The Ecology of the Salton Sea Basin: The Key is Variability.

Michael F. Allen
Distinguished Professor Emeritus
Department of Microbiology and Plant Pathology
Center for Conservation Biology
University of California, Riverside

Cameron Barrows
Conservation Ecologist, Emeritus
UCR Palm Desert Center
Center for Conservation Biology
University of California, Riverside

If there is one key feature influencing the ecology of the Salton Sea Basin, it is climatic variability. Temperatures across the Basin vary from among the hottest in North America, at elevations well below sea-level, to more moderate in desert shrublands of the Chocolate Mountains to the east, to very cold in the subalpine zone on the snowy peaks of Mount San Jacinto and the San Bernardino Mountains to the west. The Salton Sea Basin comprises much of the western half of the Colorado Desert. The Colorado Desert is often lumped as Mojave Desert, or alternatively as Sonoran Desert. But there are important differences both geologically (Norris and Webb 1976) and ecologically (Belnap et al. 2016) between these deserts.

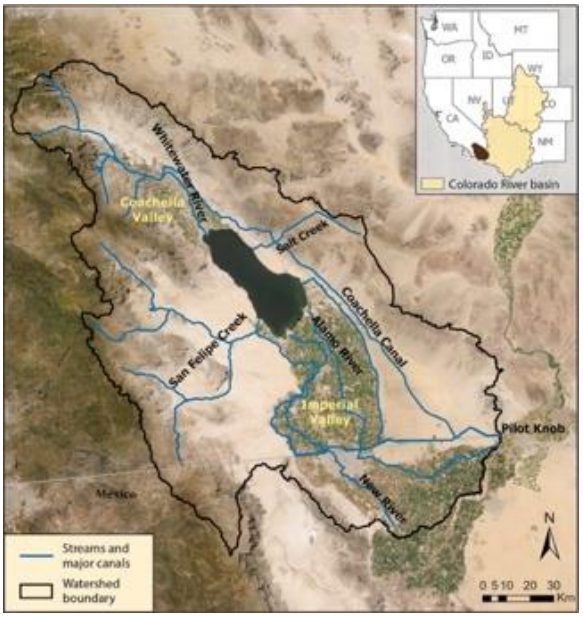
A major driver is in the multiple-scaled, variable patterns of precipitation. In the Sonoran Desert, a region dominated by columnar cacti and generally high cactus diversity, precipitation largely comes during the late summer in the monsoons tracking up the Sea of Cortéz. The Mojave Desert, dominated by Joshua Trees (*Yucca brevifolia*) and blackbrush (*Coleogyne ramosissima*) tends to rely primarily on winter precipitation from storms coming from the Pacific Ocean. The Colorado Desert lacks columnar cacti, high cactus diversity, Joshua Trees, and blackbrush. Rather it is dominated by creosote bush (*Larrea tridentata*) flats bisected by washes where smoke trees (*Psorothamnus spinosus*), palo verde (*Parkinsonia florida*), and ironwood (*Olneya tesota*) thrive. The Colorado Desert is neither Sonoran nor Mojave, with a rainfall pattern that is somewhere in between.

Precipitation at the El Cajon station in the Salton Sea Basin averages only 2.85” annually but it can rain or not rain at all in almost any month. However, rainfall averages in deserts are ecologically irrelevant. More important are the years when it rains a lot, with intense events that run into drainages, streams, and rivers. These unpredictable inputs of abundant rainfall sustain and restore desert ecosystems after extended periods of drought. The variability of these inputs, and the myriads of adaptations species have evolved in response to that variability, has resulted in an underappreciated high level of biodiversity in each of the warm deserts of North America.

The Pleistocene Lake Cahuilla was filled by periodic floods of the undammed Colorado River, floods large enough to breach the river’s banks, flowing to the lowest available elevation, -269 ft (-82 m) below sea level in the Salton Basin. The Basin dried out as recently as 300 years ago, although Colorado River flooding provided periodical inflows partially filling the basin even

during those last few centuries. In 1905 when the flooding Colorado River blew through irrigation channels then under construction and into the Salton Sea Basin, the current version of Lake Cahuilla, now known as the Salton Sea, the largest lake in California, was born. Dams on the Colorado River eliminated the floods that periodically filled the Salton Sea, so its levels were then regulated by a combination of leaked irrigation water from trans-basin water diversions (largely from the Colorado River) and a few remaining flood events, especially from the New River. Unfortunately, these brought salinity, toxic inputs from the Mexican maquiladoras, and pesticides. Because of the impacts of over-use, co-opting water from throughout the Salton Sea watershed (Figure 1 (from Bradley et al. 2022)), the ecological processes that should support the resident animals, plants, and especially migratory birds are largely constructed out of existence. This includes the many endangered species and the broad biodiversity of the Basin.

Figure 1. Watershed of the Salton Sea from (Bradley et al. 2022).



An recent example of how natural hydrologic inflows to the Sea have been altered is Hurricane Hilary, in late August of 2024 (Reinhart 2024). An unusual but not unprecedented event, Hurricane Hilary crossed from the Los Angeles Basin across Riverside, and northeasterly across the desert. Within the watershed are Mount San Jacinto, which received 11.75” of rain, Upper Mission Creek receiving 13.07”. So much rain fell that I-10 was closed. Even Palm Springs received 3.18”. Yet the water levels in the Salton Sea rose only 2” following the storm.

Where did the water between Mission Creek and the Salton Sea go? Between the points of rainfall and the lake, there are human-constructed urban, suburban, and agricultural water sinks. In pre-European years, a temporary lake would likely have frequently appeared, as happened in Death Valley, where Lake Manly, six miles long and three miles wide emerged in August 2023; it remains present as of April 2024. Desert pupfish, *Cyprinodon macularis*, entered the Salton Basin from those periodic floods from the Colorado River. During dry periods when Lake Cahuilla, now Salton Sea, disappeared, pupfish moved into tributary streams that would typically keep populations isolated. However, today’s Salton Sea desert pupfish are genetically

of a single population, despite their near isolation. This tells us that these fish populations have continued to interact, even if on intermittent time scales.

What would a pre-European Salton Sea Basin look like?

It would likely have been an intermittent shallow lake with long periods as a salt-encrusted playa. The groundwater would have been high, with emergence as mudpots in volcanically-active hotspots, and artesian wells around the Basin and under the lake. An interesting question about the microbial composition arises. Did the microbial communities form calcium carbonate layers such as exist today (Figure 2), also known as microbialites (Freund et al. 2022). Today, these may be immobilizing toxins and pollutants (or not) that have been accumulating from pollution inputs and from toxic cyanobacteria over the past century (Nightingale 2019).

Figure 2. Microbialite and salt crust in the Salton Sea.

The ancient Lake Cahuilla, when full or partially so, became a critical lifeline for migrating birds along the inland path of the Pacific Flyway. Fish and aquatic invertebrates introduced by the flooding Colorado River provided critically important sustenance for wintering, breeding, and migrating geese, ducks, pelicans, storks, herons, egrets, gulls, terns, and shorebirds of many species. These birds and fish provided a cornucopia of food for the indigenous people who lived here. With the conversion of the Colorado Delta to agriculture, the loss of the extensive wetlands as the Colorado River became over-subscribed, and the dry down of Owens Lake to water Los Angeles, the Salton Sea was one of the last refuges for a breathtaking array of bird species.

While a lake was present, the shoreline was likely highly variable as shown by the ancient fish traps, weirs along the old shorelines of Lake Cahuilla (Treganza 1945). It seems unlikely that there would not be a semi-permanent lake. Did it survive the Altithermal period as a permanent lake, or did water levels fluctuate during wet-dry periods? As Lake Cahuilla dried some 300 to 500 years ago, Owens Lake and the Colorado Estuary provided stopover and winter habitat for birds along an eastern California Pacific Flyway. Lake Cahuilla probably periodically provided an

additional stopover point following flooding events. There was also groundwater supporting springs and shallow groundwater, and floods. These washes and streams supported microphyll woodlands along old shores and arroyos. Trees with hard seeds, such as smoke tree and palo verde, require flood events to scarify their seeds allowing germination. And germination would then result in successful plant establishment because of the high groundwater in the wash. (For this reason, in a woodland patch, nearly all of the trees of the same species tend to be approximately the same size).

As the lake continued to retreat, along watersheds such as San Felipe Creek, establishing mesquite shrubs would trap sand, blowing from Coyote Wash during periods of high winds forming nutrient-rich safe sites, mounds that supported many of the animals and birds in the area (Figure 3). These mounds were not only important to wildlife. Mesquite (as well as palo verde and smoketree) plants are legumes; they fix atmospheric nitrogen. They also connect with neighboring plants through symbiotic fungi, known as mycorrhizae, and are known to transfer nitrogen to those neighbors. Native Americans were familiar with their nutritional benefit, and mounds all along the Old Kane Springs Road show evidence of use of the mounds for food (mesquite pods) and possibly even swidden maize production.

Figure 3. Photos of mesquite mounds along San Felipe Creek and the experimential restoration of mounds using new mesquite trees by simulating high groundwater during establishment. Establishment depended upon planting seedlings into an existing mound, and supplementing deep water (as would occur during a wet? period near a shoreline, or along a channel under flood, such as the nearby San Felipe Creek).

The natural mesquite mounds along highway 78, 1993

Restored mounds 1993 (left), 2022 (right)

We suggest that, in the absence of current-day water diversions, a lake would have temporarily formed in the Salton Sea, similar to Lake Manly, eight months after Hurricane Hilary. In fact, because the Salton Sea is a closed basin, water from a large rainfall event would persist for multiple years.

Today's Salton Sea ecosystem

The current Salton Sea depends upon the variation in precipitation, temperature, and physiography from the Sky Islands shooting up nearly 12,000 feet above the Sea and playas more than 200 feet below sea level. There are more species of mammals, birds, and reptiles across Southern California deserts, including the Salton Sea Basin than any other biome except the tropical rainforest. Plant species diversity is extraordinary with over half of all California native plants found in the deserts. Microbial diversity may be among the highest in the world, but is poorly known. Microphytic crusts of all types (resurrection plant, mosses, lichen, and cyanobacteria) are present, largely at the base of granitic rocks, where rainfall inputs are higher and solar radiation lower than in open areas. Large precipitation events replenish groundwater that builds microphyll woodlands and mesquite mounds far from the points of rain- and snowfall. Many of these plants have deep roots, extending more than 50m to find water. These roots and their associated microorganisms respire CO_2, fixed by their leaves, deep in the soil. This CO_2 binds with calcium to form caliche - immobilizing more CO_2 globally than exists in the atmosphere. Deserts, including the Salton Sea, are an important contribution to California's biodiversity as well as global carbon cycling (Allen et al. 2024).

Nevertheless, all of California deserts remain under threat from urbanization, trans-basin water diversion, water and air pollution, invasive species, and now climate change (Allen et al. 2014). Water pollution, especially from the New River and border factories, and from agricultural fertilizers and pesticides continue to enter the sea. Increasing nitrate runoff from agriculture, which in turn increases regional NO_x and NH_3 atmospheric deposition (Alonso et al. 2005) interacts with invasive species to increase aerial allergenic compounds. At the same time, many microorganisms (Biddle et al. 2023) and Valley Fever (Cat et al. 2019) act to create health issues for humans and wildlife. Pesticide, nitrogen, and phosphorus runoff facilitate microbial blooms that are detrimental for humans and wildlife.

The Salton Sea has already passed an unfortunate threshold. As of 2023, it is about 50% higher than the salinity of the ocean at 44,000 mg/L, which is roughly 4.4% salt. The Salton Sea is now too salty to support fish and so fish-eating birds arrive with nothing to sustain them. "Rafts" of thousands of white pelicans are gone. Egrets, herons, and storks are either gone, or are relegated to irrigated agricultural fields. Desert pupfish are again restricted to the few unpolluted tributaries.

Furthermore, with the existing water shortages, more water will be diverted from the current inputs and less water will flow into the Salton Sea. The large, dry shoreline of exposed soil laced with salts, toxins, often covered by the microbialites, will become windborne creating health problems for all residents.

It is critical that any management scenario that is considered take account of the entire Salton Sea Basin; it is all ecologically interconnected.

References:

Allen, M. F., C. W. Barrows, C. Barrows, S. Boyd, P. Flanagan, R. Kobaly, A. McCulloch, and J. Taylor. 2024. The California Desert's Role in 30x30: Carbon Sequestration and Biodiversity. Page 33.

Allen, M. F., C. W. Barrows, M. D. Bell, G. D. Jenerette, R. F. Johnson, and E. B. Allen. 2014. Threats to California's desert ecosystems. Fremontia **42**:3-8.

Alonso, R., A. Bytnerowicz, and W. I. Boarman. 2005. Atmospheric dry deposition in the vicinity of the Salton Sea, California—I: Air pollution and deposition in a desert environment. Atmospheric Environment **39**:4671-4679.

Belnap, J., R. H. Webb, T. C. Esque, M. L. Brooks, L. A. DeFalco, and J. A. MacMahon. 2016. Deserts. Pages 635-667 *in* H. A. Mooney and E. Zavaleta, editors. Ecosystems of California. University of California Press, Oakland.

Biddle, T. A., K. Yisrael, R. Drover, Q. Li, M. R. Maltz, T. M. Topacio, J. Yu, D. Del Castillo, D. Gonzales, H. L. Freund, M. P. Swenson, M. L. Shapiro, J. K. Botthoff, E. Aronson, D. R. Cocker, and D. D. Lo. 2023. Aerosolized aqueous dust extracts collected near a drying lake trigger acute neutrophilic pulmonary inflammation reminiscent of microbial innate immune ligands. Science of the Total Environment **858**:159882.

Bradley, T. J., H. Ajami, and W. C. Porter. 2022. Ecological transitions at the Salton Sea: Past, present and future. California Agriculture **76**:8-15.

Cat, L. A., M. Gorris, J. Randerson, M. Riquelme, and K. K. Treseder. 2019. Crossing the line: Human disease and climate change across borders. Journal of Environmental Health **81**:14-22.

Freund, H., M. R. Maltz, M. P. Swenson, T. M. Topacio, V. A. Montellano, W. C. Porter, and E. L. Aronson. 2022. Microbiome interactions and their ecological implications at the Salton Sea. California Agriculture **76**:16-26.

Nightingale, S. 2019. What lies beneath. UCR Magazine.

Norris, R. M., and R. W. Webb. 1976. Geology of California. John Wiley & Sons, New York.

Reinhart, B. J. 2024. Hurricane Hilary (EP092023). National Hurricane Center Tropical Cyclone Report.

Treganza, A. E. 1945. The "Ancient Stone Fish Traps" of the Coachella Valley, Southern California. American Antiquity **10**:285-294.