

EXECUTIVE SUMMARY

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

The UC Davis Tahoe
Environmental Research Center

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

This annual *Tahoe: State of the Lake Report* presents data from 2017 in the context of the long-term record. While we report on the data collected as part of our ongoing, decades-long measurement programs, we also include sections

summarizing current research on important, emerging issues. These include: the dramatic change in Lake Tahoe's clarity that occurred in 2017; a new ecology-based approach to restoring lake clarity; an intensive study of the lake's nearshore region to characterize both the physical processes that take place there and their impacts on attached algae; the health of the basin's forests and actions to imbue resilience to forest restoration efforts; some initial indications of how climate change will impact air temperature, precipitation, and soil dryness; and a comparative study initiated between Lake Tahoe and Lake Geneva, two lakes that were at the forefront of launching the field of limnology in the 19th century.

The clarity of Lake Tahoe declined in 2017 to its lowest level since

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

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

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

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

is testing whether Mysis numbers can be reduced sufficiently to sustain such a clarity improvement.

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

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

collections will be expanded to include other species.

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

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

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

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

The long-term trend shows rising air temperatures and a reduction in the number of days with below-freezing temperature. In 2017, monthly air temperatures were

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

The volume-averaged lake temperature continues to increase. In 2017, the lake was slightly warmer than the previous two years, making it the warmest ever. The absence of deep mixing for the sixth year in a row contributed to the storage of heat. The July surface water temperature was the warmest ever recorded at 68.4 °F,

an astounding 6.1 °F above the 2016 value due largely to unusually low wind speeds. The length of the stratified season (the period of time when the lake exhibits summer-like water temperature conditions) also continues to increase. Since 1968, this period has increased by 26 days. In 2017, peak snowmelt occurred on April 25, over 5 weeks later than the previous year. This was due to the extremely large snowpack and an extended precipitation season.

The input of stream-borne nutrients (nitrogen and phosphorus) and suspended sediment were all at record levels in 2017 due to the high streamflow. The suspended sediment load from the Upper Truckee River exceeded the load for the previous five years. The levels of nutrients building up at the bottom of the lake continue to rise, in large part

due to the absence of deep mixing. This internal cycling is an important source of nutrients for phytoplankton growth, particularly nitrate. Phosphorus, which was at its lowest level in 2009, has been increasing steadily over the last eight years. It is currently at levels not seen since the 1980s. However, as in the case of nitrate, a large factor in this increase is the absence of deep mixing.

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

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

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

showed significantly heavier growth. Highest growth was generally at the more urbanized locations.

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

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