Project Completion Report
Rocky Mountains Cooperative Ecosystem Studies Unit (RM-CESU)

Project Title: Atmospheric deposition of inorganic nitrogen in Grand Teton NP: determining biological effects on algal communities in alpine lakes

Project Code (such as UMT-72 and/or the "J" or "P" number):
J1465100108/UCOB-70

Type of Project (Research, Technical Assistance or Education): Research

Funding Agency: National Park Service

Partner University: University of Colorado

NPS Agreement Technical Representative (with complete contact information):

Principal Investigators (with complete contact information):
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Start Date of Project: May 1, 2010

End Date of Project: December 30, 2012

Funding Amount: $80,234 plus modification of $3,600

<u>Project Summary</u>, including descriptions of products, work accomplished and/or major results. If the information is restricted (e.g. location of endangered species or cultural resources), indicate the title and location of the final report. Also add web sites where project-related information may be found.

Key Findings:

* All sediments from the GRTE lakes exhibit a pattern of declining $\delta_{15}N$ and C:N ratio that suggest a regional change in anthropogenic nitrogen inputs during recent decades.

* The impact of the regional Nr deposition does not appear to affect each lake similarly. Instead, diatoms in the sediments have a range of intensity of ecological impacts along a continuum of nutrient concentration.

* The diatoms of Holly Lake show a response that is similar to lakes across the western United States. That is, there is an increase in *Asterionella formosa* that appears with declining $\delta_{15}N$. The other lakes, however, show a more subtle response to declining $\delta_{15}N$. We interpret these results to mean that GRTE lakes are in the early stages of biotic response to deposition of anthropogenic nitrogen.

Summary:

All sediments from the GRTE lakes exhibit a pattern of declining $\delta_{15}N$ and C:N ratio that suggest a regional change in anthropogenic nitrogen inputs during recent decades. The increase in nitrogen relative to carbon deposition concurrent with an average isotopic shift of 2.2 ‰ suggests both an increase in N supply relative to C fixation rates and a shifting source of N. The $\delta_{15}N$ and C:N trends were nearly static before 1880, as the atmospheric deposition of DIN was limited to the pre-industrial N cycle and CO_2 concentrations were relatively unimpacted by human disturbances. As settlement in the United States increased along with industry and agriculture after 1880, an additional supply of DIN with a depleted $\delta_{15}N$ signature was supplied. However, the increased availability of N (of the same or lighter isotopic signature) would also favour greater kinetic isotopic fractionation, as autochthonous primary producers will preferentially uptake the lighter $\delta_{14}N$ isotope when N limitation is diminished. An increased N_2 fixation that could be contributing to the $\delta_{15}N$ decline, however the values would approach 0 ‰ air, and not fall below 0 ‰, as in these GRTE sedimentary records. Phytoplankton tows from each GRTE sampling sites had an absence of heterocystous, N_2 fixing algal taxa that could be contributing substantially to the N budget and $\delta_{15}N$ signature. Thus, sedimentary trends in declining $\delta_{15}N$ and C:N are likely reflective of changing Nr deposition trends, irrespective of diagenesis or N_2 fixation.

The impact of this regional Nr deposition does not appear to affect each lake similarly, but sediment records follow a series of ecological impacts along a continuum of nutrient enrichment. This response continuum starts from a shift in

the relative availability of growth limiting nutrients (N and P) to greater primary production, accelerated rates of primary production and increased sedimentation rates. In many other alpine lakes, benthic communities were replaced by planktonic mesotrophic taxa, such as *Asterionella formosa*, as nutrient enrichment can result in benthic habitat loss due to reduced light penetration and self-shading that shift the ecological functioning in these lakes.

Annual Reports:

Spaulding, S.A., Otu, M., Wolfe, A. and Baron, J. 2011. Atmospheric deposition of inorganic nitrogen in Grand Teton NP*:* determining biological effects on algal communities in alpine lakes. National Park Service Annual Report.

Spaulding, S.A., Otu, M., Wolfe, A. and Baron, J. 2010. Atmospheric deposition of inorganic nitrogen in Grand Teton NP*:* determining biological effects on algal communities in alpine lakes. National Park Service Annual Report.

Publications:

Brahney, J., Ballantyne, A.P., Kociolek, P., Spaulding, S., Otu, M., Porwall, T., Neff, J.C. Dust mediated transfer of phosphorus to alpine lake ecosystems. (submitted to Ecosystems).

Brahney, J., Spaulding, S.A., Ballantyne, A.P., Otu, M. and Neff, J.C. Anthropogenic nitrogen deposition in Wyoming mountain ranges: separating diagenetic, productivity, and anthropogenic source effects on sedimentary $d^{15}N$ variations (in prep.)

Osborne, B.B. 2012. The effects of temperature and moisture on alpine microbial processes across a gradient of soil development. M.Sc. Thesis, Graduate Degree Program in Ecology, Colorado State University.

Otu, M., Spaulding, S.A., Wolfe, A.P. and Baron, J. Deposition of atmospheric reactive nitrogen on high elevation western lakes and the response of diatoms. (in preparation for Ecological Applications).

Spaulding, S.A., Baron, J., Otu, M. and Wolfe, A.P. Critical loads of nitrogen in Grand Teton National Park (in prep.)

Presentations:

Spaulding, S.A. 2012. High elevation lakes in Grand Teton NP: sentinels of environmental change. University of Wyoming / National Park Service Field Station seminar series. Invited Presenter, Moose WY.

Spaulding, S.A., Otu, M., Baron, J. and Wolfe, A.P. 2011. Response of sensitive freshwater ecosystems to reactive nitrogen deposition in western North America. American Chemical Society, Invited Presenter, Denver CO.

Otu, M. 2011. Preliminary results on analysis of Teton lake sediments. Greater Yellowstone Area Critical Loads Workshop. Jackson WY

Otu, M. 2011. Preliminary results on analysis of Teton lake sediments. Society of Canadian Limnologists. Toronto Canada

Online Project Information:

Project Page – Atmospheric Deposition of Nitrogen and Diatoms (2011) http://westerndiatoms.colorado.edu/about/project/1501/atmospheric_deposition_of_nitrogen_and_its_effects_on_diatoms

Otu, M., and Spaulding, S. (2011). *Cavinula cocconeiformis*. In Diatoms of the United States. Retrieved October 16, 2012, from http://westerndiatoms.colorado.edu/taxa/species/cavinula_cocconeiformis

Otu, M., and Spaulding, S. (2011). *Cavinula pseudoscutiformis*. In Diatoms of the United States. Retrieved October 16, 2012, from http://westerndiatoms.colorado.edu/taxa/species/cavinula_pseudoscutiformis

Otu, M., and Spaulding, S. (2011). *Chamaepinnularia mediocris*. In Diatoms of the United States. Retrieved October 16, 2012, from http://westerndiatoms.colorado.edu/taxa/species/chamaepinnularia_mediocris

Otu, M., and Spaulding, S. (2011). *Chamaepinnularia soehrensis*. In Diatoms of the United States. Retrieved October 16, 2012, from http://westerndiatoms.colorado.edu/taxa/species/chamaepinnularia_soehrensis

Otu, M., and Spaulding, S. (2011). *Karayevia nitidiformis*. In Diatoms of the United States. Retrieved October 16, 2012, from http://westerndiatoms.colorado.edu/taxa/species/karayevia_nitidiformis

Otu, M., and Spaulding, S. (2011). *Navicula schmassmannii*. In Diatoms of the United States. Retrieved October 16, 2012, from http://westerndiatoms.colorado.edu/taxa/species/Navicula_schmassmannii

Otu, M., and Spaulding, S. (2011). *Planothidium holstii*. In Diatoms of the United States. Retrieved October 16, 2012, from http://westerndiatoms.colorado.edu/taxa/species/planothidium_holstii

Number of students participating in this project: undergraduates, graduate students, degrees conferred. A number of students participated in this project and are

using samples or results from this research in their education programs.

Dr. Megan Otu, Postdoctoral Fellow, University of Colorado (2010-2011)
Atmospheric deposition of inorganic nitrogen in Grand Teton NP: determining biological effects on algal communities in alpine lakes

Dr. Janice Brahney, PhD conferred 2012, University of Colorado
Anthropogenic nitrogen deposition in Wyoming mountain ranges: separating diagenetic, productivity, and anthropogenic source effects on sedimentary $d^{15}N$ variations

Emma Jones, MS in progress, University of Alberta
Spectral signature of charcoal for interpreting fire history in Teton sediments

Heather Mosher, MS in progress, University of Alberta
Dendrochemical records of atmospheric pollution and recent climate change in western North America

Brooke Osbourne, MS conferred 2012, Colorado State University
Effects of summer warming and glacier melt on alpine nitrifier abundance and activity

Mabruka Hadya Abubaira, some work towards PhD, Colorado State University
Paleo-history of high elevation lakes in Grand Teton National Park derived from chironomid head capsules in lake sediment cores

Lauren Terry, undergraduate student, Geology Department, University of Colorado
Processing of sediment cores

Danielle Pite, undergraduate degree conferred 2012, Smith College
Worked under a Praxis Fellowship on Teton sediment cores

Lessons Learned from this project: Postdoctoral fellows, at least Megan Otu, are a very productive and cost-effective approach to addressing a research problem and obtaining results. This project was ambitious from the outset and Megan was able to accomplish a great deal of work in the one-year time span of her fellowship. We did not include funding for her to complete submission of publications, so the project has proceeded at a slower rate since completion of her fellowship in June 2011.

Other RM-CESU agencies or research partners who participated in this project:

US Geological Survey, NAWQA program
Support of Spaulding salary for the incorporation of Teton diatom species into the *Diatoms of the United States* online flora (2011-2012)

University of Wyoming/National Park Service Field Station - Spaulding, S.A. and Larson, D. Climate Change in the Alpine Zone: A continuous, multi-proxy record of Holocene glacier activity and environmental change at Grand Teton National Park. Award of $5,000 (2012).

University of Wyoming/National Park Service Field Station - Spaulding, S.A., Baron, J. and Wolfe, A. Field Support: effects of atmospheric deposition of inorganic nitrogen on high elevation lakes. Award of $5,000 (2011).

Dr. Marina Potapova, Academy of Natural Sciences of Drexel University. Curation of permanent archives and collaboration on monoraphid diatom species of GRTE lakes.

Ongoing collaboration with partners on the long-term (7,000 year) climate record from Whitebark Moraine Pond:

Darren Larsen, PhD in progress, University of Colorado
Climate Change in the Alpine Zone: A continuous, multi-proxy record of Holocene glacier activity and environmental change at Grand Teton National Park. Supported by **Boyd Evison Graduate Research Fellowship Award** 2012

Dr. Kendra McLauchlan
Department of Geography, Kansas State University
Fire and vegetation history of the Greater Yellowstone region