Biographical Statement

The summer after my freshman year at Brown University I worked in the campus greenhouse. I learned the exotic forms leaves take on pitcher plants as well as the shared characteristics that allow us to describe, recognize, and name plants. These features are like a language communicated by leaves that grow in a basal form just above the soil or singularly at random along the stem. I continued to work in the greenhouse the rest of my time in college and took classes not only in plant biology but also in geology. Geology provided a deeper context, linking plant systematics into Earth history: landscapes are made up of plants, which, on long-time scales, reflect climatic conditions.

After college I worked at the Joint Oceanographic Institutions, which is a non-profit organization that manages the Integrated Ocean Drilling Program. Editing documents and putting together educational outreach material, I was awed by how powerful ocean sediment cores are as archives of global environmental changes. Changes in the Earth-Sun relationship match changes from glacial to interglacial conditions in Earth history. Changes in Earth's climate and atmosphere have driven evolution of exotic species, like enormous insects, as well as evolution of more efficient photosynthetic pathways.

As powerful as ocean sediment cores are for reconstructing dramatic global changes, such changes can be abstract when one is concerned with drought in the Great Plains or forest dynamics in the Colorado mountains. Coming of age when human driven climate change was entering the public consciousness, I was concerned about the future of biodiversity, limited resources, and the quality of life in a warming world. Through science, I focus my fear for the future into a desire to understand the mechanisms that drove past climate changes and their subsequent effects on ecosystems and water resources. When I left the Joint Oceanographic Institutions I went to Ghana as a sediment scientist to help core Lake Bosumptwi. Ghana is currently suffering from a drought thought to be driven by weakening of the summer monsoons. The effect of this drought was palpable in the poverty and landscape in the villages around Lake Bosumptwi. Past monsoon dynamics are currently being reconstructed from these cores, and this work aims to help anticipate the best road forward for Ghanaian agriculture and water management. My experience in Ghana informed my current pursuits at the University of Minnesota on how past climate changes have affected the western United States landscapes where water is a diminishing and vital resource.

I am compelled by the creativity and curiosity that arise in the tension between learning and actively asking questions. My long-term career goal is to study the effects of climate change on landscapes and water resources and to communicate the results to the public through teaching and writing. I foresee myself deriving satisfaction in this path from the challenges, the perpetual questions, and the coupling of independent thought with teamwork in the field and in the lab.

Climate change, water supplies, and forest cover near the headwaters of the Colorado River over the past 11,000 years

Background: Increases in greenhouse gases are changing Earth's climate in ways that may strongly affect natural resources, including forests and water [1]. The western United States is one place of particular concern because water currently is a limited and diminishing resource in the region and forests play an important role in the natural-resources base of the economy. As temperatures in the region have climbed by as much as 2.5°C over the past few decades maximum annual river flows on critical rivers, like the Colorado, have dropped by 50% [2], reservoirs have been persistently low, forests are expanding, and forest fires have increased. The potential for long-term changes needs to be grounded by studies that demonstrate the sensitivity of these ecological and hydrological systems to climate.

Changes in climate affect landscapes as climate conditions pass the threshold beyond which species are able to survive [3]. Changes in vegetation are particularly important because plants are the primary producers in food webs, and because vegetation plays a critical role in human land-use from forestry to tourism. Changes in water resources also impact landscapes by lowering the water-level of lakes and rivers. Such impacts on vegetation and water supplies leave behind evidence, such as sandy lake shoreline sediments or plant pollen. New technology allows us to reconstruct temperatures with lake-water hydrogen isotopic values (isotopes are atoms of the same element that have different numbers of neutrons and thus different physical properties), which are preserved in sediment organic material [9]. My work focuses on understanding the impacts of past climate changes on ancient landscapes from evidence preserved in lake sediment archives.

To anticipate how future climate changes may impact critical water resources and ecosystems I am investigating the region around the headwaters of the Colorado River. A warm period from 8,000 to 3,000 years ago, caused by variations in the Earth-Sun relationship, may provide an analogy for the potentially complex impacts of projected future warming in the western U.S.A. For example, fossil plant materials, such as pollen, preserved in lake sediment archives contain evidence of forest expansion both up mountain slopes into modern tundra areas and down slope into modern sagebrush prairie areas during the "warm period" (Fig. 1) [4, 5]. Increased temperatures may have caused upslope forest expansion [6], and increased minimum temperatures of cold air that drains into valleys may have caused down slope forest expansion [7]. Additionally, evidence shows that lake-water levels, which are indicative of the water-table level, were low during the warm period [11]. Climate model simulations of the warm period show increased temperatures [8]. However, only qualitative temperature records, inferred from ecological conditions, exist. To understand this past warm period quantitative temperature records are needed. The existing ecological and hydrological data are spatially heterogeneous, and there are no records that integrate evidence of drought and forest expansion within a single region to determine whether increases in forest extent and drought were coupled. In my dissertation, I reconstruct a quantitative temperature record with cutting edge approaches for the last 11,000 years as well as the ecological and hydrological responses to these temperature trends. This allows me to test the hypotheses that temperatures did indeed increase during the period from 8,000 to 3,000 years ago and that this increase affected vegetation patterns and water supplies. This work will provide novel perspective on the impacts of climate change, including climate changes that may be analogous to future climate warming.

Goals and Objectives: I am focusing on the past 11,000 years around the headwaters of the Colorado River (Fig. 1) to accomplish the following goals:

1. I will investigate the relationship between the hydrogen isotopic composition of lake water and temperature, and apply this relationship to generate a quantitative temperature record.
2. I will reconstruct past water supplies and forest extent within a watershed.

Design and Methodology: I collected sediment cores from four lakes (Fig. 1) around the headwaters of the Colorado River, and I am using multiple lines of independent ecological, geochemical, and sedimentary evidence in the sediments to investigate the effects of increased temperature on forest extent and moisture availability over the last 11,000 years. The first research goal will be accomplished by measuring sediment hydrogen isotopic values, which record past temperatures of lake water [9]. To establish the exact connection between temperature and lake-water isotopes in the western U.S.A., I sampled water from lakes across the western U.S.A. and compared water isotopic values to measured climate variables [10]. I am now reconstructing temperature trends from American Lake (Fig. 1) by measuring the hydrogen isotopic value of individual compounds within the organic fraction of lake sediments on an isotope-ratio mass spectrometer.

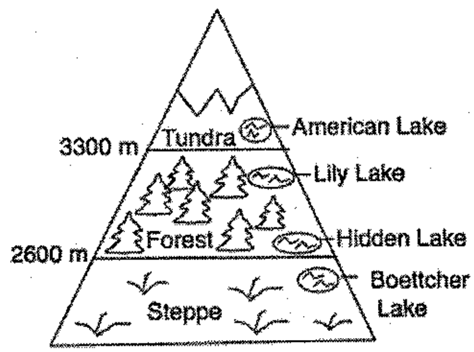

Figure 1. Mountain vegetation zones and study sites where lake sediment cores were collected.

To accomplish the second goal of reconstructing past water supplies in terms of lake-water levels, I conducted geophysical surveys of Lily and Hidden Lakes [11] (Fig. 1). Geophysical surveys are used to help determine past shoreline positions and sediment geometries. Sediment cores were collected along the survey profiles for sediment analysis and dating. Past shorelines are dated with accelerated mass spectrometer dating of organic plant fossil material.

To reconstruct forest extent in terms of the upper and lower limits of forest cover, I am analyzing fossil pollen isolated from sediments in the laboratory and then identified under a microscope based on morphological characteristics. I am investigating changes in the upper extent of forest at American Lake, which is in the tundra vegetation zone today, but within range of where forests may have grown in the past (Fig. 1). I am investigating changes in the lower extent of forest at Boettcher Lake, which is in the steppe, just below the modern elevation limit of forests (Fig. 1). I am also investigating the steppe/forest boundary at Hidden Lake, which is in the low elevation forest, just above the modern elevation limit of steppe (Fig. 1). Comparison between these two records will allow me to constrain any upward or downward movement in the forest/steppe boundary.

My research in Colorado will provide a quantitative temperature history from the isotope data, water availability from lake-level data, and past upper and lower limits of forest extent from pollen data. Thus, I can document the influence of temperature on water supplies, the influence of temperature on forest, and the relationship between forest extent and water supplies.

Potential Significance: Future climate warming is predicted to cause climate and landscape change beyond the realm of observed variability (2). Current warming has already reduced flow on the Colorado River and impacted the surrounding landscape. Water supplies in the western U.S.A. are currently stretched, and future declines could have important consequences for both human populations and natural ecosystems. If rising temperatures lead to an increase in the extent of forest this may exacerbate water resource limitations via the enhanced demands of increased tree cover. Forest expansion could also impact the occurrence and range of forest fires; carbon and nutrient cycling in ecosystems; and important landscape-climate feedbacks (e.g., tundra and steppe reflect more light from the sun than a forest). The warm period from 8,000 to 3,000 years ago may be an analogue for future warming that can help us to anticipate potential impacts of climate change. Studying landscape and climate changes around the headwaters of the Colorado River is a case study that is relevant for understanding the effects of future warming on many mid-latitude regions where increased temperatures may affect critical water and ecosystem resources (2).

Progress to date: I collected all water samples, lake sediment cores, and geophysical profiles of lakes in the summers of 2006 and 2007. I have completed work for the first project goal. My comparison of modern lake-water isotopic values and climatic data was done by collecting lake water samples from 100 lakes across the western U.S.A. I analyzed and published the results of this work in the Geologic Society of America Bulletin [10]. I used these results to interpret the hydrogen isotopic values of compounds from the American Lake sediment core and generated a quantitative temperature record. Preliminary analyses of the findings were presented at American Geophysical Union Conference in December 2008 and I plan to submit a paper on the results to the Geophysical Research Letters in the summer of 2009.

Work to accomplish the second goal is underway. I have completed sediment analysis and lake-level reconstruction of Hidden Lake [11] and I am currently completing my sediment analysis for lake level reconstructions of Lily Lake. I am also working on my fossil pollen analyses for forest cover reconstruction. I plan to finish the pollen analyses by summer of 2009, and the Lily Lake sediment analyses by the fall of 2009. I plan to submit the results as separate papers to Quaternary Science Reviews and Ecology in early 2010.

Key References

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