



LAKE MONITORING

IMPORTANCE — High-elevation lakes are critical components of the parks' ecosystems, popular visitor destinations, and habitat for aquatic and terrestrial organisms, including declining amphibian species. Lake ecosystems were selected for monitoring because they are 1) valued for their ecological importance, contribution to Wilderness character, recreational opportunities, and importance to regional water supplies, 2) threatened by multiple stressors, and 3) sensitive to environmental change. Sierra Nevada Network (SIEN) parks protect over 4,500 lakes that have some of the highest water quality in the Sierra Nevada. However, they are subjected to stressors that have the potential to adversely affect them. The stressors with greatest concern are air pollution (e.g., increased nutrient inputs), climate change, non-native invasive species (e.g., fish), and localized visitor impacts. Lakes are good indicators of aquatic and terrestrial ecosystem condition because they reflect changes within the larger watershed. Sierra Nevada lakes are especially sensitive to environmental change because the waters are very dilute and thus small changes can result in pronounced ecological effects. Prior research suggests that increased nitrogen and phosphorus inputs are contributing to changes in nutrient cycles and shifts in phytoplankton communities (Goldman et al. 1993, Sickman et al. 2003).



Processing water samples. NPS photo.



Rafting out to collect mid-lake sample. NPS photo.

OBJECTIVES AND METHODS

The primary goal of SIEN's lake monitoring program is to determine status and trends in lake water chemistry across the network and, at a few sites, determine trends in water quantity at lake outflows. In order to make network-level inferences, SIEN monitors water chemistry at a total of 76 randomly selected lakes that are sampled over a four-year period—referred to as extensive sites. Extensive sites are organized in a rotating panel design where eight sites are returned to each year and the remaining 68 are visited on a four year rotation. Sampling occurs from mid-August through September. In addition, SIEN monitors water chemistry and lake outflow levels multiple times a year at four index lakes, specifically selected by the network based on their reasonable accessibility. Index lakes are sampled once per

month from approximately late June through early October. The index sites provide more temporally intensive data that complement and inform interpretation of the spatially extensive data. The index lakes in Yosemite are Maclure and Kuna Peak, both located in the upper Tuolumne watershed. In Sequoia the index lake is Emerald, located on the western slope in the Kaweah watershed, and in Kings Canyon, the index lake is Dusy Basin, located on the eastern edge of the park near the Pacific Crest in the Kings watershed.

Water chemistry measures include water temperature, pH, specific conductance, dissolved oxygen, acid neutralizing capacity, major anions and cations, and a suite of nitrogen and phosphorus metrics.



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RESULTS

Sierra Nevada Network's long-term lake monitoring started in the summer of 2008. In the past two seasons, SIEN has sampled 25 extensive sites per year, for a total of 42 unique sites. The four index sites were each sampled eight times.

In this resource brief we present nitrate results from the 2008 and 2009 extensive and index lake outflow sampling. Late season (i.e., mid-August through September) nitrate concentrations across the network range from below the method detection level to 11.8 μM (Figures 1 and 2). The mean concentration for the extensive sites is 1.5 μM and the standard deviation is 2.8 μM ($n=49$). Mean nitrate is higher for Sequoia and Kings Canyon and lower for Yosemite---1.9 μM compared to 0.8 μM , respectively.

Nitrate concentrations at the index lakes ranged from below the method detection limit to 16.1 μM . Typically, concentrations were highest at Maclure and then in decreasing order Emerald, Kuna Peak and Dusy Basin (Figure 3). Nitrate was highest in the June and July samples and then decreased in the late season samples, with the exception of Maclure in 2009. Early season nitrate concentrations were higher in 2009 compared to 2008.

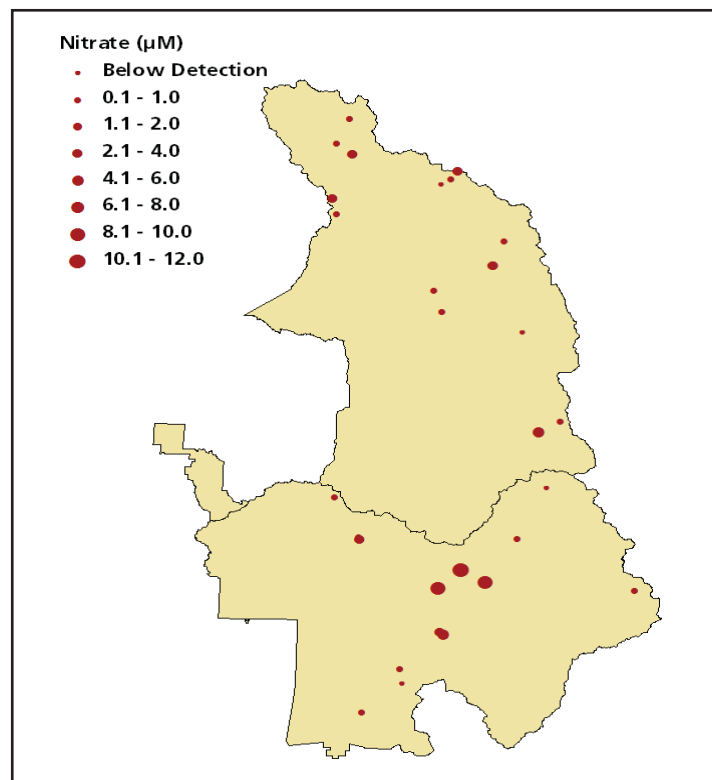


Figure 1. Nitrate concentrations for Sequoia and Kings Canyon extensive and index sites from the 2008 and 2009 lake surveys. Index site data are from the 2009 early September sampling.

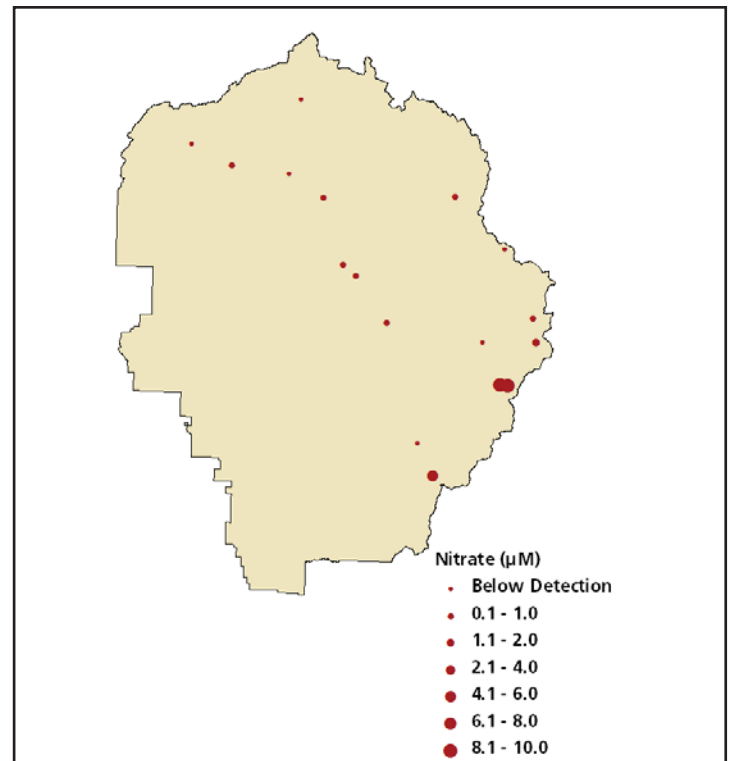


Figure 2. Nitrate concentrations for Yosemite extensive and index sites from the 2008 and 2009 lake surveys. Index site data are from the 2009 early September sampling.

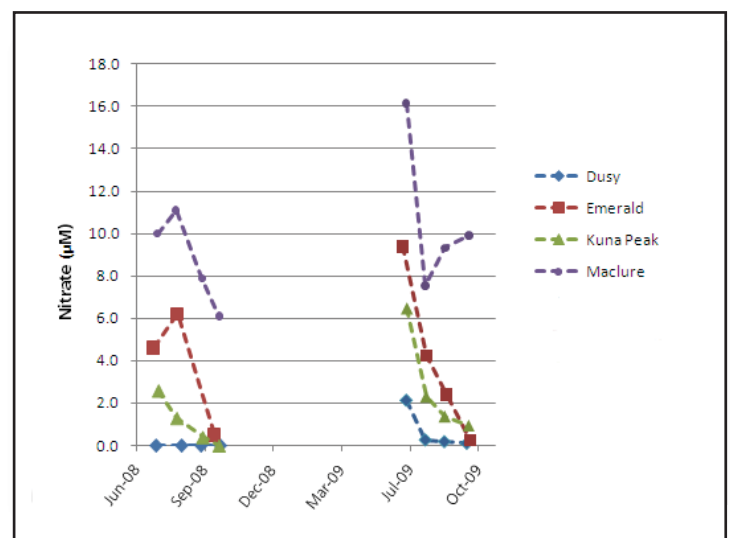


Figure 3. Nitrate concentrations at the four index sites during the 2008 and 2009 field seasons.



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DISCUSSION

Although nitrate concentrations vary across the network, mean concentrations are lower in Yosemite. This difference is likely attributed to lower rates of atmospheric deposition in Yosemite. Sequoia and Kings Canyon, Sequoia in particular, have higher deposition rates due to air patterns that concentrate pollutants in the southern Central Valley. These pollutants, which include nitrogen oxides primarily from car emissions and agricultural activities, travel from the San Francisco Bay Area and down the Central Valley, where they collect on the western edge and rise into the parks. This additional nitrogen is deposited in the parks in wet and dry deposition. Other factors that can contribute to nitrate variability across the network include, but are not limited to, watershed area, in-lake processes, and watershed characteristics such as vegetation cover and type, geology, and soils.

Although Yosemite mean nitrate concentrations were lower, the highest concentration measured was in Yosemite at Maclure Lake (16.1 μM). Maclure was selected because it has been identified as especially sensitive to change from atmospheric deposition based on chemical and physical characteristics and it has moderate to high

the network's goal to report the proportion of SIEN lakes that exceed given ecological thresholds for key water chemistry indicators. However, additional research is needed before the parks can determine meaningful thresholds. SIEN is collaborating with the University of California, Riverside to obtain the needed information. A minimum of five years of data (ten is often recommended) is needed before SIEN can report on lake chemistry trends.

Parks may use status and trend information from the lake monitoring protocol to make park-level management decisions, monitor compliance with state water quality standards, inform regional permitting of point-source industrial emissions, influence regional, state, and national environmental policies, and provide information to the public.

At the local park-level these data may be used to inform park planning projects, regulate visitor use, inform fire management, meet government reporting requirements, and contribute to the protection and restoration of aquatic ecosystems.



Davis Lake, Kings Canyon National Park. NPS photo.

nitrogen concentrations. The watershed is granitic, sparsely vegetated, and receives above average precipitation and thus higher nitrogen inputs.

Index site results are useful for understanding both inter- and intra-annual patterns in lake chemistry. Within a season, high nitrate concentrations in the early season that decrease over the summer and fall are consistent with previous research and monitoring in the parks. Nitrate typically peaks during spring snowmelt when it is flushed out of the watershed and into receiving waters. The decrease is attributed initially to decreased snowmelt rates and then later in the season to biological uptake.

In order to provide more meaningful information to the parks, it is



Spillway Lake, Yosemite National Park. NPS photo.

SIEN water chemistry data will be publicly accessible through the Environmental Protection Agency's STORET database

WHERE MONITORED

Yosemite, Sequoia, and Kings Canyon National Parks

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