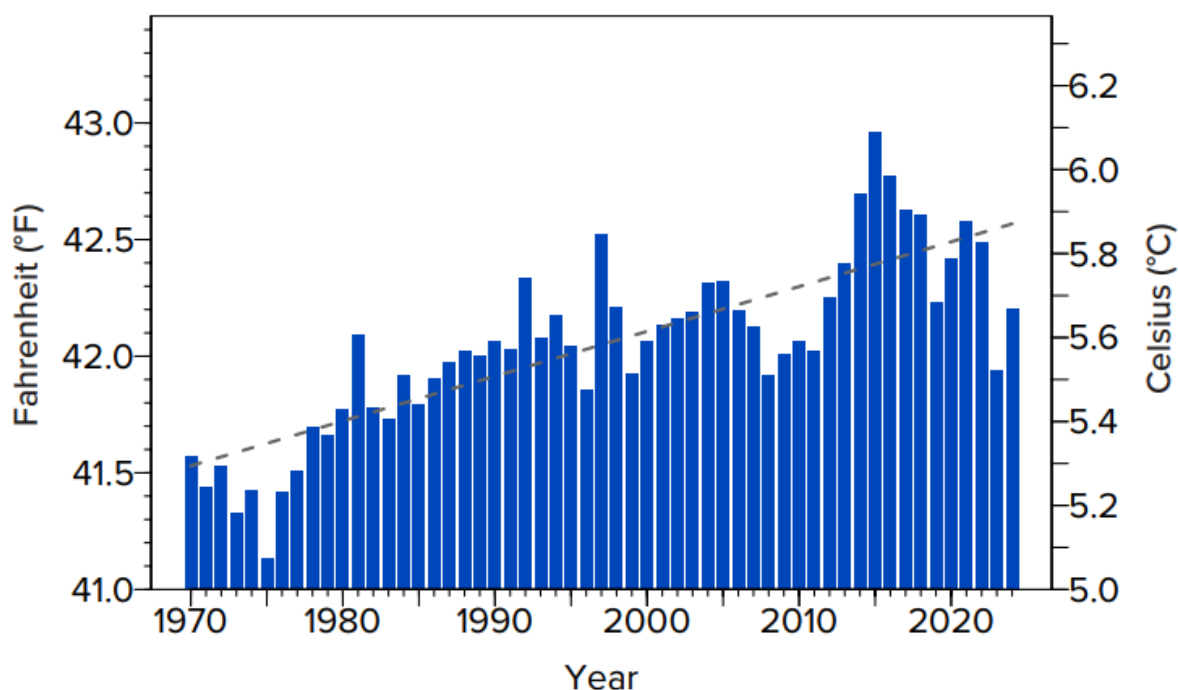
Lake Tahoe is a high mountain lake known for its clear, blue water and is often called a jewel of the Sierra. It is the third deepest lake in North America, at 1645 feet (501 meters). Lake Tahoe waters are warming in response to changing climate conditions in the Sierra Nevada.



Figure 3.15.1. Annual Average Water Temperatures at Lake Tahoe.

A) Surface water temperature (1968–2024).



B) Volume-averaged temperature (1970–2024).

Source: Getty Images (photo) and UC Davis (2025a)

What does the indicator show?

Annual average surface water temperatures at Lake Tahoe, which vary greatly from year to year, have increased by 2.6 degrees Fahrenheit (°F) since 1968, or 1.4 degrees Celsius (°C), at a rate of 0.39°F (0.22°C) per decade (**Figure 3.15.1A**). Nine of the ten highest average surface temperatures were reported since 2010, and 2015 was the warmest year on record (53.29°F, or 11.8°C). Warming trends for water temperatures follow the overall warming trends for air temperatures at Lake Tahoe (warming air temperatures have also contributed to more rain and less snow and earlier snowmelt at Lake Tahoe).

Figure 3.15.1B shows annual average lake water temperatures across multiple depths (“volume-averaged”). Volume-averaged temperatures have warmed overall over the past fifty years by approximately 1.1°F (0.61°C), at a rate of 0.22°F (0.12°C) per decade, a smaller increase compared to surface water temperatures (**Figure 3.15.1A**). After peaking in 2015, volume-averaged temperatures trended downward until 2019, but



showed an uptick in 2020 and 2021, aligning with trends seen for air temperature in the area.

In addition to the surface and volume-averaged temperatures shown in [Figure 3.15.1](#), it is worth noting that the maximum daily surface temperature (summer) for Lake Tahoe in 2024 was 74.9°F (23.8°C), recorded on July 22, the highest observed value since 2019 (UC Davis, 2025a).

While Lake Tahoe is unique, the physical, chemical and biological forces and processes that shape it are the same as those acting on most natural ecosystems. Thus, Lake Tahoe can serve as an indicator for other systems, both in California and worldwide (UC Davis, 2025a).

Warming has also been reported in other lakes in the western United States. Clear Lake water temperature has increased since measurements began in 1968 (De Palma-Dow, 2022). Temperature data derived from satellite observations show increasing summertime surface water temperatures in a 16-year study of four lakes in Northern California (Lake Tahoe, Mono Lake, Clear Lake, and Lake Almanor) and two in Nevada (Pyramid Lake and Walker Lake) (Schneider et al., 2009). From 1992 to 2008, these six lakes showed a significant warming trend for summer (July through September) nighttime surface temperatures, ranging from 0.09°F (0.05°C) per year at Clear Lake to 0.27°F (0.15°C) per year at Lake Almanor and Mono Lake. The lakes exhibited a similar rate of change, with the mean warming rate of 0.22 ($\pm$ 0.05)°F, or 0.11 ($\pm$ 0.03)°C, per year.

Why is this indicator important?

Lakes serve as good sentinels for climate change. They are sensitive to climate, respond rapidly to change, and integrate changes in the land areas that drain into them. Lakes in mountain regions may be particularly sensitive to ongoing changes in climate, in part because high-elevation ecosystems are warming among the fastest rates found globally (Pepin et al., 2015).

Warming lake water temperatures pose a significant threat to aquatic ecosystems (O'Reilly et al., 2015). Rates of freshwater biodiversity loss outpace those of other



environments (Parisek et al., 2025). Temperature is one of the most important factors influencing growth, metabolism, and survival of cold-blooded aquatic animals. High-altitude lakes like Lake Tahoe are especially vulnerable, as they are among the fastest-warming lakes in the world (O'Reilly et al., 2015). Even small temperature increases disrupt the physical and biological processes that sustain these ecosystems (Sadro et al., 2019). Approximately 19% of mountain lake environments in the United States are vulnerable to heat stress, and this number is expected to increase to 33% by 2100 (Parisek et al., 2025)

Tribal Connection 3.15.1

Lake warming can significantly disrupt tribal lifeways. Clear Lake in Lake County is the largest freshwater lake contained wholly in California, and one of the oldest lakes in North America. It has also been home to several tribes, including the Big Valley Band of Pomo Indians, since time immemorial. At one Lake monitoring site where many Tribal cultural activities take place, *“Notably warm temperatures were observed from February to April in 2013, in December 2014, in October 2015, and through the second half of 2024. The highest temperatures on record were observed during the July 2024 heatwave. [...] Even seemingly small increases in water temperature can significantly affect key physical and biological processes in lakes. Lake impacts have also affected the Tribe. Fish and other aquatic species often do best within a certain range of water temperatures. As water temperatures rise, native populations of fish and other species which are important to the Tribe might not thrive, while introduced species that previously would not survive in the lake are absent their natural predators. Balance is key for a healthy lake”* (Big Valley Band of Pomo Indians, 2026).

In the Sierra, interrelated factors such as the amount of snowpack, the timing and magnitude of snowmelt, and water temperature have important implications for growth of benthic algae and phytoplankton, primary productivity and food web dynamics. Elevated water temperatures, as well as other climate-driven stressors like exposure to wildfire smoke, disrupt metabolic rates of organisms, from plankton to fish (UC Davis, 2025a; Smits et al., 2024). Changing snowpack and winter conditions can also extend



plant growing seasons for lakes in the summer, enabling invasive aquatic plant species in lakes to expand their range.

One major consequence of rising temperatures is increased stratification — when water forms distinct layers based on temperature (O'Reilly et al., 2015). Normally, cooler surface water sinks in fall and winter, circulating oxygen and nutrients vital to aquatic life. As winters warm, this mixing becomes shallower (Sahoo et al., 2015). Since 1968, Tahoe's stratified summer period has lengthened by approximately a month (UC Davis, 2025a). These changes jeopardize the survival of native fish and invertebrates, already stressed by warming temperatures and competition of warmer-adapted invasive species like bass and blue gill (California Tahoe Conservancy, 2021a and 2020).

Stratification influences algal growth and water clarity. When mixing is limited, larger algae sink while smaller ones remain near the surface, scattering light and reducing clarity. This reduced clarity leads to greater surface warming, which strengthens stratification and further favors small algae—creating a feedback loop. Cyanobacteria is a type of freshwater bacteria that produces harmful algal blooms and thrives in warm, slow-moving water. In addition, limited mixing can trap fine particles from stream runoff in the lake's upper layers, keeping the water cloudy for longer (Coats et al., 2006).

Long-term monitoring shows a decline in summer clarity, reflecting changes in temperature, precipitation, and nutrient and sediment inputs. Because water clarity influences light penetration, it plays a key role in shaping the diversity and productivity of aquatic life. It also contributes to the lake's aesthetic and recreational value, making it an important indicator of ecological and economic health (UC Davis, 2025a and b).

Dissolved oxygen levels declined in 393 temperate lakes across the U.S. from 1941 to 2017 (Jane et al., 2021). In surface waters, the drop was mainly due to warmer temperatures reducing oxygen solubility. In deeper waters, stronger stratification and reduced clarity were the main causes. Deoxygenation can harm cold-water and oxygen-sensitive species, increase harmful algal blooms, and raise the risk of methane buildup and release.

A decline in the water clarity and ecosystem health of the lake jeopardizes future tourism. The scenic beauty of Lake Tahoe offers cultural and recreational opportunities,



such as hiking, skiing, camping and boating. The annual visitor population of approximately 15 million (California Tahoe Conservancy, 2021b) makes it a region of national economic significance, with estimated annual revenues of \$4.7 billion (Mooney and Zavaleta, 2016).

What factors influence this indicator?

Key drivers controlling lake water temperature are solar radiation, air temperature (influenced by greenhouse gas concentrations), ice cover, cloud cover, humidity, and wind. In addition, suppressed lake mixing (discussed above) can enhance warming of surface waters. Landscape characteristics such as latitude, elevation, and catchment features or land cover can modulate climate effects on individual lakes (Schmid et al., 2014). The climate signal might be further modified by a lake's morphometric attributes, such as lake size and shape, or through differences in the source and magnitude of water inputs (Rose et al., 2016).

Summer air temperature is the single most consistent predictor of lake summer surface water temperature (O'Reilly et al., 2015), largely because so many of the factors that control lake temperature are correlated with air temperature. Lake summer surface water temperature is warming significantly, with a mean trend of 0.19°F (0.34°C) per decade across 235 globally distributed lakes between 1985 and 2009 (Woolway et al., 2020). This warming water surface rate is consistent with the annual average increase in air temperatures and ocean surface temperatures over a similar time period (1979–2012).

By 2100, average maximum air temperature is projected to increase by approximately 4°F to 9°F (2°C to 5°C) (California Tahoe Conservancy, 2020). By the end of the century, air and water temperatures could remain warm late enough into the season that water would be trapped at the surface for more than 60 days longer than in 1968 (Sahoo et al., 2015).

In California lakes that experience ice cover, the amount of snowpack, timing of snowmelt runoff, and ice formation and ice-off (date of ice thawing and breakup) influence lake water temperatures (Melack et al., 2021; Sadro et al., 2019; Smits et al., 2020). For example, Emerald Lake is a high-elevation lake in the southern



Sierra Nevada that is covered with ice six to nine months of the year. Despite a strong warming trend in regional air temperature over the past three decades, researchers found warming water temperatures occurred only during drought years, when snowpack was reduced (Sadro et al., 2019). Snowpack and lake temperature are strongly correlated in mountain systems likely due to tight coupling between snowpack and ice cover in lakes (Smits et al., 2020). Years with low snowpack at Emerald Lake were accompanied by a reduction in the duration of ice-cover, which acts to buffer lake water from exposure to solar radiation and warming.

Although year-to-year variability is high, the number of days when air temperatures averaged below-freezing has declined by 27 days since 1911. Snow has declined as a fraction of total precipitation, from an average of 51% in 1910 to 34% in 2024. A warming climate is affecting other physical changes at Lake Tahoe -- including a shift in snowmelt timing to earlier dates—that may have significant impacts on lake ecology and water quality (UC Davis, 2025a).

As snowpack declines in the Sierra Nevada and other mountain ranges, lake temperature will become increasingly sensitive to warming with reduced ice cover. This regional trend is especially significant given that lakes worldwide are rapidly losing winter ice cover in response to warming, and the rate of loss has accelerated over the past 25 years. Ice melting in parts of the Northern Hemisphere is occurring 45 days earlier per century, with many lakes showing more intermittent or even ice-free winters. While Lake Tahoe does not typically have ice in the winter, the smaller lakes and streams in the Tahoe basin and across the mountains of California rely on ice conditions as an important variable which drives the ecology in the ice-free, summer season (Hampton et al., 2024).



Technical considerations

Data characteristics

The University of California, Davis and its research collaborators collect the measurements used for monitoring Lake Tahoe. They have recorded water temperature measurements at two locations in Lake Tahoe since 1968:

- (1) at the Index Station (approximately 0.6 kilometers off the California side west shore) at depth increments of 2 to 15 meters starting at the surface to a depth of about 100 meters, on an approximately weekly basis, and at 20-centimeter increments to a depth of 125 meters biweekly since 1996. It became continuous measurements at a rate of 8 times per second as it falls through the water at a velocity of 60 centimeters/sec of since 2005;
- (2) at the Midlake Station, the exact location of which varied slightly over time, at nominal depths of 0, 50, 100, 200, 300 and 400 meters, at least once a month. History of depth resolution is similar to that of the index station above.

Strengths and limitations of the data

A variety of thermometers and digital thermographs have been used at the Index Station over the years. Although the sensitivity, accuracy, and calibrations of these instruments have varied over time, these data are adequate for characterizing the thermal structure of the epilimnion and thermocline. Temperatures at the Midlake Station were originally measured at 13 depths with mercury-reversing thermometers, as follows: a protected thermometer, unaffected by pressure, records the temperature at reversal depth; readings from this thermometer are corrected for glass expansion and, along with a second, unprotected thermometer affected by pressure in deep water, provide measure of the actual depth of the temperature reading (Coats et al., 2006). These instruments were accurate to 0.01°C. More recently, temperature has been measured using a high precision thermistor that is part of a suite of instruments on a Seabird SBE-25plus profiler. Accuracy of the thermistor is 0.001°C. Lake surface temperature data derived from thermal infrared satellite imagery (ATSR and MODIS), when validated against corresponding *in situ* data for Lake Tahoe, were found to agree very well over the entire range of temperatures. This, along with an additional assessment of inter-sensor bias between all ATSR sensors, indicates that accurate and



stable time series of lake surface temperature can be retrieved from ATSR and MODIS satellite data.

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