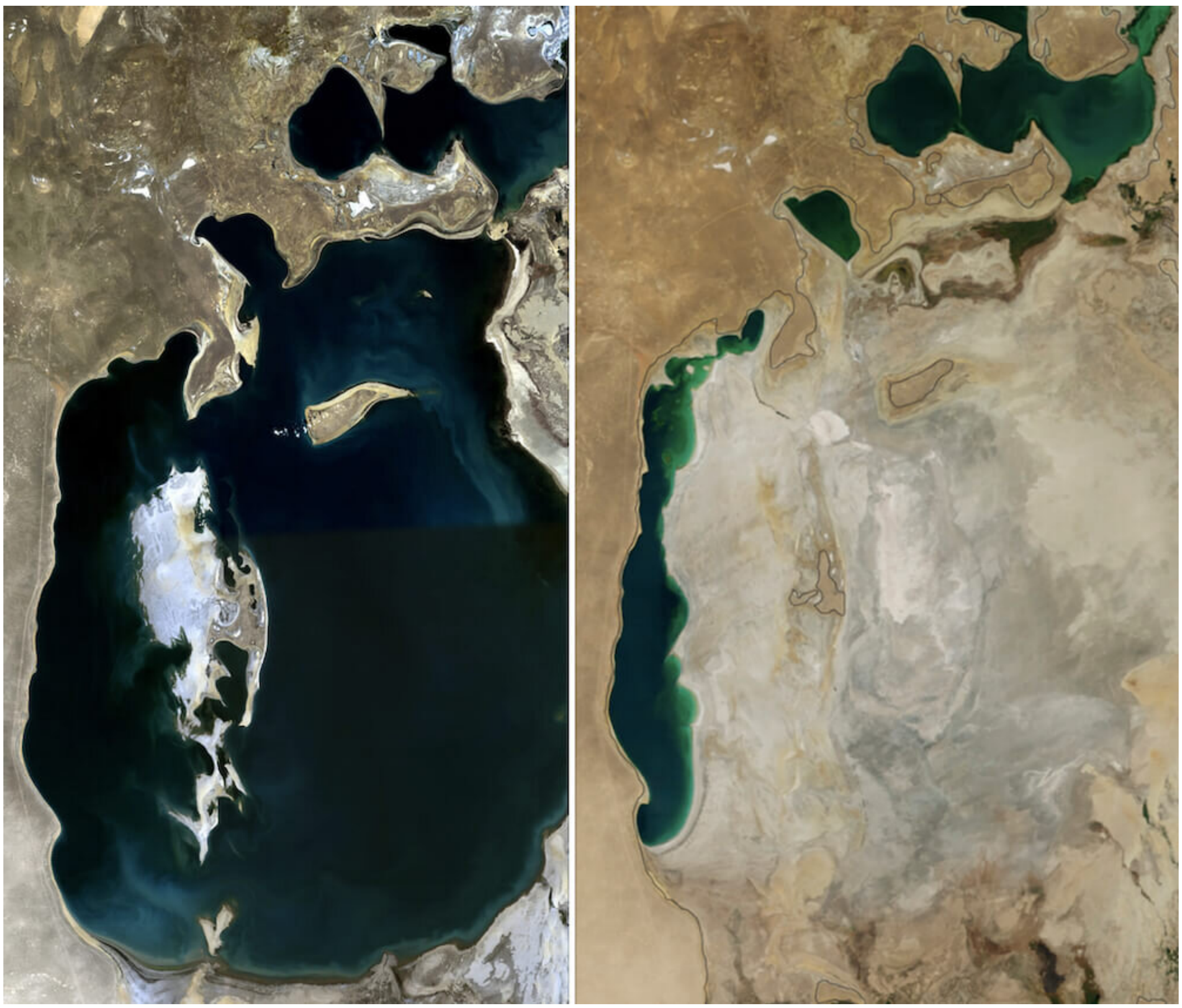
From sanguine to hypersaline: Global salt lakes in decline

April 24 2023, by Christy Clutter



The Aral Sea in 1989 vs. 2014. Credit: Wikipedia

At its grand opening in 1913, the Los Angeles Aqueduct sent a torrent of fresh mountain water cascading into the Los Angeles valley to the cheers of an onlooking crowd of 30,000 people. The water, diverted from the Owens Valley more than 200 miles away, would fuel meteoric growth in the L.A. suburbs in the decades to come, but it would ultimately come at the cost of Owens Lake, the terminal lake from which the water was diverted, which effectively ran dry only 13 years later.

The drainage of Owens Lake is a particularly unsightly smirch on the history books of American conservation, but the fate of Owens Lake is unfortunately not altogether unique—nor is it complete. Owens Lake is one of many important hypersaline environments, which in recent decades have been threatened by diversions for human water use. Salt lakes, such as Owens Lake, Utah's Great Salt Lake, the Eurasian Aral Sea between Kazakhstan and Uzbekistan and Lake Urmia in Iran, support important ecological niches that are rooted in their ability to support microbial life. This prokaryotic niche lays the foundation for the entire food chain above it. With each of these lakes under imminent threat of desiccation, what is at stake for the microbiological—and macrobiological—life in their purview?

Salt lake hydro-geography

Hypersaline lakes form as arid basins that catch incoming water from mountain precipitation, often in the form of slowly-melting snowpack. This means that salt lakes exist in a constant state of flux, as seasonal snowmelt boosts the lake's water level and summer heat whisks it away in evaporation. As many such salt lakes are the remnants of much larger lakes from the Pleistocene epoch over 10,000 years ago (such as Utah's Lake Bonneville, which preceded the present-day Great Salt Lake), the lake bed serves as a concentrated flat of salt and minerals.

The salinity of the lakebed is a particularly important—and, ironically, often overlooked—variable relating to the health of salt lakes, because it means that lake health is not just a function of the amount of water, but also of how concentrated the water is with salt and other minerals. A lower lake level means that the salt from the lakebed gets concentrated into a smaller volume of water, resulting in a saltier lake. Likewise, a higher water level from extra precipitation means a reprieve from such high salt concentration.

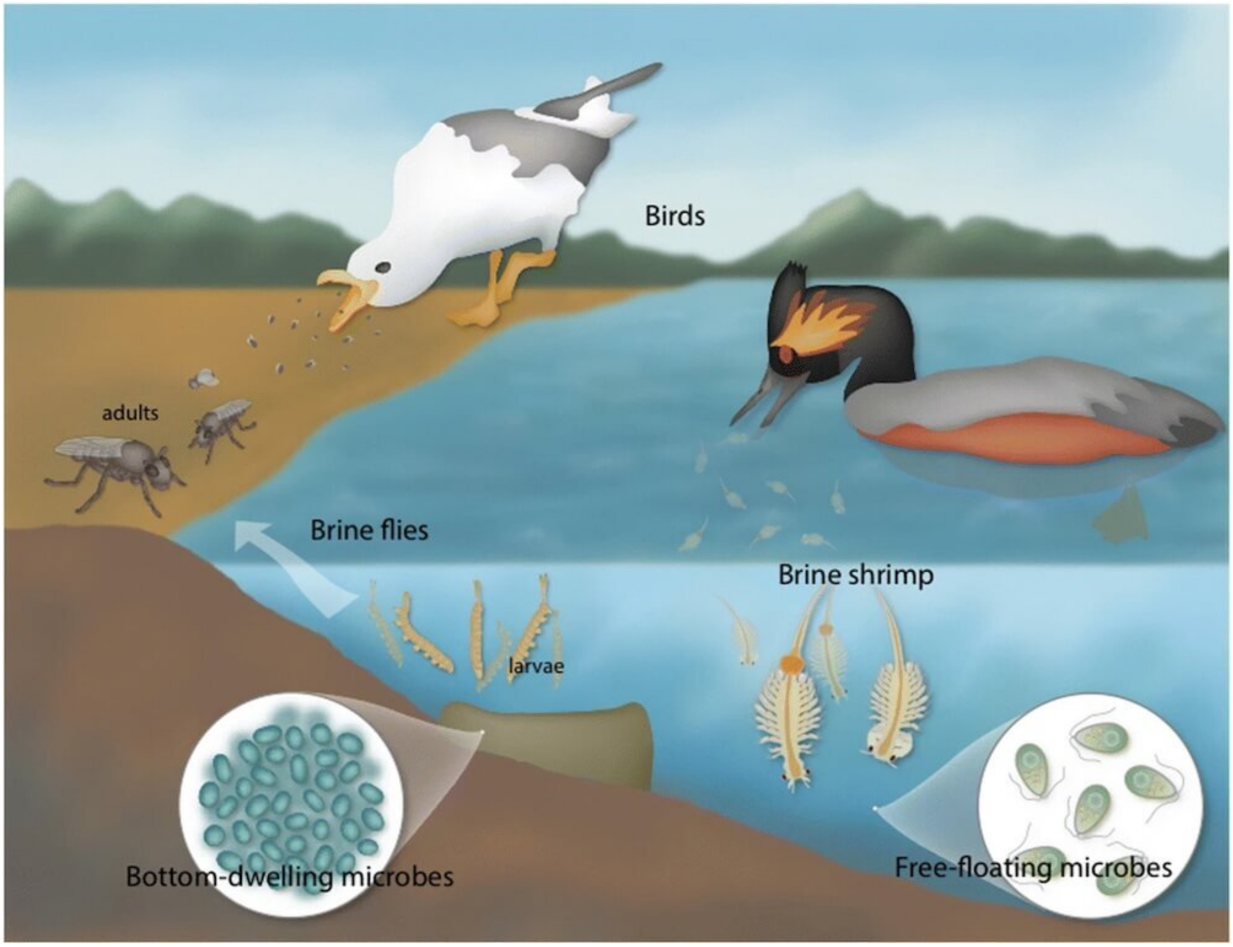
The salinity of these environments has a significant impact on the types of organisms that can optimally survive and thrive in, and around, the lake. This makes the issue of water diversion from such lakes especially impactful, since overdrawing from the amount of water that makes it to the basin slowly depletes water levels over time, resulting in not just a smaller body of water, but an increasingly briny one. The loss of water also exposes mineral-heavy lake beds that can be kicked up into hazardous dust storms, threatening the health of human populations around it. Moreover, the loss of lake volume is an unkind cycle, as less water leads to less opportunity for evaporation and subsequent rains or snows that would again lead back into the lake.

Salt lake ecosystems

The foundation of life in hypersaline lakes is microbial. Cyanobacteria and microalgae "bring the sun's energy into the water," Bonnie Baxter, Ph.D., Professor of Biology at West Minster College in Salt Lake City, Utah explains. The photosynthetic capacity of these microorganisms converts sunlight into sugars that are readily consumed by brine shrimp and brine fly larvae. These small organisms are, in turn, the major food source for numerous bird species, which descend upon the lakes in the hundreds of thousands to rest and feed during their passage.

But that's not where the microbial ecology ends. Much of Baxter's work has also focused on microbialites, or mineralizations that grow from microbial mats below the lake's surface. These microbes can impact the pH of the water so dramatically that the calcium carbonate from the water precipitates out to form rocks. In Baxter's words, these are "living rocks...biology that forms geology." Critically, these velvety and teeming microbialites are the perfect habitat for brine fly pupae to attach and grow. As these pupae feed off of the microbes in the mats, they themselves provide the second primary food source for migrating waterfowl that are able to dive and consume the pupae from the microbialites.

Microbialites are especially endangered by dwindling lake levels as they are primarily located on the outer edges of the lake, in the shallows, which are most strongly affected by evaporative water loss. It is not yet known how resilient such microbial communities are to being beached for extended periods of time, but in especially shallow lakes, such as the Great Salt Lake, even seemingly small losses in water level can have widespread impacts. Moreover, these microbes are sensitive to increasing salinity levels, so relocating some of these "living rocks" to the center of a shrinking lake is unlikely to be successful, as such a desiccated lake would be too briny for the microbes to survive, and the ecosystem they support may not be able to withstand the ecological stress.



The ecology of the Great Salt Lake depends on free-floating and bottom-dwelling microbes. Credit: Baxter et al/*International Microbiology*, 2018

Halophiles

Perhaps the only microbes that don't mind the increased salinity are the halophiles, or extremophilic microbes that are particularly adapted to thrive in very salty conditions. Halophiles in salt lakes include archaea, bacteria, fungi and algae, and often have a distinctive pink-to-reddish hue, making them especially unique and even beautiful to observe. Abundance of such halophiles, and thus the color they produce, vary seasonally with changing water level (and therefore salinity) and temperature. These natural fluctuations give salt lakes a sort of seasonality in the colors and smells they exude.

Salt lakes have likely always had some of these microbes in their waters, but populations explode when salinity climbs especially high, as it did when Iran's Lake Urmia shrank to critical levels in 2016. Similarly, when Utah's Great Salt Lake was bisected by a railway causeway in the 1950s that isolated the northern part of the lake (called the North Arm), its salinity levels skyrocketed, and it took on a distinctive pinkish color that it maintains to this day.

While such halophiles are beautiful and interesting microbial species, they are not necessarily foundational to the other life forms of the lake the way that the photosynthetic cyanobacteria and microalgae are, and can indicate that the lake is becoming too saline for other non-halophilic species to compete in the present conditions.

Why are salt lakes around the world shrinking?

Lake Owens isn't the only salt lake to have effectively dried up. The Aral Sea between Khazakstan and Uzbekistan and Lake Urmia in Iran have lost almost all of their water volume in recent decades, leaving entire regions high and dry. The Great Salt Lake reached its record low in fall 2022, and remains on the brink of ecosystem instability. Why?

Many people assume that climate change must be driving the shrinkage of these lakes. While climate is certainly a factor, it is not the primary reason. Studies in multiple regions have shown that changes to precipitation have not been substantial enough to cause these changes. Rather, each of the lakes that have dried up were subject to human intervention that diverted water for agricultural, industrial or residential use. According to a somewhat outdated 2010 survey, 72% of Utah's water is used for agricultural purposes, in large part, to grow hay and alfalfa. However, in the time since this survey, the area has also experienced explosive population growth, and many new housing developments have taken their share as well.

While various water-saving measures have been established in Utah since this survey was conducted, it's worth noting that these stressors fit the pattern of other lakes that have already largely disappeared. In fact, water intensive cotton farming played a large role in the 40 year decline of the Aral Sea, which was once one of the world's largest lakes. Damming and agricultural irrigation also played an important role in the desiccation of Lake Urmia. As discussed above, Lake Owens fell prey to a population explosion in LA. The Great Salt Lake is, at the behest of multiple pressures, already suffering from irrigational overdrafts and increasingly from new housing developments in a burgeoning population. Wise and conservative water use in this region will be absolutely critical to preserving the lake and its ecosystem.

Ecosystem resilience

Scientists don't yet know how resilient the microbial communities and the ecosystems they support are to disruptive changes. This article arrives at the tail end of a record-setting and historic year for snowfall and precipitation in the Western United States. Owens Lake has partially refilled for the first time in nearly 100 years. The Great Salt Lake has risen over 3 feet from its historic low just several months before, with spring floods still flowing strong. Even Lake Urmia in Iran is showing signs of hope, following widespread water use reform.

However, it's important to underline that one good season is not enough to outpace human water use, in the same way that one decent bank deposit is not sufficient to make up for habitual overspending. These banner years are life rafts, perhaps literally, for the ecosystems in question. It's absolutely critical that we aim to steward and conserve our resources well in order to continue to hold onto these precious landscapes.

Provided by American Society for Microbiology