

TAHOE: STATE OF THE LAKE REPORT 2016

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) has developed sophisticated computer models that better predict and understand how Lake Tahoe's

water moves and how the entire ecosystem behaves. Long-term data sets are an essential element in constantly refining the accuracy of those models and in developing new models as knowledge increases and new challenges arise. These models are used to address a variety of questions: Where would a contaminant spill be carried? What are the likely next locations for the spread of invasive species within the lake? And what drives movements deep down in the lake? The application of these models this year has helped understand the seiche waves that would prevent stagnation of Lake Tahoe's depths.

This annual *Tahoe: State of the Lake Report* presents data from 2015 in the context of the longterm record. While the focus is on data collected as part of our ongoing, decades-long measurement programs, we have also included sections summarizing current research on the drivers of variability of water quality around the lake's nearshore regions, the periphyton covering many parts of the rocky shoreline, forest health, new techniques for determining the lake's metabolism, stream water intrusions, the unnoticed seiche waves, and the identification of climate change as a driving process in eutrophication.

It is often believed that a poor measure of water quality at one 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 is showing, using data from around the lake and measured continuously, is that part of what we are experiencing is the normal system behavior. The challenge is to separate those natural signals from the true degradation that is occurring, so that appropriate solutions can be found and implemented in those locations where they are applicable.

A debate around Lake Tahoe is whether the nearshore is actually any worse than it was in the past. In the last two years alone, periphyton (attached algae) levels have significantly decreased. A comprehensive review of all the data on periphyton that TERC has collected over several decades indicates that the trend is not crystal clear. Part of the reason is the way in which periphyton are measured is strongly influenced by lake level, something that has been changing more frequently in recent decades. As lake level rises or falls (sometimes

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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 2015 report, water year data are from Oct. 1, 2013 through Sept. 30, 2014. Calendar year data are from Jan. 1, 2014 through Dec. 31, 2014.



EXECUTIVE SUMMARY

(CONTINUED FROM PAGE 2.1)

several feet in a year), periphyton must re-establish on rocks that may have been in the sun the previous year. Possibly the largest reason for this lack of a clear trend is that the monitoring was initiated after most of the destructive changes at Lake Tahoe had occurred. Whereas the measurement of clarity started in the 1960s, and we witnessed the initial decline followed by the recent 15 year period in which clarity has stabilized, periphyton monitoring has largely been conducted during this more recent, stable period of the lake ecosystem.

Dissolved oxygen in Tahoe's waters is emerging as major topic of concern. It is recognized in many ecosystems around the world that one of the impacts of climate change is the potential for the formation of dead zones, where all the available oxygen has been consumed. Research is being conducted but more needs to be done to better understand what processes are at play to keep oxygen well distributed in the lake's hypolimnion (deep waters). Are the nutrient reduction strategies embedded in the TMDL sufficient to provide the lake the resilience it needs to withstand even longer droughts in the future? Can studying the lake's metabolism yield new understanding of how warmer water temperatures are changing the conditions at the base of the food web?

2015 saw the continuation of warming and drying conditions for a fourth year at Lake Tahoe. The winter of 2014-2015 had the lowest number of freezing days (24) recorded in over a century of data collection, eclipsing last year's record. In 2015, precipitation was well-below the long-term average and the fraction of precipitation that fell as snow was the lowest ever recorded, being only 5.4 percent. Lake level rose by only 9" during the spring snowmelt, well below the typical seasonal rise. Lake Tahoe was below its rim for almost the entire year, except for one day on December 9, 2015. When the lake is below its rim, outflow via the Truckee River ceases. The lake had a final level of 1.39 feet below the rim at the end of 2015. The outflow from Lake Tahoe to the Truckee River was zero in 2015, owing to the fact that the lake was at or below the lake's rim for the entire year.

The volume-averaged lake temperature increased in 2015 by 0.48 °F (0.26 °C) over the previous year. Following the cooler temperatures of the last decade, 2015 exceeded the long-term trend of increasing temperature. Similarly the annual-averaged surface temperatures were at an all-time high in 2015 at 53.3 °F. In the last 4 years the lake has warmed at an alarming rate of over 0.3 °F/year, 15 times faster than the long-term warming rate. The average surface water temperature was 53.3 °F (11.8 °C), making 2015 the warmest year yet recorded. The maximum daily summer surface water temperature in 2015 was similar to the previous year, and for the winter-time maximum, it was the warmest surface water temperature observed for the length of the record.

Lake Tahoe did not mix to its full depth in 2015, the fourth consecutive year in which this has occurred. Instead, the maximum depth of mixing was only 262 feet (80 m), reached between February and March. The lack of mixing was due to a fourth year of above average lake stability, driven by the generally warmer weather. The upper 330 feet of the lake stayed stratified for 189 days, three weeks longer than what was typical when the record began.



EXECUTIVE SUMMARY

(CONTINUED FROM PAGE 2.2)

The input of stream-borne nutrients (nitrogen and phosphorus) to the lake was low again in 2015 due to the low precipitation and subsequent run-off. The last four years have all had nutrient and particle loads a factor of four to five below the long-term mean.

Overall in-lake nitrate concentrations have remained relatively constant over the 33 years of record. In 2015, however, the volume-weighted annual average concentration of nitrate-nitrogen reached an all-time high of 20.6 micrograms per liter, exceeding the previous high of 20.0 micrograms per liter set in 2014. This increase is in part due to the record low mixing this year; nutrients from the bottom of the lake were not brought up to levels where they can be utilized by phytoplankton. The lack of deepwater mixing allows a continued build-up of nitrate in the deep water. Surprisingly, in-lake phosphorus concentrations which had been on a long-term decline, displayed an increase in 2015, to the highest level in the last six years.

Biologically, the primary productivity of the lake has increased dramatically since 1959. In 2015, there was a decrease in primary productivity to 206.1 grams of carbon per square meter, the third successive year of reduced productivity. By contrast, the biomass (concentration) of algae in the lake has remained relatively steady over time. The annual average concentration for 2015 was 0.63 micrograms per liter, slightly lower than the previous two years. For the period of 1984-2015 the average annual chlorophyll-a concentration in Lake Tahoe was 0.70 micrograms per liter.

This year the annual average Secchi depth, a measure of lake clarity, continued the long-term halt in clarity degradation. The value for 2015 was 73.1 feet (22.3 m), a decrease of 4.8 feet over 2014, 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 must be seen as attaining a level of clarity which on average meets the basin's standards. Winter (December-March) clarity declined by 7.6 feet to 71.5 feet (21.8 m). The low level of snowfall compared to rain this year caused the water entering the lake to be warmer in 2015, and this introduced fine particles closer to the surface. Summer (June-September) clarity in Lake Tahoe in 2015 was 72.8 feet (22.2 m), a 4.2 foot decline over the value from 2014.

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