

Annual Report for Period: 12/1999 - 11/2000

Submitted on: 08/17/2000

Principal Investigator: Seastedt, Timothy R.

Award ID: 9810218

Organization: U of Colorado Boulder

LTERR: The Niwot Ridge LTER Research Program 1998-2004: Controls on the Structure, Function & Interactions of Alpine & Subalpine Ecosystems of the Colorado Front Range

Project Participants

Senior Personnel

Name: Seastedt, Timothy
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Townsend, Alan
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Wessman, Carol
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Williams, Mark
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Bowman, William
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Caine, Nel
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Diggle, Pamela
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Elias, Scott
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Monson, Russell
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Sanford, Robert
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Schmidt, Steven

Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Sievering, Herman
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Walker, Donald
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: McKnight, Diane
Worked for more than 160 Hours: Yes
Contribution to Project:

Post-doc

Graduate Student

Undergraduate Student

Organizational Partners

Other Collaborators or Contacts

Cross-site, Synthesis and LTER Network Activities

LTER-PI Mark Williams et al. have submitted a cross-site proposal to expand upon activities to quantify the relationships between organic N and organic carbon in soils and streams of diverse ecosystem types. This effort follows up on the creation of an organic N and organic C analytical facility at CU-INSTAAR. The combined laboratories of LTER PIs McKnight, Townsend, and Williams are developing a suite of analytical procedures to evaluate the fate of organic N and C generated in soils and transformed into a variety of recalcitrant organic fractions. This activity is particularly timely and appropriate at our site where enhanced N deposition and, potentially, enhanced precipitation are directly modifying N inputs and indirectly modifying transformations by affecting species composition of the site.

LTER-PI William Bowman participated in three European activities this year. These included:

1) Bowman William D. and Katherine Nash Suding. Biotic Influences on the Response of the Rocky Mountain Alpine to Environmental Change. Third Annual ILTER workshop, Central and Eastern Europe, Nitra, Slovak Republic. 2) Bowman, William D. On the role of biotic interactions in structuring alpine plant communities- keynote address in Community Ecology, Third Annual Conference on the Physiology, Ecology and Evolution of Alpine Plants, Lautaret Alpine Field Station, France, and 3) Bowman, William D. and Mary Damm. Causes and consequences of vascular plant diversity in the Rocky Mountain alpine. workshop on Global Mountain Biodiversity Assessment, Rigi, Switzerland.

LTER-PI Mark Williams spent part of the year in the South American Alpine as part of a sabbatical activity. During that time, he acted as LTER representative (along with Bob Waide) at the Patagonia Ice Fields Scientific Task Force, Valdivia, Chile, March 2000. He was a Participant, IGBP Mountain Initiative Workshop for Latin America, March 8-10, 2000, Papallacta, Ecuador. He also received a Fulbright Commission, Research Fellowship, to study GLACIAL HYDROLOGY, MASS BALANCE, AND RESPONSE TO CLIMATE CHANGE, COTOPAXI AND CARIHUAYRAZO VOLCANOES, ECUADOR, 9/99-12/99. He participated in a NATO Scientific Exchange, Kazakhstan, Kyrgyzia, and Uzbekistan, 7/99-8/99 and 5/00-7/00. He also sponsored ILTER PI Wenbo Jiang from the Chinese Ecological Research Network as a visiting scholar.

LTER-PI Patrick Bourgeron was host for a group of potential ILTER scientists from France. He reciprocated by visiting France this summer, and is now organizing an ILTER workshop activity in France for this coming January.

Activities and Findings

Project Activities and Findings: (See PDF version submitted by PI at the end of the report)

Our LTER program is now 20 years old. Our major science and research objectives have evolved during the interval. As a site where substantial long-term research has been conducted, we now feel like our paradigm for understanding the structure and functioning of the alpine system has been substantially altered from the model used in earlier proposals. While our official title for the 1998-2004 funding interval remains unchanged, we see an emerging theme that might best be referred to as 'Biogeochemical Linkages Among High Elevation Systems and the Regional Environment'

The River Continuum Concept (Vannote et al. 1980) has proven to be a robust and powerful descriptor of both ecosystem processes and structural components of stream systems. The continuum concept has also been used to show linkages between wetland ecosystems and their dominant sources, upland terrestrial ecosystems, and their sinks, the aquatic ecosystems (Mitsch and Gosselink 1986). Here, we apply similar concepts to view the ecological processes and structural patterns observed in high elevation ecosystems. The resulting model indicates that ecological processes such as biogeochemical cycles and structural patterns such as life form and species diversity properties cannot be fully appreciated or understood without explicit recognition of 1) the subsidies of materials from sources external to the ecosystem 2) the composition of the biota receiving these inputs, and 3) the consequences of exports or sinks of materials to the 'downstream' and aquatic portions of our system.

High elevation ecosystems represent a terrestrial continuum of heterotrophic and/or autotrophic dominated biotic communities. Heterotrophy is proposed to dominate at highest elevations. The majority of energy in these systems is provided as organic materials produced at lower elevation sites. Ammonium in rainfall also provides an energy and nutrient source that is largely of biotic (possibly anthropogenic) origin. Thus, nival areas can be thought of as subsidized ecosystems. The consequences of this phenomenon are identical to those of high-elevation, low order streams. Decomposition and mineralization processes dominate, and this produces a pulse of plant-available nutrients to ecosystems beneath these zones. This material combines with redistributed precipitation inputs and contributes to enhanced NPP. These systems in turn provide organic matter subsidies to lower elevation systems. The magnitudes of these subsidies are largely unknown, but may greatly exceed atmospheric inputs at certain alpine-subalpine 'hotspots'.

Understanding of the biogeochemistry of high elevation ecosystems therefore requires an understanding and appreciation of the landscape continuum that is compressed into elevational gradients of only 1000-2000 meters. Due to extremes in elevational gradients and the propensity for materials to be redistributed within this gradient, the heterogeneity of the environment is greatly enhanced. While such heterogeneity can also be found in desert ecosystems, generated only by a water availability gradient, the high elevational continuum is generated by both water and energy gradients, producing patterns unlike any other ecosystem. The variable ages of soils of glaciated and unglaciated surfaces affect weathering rates and nutrient availability, and these differences are not linearly related to the elevational gradient. Further, the diversity of plant lifeforms (forest, krummholz, tundra) exhibits maximum ability to amplify or attenuate energy and moisture gradients (Seastedt and Adams 1991). And, at a finer scale, individual plant species characteristics (Bowman and Steltzer 1998), and keystone species such as the gopher (Sherrod 1999) further contribute to this heterogeneity in biogeochemical processes. A spatially explicit hierarchy of biotic and abiotic interactions therefore generates the structure and function of the alpine. Understanding and prediction of these phenomena are possible, but the 'important variables' change as the object of the study or the spatial scale of the object of study change. While this general principle of hierarchy theory has been known for some time, its application to high elevation ecosystems has not been emphasized, nor has it been nested within the continuum concept.

Project Training and Development:

During 1999 and 2000, we published or have in press 41 papers in refereed journals and had 7 articles published as book chapters, exclusive of our own in press volume. This includes a few articles using NWT LTER data but written by non-NWT LTER investigators. We have about 20 manuscripts in review. A synthesis volume of LTER findings has been edited by the publisher and we expect galley proofs prior to the end of this year, with an early 2001 publication date. The NWT LTER made 25 presentations, exclusive of workshop participation activities, at the recent LTER/ESA meetings in Utah. During this period we had six graduate students complete theses and dissertations. Among our publications are several from undergraduates, including both REU and honors thesis efforts. In addition to ongoing LTER measurements and experiments, Scientists at our site have begun the new series of projects associated with an analysis of subalpine-alpine interactions. New collaborative projects and new outreach efforts have also been initiated this year. An online version of this report, as well as summaries of our 1999 and 2000 annual workshops are available at our website, http://culter.colorado.edu:1030/Niwot/Niwot_Ridge_LTER_reports.html.

The completion of the Niwot Synthesis Volume has been delayed somewhat due to a backlog at the publisher (Oxford University Press), but is

now anticipated to be available in early 2001. This effort has been ongoing since 1996, and represents a major accomplishment by the site PIs. To our knowledge, this is the first comprehensive summary of alpine ecology in North America. While the focus is on Niwot Ridge, most chapter authors attempted a strong comparative approach whenever possible, which allows us to make statements regarding the generality of findings. In addition to this effort, former NWT graduate student David Bryant has submitted a synthesis effort comparing arctic and alpine decomposition patterns using the LTER LIDET data set (Bryant et al. submitted).

I. Research highlights:

1. Nitrogen deposition and climate change. Efforts to understand sources and fates of nitrogen inputs have remained an active area of research (Baron and Caine 2000, Losleben et al. 2000). Continued monitoring of N inputs from NADP sources indicates an increase of about 0.05 g N . m⁻² . y⁻¹. Previous and ongoing studies have documented the effects of enhanced N deposition on vegetation (e.g., Bowman and Steltzer 1998; Seastedt and Vaccaro, in press).

2. Phosphorus - Nitrogen interactions. Concurrently with the N deposition work, preliminary sampling for plant-available phosphorus in alpine and subalpine soils suggests that the age of these soils influences the strength of P limitation (Townsend et al., unpublished results). We see this line of research as one that's critically important to predict species composition shifts associated with the reduction of N limitation in these ecosystems.

3. Ecosystem responses to climate and atmospheric changes. Ongoing studies of the snowpack manipulation site (snowfence) continue to define and expand upon earlier studies by Brooks et al. (1996, 1997). Work has further substantiated snowpack effects on decomposition and mineralization and decomposer organisms. These results support the contention that increased moisture can enhance the carbon flux from the soil, thus converting alpine regions into a carbon source under a wetting but otherwise unchanged climate. Ongoing vegetation studies will be continued to see if productivity changes in the plant community can compensate for enhanced decomposition losses.

4. Understanding of alpine-subalpine linkages. Studies initiated in summer of 1999 include a) variation in ecosystem sensitivity to N additions, b) analysis of factors controlling treeline, c) comparisons of soil carbon and N characteristics across an altitudinal gradient and among ecosystem types in snow. These studies were continued in 2000, with two Ph.D. students initiating work on consequences of treeline establishment in terms of both vegetation composition and ecosystem processes.

Research Training:

Our graduate and undergraduate contributions are documented above.

Outreach Activities:

1. Completion of Virtual Fieldtrip.

The Niwot Ridge virtual fieldtrip was put online in 1998 and has been updated with reports prepared by environmental journalists supported by our LTER-REU supplements. The present material located at http://culter.colorado.edu:1030/Field_trip/. Additional links to real-time weather on the tundra, a real-time, interactive camera (the Tundra-cam), and another virtual field trip to the site created by a former geography graduate student are included. The Tundra-cam is remarkably popular, with over 299,000 images viewed since its establishment in December, 1999. We continue to form partnerships with other outreach activities and web sites to expand access to this activity.

2. K-12 Outreach

Our outreach program is a continuation of the involvement of teachers from the Boulder/Denver area achieved through our LTER Schoolyard LTER program. This program has four aspects: 1) teaching in-service and pre-service teachers alpine ecology in a summer course at the Mountain Research Station (MRS) 2) bringing elementary and middle school students to the MRS for field trips in the summer 3) development of a schoolyard monitoring program for streams on the lowlands to follow the spring flush of colored organic material (DOC) from the alpine and sub-alpine and 3) development of instructional materials about the Colorado alpine to be used by educators that complement the summer field programs.

An LTER supplement obtained in 1999 purchased PC computers for teachers participating in this program. These computers have been used by the teachers in classroom activities, and a data analysis program has been made available for accessing LTER data.

In summer, 2000, the Schoolyard activity course was taught at the MRS for the 3rd consecutive summer, and elementary and middle school students participated from three programs (Science Discover, Wild Bear Science School, and Bixby School) totaling about 70 students. A field trip guide was prepared by this year's class.

A student from the 1998 MRS course became a 3rd grade teacher, and in 2000 conducted a class project on the Boulder Watershed. We are in the process of completing a children's book on the watershed using the material (artwork and text) created by the children and the former student, in coordination with the City of Boulder Water Department.

In late August, a video production company will be at our site filming for two programs on alpine tundra and subalpine forest. These will be used for their educational series on biomes of the world. The children participating in the filming are from two schools involved with the MRS schoolyard course.

A popular story, 'Twisted Trees' written by environmental journalist (and REU mentor) Tom Yulsman was published in Audubon Magazine in November 1999 based upon our research on tree islands.

Journal Publications

- Gross, K.L., M.R. Willig, L. Gough, R. Inouye, and S.B. Cox., "Patterns of species density and productivity at different spatial scales in herbaceous plant communities.", *Oikos*, p. 417, vol. 98, (2000).) Published
- Baron, J.S. and N. Caine., "Temporal coherence of two alpine lake basins of the Colorado Front Range, U.S.A.", *Freshwater Biology*, p. 463, vol. 43, (2000).) Published
- Conley, A.H., E.A. Holland, T.R. Seastedt and W.J. Parton, "Simulation of carbon and nitrogen cycling in an alpine tundra", *Arctic, Antarctic, and Alpine Research*, p. 147, vol. 32, (2000).) Published
- Lipson, D.A., S.K. Schmidt and R.K. Monson, "Carbon availability and temperature control the post-snowmelt decline in alpine soil microbial biomass", *Soil Biology and Biochemistry*, p. 441, vol. 32, (2000).) Published
- Losleben, M.V., N. Pepin, S. Pedrick, "Relationships of precipitation chemistry, atmospheric circulation, and elevation at two sites on the Colorado Front Range", *Atmospheric Environment*, p. 1723, vol. 34, (2000).) Published
- Addington, R.N. and T.R. Seastedt, "Activity of soil microarthropods beneath snowpack in alpine tundra and subalpine forest", *Pedobiologia*, p. 47, vol. 43, (1999).) Published
- Bowman, W.D., A. Keller, and M. Nelson, "Altitudinal variation in leaf gas exchange, nitrogen and phosphorus concentrations and leaf mass per area in populations of *Frasera speciosa*", *Arctic, Antarctic, and Alpine Research*, p. 191, vol. 31, (1999).) Published
- Brooks, P.D., M.W. Williams, "Snowpack controls on nitrogen cycling and export in seasonally snow-covered catchments", *Hydrologic Processes*, p. 2177, vol. 13, (1999).) Published
- Chase, T.N., R.A. Pielke, T.G.F. Kittel, J.S. Baron, and T.J. Stohlgren, "Potential impacts on Colorado Rocky Mountain weather and climate due to land use changes on the adjacent Great Plains", *Journal of Geophysical Research*, p. 16673, vol. 104, (1999).) Published
- Greenland, D., "ENSO-related phenomena at long-term ecological research sites", *Physical Geography*, p. 491, vol. 20, (1999).) Published
- Hood, E., M. W. Williams, and D. Cline, "Sublimation from a seasonal snowpack at a continental, mid-latitude alpine site.", *Hydrologic Processes*, p. 1781, vol. 13, (1999).) Published
- Lipson, D.A., T.K. Raab, S.K. Schmidt, and R.K. Monson, "Variation in competitive abilities of plants and microbes for specific amino acids", *Biology and Fertility of Soils*, p. 257, vol. 29, (1999).) Published
- Lipson, D.A., C.W. Schadt, S.K. Schmidt, and R.K. Monson, "Ectomycorrhizal transfer of amino acid-nitrogen to the alpine sedge *Kobresia myosuroides*", *New Phytologist*, p. 163, vol. 142, (1999).) Published
- Lipson, D.A., S.K. Schmidt, and R.K. Monson, "Links between microbial population dynamics and nitrogen availability in an alpine ecosystem", *Ecology*, p. 1623, vol. 80, (1999).) Published
- Parker, E.R., and R.L. Sanford, "The effects of mobile tree islands on soil phosphorus concentrations and distribution in an alpine tundra ecosystem", *Arctic, Antarctic, and Alpine Research*, p. 16, vol. 31, (1999).) Published
- Raab, T.K., D.A. Lipson and R.K. Monson, "Soil amino acid utilization among species of the Cyperaceae: Plant and soil processes", *Ecology*, p. 2408, vol. 80, (1999).) Published
- Reich, P.B., D.S. Ellsworth, M.B. Walters, J.M. Vose, C. Gresham, J.C. Volin, and W.D. Bowman, "Generality of leaf traits: a test across six biomes", *Ecology*, p. 1955, vol. 80, (1999).) Published
- Soranno, P.A., K.E. Webster, J.L. Riera, T.K. Kratz, J.S. Baron, P.A. Bukaveckas, G.W. Kling, D.S. White, N. Caine, R.C. Lathrop, and P.R. Leavitt, "Spatial variation among lakes within landscapes: Ecological organization along lake chains", *Ecosystems*, p. 395, vol. 2, (1999).) Published
- Toetz, D., "Multiple limiting nutrients in a subalpine stream, Colorado Front Range", *Journal of Freshwater Ecology*, p. 349, vol. 14, (1999).) Published
- Welker, J. M., Brown, K. A., and Fahnestock, J. T., "CO₂ flux in arctic and alpine dry tundra: comparative field responses under ambient and experimentally warmed conditions", *Arctic, Antarctic and Alpine Research*, p. 308, vol. 31, (1999).) Published
- West, A.E., P.D. Brooks, M.C. Fisk, L.K. Smith, E.A. Holland, C.H. Jaeger III, S. Babcock, R. Lai, and S.K. Schmidt, "Landscape patterns of CH₄ fluxes in an alpine tundra ecosystem", *Biogeochemistry*, p. 243, vol. 45, (1999).) Published
- Wickland, K.P., R.G. Striegl, S.K. Schmidt and M.A. Mast, "Methane flux in subalpine wetland and unsaturated soils in the southern Rocky Mountains", *Global Biogeochemical Cycles*, p. 101, vol. 13, (1999).) Published
- Williams, M.W., D. Cline, M. Hartman, T. Bardsley, "Data for snowmelt model development, calibration, and verification

- at an alpine site, Colorado Front Range", *Water Resources Research*, p. 3205, vol. 35, (1999).) Published
- Williams, M.W., R. Sommerfeld, S. Massman, and M. Rikkers, "Correlation lengths of meltwater flow through ripe snowpacks, Colorado Front Range, USA", *Hydrologic Processes*, p. 1807, vol. 13, (1999).) Published
- Walker, M.D., D.A. Walker, J.M. Welker, A.M. Arft, T. Bardsley, P.D. Brooks, J.T. Fahnestock, M.H. Jones, M. Losleben, A.N. Parsons, T.R. Seastedt, and P.L. Turner, "Long-term experimental manipulation of winter snow regime and summer temperature in arctic and alpine tundra.", *Hydrological Processes*, p. 2315, vol. 13, (1999).) Published
- Arft, A.M., et al., "Responses of tundra plants to experimental warming: Meta-analysis of the international tundra experiment", *Ecological Monographs*, p. 491, vol. 69, (1999).) Published
- Calanni, J., E. Berg, M. Wood, D. Mangis, R. Boyce, W. Weathers, and H. Sievering, "Atmospheric nitrogen deposition at a conifer forest: response of free amino acids in engelmann spruce needles", *Journal of Environmental Pollution*, p. , vol. , ().) Accepted
- Calanni, J., E. Berg, M. Wood, D. Mangis, R. Boyce, W. Weathers, and H. Sievering, "Atmospheric nitrogen deposition at a conifer forest: response of free amino acids in engelmann spruce needles", *Journal of Environmental Pollution*, p. , vol. , ().) Accepted
- Gonzalez, G., R.E. Ley, S.K. Schmidt, X. Zou, and T.R. Seastedt, "Interactions between invertebrates and microbes: comparisons between tropical and subalpine forests", *Oecologia*, p. , vol. , ().) Accepted
- Gonzalez, G. and T.R. Seastedt, "Soil fauna and plant litter decomposition in tropical and subalpine forests", *Ecology*, p. , vol. , ().) Accepted
- Gonzalez, G. and T.R. Seastedt, "Comparison of the abundance and composition of soil fauna in tropical and subalpine forests", *Pedobiologia*, p. , vol. , ().) Accepted
- Gough, L., C.W. Osendberg, K.L. Gross, and S.L. Collins, "Fertilization effects on species density and primary productivity in herbaceous plant communities", *Oikos*, p. , vol. , ().) Accepted
- Jaeger, C.H., R.K. Monson, M. Fisk, and S. Schmidt, "Interaction of plants and microorganisms in the partitioning of soil nitrogen in an alpine ecosystem", *Ecology*, p. , vol. , ().) Accepted
- Korb, J. E. and T. A. Ranker, "Changes in stand composition and structure between 1981 and 1996 in four Front-Range plant communities in Colorado", *Plant Ecology*, p. , vol. , ().) Accepted
- Meixner, T. M., R. C. Bales, M. W. Williams, D. H. Campbell, and J. S. Baron, "Stream chemistry modeling of two watersheds in the Front Range, Colorado", *Water Resources Research*, p. 77, vol. 36, (2000).) Published
- Seastedt, T.R., and G.A. Adams, "Effects of Mobile Tree Islands on Alpine Soils", *Ecology*, p. , vol. , ().) Accepted
- Seastedt, T.R. and Lynn Vaccaro, "Plant species richness, productivity and nitrogen and phosphorus limitations across a snowpack gradient in alpine tundra", *Arctic, Antarctic, and Alpine Research*, p. , vol. , ().) Accepted
- Sherrod, S. K. and T.R. Seastedt, "Effects of the northern pocket gopher (*Thomomys talpoides*) on alpine soil characteristics, Niwot Ridge, CO", *Biogeochemistry*, p. , vol. , ().) Accepted
- Toetz, D., "Multiple limiting nutrients in a subalpine stream, Colorado Front Range", *Journal of Freshwater Ecology*, p. , vol. , ().) Accepted
- West, A.E. and S.K. Schmidt, "Acetate stimulates atmospheric CH₄ oxidation by an alpine tundra soil", *Soil Biology and Biochemistry*, p. , vol. , ().) Accepted
- Sievering, H., "Nitrogen deposition and carbon sequestration", *Nature*, p. 629, vol. 400, (1999).) Published

Books or Other One-time Publications

Seastedt, T.R., "Soil Fauna and controls of carbon dynamics: comparisons of grasslands and forests across latitudinal gradients", (2000). *Book*, Published

Editor(s): Coleman, D.C., and P. Hendrix

Collection: Invertebrates as webmasters in Ecosystems

Bibliography: Univ. Georgia Press.

Groffman, P.M., E.A. Holland, D.D. Myrold, G.P. Robertson, "Denitrification", (1999). *Book*, Published

Editor(s): Robertson, G.P., et al.

Collection: Standard Soil Methods for Long-Term Ecological Research

Bibliography: Oxford Press

Holland, E.A., G.P. Robertson, J. Greenberg, P.M. Groffman, R.D. Boone, and J.R. Gosz, "Soil CO₂, N₂O, and CH₄ exchange", (1999). *Book*, Published

Editor(s): Robertson, G.P., et al.

Collection: Standard Soil Methods for Long-Term Ecological Research

Bibliography: Oxford Press

Robertson, G.P., D. Wedin, P.M. Groffman, J.M. Blari, E.A. Holland, K.J. Nadelhoffer, D. Harris, "Soil carbon and nitrogen availability: Nitrogen mineralization, nitrification and soil respiration potentials", (1999). *Book*, Published

Editor(s): Robertson, G.P., et al.

Collection: Standard Soil Methods for Long-Term Ecological Research
Bibliography: Oxford Press

Schmidt, S. K. and R.L. Ley, "Microbial competition and bioavailability limit the expression of allelochemicals in natural soils", (1999). *Book*, Published
Editor(s): In Inderjit, S., K.M.M. Dakshini and C.L. Foy
Collection: Principles and Practices in Plant Ecology: Allelochemical Interactions
Bibliography: CRC Press, Boca Raton.

Bowman, W.D. and T.R. Seastedt, "Structure and Function of an Alpine Ecosystem: Niwot Ridge, Colorado", (). *Book*, Accepted
Editor(s): Bowman, W.D. and T.R. Seastedt
Collection: Structure and Function of an Alpine Ecosystem: Niwot Ridge, Colorado
Bibliography: Oxford University Press, New York

Elias, S.A., "Natural History of the Rocky Mountains.", (). *Book*, Accepted
Bibliography: Smithsonian Institution Press.

Walker, D.A., J.G. Molenaar, and W.D. Billings., "Plant processes and patterns in relation to snow in arctic and alpine environments", (). *Book*, Accepted
Editor(s): Jones, H.G., J. Pomeroy, D.A. Walker, and R. Wharton
Collection: Snow Ecology
Bibliography: Cambridge University Press
Science Series

Web/Internet Sites

URL(s):

<http://culter.colorado.edu:1030/>

Description:

This is our core LTER website

Other Specific Products

Contributions

Contributions within Discipline:

Contributions to Other Disciplines:

Contributions to Human Resource Development:

Contributions to Science and Technology Infrastructure:

Please see the outreach section of our activities.

Beyond Science and Engineering:

Our virtual fieldtrip (http://culter.colorado.edu:1030/Field_trip)

and tundra-cam (<http://tundracam.colorado.edu>) provides aesthetic dimensions not normally included in scientific investigations.

Special Requirements

Special reporting requirements: None

Change in Objectives or Scope: None

Unobligated funds: less than 20 percent of current funds

Animal, Human Subjects, Biohazards: None

Categories for which nothing is reported:

Organizational Partners

Any Product

Contributions: Any within Discipline

Contributions: To Any Other Disciplines

Contributions: To Any Contributions to Human Resource Development

**DEB 0028 The Niwot Ridge Long Term Ecological Research Program 10
004 Control on the Structure, Function and Interactions of Alpine and Subalpine
Ecosystems of the Colorado Front Range**

10 Annual Report

I. Research

During 1998 and 1999, we published or have in press 36 papers in refereed journals and had 6 articles published as book chapters. One book, written by NWT PI Scott Elias, included LTER information. We currently have 16 manuscripts in review. A synthesis volume of LTER findings that has been through external review and submission of this book to the publisher is anticipated before the end of this year. During this period we had five graduate students complete theses and dissertations. Among our publications are several first-authored papers from undergraduates, including both REU and honors thesis efforts. All publications are included at the end of this document. In addition to ongoing LTER measurements and experiments, Scientists at our site have begun the new series of projects associated with an analysis of subalpine-alpine interactions. New collaborative projects and new outreach efforts have also been initiated this year. An online version of this report, as well as summaries of our 1998 and 1999 annual workshops are available at our website,

http://culter.colorado.edu:1030/Niwot/Niwot_Ridge_LTER_reports.html.

Research highlights:

1. Species control of nitrogen flux.

Bowman and Steltzer (1998) presented a general model based on empirical studies (Steltzer and Bowman 1998) demonstrating that positive feedback loops can be generated when N enrichment causes a change in plant species composition in the alpine tundra. This work accompanies a suite of studies by Lipson et al. (1997, 1998, 1999) demonstrating patterns of microbial and plant uptake of N, as well as plant uptake of amino-N from soils. Since our renewal, Steve Schmidt and others have received substantial independent funding from NSF to conduct investigations on microbial processes

The change of lifeform from tundra to woody species also strongly influences community microclimate conditions, which strongly affect patterns of organic matter decomposition and N flux (Seastedt and Adams, in press). Finally, a study of the role of an alpine pocket gopher, *Thomomys talpoides*, demonstrates that this species is capable of modifying soil texture, soil chemistry, and manipulating the vegetation community via non-trophic mechanisms (Sherrod 1999; Sherrod et al. submitted). These works collectively demonstrate that individual species do influence ecosystem-level biogeochemical processes.

2. A new model for patterns of methane flux.

West and Schmidt (in press) and West et al. (1999) have proposed that observed patterns of methane consumption observed in the alpine tundra and elsewhere are generated by a population of methane-feeding microbes that are subsidized by a heretofore unrecognized population of methane-producing organisms. The latter group

occupies anaerobic microsites that are found in mostly aerobic terrestrial ecosystems. This conclusion is based on observations and experiments demonstrating that consumption rates of atmospheric methane are simply too high to be explained on the basis of atmospheric concentrations of this greenhouse gas.

3. Ecosystem responses to climate and atmospheric changes.

Ongoing studies of the snowpack manipulation site (snowfence) continue to define and expand upon earlier studies by Brooks et al. (1997). Work by Bryant et al. (1998), Hamann (1998), Williams et al. (1998) and Addington and Seastedt (1999) have further substantiated snowpack effects on decomposition and mineralization and decomposer organisms. These results support the contention that increased moisture can enhance the carbon flux from the soil, thus converting alpine regions into a carbon source under a wetting but otherwise unchanged climate. Ongoing vegetation studies will be continued to see if productivity changes in the plant community can compensate for enhanced decomposition losses.

4. Understanding of alpine-subalpine linkages

New studies initiated in summer of 1999 include a) variation in ecosystem sensitivity to N additions, b) analysis of factors controlling treeline, c) comparisons of soil carbon and N characteristics across an altitudinal gradient and among ecosystem types, and d) effects of soil age on nitrogen and phosphorus dynamics. New studies were emphasized at our 1999 annual workshop, and summary reports of these can be found on the web page. A central focus of these studies is the potential mitigation of increased anthropogenic N deposition by different ecosystems found along a short elevational gradient at the alpine-subalpine interface.

1999 was our first year of operation for the subalpine ecotone subnivean laboratory. This effort is for instrumentation in snow hydrology research to support ongoing and new research efforts to understand the physical processes that control snowpack dynamics. Funding for the project is a cooperative endeavor between the Army Research Office and NWT LTER. Instrumentation includes an underground/undersnow laboratory with dimensions of 30'x10'8', 106 snow lysimeters each connected to dedicated tipping buckets housed in the laboratory by over 10,000 feet of 1.5" pvc pipe, a fully equipped meteorological tower to measure snow-energy transfers, zero-tension soil lysimeters to better understand snow-soil interactions, and a host of other equipment. Additionally, we now have AC power to the site. Additional funding was received from ARO for supplemental instrumentation, including high-precision thermister arrays and liquid moisture meters for use in snow.

5. New collaborations.

Alan Townsend has recently been awarded a Mellon Foundation grant to study how variations in nitrogen availability affect decomposition of soil organic matter. The study will use recent advances in ^{14}C accelerator mass spectrometry which allows the investigators to assign turnover rates to organic matter pools. Most importantly, the study looks beyond the 'how' questions and addresses why these effects occur. This study will involve the alpine and arctic tundra, the tallgrass prairie, and at Harvard Forest.

Russell Monson has constructed a 30-meter tower in the subalpine zone of Niwot Ridge to study-atmosphere interactions. Project goals for this multi-investigator effort

include 1) measurement of the patterns and capacity for carbon sequestration, 2) identification of possible influences of ozone and nitrogen oxide deposition from the Denver airshed, 3) study seasonal and interannual variation in the components of the carbon balance, 4) study controls and emission of biogenic hydrocarbons from this ecosystem, and 5) study environmental and physiological controls over ammonia production and consumption. The last goal is an LTER-supported effort and collaboration with Herm Sievering and will be compared with similar estimates obtained from the tundra.

Summer visiting scientists included Patricia Weigant, Peace College, Raleigh NC and Iggy Litaor from Israel. Dr. Weigant was studying the relationship between local plant diversity and elevational gradients. Dr. Litaor was attempting a new soil analysis technique that may allow for rapid determination of soil organic matter and phosphorus content. The new procedure was also used in a geostatistical analysis of these variables.

II. Information Management

Niwot Ridge LTER site continues to be a leader on data availability and data transfer. Hydrological data from the Niwot Ridge LTER site is now in press with Water Resources Research, and will be one of the first papers published in that journal to feature important data sets that are available to all scientists through the internet (Williams et al. in press).

In addition to the hydrological data, the NWT LTER WWW server provides unrestricted access to 97 other data sets, and metadata for an additional 28 data sets that are available with permission from the investigator. The WWW server also now provides current meteorological data from the climate stations at 10,000 and 11,600 feet.

In the summer of 1998 the LTER program purchased a high resolution GPS unit (\pm 70cm accuracy in x,y geo-space), which is being used to accurately map all known plots both past and present.

Drs. Mark Williams and Barbara Buttenfield have been awarded a CU Boulder Advanced Technology Learning grant to use LTER data in a project designed to provide a "Vertical integration of technology into the Geography curriculum".

Finally, the NWT LTER program has requested all investigators and students to test all their electronic equipment for Y2K compliance, and has taken the appropriate steps to ensure that all Data Management computers and field recording equipment will make the transition to the year 2000 with no anticipated problems.

III Outreach Activities

1. Completion of Virtual Fieldtrip.

The Niwot Ridge virtual fieldtrip was put online in 1998. The present material located at http://culter.colorado.edu:1030/Field_trip/ focuses on two general topic areas. First,

information on the natural history (flora and fauna) of the alpine is presented. Second, the trip emphasizes information about nitrogen and nitrogen saturation issues and biodiversity issues. Our former REU Environmental Journalist students have developed the second group of topics. Also, additional links to real-time weather on the tundra and another virtual field trip to the site created by a former geography graduate student are included. A videocamera has been purchased so that real-time pictures of the alpine will be available. The virtual field trip will be enhanced by linking this to real-time data acquisition activities at the alpine weather station (D1 microwave relay) for comparison with the tundra weather data currently available from the Tundra Laboratory.

This web site has, to date, not received extensive attention, with only about 1300 visits since its creation about 9 months ago. Recently, however, we've formed a collaboration with the Boulder Areas Sustainability Information Network (BASIN), a group interested about environmental issues of the Boulder watershed (which includes much of Niwot Ridge and all of the Green Lakes Valley areas of our LTER). This group is funded by the Environmental Monitoring for Public Access and Community Tracking (EMPACT) program of EPA. BASIN will now add our information to their system, which should enhance our visibility to the public. Similar efforts to connect our outreach activities with Colorado and national mountain clubs are underway.

2. K-12 Outreach

Our outreach program is a continuation of the involvement of teachers from the Boulder/Denver area achieved through our LTER Schoolyard LTER program. This program has four aspects: 1) teaching in-service and pre-service teachers alpine ecology in a summer course at the MRS, 2) bringing elementary and middle school students to the MRS for field trips in the summer 3) development of a schoolyard monitoring program for streams on the lowlands to follow the spring flush of colored organic material (DOC) from the alpine and sub-alpine and 3) development of instructional materials about the Colorado alpine to be used by educators that complement the summer field programs. We take advantage of the fact that children in elementary and middle school years are most receptive to environmental education that emphasizes discovery, exploration and empathy of their local environment. As discussed by D. Sobel in his text *Beyond Ecophobia*, a locally based approach to environmental education is more effective in both conveying ecological concepts and developing empathy than are approaches emphasizing more distant and abstract environmental crises, such as destruction of rain forests.

We are in the process of improving the connectivity at the MRS by installing a T1 line to Kiowa Laboratory and to the new Hostel that is currently under construction. The new Hostel will be used by the teachers when they take the course in alpine ecology as a classroom and computer laboratory facility. We will further improve the access to computers for the teachers at the MRS by having 6 workstations available at MRS. We are providing the teachers participating in this program PC's and high speed modems for their use in the classroom. In this manner, the teachers and their students will be able to access the NWTLTER database from their class in a straightforward manner. During the spring snowmelt and the rise of the color in the streams, the students and teacher will be

able to enter their data and also follow the changes in color at the other streams being monitored by other classes. This real time aspect and easy accessibility should make the monitoring activity more immediate and interactive, and increase its value as an educational activity.

IV. Cross-site, Synthesis and LTER Network Activities

A. Alpine-Arctic comparisons

Work continues on collaborations with research involving a) snow depth manipulations and b) greenhouse warming studies with the arctic LTER site, and in conjunction with ITEX (International Tundra Experiment). Former NWT LTER PIs, Marilyn and Skip Walker, are now formally associated with the Taiga LTER and the University of Alaska, respectively. We anticipate these collaborations to continue.

Another collaboration between graduate student Heidi Steltzer and Guis Shaver involves setting up a cross-site comparison of plant species feedbacks on N dynamics at Toolik Lake and Niwot Ridge. This effort should establish the generality regarding the positive feedback loops associated with species shifts induced by enhance N deposition.

B. Soil carbon

In addition to the Townsend collaboration described above, other LTER researchers continue to evaluate climate-vegetation-soil interactions on soil carbon storage and flux (e.g., Seastedt, in press). A suite of studies initiated this year will document elevational and vegetation effects on soil carbon and C:N ratios on Niwot Ridge. These data are essential for participation in cross-site comparisons and modeling efforts.

C. Regionalization and Regional Networking

Perhaps the most significant new activity is the establishment of a research facility within Rocky Mountain National Park, the McGraw Ranch Research Center that will have formal ties to the University of Colorado. The park's interest in this activity is to address "emerging threats to park resources." Niwot LTER's history of climate and vegetation studies in the alpine, in addition with the commitment to archive and maintain a 40-yr. study of plant species composition within RMNP, has made our group visible to park personnel. Moreover, the use of procedures developed for our information management system (Ingersoll et al. 1997), should also facilitate the development of this center.

Our interests are in combining LTER efforts with other formal, long-term research programs to develop a Front Range environmental monitoring and research center. We anticipate a formal proposal to the NSF NEON program.

D. National and international activities.

William Bowman participated in a Diversity workshop, sponsored by the Swiss Academy of Sciences and DIVERSITAS. The purpose of this workshop was to plan a global network of sites monitoring biotic diversity and experimentally addressing the relationship between diversity and ecosystem function and resilience.

Mark Williams received the US Environmental Protection Agency (EPA) Region VIII Outstanding Environmental Achievement Award, for community based work on ecosystem protection in the San Miguel river basin. The applied research in the San Miguel river basin evolved from process-based research conducted at the NWT LTER site. Mark Williams was also a member of the White House Office of Standards,

Technology, and Policy committee on national index sites, chaired by Jim Gosz and Peter Murdoch. The draft report from the committee featured research results from the NWT LTER program.

A graduate student working with Pam Diggle, Tara Forbis, has been awarded the Karling Award from the Botanical Society, and she used the award money to attend the International Botanical Congress and present an poster on her LTER-supported research. Dr. Diggle is also been charged to prepare a special feature for Ecology on phenotypic plasticity that will feature the LTER alpine work.

V. Publications

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