Sierra Nevada Network
Resource Brief

U.S. Department of the Interior
National Park Service

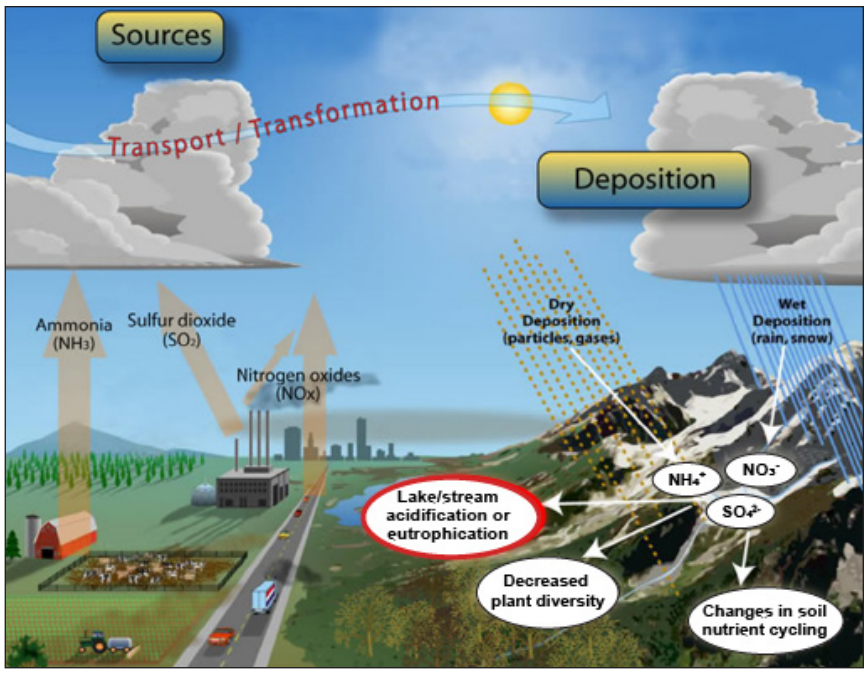
Inventory and Monitoring Division

Environmental Policy Making a Difference: The Clean Air Act and Mountain Lakes

As early as the 1920s, Sierra Nevada lakes, despite their remote wilderness locations, showed increased acidification associated with industrialization. By the late 1970s, acidification began declining. A clear example of environmental policy making a difference, water quality in lakes improved in response to implementation of the Clean Air Act initiated in 1970 and further amended in subsequent years.

Getting the Drift - Linking Air and Water

How do air pollutants end up in remote lakes? As shown in the image to the right, nutrients and acids produced by industry, agriculture, and vehicles drift into the mountains on air currents and are deposited via rain, snow, and dry deposits (such as particles of dust). These pollutants travel from California's Central Valley, the San Francisco Bay Area, and as far away as Asia. Pollutants such as ammonium, nitrate, and sulfate acidify mountain lakes, decreasing their acid-neutralizing capacity, and altering the biotic communities of plants and animals in these lakes.



The Sierra Nevada mountains receive atmospheric pollutants through precipitation events and dry deposition. Sources of pollutants include industry, agriculture, and vehicles. Pollutants that can affect lake acidity include ammonium, nitrate, and sulfate. Graphic: NPS Air Resources Division.

How Do We Know Lakes Have Changed?



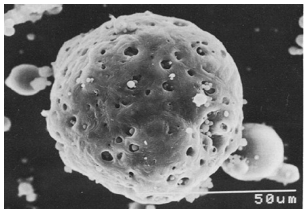
A sediment core extracted from a Sierra Nevada lake. Cores are sliced into 1-centimeter-thick segments and the chemical composition of each segment analyzed to determine how lake chemistry has changed over time.

Aspects of a lake's history can be revealed by examining biological and chemical measures that are preserved in lake sediment layers through time. Scientists have reconstructed historic acidification trends using a Sierra Nevada lake sediment core (Sickman et al. 2013). They found by examing changes in algae presence over time, the lake was changing as early as the 1920s with acidification increasing through 1970. However, from 1970 through the mid-2000s, the trend reversed and the lake became less acidified - an apparent response to enactment of the Clean Air Act and its Amendments.

Were the observed changes in acidity definitely linked to air pollutants being deposited in the Sierra Nevada? A second study examined multiple lines of evidence to understand the effect of human actions on Sierra Nevada lakes throughout the 20th century.

By-products of industrial fossil fuel combustion, known as spheroidal carbonaceous particles (or SCPs), were quantified in lake cores. SCPs are transported and deposited in mountain lakes, where they are preserved in the sediments. As there are no natural sources of SCPs, they are an excellent indicator of human-caused atmospheric deposition.

SCP patterns were strongly correlated with the acidification trends, as were 20th century sulfur emissions. These correlations between acidification, air pollution, and deposition suggest that acid deposition caused the early 20th century acidification (Heard et al. 2014).



Example of a spheroidal carbonaceous particle. Photo from Rose (1990).

How Did These Lakes Change?

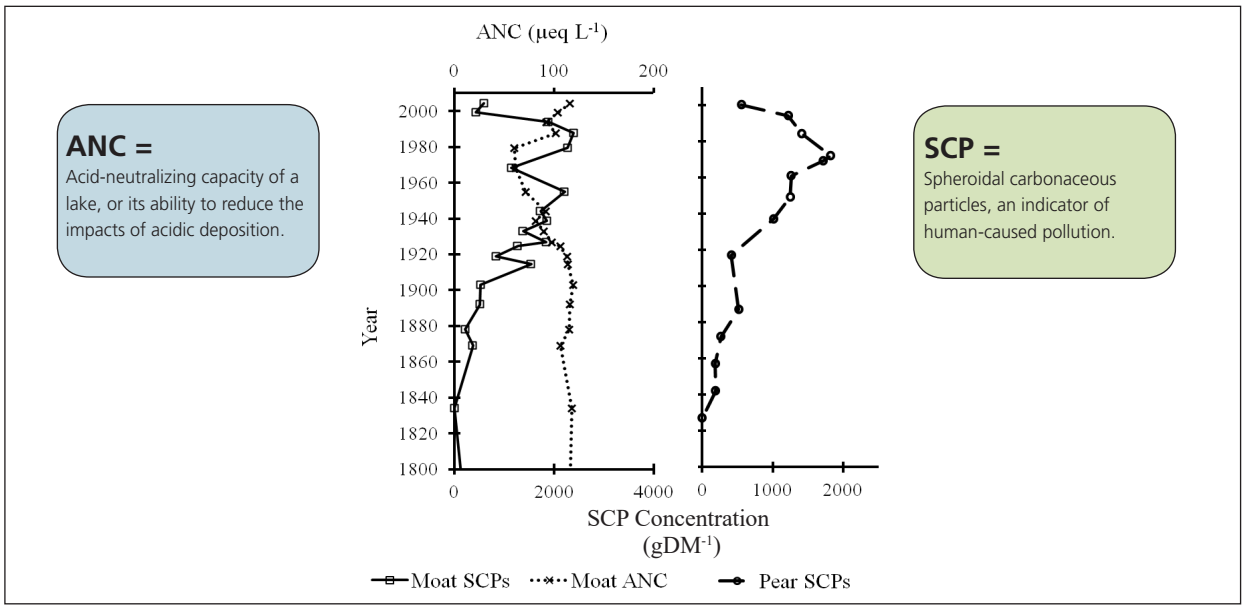


Figure 1. Moat Lake SCP concentrations and reconstructed ANC (left) and Pear Lake SCP concentrations (right).

How did SCPs change in Moat and Pear Lakes?

Patterns were similar between Moat and Pear lakes: As shown in Figure 1, SCP concentrations gradually increased in the mid to late 19th century and then rose faster in the early part of the 20th century. SCPs in Pear and Moat lakes began to decline from approximately 1970 to 1985 in response to declining pollution from industrial fossil fuel burning.



Field scientist collects lake data in Sequoia National Park as part of a long-term monitoring project in Sierra Nevada parks. Photo by: Glauco Puig-Santana.

How are SCPs and ANC related?

A reconstruction of acid-neutralizing capacity (ANC) is shown for Moat Lake in Figure 1. Statistical analyses demonstrate negative correlations between ANC and SCPs. This relationship is visibly evident in the Moat Lake graphic showing acid neutralizing capacity being low when SCPs are high. ANC begins to recover (i.e., increase) by around 1980 as SCPs decline following enactment of the Clean Air Act. This change was attributed to the reduction in pollution indicated by declining SCPs.

Lake Pollution Remains A Problem

While the recovery of Moat Lake ANC is a positive outcome that further documents the already noted successes of the Clean Air Act and Amendments, Sierra Nevada lakes need continued monitoring and protection. Research being conducted at a larger spatial scale suggests that lakes in this region are still affected by acid deposition. Current emissions reductions are not sufficient to allow for full recovery of more sensitive lakes.

Continued long-term monitoring of Sierra Nevada lakes provides data for evaluating change, informing management and research, and assessing the effectiveness of environmental policies.

More Information

This was a collaborative project involving: University of California Riverside, University of California Santa Barbara, University of Florida, University College London, and the National Park Service. Contact Andi Heard (andi_heard@nps.gov), Physical Scientist, Sierra Nevada Network, for more information.

Sierra Nevada Network Inventory & Monitoring Program web page

Heard, A. M., J. O. Sickman, N. L. Rose, D. M. Bennett, D. M. Lucero, J. M. Melack, and J. H. Curtis. 2014. 20th century atmospheric deposition and acidification trends in lakes of the Sierra Nevada, California, USA. Environmental Science & Technology 2014, 48, 10054-10061.