EXECUTIVE SUMMARY

The long-term data set collected on the Lake Tahoe ecosystem by the University of California, Davis and its research collaborators is an invaluable tool for understanding ecosystem function and change. It has become essential for responsible management by elected officials and public agencies tasked with restoring and managing the Tahoe ecosystem. This is in large part because it provides an independent basis for assessing the progress toward attainment of Tahoe's restoration goals and desired conditions, while at the same time building our understanding of the natural processes that drive the ecosystem.

The UC Davis Tahoe Environmental Research Center (TERC) is increasingly using new approaches to enrich the long-term data record for Lake Tahoe. These include real-time measurements at over 25 stations around the basin; remote sensing from autonomous underwater vehicles, satellites, and aerial drones; and the deployment of a suite of numerical models. These tools are all focused on quantifying the changes that are happening, and at the same time, understanding what actions and measures will be most effective for control, mitigation, and management.

This annual Tahoe: State of the Lake Report presents data from 2016 in the context of the long-term record. While we report on the data collected as part of our ongoing, decades-long measurement programs, we also include sections summarizing current research that is being driven by the important questions of the day. These include: the causes of the increasing levels of filamentous algae seen on the shoreline; the health of Lake Tahoe's forests in response to drought; climate change and its impacts on the lake physics and the entire lake ecosystem; the driving force behind the variability of water quality around the lake's nearshore regions; a first look at what is happening in the very deepest parts of the lake; and the threat of invasive species spread by in-lake boating activities.

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

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

The number of dead and dying

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[1] *"Previous year" for some parameters means data collated in terms of the water year, which runs from October 1 through September 30; for other parameters, it means data for the calendar year, January 1 through December 31. Therefore, for this 2017 report, water year data are from Oct. 1, 2015 through Sept. 30, 2016. Calendar year data are from Jan. 1, 2016 through Dec. 31, 2016.*

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

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

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

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

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

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

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

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

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

Biologically, the primary productivity of the lake has increased dramatically since 1959. In 2016, there was an increase in primary productivity to 225.1 grams of carbon per square meter. By contrast, the biomass (concentration) of algae in the lake has remained relatively steady over time. The annual average concentration for 2016 was 0.59 micrograms per liter, slightly lower than the previous eight years. For the period of 1984-2015, the average annual chlorophyll-a concentration in Lake Tahoe was 0.70 micrograms per liter. From an abundance viewpoint, diatoms were the most common algal group (60 percent of the cells). Of these, Cyclotella gordonensis was by far the most common, representing 90 percent of the biovolume during summer. This impacted summer clarity with a large decline in Secchi depth.

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

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