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Water quality decline in California's drying Salton Sea: Relationships between nutrient pollution, water column redox, and regional ecosystem health

Caroline Hung, Charles Diamond, and Timothy Lyons
Department of Earth and Planetary Sciences, University of California-Riverside, Riverside, USA (chung041@ucr.edu)

Desiccating arid lakes are a global problem in the face of dwindling water supplies through climate-induced droughts and intensified human activities, including damming, agriculture, and urban expansion. The deleterious consequences of declining water supplies are exacerbated by anthropogenic pollution, which increases rates of ecosystem collapse. The Salton Sea, California's largest lake with a current maximum depth of only 10 meters, is suffering in these ways. Despite significant investments in the creation of wetlands and planning in-basin restructuring to combat salinity increases, the lake's primary purpose, as stated in the Water Quality Control Plan for the Colorado River Basin, remains drainage collection from irrigated cropland. This long-standing policy allowed unchecked inputs of nutrient-rich agricultural runoff for the last century. Because surface flow from tributaries and agricultural canals is the primary input to this terminal lake, extreme eutrophication results in ecosystem challenges made worse by declining lake level. For example, eutrophication via excessive nitrogen and phosphorus influx and evapoconcentration trigger algal blooms and concomitant suboxia/anoxia and sulfidic conditions in deeper waters. These conditions threaten aquatic life as well as human health through likely pathogen production.

Data spanning the past two decades reveal critical patterns of nutrient cycling and related consequences for basin chemistry and ecologies. Summer is marked by an overall decrease in total phosphate and nitrate concentrations due to increased primary production, which is sustained by the combination of enhanced release of phosphorus from sediments during summer anoxia and surface water inputs. Year-round N:P molar ratios in the water column exceed 50:1 to 100:1, deviating from the Redfield ratio of 16:1. However, phosphorus, which is persistently loaded through surface runoff and release from sediments, is never strongly depleted in the water column, challenging previous studies in the Salton Sea that suggest phosphorus limitation. Rapidly declining lake levels show significant changes in thermo- and chemo- stratification of the water column, including declines in dissolved oxygen and changing seasonal redox patterns. These trends suggest that the Salton Sea will become increasingly unsuitable for wildlife due to worsening water quality, which could undermine at least some habitat restoration efforts planned or already underway, such as those focused primarily on controlling salinity. As such, the more effective approach will require dramatic reduction in nutrient loading, necessitating the establishment and enforcement of Total Maximum Daily Loads (TMDLs) maintained via wetlands and/or treatment facilities at tributary mouths. Beyond regional concerns, the Salton Sea serves as an important example of the many interwoven threats to ecology, regional public health, and overall quality of life for those living in the basins of drying lakes. These are system experiencing complex chemical evolutions driven by direct human activities, such as agricultural runoff, and indirectly through anthropogenic climate change. The Salton Sea serves as an important case study for the importance of comprehensive integration of an atypically broad range of chemical, biological, and physical data and interpretations in policy decisions.