EXECUTIVE SUMMARY

The long-term data set collected on the Lake Tahoe ecosystem by the University of California, Davis and its research collaborators provides a unique tool for understanding ecosystem function and change. It has become an important resource for decision-making by elected officials and public agencies tasked with restoring and managing the Tahoe ecosystem and other lake ecosystems. This is, in part, because it provides an independent basis for assessing the progress toward attaining 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 innovating with new approaches to enrich the long-term data record for Lake Tahoe and to address emerging questions. These approaches include real-time measurements at over 25 stations around the basin and remote sensing from autonomous underwater vehicles, satellites, aerial drones, helicopters, and computer modeling tools. These efforts 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 in the future. Our newest nearshore station was installed in July 2023. This real-time water quality station at Cedar Point on the west shore will provide new data on the behavior of the lake's nearshore region. In June 2023, an Acoustic Doppler Current Profiler was installed at a depth of 300 feet on the west side of the lake to provide continuous water velocity measurements and to track the expected resurgence of the *Mysis* shrimp in the coming years.

This Tahoe: State of the Lake Report 2023 presents data from 2022 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:

- The impacts of food web change on lake clarity. Data showing the change in multiple lake biological variables that followed the collapse of the *Mysis* shrimp population are presented.

- The extremes in conditions experienced over this last 2022/2023 winter including the freezing of the entirety of Emerald Bay and the very extended period of complete vertical lake mixing in February 2023.

- The Secchi disk, a simple

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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 2022 report, Water Year data are from October 1, 2020 through September 30, 2021. Calendar year data are from January 1, 2021 through December 31, 2021.

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and widely used tool for measuring lake clarity is shown to provide highly repeatable data with three independent field researchers.

- Microplastic pollution, a growing global issue is also an issue at all depths of Lake Tahoe. The values found at Tahoe approach those measured in San Francisco Bay.

- New machine-learning approaches used to monitor the beaches and nearshore of Lake Tahoe are described, along with the motivation of why they are needed to better describe the growing severity and extent of metaphyton and periphyton growth.

- The power of modeling tools that increase our understanding of complex lake motions, better track where contaminants are transported in the lake, and even inform how future monitoring should be conducted.

- No-wake zones are in place around the periphery of Lake Tahoe. Are they scientifically meaningful?

- The heavy coating of pollen across the basin this summer has people concerned about its effect on lake health. The question was actually answered over 50 years ago.

- A new undergraduate student summer internship program launched in June provides opportunities for the next generation of environmental scholars and leaders to work at Lake Tahoe on some of the most pressing issues.

Meteorologically, the persistent, long-term trends have not changed from year-to-year. However, a changing climate is evident in almost all the long-term meteorological trends, including rising air temperature and the declining fraction of precipitation as snow. The weather experienced each year can be far more variable. For most of 2022, the monthly average temperatures were similar to the previous two years and the long-term average. The monthly average air temperatures for November and December, however, were much colder than the long-term average, with November being the third coldest on record since 1910. At 32.7 inches, 2022 precipitation was just 1.2 inches above the long-term average. Snow, measured at Tahoe City, has declined as a fraction of total precipitation from an average of 52 percent in 1910 to 33 percent in 2022.

The water level in Lake Tahoe varies throughout the year due to inflows, outflows, precipitation, and evaporation. In 2022, the highest lake level was 6,224.52

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feet on June 13, and the lowest was 6,222.58 feet on November 30, 2022. The natural rim of the lake is at an elevation of 6,223 feet. The subsequent wet winter of 2022/2023 has brought the lake back to almost maximum capacity.

Despite year-to-year variability, the annual average surface water temperatures show an increasing trend. For 2022, the average surface water temperature was 52.5 °F slightly below the long-term trend line. The overall rate of warming of the lake surface is 0.39 °F (0.22 °C) per decade since 1970. In 2022, July surface water temperature was relatively cool. It averaged 63.8 °F (17.7 °C). This was a decline of over 4.8 °F from the record-setting value of the previous year. Lake Tahoe mixes vertically each winter as surface waters cool and sink downward. Mixing depth has profound impacts on lake ecology and water quality. Deep mixing brings nutrients to the surface, where they promote algal growth. It also carries oxygen downward to deep waters, promoting aquatic life throughout the water column. On February 18, 2022, Lake Tahoe was observed to have mixed to a maximum depth of 328 feet (100 m), the second lowest value on record.

The stability of the lake is an important concept that expresses its resistance to vertical mixing and determines its length of stratification. High stability can mean that oxygen is not transferred to deep portions of the lake, pollutant-bearing inflows enter the lake closer to the surface, and the types and vertical distribution of phytoplankton change. The length of time that Lake Tahoe is stratified has generally increased each year, another consequence of climate change. Since 1968, the length of the stratification season has increased by 29 days, albeit with considerable year-to-year variation. In 2022, the length of the stratified season was only 181 days, the lowest value in over ten years.

The reduction of nutrient and fine particle loads to the lake is a fundamental part of the restoration efforts driven largely by the Total Maximum Daily Load (TMDL) program. The stream-borne nitrogen and phosphorus loads from the Upper Truckee River were again low in 2022, which was in line with the average precipitation for the year. Total nitrogen load from the Upper Truckee River, the largest inflowing stream, was 11.1 MT/yr, compared to the long-term mean annual load of 17.3 MT/yr. Total phosphorus inputs decreased to 1.68 MT, the lowest annual load on record. In-lake nitrate and total hydrolyzable phosphorus concentrations increased slightly, partly due to the absence of deep mixing in 2021 and 2022 and possibly the influence of wildfire smoke. Surface nitrate

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levels were moderate in the first few months of the year but declined to near-zero for most of 2022. The concentration of fine particles in the surface of the lake was markedly lower in 2022, particularly from August onwards. The levels have been elevated since the record inflows of 2017 but have now fallen below those levels.

The lake saw the greatest areas of change in 2022 related to its biology. Biologically, the primary productivity of the lake has increased dramatically since 1959. In 2021 and 2022, primary productivity reached the highest values ever. This coincided with high algal biovolume, at levels similar to observations from the 1980s and earlier. The Deep Chlorophyll Maximum (DCM) of the lake formed in spring, but in early fall it disappeared. Cyanobacteria were the most abundant phytoplankton (by number) in Lake Tahoe for a second successive year, but their biovolume was low. The data indicates that the occurrence of the cyanobacteria started in late 2021 and continued in the first few months of 2022. Diatoms were still the dominant group by volume. Of these, *Synedra* formed the largest percentage of the biomass. Biovolume was significantly higher than previous years. The collapse of the *Mysis* population was probably the largest singular change in Lake Tahoe in 2022. Changes in phytoplankton and zooplankton regimes continued throughout 2022 and also coincided with the large improvement in lake clarity. These food web changes have continued to evolve since that time.

The attached algae (periphyton) on the rocks around the lake were elevated in 2022, based on a synoptic survey. As usual, the California side of the lake continued to display higher concentrations of periphyton. 2022 was the last year in which the traditional fixed- point measurements of attached algae will be collected. In 2023, a remotely sensed approach using helicopters and drones will be used to focus on the aerial extent of nearshore algae.