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 natural bacterial community in lakes throughout the region. Landscape analyses of fourteen lake chains have identified how bacterial communities change as water flows through catchments. Using this spatial survey approach, we have successfully defined linkages between bacterial species composition and a host of physical and chemical parameters, including catchment vegetation cover, elevation, and the composition of dissolved organic matter.

High-elevation lakes of the Sierra Nevada, once considered isolated from human impacts, are increasingly experiencing the effects of population expansion. 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 eradication of endangered species, alterations to algal productivity, and changes in zooplankton population dynamics. 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. 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.

Previous work in 2004-2006 characterized the phenology of microbial community structure and metabolism in Emerald Lake (Sequoia National Park). Results of that work indicated that snowmelt processes and seasonal flushing of dissolved organic matter played a key role in determining the species composition of bacteria in the lake. Bacterial metabolism was very variable and remained high year-round, even under the cover of snow and ice.

Steve Sadro and Craig Nelson filtering water for bacterial and solute analyses at Ediza Lake in September of 2006.

Work conducted in 2005 focused on assessment of the microbial response to predicted levels of atmospheric nutrient deposition. Experiments were conducted in Emerald Lake 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. A key result of this work was the finding that phosphorus clearly 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.

In 2006 a comprehensive survey of freshwater bacterial species and biogeochemical characteristics was carried out in fourteen lake-chains throughout the Sierra Nevada. Bacterial communities were found to closely track the composition of organic matter throughout catchments, which in turn was closely linked to vegetation cover and elevation. Results of this work have provided a comprehensive database of bacterial biogeography in Sierran lakes and demonstrated that 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, 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 2006 Summer Meeting, Victoria, BC, Canada, June 4-9.

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 California, Riverside, 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. This work has relied heavily on the cooperation of the USDA-Forest Service and the National Park Service, both through administrative support and the provision of key biological and geographic data sets.

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