



Nutrient Deposition and Food Web Alteration in High Sierran Lakes: Microbial Community Response

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Growing evidence for ecosystem-scale impacts to remote lakes of the Sierra Nevada by nutrient deposition and fisheries manipulations demands an understanding of the role of microbes in these systems. Our initial research indicates a remarkably active and diverse bacterial community in lakes throughout the region. Recent experiments demonstrate that microbial communities in high-elevation Sierran lakes respond rapidly and strongly to phosphorus enrichment, indicating that continuing deposition of this nutrient may lead to significant changes in the rate of organic matter metabolism and overall ecosystem function of these lakes.

High-elevation lakes of the Sierra Nevada, once considered isolated from human impacts, are increasingly experiencing the effects of human activities. Nutrient loading, the result of increasing atmospheric deposition, and the stocking of non-native trout, halted in National Parks but continuing on Forest Service lands, are major anthropogenic impacts to these remote ecosystems. The ecological impacts of both trout stocking and atmospheric pollutants have been studied in high-elevation lakes of the Sierra for nearly two decades, and have been shown to impose significant and lasting impacts at a regional scale, including loss of endangered species, alterations to algal productivity, and changes to zooplankton populations. Connecting these shifts to ecosystem function and biogeochemical cycling is necessary for understanding and predicting ecological impacts in these lakes, yet this has not yet been a focus, despite the documented sensitivity of alpine lake ecosystems to even minor changes in water chemistry or nutrient availability. In oligotrophic (low-productivity) aquatic ecosystems, including most alpine lakes worldwide, the microbial food web (bacteria and their protozoan grazers) is predicted to

dominate the metabolism of carbon, nitrogen, and phosphorus. Our research is investigating potential regional ecosystem impacts of eutrophication and trout introductions by examining the role of microbes in the structure and function of Sierran lakes.

Work in 2005-2006 focused on experimental assessment of the microbial response to predicted levels of atmospheric nutrient deposition. Experiments were conducted in Emerald Lake (Sequoia National Park) using *in situ* mesocosms amended with nitrate and phosphorus to examine how bacterial community composition and metabolic rates would be affected by increased availability of inorganic nutrients. Initial phylogenetic sequencing work to identify the species composition of bacteria in Emerald Lake was also completed. In addition, we continued year-round sampling of microbial and biogeochemical variables in Emerald Lake to establish a baseline understanding of bacterioplankton communities and insight into links between bacterioplankton dynamics and seasonal physical and chemical parameters. A second annual survey of six fishless and trout-stocked lakes in Humphrey's Basin

(Inyo National Forest) was conducted in mid-September of 2005 to evaluate differences in bacterioplankton and organic matter stocks attributable to the presence or absence of introduced trout.

Key findings from this second year of research include the following:

- 1) Bacterial communities in high-elevation Sierra Nevada lakes exhibit predictable annual successional patterns linked to the timing and magnitude of snowmelt.
- 2) Phosphorus strongly limits the metabolism of bacteria in Sierran lakes, suggesting that continued depositional enrichment will alter rates of respiration and organic matter cycling in high-elevation catchments.
- 3) Bacteria change the composition of their communities in concert with seasonal changes in the source of organic matter in alpine lakes: from terrestrial runoff in spring to phytoplankton-derived organic matter in autumn.
- 4) The phylogenetic identities of bacteria in high-elevation lakes are similar throughout the world, with Sierran communities closely related to studies conducted in Crater Lake (USA), the Austrian Alps, and Hawaii.

Professional Presentations

Nelson, C.E., C.A. Carlson, J. O. Sickman, and J.M. Melack. Community composition and metabolism of high-elevation bacterioplankton linked to catchment inputs, landscape position, and seasonal limnological transitions. American Society of Limnology & Oceanography Summer Meeting, Victoria, British Columbia, Canada, June 4-9, 2006.

Collaborative Efforts

The interdisciplinary nature of this research has involved close collaboration with several research groups. Dr. Craig Carlson, a marine microbial ecologist at UCSB, has assisted with analyses of microbial parameters. Dr. James Sickman, a watershed biogeochemist at the University of Florida, has provided assistance with various analyses of organic matter composition. Drs. Roland Knapp and Orlando Sarnelle, respectively of the Sierra Nevada Aquatic Research Laboratory and Michigan State University, have provided access to and supporting data on lakes undergoing experimental fisheries manipulation.

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