

Project Completion Report

Rocky Mountains Cooperative Ecosystem Studies Unit (RM-CESU)

Project Title: Investigation of Nitrogen Deposition into Loch Vale, Rocky Mountain National Park , phase 2, Jan 2011- Jan 2012

Project Code: CSURM-193, P10AC00217

Type of Project: Research

Funding Agency: National Park Service

Partner University: Colorado State University

NPS Agreement Technical Representative: Mary Kay Watry and Jim Cheatham, Rocky Mountain National Park, 1000 Highway 36, Estes Park, Colorado 80517, (970) 586-1301; Mary_kay_watry@nps.gov; jim_cheatham@nps.gov

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Start Date of Project: September 15, 2009

End Date of Project: January 31, 2013

Funding Amount: \$10,000

Project Summary, including descriptions of products, work accomplished and/or major results.

Wet inorganic nitrogen deposition to Loch Vale (NADP site CO98) is estimated to be between 3.0 and 4.25 kg N/ha/yr. A concerted effort has been made as part of this project to upgrade the NADP wet deposition collection capability. In 2009 a replicate set of NADP equipment (NADP site CO89) was installed, the CO98 Belfort rain gage was replaced with a NOAA IV gage, and trees were trimmed near all collectors so that both CO98 and CO89 now meet NADP siting criteria. Data from both sites are now telemetered, and new no-glare solar panels were installed on new scaffolding in 2010. Loch Vale now also maintains a passive ammonia monitor, installed in 2010. Loch Vale data contributed to a NPS Natural Resource Condition Assessment for Rocky Mountain National Park and the 2008, 2009, 2010, and 2011 (draft) NPS Natural Resource Reports: Monitoring and Tracking Wet Nitrogen Deposition in Rocky Mountain National Park.

Loch Vale stream discharge, weather, and water quality data are available both in text file and real time from NWIS, the USGS National Water Information Source. A quality assurance report for all Loch Vale water quality data was published as a USGS Open-File report in 2011 and is available on the web page (as are all previous QA reports). The Loch Vale website and

methods manual were updated in 2011: <http://www.nrel.colostate.edu/projects/lvws>. Active research currently includes microbial and biogeochemical studies of glaciers, waters, and soils, studies of algal responses to temperature and nutrients in laboratory and field, and studies of microbial responses to soil organic matter composition in forest plots that have been fertilized since 1996. LiDAR data obtained in 2010 have been used to support three M.Sc. theses related to topographic flowpaths.

Field trips are routinely provided for summer students from high schools and universities, and for state and federal air quality officials.

The following activities were conducted as part of this agreement in 2012:

1. New windshield installed on CO89 (the old one blew off during ferocious windstorm)
2. 2011 data uploaded to NWIS
3. Members of the RMNP Agricultural Subcommittee visited LVWS
4. Members of the Western Mountain Initiative visited LVWS. Forest ecologists Adrian Das, Phil van Mantgem, Craig Allen, and Don McKenzie convinced us to follow up on extensive forest mortality with resampling of long-term plots in 2013 and establishment of a more regular forest health monitoring program.
5. NADP performed a site visit on September 27, 2011 to conduct a systems and performance survey. Technicians from Environmental, Engineering & Measurement Services, Inc found both CO98 and CO89 were operating properly with no safety concerns.
6. Research began on benthic algal blooms in The Loch, with weekly samples and continuous temperature measurements from June through September.
7. Andrew's and Taylor Glaciers and downstream waters were surveyed (along with unglaciated Loomis Lake, and two other sets of glaciated, rock glacier, and unglaciated sites in Colorado) for microbial activity, N isotopes, nutrients, and weathering products.
8. Soils and lake water were collected and extracted for a study of lability and microbial uptake capacity of dissolved organic matter from fertilized and control forest soils.
9. Dr. Ellen Wohl visited LVWS to document forest blow down event
10. We took several high school and college students up with us to perform field work and gain experience
11. We hosted six undergraduate interns - Austin Sebeck (winter intern), Megan Carroll (winter intern), Lisa Windom, Tim Fegel, Gillian Gunderson, Nicole Tilley
13. Three students completed their graduate studies (listed below).

Publications:

Hartman, M.D., J.S. Baron, H.E. Ewing and K.T Weathers. Combined effects of warming and atmospheric nitrogen deposition on net ecosystem production, greenhouse gas flux and water quality in nine United States mountain ecosystems. *Biogeochemistry*, in review.

Heath, T.J., and J.S. Baron. Direct and indirect effects of climatic drivers on the mass balance of a mountain watershed. *Aquatic Geochemistry*, in review.

Greaver TL, Sullivan T, Herrick JD, Barber M, Baron J, Cosby B, Deerhake M; Dennis R, Dubois JJD, Goodale C, Herlihy A, Lawrence G, Liu L, Lynch J, Novak K. 2012. Ecological effects from nitrogen and sulfur air pollution in the United States: what do we know? *Frontiers in Ecology and Environment* 7:365-372.

Moore, C. 2012. A climatological study of snow-covered areas in the western United States. Department of Ecosystem Science and Sustainability M.Sci. thesis, Colorado State University. 114 pp.

Hastings, B., 2012. Influence of digital model resolution on terrain-based hydrologic parameters for a subalpine catchment, Front Range, CO. Department of Ecosystem Science and Sustainability M.Sc. thesis, Colorado State University 98 pp.

Osborne, B.B. 2012. The effects of temperature and moisture on alpine microbial process across a gradient of soil development. Graduate Degree Program in Ecology M.Sci. thesis, Colorado State University. 79 pp.

Baron, J.S., M. Barber, A. Feest, F. Gilliam, X. Lu, C.J. Stevens, S. Woodin, R. Bobbink, M. Adams, J. Agboola, E. Allen, B. Bealy, M. Bobrovsky, W.D. Bowman, C. Branquinho, M. Bustamente, C.M. Clark, E. Cocking, C. Cruz, E. Davidson, T. Denmead, T. Dias, N. Dise, I. Harrison, J.N. Galloway, L. Geiser, L. Khanina, E. Manrique, R. Ochoa-Hueso, J.P. Ometto, R. Payne, T. Scheuschner, L.J. Sheppard, G. Simpson, Y.V. Singh, I. Strachan, H. Sverdrup, N. Tokuchi, H. van Dobben. 2013. The effects of atmospheric N deposition on terrestrial and freshwater biodiversity. Ch. X in K. Hicks and R. Haeuber, eds. Nitrogen Deposition, Critical Loads, and Biodiversity. Springer, New York, in press.

Burns, D.A., M.E. Fenn, J.S. Baron. 2012. Effects of Acid Deposition on Ecosystems: Advances in the State-of-the-Science. Chapter 3, pp. 45-70 in D.A. Burns, Lead Author, National Acid Precipitation Assessment Program Report to Congress 2011: an integrated assessment. Report to Congress, US Office of Science and Technology Policy. 132 pp.

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Baron, J.S., C.T. Driscoll, J.L. Stoddard, and E.E. Richer. 2011. Critical loads of atmospheric nitrogen deposition for nutrient enrichment and acidification of U.S. freshwaters. BioScience 61:602-613.

Morris, K., A. Mast, G. Wetherbee, J. Baron, C. Taipale, T. Blett, D. Gay, E. Richer. 2011. 2009 Monitoring and Tracking Wet Nitrogen Deposition at Rocky Mountain National Park. NPS Natural Resource Report NPS/NRSS/ARD/NRR-2011-442. 36 pp,

Pardo, L.H., Robin-Abbott, M.J., Driscoll, C.T, Eds., Assessment of N deposition effects and empirical critical loads of N for ecoregions of the United States. General Technical Report NRS-80. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station, 291 p

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Hartman, M.D., J.S. Baron, D.W. Clow, I.S. Creed, C.T. Driscoll, H. Ewing, B.D. Haines, K. Lajtha, J. Knoepp, H. van Migroet, D.S. Ojima, W.J. Parton, J. Renfro, B. Robinson, K. Weathers, M.W. Williams. 2009. DayCent-Chem Simulations of Ecological and Biogeochemical Processes of Eight Mountain Ecosystems in the United States. USGS Scientific Investigations Report SIR 2009-5150; <http://pubs.usgs.gov/sir/2009/5150/>

Elser, J.J., T. Anderson, J.S. Baron, A-K Bergström, M. Kyle, K.R. Nydick, L. Steger, D.O. Hessen. 2009. Shifts in lake N:P stoichiometry and nutrient limitation driven by atmospheric nitrogen deposition. *Science* 326:835-837.

Elser, J.J., M. Kyle, L. Steger, K.R. Nydick, and J.S. Baron. 2009. Nutrient availability and phytoplankton nutrient limitation across a gradient of atmospheric nitrogen deposition. *Ecology* 90:3062-3073.

U.S. EPA. Integrated Science Assessment (ISA) for Oxides of Nitrogen and Sulfur – Ecological Criteria (Final Report). EPA/600/R-08/082F, 2008 (Baron was contributing author)

Baron, J.S., T.W. Schmidt, M.D. Hartman. 2009. Climate-Induced Changes in High Elevation Stream Nitrate Dynamics. *Global Change Biology* 15:1777-1789.

Number of students participating in this project: 11 undergraduates, 4 graduate students, degrees conferred. Graduate students Cara Moore (M.Sc. defended Feb 27, 2012), Katie Williams (M.Sc. defended in 2010), Blaine Hastings (M.Sc. defended in 2012) and Brooke Osborne (M.Sc. defense April 2, 2012) benefited from this project. Undergraduates Shenavia Balcom, Matt Schoonmeester, William Magee, Michelle Bahnick, Julie Spencer, Austin Sebeck, Megan Carroll, Lisa Windom, Tim Fegel, Gillian Gunderson, Nicole Tilley either did summer internships or worked in the laboratory.

Lessons Learned from this project. Longer is better! 2013 is Loch Vale's 30th year of continuous measurements, and the results of the monitoring reveal unexpected climate changes with unexpected ecological responses that we are now trying to understand. A celebratory field trip and symposium is planned for October 2013.

Other Agency involvement: The USGS FORT is a partner in these long term studies at Loch Vale, ROMO. The Interagency National Atmospheric Deposition Program ensures the long term quality of the deposition data. Many of the associated watershed studies and monitoring are sponsored by the USGS-Colorado Water Center, through the Water, Energy and Biogeochemical Budgets program.