# Global Change in Alpine Aquatic Ecosystems

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**Background:**

Alpine lakes serve important roles to downstream ecosystem processes and services. Climate change is predicted to strongly affect alpine lakes, in part because they integrate broader-scale environmental change. The rate of climate warming is amplified at high elevations (Pepin et al. 2015) and alpine lakes are expected to be highly sensitive to projected change (Thompson et al. 2005). Consequently, minute changes in climate have the potential to drive large shifts in hydrological, geochemical and biological processes- a feature that is exacerbated by the minimal water storage capacity and sparse vegetation of thin alpine soils (Williams et al. 2002, Beniston 2003). Furthermore, heterogeneous changes in atmospheric, terrestrial and aquatic environments, can become integrated in the ecosystem responses of lakes due to the transport of water through the catchment (Adrian et al. 2009, Williamson et al. 2009). Previous studies examining ecosystem shifts of lower elevation lakes in cold regions suggest that these lakes show similar responses to climate warming compared to higher altitude lakes in some instances (earlier ice-out and stratification, deeper thermoclines, higher phytoplankton biomass), but they diverge in other responses (e.g. nutrient concentrations, DOC and major ions) (Schindler et al. 1990, Winder and Schindler 2004, Parker et al. 2008). Alpine lakes in general, and lakes distributed along an elevational gradient ranging from sub-alpine to alpine, thus offer valuable opportunities to understand and predict ecosystem responses to climate change and to monitor the ecological integrity of these environments.

The overall goal of this study is to monitor plankton community assemblages, water chemistry, and nitrogen deposition to determine potential variables sensitive to climate change at an elevational gradient. Because zooplankton are sensitive to UV, we suspect zooplankton assemblages to differ with elevation. Earlier flushing times caused by earlier ice-off can also have cascading effects on the inhabitants of alpine lakes as well and we suspect the elevational gradient will compound the effects of climate change. OSMP provides relatively easy access to lower elevation sub-alpine and alpine lakes that would be ideal for comparisons with lakes in Green Lakes Valley. In order to accomplish this goal we sampled 18 different lakes throughout the Front Range of Colorado's Rocky Mountains at three different stratification intervals. These lakes are along an elevation gradient, within similar drainage networks, with comparable relative depths and surface areas. The data collected from this project contributes to previous research on how elevation effects, nutrients affects, water quality effects, and lake morphology influence patterns in biotic communities, especially in regards to zooplankton.

**Data Collection:**

Throughout the summer of 2016 we sampled Mud Lake 3 times, May, June, and July, in order to compare the characteristics of this lake to the characteristics of the other lakes located in Niwot Long Term Ecological Research (LTER) sites. During each sampling we collected water samples using a Van Dorn vertical water sampler for total nutrients, dissolved organic carbon (DOC), chlorophyll, and phytoplankton analysis in

acid washed Nalgene bottles from the pond's surface, as well as from the area of deepest depth from an inflatable two person Alpacka Raft. 1000 mL of water was used for Chlorophyll-a analysis, 500 mL for chemical analyses, 250 mL for DOC and DOM measurements, 500 mL for phytoplankton identification and about 200 mL for zooplankton identification. We located the area of deepest depth using a Vectorcom Wired Fish Finder. All water samples were refrigerated immediately after collected and filtered within 24 hours. Filtered samples were then stored in a standard freezer until processed by Arikaree Lab using standard methods (https://instaar.colorado.edu/research/labs-groups/arikaree-environmental-lab/free-play). We used portable YSI 556 meter to measure the amounts of dissolved oxygen, the temperature, the conductivity, and the pH from the surface, through out the water column in half-meter increments. We used a Secchi disk to measure water clarity as well as a portable Li-Cor meter with a quantum sensor probe to measure the amount of solar radiation present at the surface and at each half-meter depth. Zooplankton were collected using a meter long 80µm WI net, in two vertical tows and examined at University of Colorado Boulder's campus, in the Johnson Laboratory facilities at, Ramaley, N333.

**Data Analysis:**

Upon arrival at the lab, samples for chemical analyses were filtered through pre-rinsed Millipore 47 mm GF/F filters (0.7 µm pore-size) into new, clean HDPE bottles and stored at 4$^{o}$C until analysis by the KIOWA lab. A 60 mL subsample is filtered to the same kind of filter and kept frozen for pH and conductivity analyses in the ab at a later time. Water for DOC analysis was filtered through pre-combusted Whatman 47 mm GF/F filters (0.7 µm pore size) into pre-combusted amber glass bottles. Filtered DOC samples are stored at 4$^{o}$C until analysis. Two replicates of 500 mL water each are filtered through the same kind of pre-rinsed Whatman GF/F filters for Chlorophyll-a analysis. This filtration process has to be performed in the dark and on a clean surface in an acid-free environment. Chl-a filters are subsequently frozen until analysis.

Zooplankton samples are preserved with 95% Ethanol to a final concentration of 80% and stored in a cool place in 250mL of solution. Samples of captured zooplankton were analyzed using an Olympus SZX10 stereo dissection microscope. We in inverted each sample in order to homogenize and then used a Hensen Stempel pittetter to measure 10mL into a gridded plastic dissection tray for analysis. To calculate average individual size we measured the length of the carapace, or the chitinous body structure, of the first 50 adult zooplankton of every species. To determined zooplankton species richness and abundance at each pond we counted and identified all zooplankton within the first 50mL of every sample. Zooplankton were identified to the species level for all large bodied cladocerans, as previous literature has identified specific species response in certain cladoceran species and to the family level for all other organisms, copepods, ostracods, rotifers, mites, and other insects using taxonomic keys (Ryther et al. 1980, Pace et al. 1981, Dodson 1989, Havel et at. 2004, Haney et al. 2013). Phytoplankton samples are preserved in Lugol's solution (1% final concentration).

Phytoplankton identification (primarily to genus) and cell counts were carried out using a FlowCAM, an imaging based particle analysis system, which represents a combination of an automated microscope for detailed morphological analysis (size,

shape, etc.) of algal cells with the ability to additionally add in fluorescence values to further discriminate cell types similar to a flow cytometer. After a 24 h settling procedure, followed by water aspiration to concentrate cells, three replicates of each 5 mL were run through the FlowCAM.

**Results:**

Out of the 18 lakes we sampled, Mud Lake had the greatest amount of species richness. In the three zooplankton samples we collected throughout the summer we identified the presence of 5 different genera, *Daphnia pulicaria, Diaphanosoma brachyurum, Scapholebris mucronata, Calinoida* spp*., Cyclopodia* spp*.,* and *Ostracods.* Mud lake had fairly large zooplankton, the average individual was 0.8837± 0.056 mm in length. Zooplankton community abundance increased from May to July, from 47.74 individual plankton per liter to 75.02 individual plankton per liter, with an average of 56.93 ± 9.04 individual plankton per liter, which was the highest level of abundance for all 18 sites. Phytoplankton genera richness ranged from 21 to 25 with average genera richness of 23± 1.16. Phytoplankton biovolume ranged from 927.15$\mu m^3$ to 5145.73$\mu m^3$ with and average biovolume of 2419.08$\mu m^3$ ± 1365.35$\mu m^3$. Diatom biovolume in the lake ranged from 1.60$\mu m^3$ to 39.43$\mu m^3$ with an average biolvolume of 15.21$\mu m^3$± 12.14 $\mu m^3$.

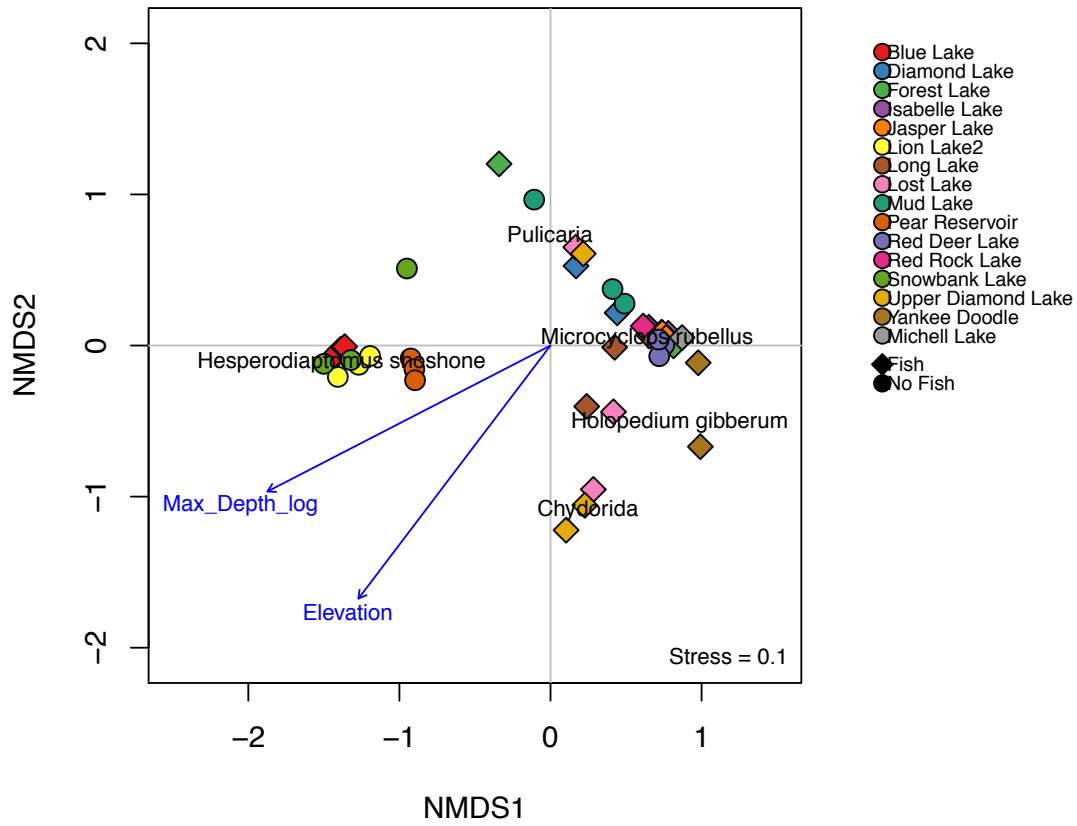


**Figure 1.** This figure depicts the distribution of zooplankton species across the 15 comparative lakes distributed within 50 km North and South of Green Lakes Valley. This figure was created by Dr. Eric Sokol,postdoctoral scholar at the Institute of Artic and Alpine research .

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