Climate change could alter Tahoe’s chemistry

By Alexander L. Forrest, The Conversation

In an age of rapid global population growth, demand for safe, clean water is constantly increasing. In 2010 the United States alone used 355 billion gallons of water per day. Most of the available fresh water on Earth’s surface is found in lakes, streams and reservoirs, so these water bodies are critical resources.

As a limnologist, I study lakes and other inland waters. This work is challenging and interesting because every lake is an ecosystem that is biologically, chemically and physically unique. They also are extremely sensitive to changes in regional and global weather and long-term climate patterns.

For these reasons, lakes are often called “sentinels of change.” Like the figurative canary in the coal mine, lakes may experience change to their ecosystem dynamics before we start to see shifts in the greater watersheds around them.

In a study I recently co-authored with Goloka Behari Sahoo, Geoff Schladow, John Reuter, Robert Coats and Michael Dettinger, we projected that future climate change scenarios will significantly alter natural mixing processes in Lake Tahoe in the Sierra Nevada range that are critical to the health of the lake’s ecosystem. This could potentially create a condition that we termed “climatic eutrophication.”

While many groups have studied the long-term impact of climate change on lakes, this process can now be added to the growing list of drivers of eutrophication. This is a potentially damaging phenomenon that could affect a number of vital deep-water lakes around the world, degrading water quality and harming fish populations.

Eutrophication is a condition that occurs when lakes and reservoirs become overfertilized. Cultural eutrophication is a well-understood process in which lake and reservoir ecosystems become overloaded with chemical nutrients, mainly nitrogen and phosphorus. These nutrients come from human activities, including fertilizer runoff from farms and releases from sewage systems and water treatment plants. Natural weathering processes, atmospheric deposition of air pollutants, and erosion also transport nutrients that are already present in the watershed into the water supply.

In water bodies, these heavy nutrient loads fertilize algae, causing surface algal blooms. When the algae die, they sink and are broken down as they decompose. This decomposition process consumes dissolved oxygen in the water. As oxygen levels become depleted, hypoxic (dead) zones develop in the bottom waters where oxygen levels are too low to support life. Dead zones harm fisheries and tourism, and algal blooms can contaminate drinking water.

Over the past several decades, state and federal regulators have developed many initiatives to eliminate or reduce nutrient sources. In some cases, such as Seattle’s Lake Washington, water quality has improved through management. In other, larger watersheds – notably, the Great Lakes – nutrient pollution is still a major problem.

As anyone who has swum in a lake knows, the water is typically warmest on the surface where the sun shines on it. Cold water is denser than warmer water, so it sinks. For much of the year, deep lakes will remain stratified (separated into layers).

In fall and late winter, large storms disrupt natural stratification and cause lake waters to overturn. This mixes surface waters down into the lake’s depths and brings deep water up to the surface, where it can absorb oxygen from the atmosphere. This process, which transfers dissolved oxygen from the surface to the lake bottom, is critical for an ecosystem's health.

But our study showed that surface warming in Lake Tahoe could cause climatic eutrophication by reducing or even ending mixing, thus interrupting the vertical movement of dissolved oxygen from the lake's surface to the lake bed.

Scientists, spearheaded by UC Davis, have been monitoring conditions at Lake Tahoe for nearly 50 years, so we have good records of short- and long-term changes in water temperatures and quality. Since 1968, the average temperatures of the lake's surface waters (down to a depth of 80-120 feet) have increased by nearly 0.5 degrees Celsius. That change has increased the lake's stability – a measurement of how resistant it is to overturning – enough to reduce the probability that surface waters will mix all the way to the lake bottom.

To model possible future conditions, we estimated Lake Tahoe's annual stability by combining a lake hydrodynamic model – representing how water is moved around the lake – with two different greenhouse gas emission scenarios published by the Intergovernmental Panel on Climate Change. In one scenario, emissions increased rapidly throughout this century; in the other, emissions leveled off by the year 2100.

Under both scenarios, meteorological conditions influencing the lake are projected to change. Notably, wind speeds would decrease by 7-10 percent, and air temperatures would increase by 2.5-4 degrees Celsius. These warmer, less windy conditions across the lake will extend and magnify the warming and stratification trends that we are already seeing.

As the lake remains stratified for longer periods each year and less overturning occurs, dissolved oxygen levels at the bottom will decline. Under these conditions, nutrients stored in the lake bed will be released to the water through chemical reactions that occur in low-oxygen environments. This new source of nutrients, known as internal loading, will further contribute to the process of climatic eutrophication.

Although all lakes are unique ecosystems, this process could also occur in other deep-lake settings around the world, such as Japan’s Lake Biwa or Lake Baikal in southeastern Siberia. Climate change is already shortening the periods each year when many temperate and polar lakes are covered with ice. As water temperatures rise in the upper layers of deep lakes, they will remain stratified for more of the year and will be less subject to mixing. Less dissolved oxygen will be returned to deep waters, which will stress fish populations.

And unlike cultural eutrophication, climatic eutrophication could affect entire watersheds or regions, since it is driven by climatic influences rather than by discharges of nutrients into a lake from farms or cities.

Climatic eutrophication has serious implications for long-term water supplies and aquatic ecosystem health around the world. To recognize and track it, we need to identify lakes in North America and around the world that could be at high risk.

In areas where scientists and regulators are working to reduce conventional eutrophication, these experts will also need to factor the possibility of climate-forced eutrophication into their strategies. The first step is to support more monitoring of lakes’ physics and chemistry so that we can recognize, track and predict climatic eutrophication of our lakes and reservoirs.

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