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# LTREB: Biogeochemical Mechanisms of Response in the Third Decade of Whole-Ecosystem Experimental Manipulations at the Bear Brook Watershed in Maine (BBWM)

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## Preview of Award 0639902 - Final Project Report

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### Cover

Federal Agency and Organization Element to Which Report is Submitted:	4900
Federal Grant or Other Identifying Number Assigned by Agency:	0639902
Project Title:	LTREB: Biogeochemical Mechanisms of Response in the Third Decade of Whole-Ecosystem Experimental Manipulations at the Bear Brook Watershed in Maine (BBWM)
PD/PI Name:	Ivan J Fernandez, Principal Investigator Stephen A Norton, Co-Principal Investigator Lindsey E Rustad, Co-Principal Investigator
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Submitting Official (if other than PD\PI):	Ivan J Fernandez Principal Investigator
Submission Date:	04/15/2013
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	Ivan J Fernandez

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### Accomplishments

**\* What are the major goals of the project?**

**The major goals** of this LTREB were to continue to monitor key biogeochemical fluxes into and out of the paired watershed experiment known as the Bear Brook Watershed in Maine. This past year was our 25th year of research, and 23rd year of whole-watershed bimonthly chemical manipulation with sulfur and nitrogen (added as  $(\text{NH}_4)_2\text{SO}_4$ ) in the treated West Bear watershed. Specific hypotheses that have guided the research under this LTREB are as follows.

H1) With a continued reduction in ambient  $\text{SO}_4$  deposition, the governing mechanism of acidification in East Bear will no longer be dominated by strong acids ( $\text{H}_2\text{SO}_4$  and  $\text{HNO}_3$ ), but will reflect a range of acidification processes including variable  $\text{NO}_3$  production, variable DOC quality and quantity, sea-salt effects, biological storage and release of nutrients, and variable soil air  $\text{CO}_2$  partial pressures. The influence of these changing mechanisms on chronic and episodic acidification in East Bear is signaled by changes in stream chemistry that serve as the integrated indicator of watershed processes. Complementary research not funded through LTREB is providing insight on the source of temporal shifts in responses to acidification by evaluating foliage chemistry, biomass accumulation, litter decomposition, nitrification, leaching of Al, base cations and P from soils, forest nutrient uptake, and fine root growth and turnover.

H2) With continued acidification of West Bear, caused by additions of  $(\text{NH}_4)_2\text{SO}_4$ , soil exchangeable base cation pools will be depleted and eventually stream base cation export will be in equilibrium with the primary mineral weathering rate, aiding the interpretation of East Bear trends. Neutralization of excess strong acids will be primarily by release of inorganic Al. These changes will reflect a new equilibrium for base and Al saturation on soil exchange sites.

H3) With continued acidification of West Bear, caused by additions of  $(\text{NH}_4)_2\text{SO}_4$ , stream  $\text{SO}_4$  concentrations will achieve a new equilibrium governed by the solubility of secondary mineral phases in the soil and not  $\text{SO}_4$  adsorption equilibria that controlled  $\text{SO}_4$  export during the first decade of experimental acidification.

H4) With continued acidification of West Bear, caused by additions of  $(\text{NH}_4)_2\text{SO}_4$ , stream P export will increase as soil P pools sequestered with secondary mineral Al and Fe phases are mobilized by chronic long-term acidification. Accelerated P export will be manifest in high discharge episodes, depleting labile soil pools of P for terrestrial biota, enriching latent stream pools by precipitation in the water column and storage in the streambed, and increasing stream export.

H5) With the continued additions of  $(\text{NH}_4)_2\text{SO}_4$ , West Bear will move from Stage 2 to Stage 3 of N Saturation. Notable indicators of this transition will be "NO<sub>3</sub> breakthrough" in which  $\text{NO}_3$  concentrations in surface waters will be detectable year round, foliar N concentrations in all species will be significantly higher than in the reference watershed, stream base cation and Al export will be increasingly driven by  $\text{NO}_3$  rather than only  $\text{SO}_4$ , the proportion of N export attributable to DON will decline, and nitrification will move through a phase from increasing involvement of forest components (i.e., softwoods and hardwoods, organic and mineral soils) in accelerated  $\text{NO}_3$  production to an overall decline in rates of nitrification in all ecosystem components.

**\* What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?**

Major Activities:

H1) Recovery in East Bear:

We continued to do periodic (typically biweekly) stream sampling and chemical analyses in the reference East Bear watershed.

H2) Experimental Acidification and N Enrichment in West Bear:

We continued treatments of the West Bear watershed bimonthly by helicopter that provides a chronic, multi-decadal scale acidification and N enrichment treatment.

### H3) Testing the Secondary Sulfur Mineral Hypothesis:

No specific experiments were conducted in the past year on sulfur mechanisms.

### H4) Testing the Phosphorus Mobilization Hypothesis:

The initial hypotheses from the earlier years of this LTREB were carried out to look at P fractions in mineral soils as well as stream N and P dynamics. In the past several years, which continued this year, we have done a series of experiments to look at extracellular enzyme activities in soils and stream sediments (phosphatase) as a measure of P bioavailability in soils and streams. In addition, coupled with the N studies mentioned in H5, we have implemented both field and laboratory N and P experiments to study the influence of P on N dynamics.

### H5) Testing the Nitrogen Enrichment Hypothesis:

This past year we conducted extensive natural abundance  $^{15}\text{N}$  research in all major compartments (tree foliage, wood, bark, herbaceous vegetation, roots, all major soil horizons, streams) of both the reference and treatment watersheds as part of an ongoing NSF funded study of N dynamics in both watersheds. In addition, through this same funding combined with this NSF LTREB, we initiated a whole-watershed scale pulse-chase experiment where we treated both the reference (East Bear) and treated (West Bear) watersheds by backpack sprayers with a small mass of 98+ atom %  $(^{15}\text{NH}_4)_2\text{SO}_4$ . We are now in the process of “chasing” the tracer through both watersheds in order to learn about altered N dynamics in both the reference and chronically acidified and N enriched ecosystems. This research is timely as it returns to a focus on understanding N processes now, in the third decade of whole-ecosystem alteration. Part of the base program at BBWM includes air, soil and stream temperature measurements that are critical to the N dynamics research and for studying weather and climate interactions with decadal scale processes in these watersheds.

## Specific Objectives:

### H1) Recovery in East Bear:

Continue precipitation and stream monitoring.

### H2) Experimental Acidification and N Enrichment in West Bear:

Continue precipitation and stream monitoring.

### H3) Testing the Secondary Sulfur Mineral Hypothesis:

No objectives under this hypothesis in the past year.

### H4) Testing the Phosphorus Mobilization Hypothesis:

Continue the sequence of both monitoring and P addition experiments to define P dynamics over decadal time scales.

### H5) Testing the Nitrogen Enrichment Hypothesis:

Building on the long-term data of this NSF LTREB and other research, this past

year focused on the implementation of the natural abundance ecosystem sampling phase of the N project, the subsequent isotopic enrichment phase, and initial enrichment phase measurements for the  $^{15}\text{N}$  studies in both watersheds.

**Significant Results:** Significant results over the past year under each hypothesis are as noted below.

#### H1) Recovery in East Bear:

Recovery in East Bear continues, primarily expressed as declining  $\text{SO}_4$  and base cation concentrations in streamwater. To date, there is no indication of achieving a new equilibrium as originally hypothesized when this project period began. We attribute this, in part, to the continuous decline of ambient atmospheric S deposition over the study period. This leaves the question unanswered as to whether the reference East Bear watershed is in recovery, or simply is acidifying at a reduced rate.

#### H2) Experimental Acidification and N Enrichment in West Bear:

The multi-decadal trend in streamwater chemistry suggests that the first decade resulted in rapid changes in base cation chemistry, Al,  $\text{SO}_4$  and  $\text{NO}_3$  export with declining ANC, resulting in a steadily increasing difference between East and West Bear watersheds. The second decade continued the trend of a difference between watersheds in these key stream solutes, but the magnitude of the difference between the two watersheds has shown little change in the last decade.

#### H3) Testing the Secondary Sulfur Mineral Hypothesis:

No additional studies were done in the past year on ecosystem processes, beyond stream monitoring, on the S hypothesis. A new doctoral student will begin her program in the summer of 2013 under a subsequent NSF LTREB to pursue mechanisms of ecosystem S retention and response to declining atmospheric S deposition that follows on the secondary mineral studies conducted in the early phases of this NSF LTREB.

#### H4) Testing the Phosphorus Mobilization Hypothesis:

Earlier studies under this NSF LTREB and other NSF funding has shown evidence of a period of P mobilization from soils with acidification. The most recent data under this NSF LTREB (in 2010) showed ambiguous results for comparisons of extractable soil P pools in West Bear compared to East Bear. We have also continued to investigate the role of P in N cycling, hypothesizing that the increased mobilization of P would alleviate potential P limitations on N dynamics in the N enriched West Bear watershed. There is some evidence that this is the case, particularly for microbial communities in both soil and stream data.

This past year we have published on the data from some of our stream studies showing significant increases in stream N uptake with P additions. We have also done additional assays of soil phosphatase activities in contrasting watersheds and forest types, with suppression of phosphatase activity consistently evident following experimental P additions. At this point, it appears that there was P mobilization from soil pools associated with secondary Al that was mobilized in the second decade after the treated West Bear watershed transitioned from base cation to Al buffering. However, it does not appear clear in the third decade that this elevated P mobilization persists, with possibly two exceptions. During hydrologic episodes, there remains evidence in streams for particulate transport of Al and P at significantly higher concentrations than soluble phases. There is also

the possibility that P mobilized during the second decade was lost from the coniferous stand types, but may be at least partly biocycling and therefore retained in the deciduous forest type. This remains to be demonstrated with subsequent research. As part of the stable isotope tracer research ongoing, we have new P addition plots throughout the watersheds that will help further define these trends.

#### H5) Testing the Nitrogen Enrichment Hypothesis:

The West Bear stream continues to be elevated in NO<sub>3</sub> concentrations as a result of the enrichment of West Bear with NH<sub>4</sub>, while the East Bear watershed continues to strongly retain N during the growing season. There is little evidence in the most recent data for an escalating difference between the reference and treated watershed, and there is no evidence of the evolution of the West Bear watershed from Stage 2 to Stage 3 of N saturation. The initiation of both the natural abundance and enrichment studies with <sup>15</sup>N this past year will provide important insights on rates of N cycling between these two watersheds after over two decades of N enrichment. The last evaluation of tree growth was from increment core data in 2011 that indicated there was little evidence of either a growth decline (from acidification) or increase (from N fertilization) in American beech, red maple, yellow birch or red spruce. Sugar maple, however, continues to show evidence of a growth decline across both watersheds. Although West Bear sugar maple appeared to have increased growth rates for a period during the first decade (when there was increased Ca availability as it was displaced from soils), growth declines occurred following that period. The fact that sugar maple is declining in East Bear as well is taken to reflect ambient base cation declines from long-term acidification in the region.

#### Key outcomes or Other achievements:

Over the past year the key outcome would be the continuation of multi-decadal whole-watershed mass balance, and precipitation and stream chemistry, defining the long-term response of these representative northern New England forested ecosystems to ambient and experimental conditions. This framework then provides an ongoing series of intensive studies of ecosystem function that, in the past year, emphasize N dynamics. This is particularly important because we still have an incomplete understanding of changing N dynamics with altered atmospheric deposition and climate change, and incomplete numerical models by which to frame policy. This is made even more important as N remains the most important limiting nutrient to a forest resource that is increasingly pressured for raw materials in pursuit of traditional (e.g., paper, wood) and new (e.g., biofuels) products as well as ecosystem services (e.g., water quality, carbon sequestration). Over the past year we have published and conducted research that contributes to these societal priorities.

#### **\* What opportunities for training and professional development has the project provided?**

This NSF LTREB has directly supported the training of graduate students and undergraduate student staff through their participation and mentoring in all phases of field and laboratory research. NSF LTREB supports the base program that allows all research at the Bear Brook Watershed in Maine to occur by building upon the base support and research activities of this NSF LTREB project. Complementary funding has also supported additional undergraduate students, graduate students, and a postdoctoral fellow (Marie-Cecile Gruselle) in the past year, as well as the development of K-12 outreach programs. The most significant K-12 initiative is associated with the N dynamics research at Bear Brook where we are working in collaboration with the Schoodic Education and Research Center (affiliated with Acadia National Park) and have developed a curriculum on N available on-line at the Participatory Science web site (<http://participatoryscience.org/>) under the Nitrogen Cycling in Watersheds link. This project involves 6 schools in 3

states (Maine, Vermont, New Hampshire). Bear Brook continues to be the site of numerous visits and field tours by visiting and collaborating scientists and students.

### \* How have the results been disseminated to communities of interest?

Also this past year, PIs Fernandez and Norton hosted BIOGEOMON 2012 in Maine. This conference hosted over 200 registrants from 25 countries, included 122 contributed papers, 6 conference plenary talks, 14 theme plenary talks, and involved 53 students. Of these, 15 graduate students were volunteer staff from Villanova University and the University of Maine. The week-long conference included a number of full day field trips, the largest of which was to BBWM with nearly 60 scientists visiting the site from around the world to learn about the long-term project being supported by this and prior NSF LTREB funding. The conference book, pictures, and other information are available at <http://www3.villanova.edu/conferences/biogeomon/>.

The BBWM project continues to also be a source of pride for the University and the region, and was highlighted in the summer edition of the University of Maine research magazine (UMaine Today - <http://umainetoday.umaine.edu/past-issues/summer-2012/a-watershed/>) marking the 25th anniversary of the project.

## Products

### Books

#### Book Chapters

Norton, S. A., Kopáček, J., and Fernandez (2013). Acidification and Acid Rain. *Treatise on Geochemistry, 9, 2nd Edition*. Holland, H. D. and Turekian K. K. (eds.). Pergamon Press. 1. Status = AWAITING\_PUBLICATION; Acknowledgement of Federal Support = No ; Peer Reviewed = Yes

#### Conference Papers and Presentations

Fernandez, Ivan J., Stephen A. Norton, and Tiffany Wilson (2012). *BIOGEOMON 2012, The 7th International Symposium on Ecosystem Behavior*. BIOGEOMON 2012. Northport, Maine. Status = PUBLISHED; Acknowledgement of Federal Support = No

Rancatti, R., K. Simon, M. Mineau, D. Anderson, I.J. Fernandez, S.A. Norton, and M.B. Adams (2012). *Effects of watershed acidification on abiotic and biotic phosphorus uptake in streams draining two whole-watershed experimental forests*. BIOGEOMON 2012. Northport, Maine. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Fernandez, I.J., S.A. Norton, S.J. Nelson, and C. Salvino (2012). *Evidence of transient alteration of N dynamics from an ice storm at the Bear Brook Watershed in Maine, USA*. BIOGEOMON 2012. Northport, Maine. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Raymond, J., I.J. Fernandez, T. Ohno, and K.S. Simon (2012). *Soil drainage class influences on soil carbon in a New England forested watershed, USA*. BIOGEOMON 2012. Northport, Maine. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Nelson, S.J., I.J. Fernandez, S.A. Norton (2012). *Teachers' Workshop exhibit. 2012 Maine EPSCoR State Conference, "Building Partnerships for Sustainability Solutions"*. BIOGEOMON 2012. Northport, Maine. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Norton, S.A., I.J. Fernandez, T. Navratil, K.S. Simon, and S. Jain (2012). *The Bear Brook Watershed in Maine (BBWM) at 25: manipulation, monitoring, mechanisms, and modeling*. BIOGEOMON 2012. Northport, Maine. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Mineau, M.M., K.S. Simon, I.J. Fernandez, S.A. Norton, and H.M. Valett (2012). *The effect of chronic watershed nitrogen deposition and acidification on the interaction among phosphorus, carbon, and nitrogen uptake in streams*.

BIOGEOMON 2012. Northport, Maine. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

SanClements, M.D., G.P. Oelsner, D.M. McKnight, I.J. Fernandez, S.J. Nelson, M.B. Adams, M. Mineau, and K. Simon (2012). *The effects of acidification and recovery on DOM quality and source in temperate forested watersheds*. BIOGEOMON 2012. Northport, Maine. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Fernandez, Ivan J., Madeleine M. Mineau, Kevin S. Simon, and Stephen A. Norton (2012). *The influence of decadal-scale N enrichment on N dynamics and 15N discrimination in a New England Forested Watershed*. Soil Science Society of America Conference. Cincinnati, Ohio. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

## Inventions

Nothing to report.

## Journals

Fatemi, Farrah R., Ivan J. Fernandez, Stephen A. Norton and Lindsey E. Rustad (2012). Soil solution response to two decades of experimental acidification at the Bear Brook Watershed in Maine. *Water Air Soil Pollution*. 223 6171-6186. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Lawrence, Gregory B., Ivan J. Fernandez, Daniel D. Richter, Donald S. Ross, Paul W. Hazlett, Scott W. Bailey, Rock Ouimet, Richard A. F. Warby, Arthur H. Johnson, Henry Lin, James M. Kaste, Andrew G. Lapenis, and Timothy J. Sullivan (2013). Measuring environmental change in forest ecosystems by repeated soil sampling: A North American Perspective. *Journal of Environmental Quality*. 42 1. Status = AWAITING\_PUBLICATION; Acknowledgment of Federal Support = No ; Peer Reviewed = Yes ; DOI: [10.2134/jeq2012.0378](https://doi.org/10.2134/jeq2012.0378)

Mineau, M. M., Rigsby, C. M., Elya, D. T., Fernandez, I. J., Norton, S. A., Ohno, T., Valette, H. M., and Simon, K. S. (2013). Stoichiometric constraints on the bioavailability of leaf leachate dissolved organic matter under chronic catchment nitrogen enrichment. *Freshwater Biology*. 58 1. Status = AWAITING\_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Raymond, Jay E., Ivan J. Fernandez, Tsutomu Ohno, and Kevin Simon (2013). Soil drainage class influences on soil carbon in a New England Forested Watershed. *Soil Science Society of America Journal*. 77 307. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

## Licenses

Nothing to report.

## Other Products

*Educational aids or Curricula.*

As part of a nitrogen initiative built on this funding and other NSF support, the following web site contains a curriculum used in 6 high schools in three states (Maine, New Hampshire and Vermont). The programs are hosted by Acadia Learning which is part of the Schoodic Education and Research Center associated with Acadia National Park in Maine.

[participatoryscience.org](http://participatoryscience.org)

## Other Publications

## Patents

Nothing to report.

## Technologies or Techniques

Nothing to report.

## Thesis/Dissertations



## Websites

*Real-Time and Archive Hydrologic Flux at the Reference East Bear*

<http://waterdata.usgs.gov/me/>

This is the hydrologic flux at the weir for our reference watershed (East Bear) monitored in collaboration with the US Geological Survey. This site also contains access to archived data from the study period. The specific web site URL is noted below, since only the agency web address was accepted by this web reporting interface.

[http://waterdata.usgs.gov/me/nwis/uv/?site\\_no=01022294&PARAMeter\\_cd=00065,00060](http://waterdata.usgs.gov/me/nwis/uv/?site_no=01022294&PARAMeter_cd=00065,00060)

*The Bear Brook Watershed in Maine*

<http://www.umaine.edu/bbwm/>

This is the project web site located on the University of Maine servers. This was revised in 2012 and remains under development. This has been used widely by the public, university students, and K-12 teachers and students. Data archives from the project will be developed in the coming years.

## Participants/Organizations

### What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Fernandez, Ivan	PD/PI	4
Norton, Stephen	Co PD/PI	1
Rustad, Lindsey	Co PD/PI	1
Gruselle, Marie-Cecille	Postdoctoral (scholar, fellow or other postdoctoral position)	8
Mineau, Madeleine	Postdoctoral (scholar, fellow or other postdoctoral position)	4
Anderson, Dennis	Technician	4
Handley, Michael	Technician	12
Spencer, Cheryl	Technician	12
Fatemi, Farrah	Graduate Student (research assistant)	8
Fuller, Morgan	Graduate Student (research assistant)	2
Rancatti, Regina	Graduate Student (research assistant)	12
Salvino, Cayce	Graduate Student (research assistant)	3
Dohm, Jacob	Undergraduate Student	8

Herr, Catherine	Undergraduate Student	12
Hopkins, Hope	Undergraduate Student	10

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**Full details of individuals who have worked on the project:**

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**Ivan J Fernandez****Email:** ivanjf@maine.edu**Most Senior Project Role:** PD/PI**Nearest Person Month Worked:** 4

**Contribution to the Project:** This is the lead PI of the project who oversees all administration and science, as well as advises many of the graduate and undergraduate students on the project.

**Funding Support:** University of Maine and other NSF.

**International Collaboration:** No

**International Travel:** No

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**Stephen A Norton****Email:** norton@maine.edu**Most Senior Project Role:** Co PD/PI**Nearest Person Month Worked:** 1

**Contribution to the Project:** This co-PI is involved in all many aspects of the biogeochemical research at this site, as well as serving on student advisory committees.

**Funding Support:** Retired.

**International Collaboration:** No

**International Travel:** No

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**Lindsey E Rustad****Email:** rustad@maine.edu**Most Senior Project Role:** Co PD/PI**Nearest Person Month Worked:** 1

**Contribution to the Project:** Lindsey Rustad provides input on forest ecology to both student training and results interpretation.

**Funding Support:** USDA Forest Service

**International Collaboration:** No

**International Travel:** No

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**Marie-Cecille Gruselle****Email:** mariececile.gruselle@maine.edu**Most Senior Project Role:** Postdoctoral (scholar, fellow or other postdoctoral position)**Nearest Person Month Worked:** 8

**Contribution to the Project:** This is a postdoctoral fellow working on the stable isotope nitrogen experiment at

BBWM.

**Funding Support:** Other NSF support.

**International Collaboration:** No

**International Travel:** No

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**Madeleine Mineau**

**Email:** streamnerd@gmail.com

**Most Senior Project Role:** Postdoctoral (scholar, fellow or other postdoctoral position)

**Nearest Person Month Worked:** 4

**Contribution to the Project:** Dr. Mineau was supported from other NSF funding at BBWM but collaborated on many phases of BBWM research.

**Funding Support:** Other NSF funding.

**International Collaboration:** No

**International Travel:** No

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**Dennis Anderson**

**Email:** dennis.anderson@umit.maine.edu

**Most Senior Project Role:** Technician

**Nearest Person Month Worked:** 4

**Contribution to the Project:** This is a technician involved with water sampling and analysis and the whole watershed treatments.

**Funding Support:** Other NSF.

**International Collaboration:** No

**International Travel:** No

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**Michael Handley**

**Email:** handley@maine.edu

**Most Senior Project Role:** Technician

**Nearest Person Month Worked:** 12

**Contribution to the Project:** This technical staff member is responsible for the periodic stream and precipitation collections at BBWM, as well as participating in other aspects of BBWM research.

**Funding Support:** Other NSF support.

**International Collaboration:** No

**International Travel:** No

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**Cheryl Spencer**

**Email:** rpt372@maine.edu

**Most Senior Project Role:** Technician

**Nearest Person Month Worked:** 12

**Contribution to the Project:** This staff member coordinates all sample flow and analysis in our laboratory and has

been part of this BBWM contract throughout the student.

**Funding Support:** This grant and other university funds.

**International Collaboration:** No

**International Travel:** No

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**Farrah Fatemi**

**Email:** farrah.fatemi@villanova.edu

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 8

**Contribution to the Project:** Farrah was a doctoral student who completed her research on soil extracellular enzyme and soil solution processes at BBWM.

**Funding Support:** Other NSF and Maine Agricultural and Forest Experiment Station

**International Collaboration:** No

**International Travel:** No

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**Morgan Fuller**

**Email:** morgan.fuller@maine.edu

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 2

**Contribution to the Project:** This is an MS student who also worked at BBWM as an undergraduate, and is developing a thesis on ecosystem services and climate change. She helped extensively in 2012 on soil sampling at BBWM.

**Funding Support:** Maine Agricultural and Forest Experiment Station

**International Collaboration:** No

**International Travel:** No

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**Regina Rancatti**

**Email:** regina.rancatti@umit.maine.edu

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 12

**Contribution to the Project:** This is a current doctoral student working on stream ecology and biogeochemistry at BBWM. Her focus is on nitrogen dynamics.

**Funding Support:** Other NSF funding.

**International Collaboration:** No

**International Travel:** No

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**Cayce Salvino**

**Email:** cjsalvino@gmail.com

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 3

**Contribution to the Project:** This is a current MS student focusing on phosphorus controls on nitrogen cycling. She has contributed to the temperature and moisture monitoring program at BBWM and her own thesis research focuses on BBWM.

**Funding Support:** She is supported by the Maine Agricultural and Forest Experiment Station.

**International Collaboration:** No

**International Travel:** No

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**Jacob Dohm**

**Email:** Jacob\_Dohm@umit.maine.edu

**Most Senior Project Role:** Undergraduate Student

**Nearest Person Month Worked:** 8

**Contribution to the Project:** This student assisted in laboratory and field work sampling soil and tree foliage.

**Funding Support:** Other NSF.

**International Collaboration:** No

**International Travel:** No

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**Catherine Herr**

**Email:** Catherine\_Herr@umit.maine.edu

**Most Senior Project Role:** Undergraduate Student

**Nearest Person Month Worked:** 12

**Contribution to the Project:** This student has worked on all phases of the research at BBWM from multiple grants over the past two years.

**Funding Support:** Other NSF.

**International Collaboration:** No

**International Travel:** No

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**Hope Hopkins**

**Email:** hope\_hopkins@umit.maine.edu

**Most Senior Project Role:** Undergraduate Student

**Nearest Person Month Worked:** 10

**Contribution to the Project:** This student has worked on several projects at BBWM in both field and laboratory settings.

**Funding Support:** This grant and other NSF.

**International Collaboration:** No

**International Travel:** No

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**What other organizations have been involved as partners?**

Name	Type of Partner Organization	Location
American Forest Management LLC	Industrial or Commercial Firms	Milford, Maine

Cary Institute for Ecosystem Studies	Other Nonprofits	Millbrook, New York
University of Colorado at Boulder	Academic Institution	Boulder, Colorado
University of Michigan	Academic Institution	Ann Arbor, Michigan
University of New Hampshire	Academic Institution	Durham, New Hampshire
University of Strasbourg	Academic Institution	Strasbourg, France
University of Western Ontario	Academic Institution	London, Ontario, Canada
Cornell University	Academic Institution	Ithaca, New York
Czech Academy of Sciences	Other Organizations (foreign or domestic)	Prague, Czech Republic
Nacional de Ciencias Forestales Honduras	Academic Institution	Honduras
SUNYH - ESF	Academic Institution	Syracuse, New York
Syracuse University	Academic Institution	Syracuse, New York
Trent University	Academic Institution	Peterborough, Ontario, Canada
US Geological Survey	Other Organizations (foreign or domestic)	Augusta, Maine
USDA Forest Service	Other Organizations (foreign or domestic)	Durham, New Hampshire

### Full details of organizations that have been involved as partners:

#### American Forest Management LLC

**Organization Type:** Industrial or Commercial Firms

**Organization Location:** Milford, Maine

**Partner's Contribution to the Project:**

In-Kind Support

**More Detail on Partner and Contribution:** American Forest Management LLC manages forest lands owned by BBC LLC (managed by John Malone of Englewood, CO) which includes the land for the Bear Brook Watershed in Maine. Staff from AFM help in supporting administrative logistics of the long-term lease, logistics of site maintenance, and other logistical assistance.

#### Cary Institute for Ecosystem Studies

**Organization Type:** Other Nonprofits  
**Organization Location:** Millbrook, New York

**Partner's Contribution to the Project:**

In-Kind Support  
Collaborative Research

**More Detail on Partner and Contribution:** We collaborated with Dr. Peter Groffman on a multi-site research effort to understand denitrification in forested watersheds, including the effects of the experimental nitrogen enrichment at BBWM and other sites. This involved soil sampling, measurements of denitrification, and dissolved oxygen monitoring at BBWM.

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**Cornell University**

**Organization Type:** Academic Institution  
**Organization Location:** Ithaca, New York

**Partner's Contribution to the Project:**

In-Kind Support  
Collaborative Research

**More Detail on Partner and Contribution:** We have collaborated with Dr. Christy Goodale and her program in collaborative research on several initiatives that have resulted in regional data syntheses. The most recent effort was a collaboration through Madeleine Stone's thesis research looking at temperature sensitivity of soil enzyme kinetics at a number of sites including sampling from BBWM.

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**Czech Academy of Sciences**

**Organization Type:** Other Organizations (foreign or domestic)  
**Organization Location:** Prague, Czech Republic

**Partner's Contribution to the Project:**

In-Kind Support  
Collaborative Research  
Personnel Exchanges

**More Detail on Partner and Contribution:** We have had an ongoing exchange of scientists and sampling between BBWM and Czech colleagues. Dr. Tomas Navratil has hosted our visits to the Czech Republic and facilitated sampling at their Lesni potok watershed, supported by other NSF funding. Dr. Navratil was on a Fulbright Fellowship during the 2008-2009 academic year at the University of Maine working with us to study geochemical processes at the BBWM which has resulted in several publications listed in this report.

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**Nacional de Ciencias Forestales Honduras**

**Organization Type:** Academic Institution  
**Organization Location:** Honduras

**Partner's Contribution to the Project:**

In-Kind Support  
Collaborative Research

**More Detail on Partner and Contribution:** Dr. Alex Elvir is a faculty member at Escuela Nacional de Ciencias Forestales in Honduras in forestry but has had an ongoing scientific collaboration with us on the Bear Brook

Watershed in Maine project. He spent the 2008 summer in Maine collaborating on vegetation research that focused on the sugar maple decline hypotheses we are testing. He continues as a collaborator on aboveground vegetation dynamics at BBWM.

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### **SUNYH - ESF**

**Organization Type:** Academic Institution

**Organization Location:** Syracuse, New York

**Partner's Contribution to the Project:**

Collaborative Research

**More Detail on Partner and Contribution:** We have collaborated with Dr. Myron Mitchell on a multi-site synthesis in North America, Europe and Japan to study nitrate dynamics in forested watersheds. We contributed BBWM data and collaborated on this effort.

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### **Syracuse University**

**Organization Type:** Academic Institution

**Organization Location:** Syracuse, New York

**Partner's Contribution to the Project:**

In-Kind Support

Collaborative Research

**More Detail on Partner and Contribution:** We collaborated with Dr. Charles Driscoll and his colleagues who applied the PnET-BGC model to a suite of long-term watershed sites to model climate change effects on future watershed processes. We provided BBWM long-term data in support of this effort.

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### **Trent University**

**Organization Type:** Academic Institution

**Organization Location:** Peterborough, Ontario, Canada

**Partner's Contribution to the Project:**

In-Kind Support

Collaborative Research

**More Detail on Partner and Contribution:** We collaborated with Dr. Catherine Eimers on a multi-site comparison study to determine the effects of drought on sulfate dynamics in these small, forested watersheds. We have contributed BBWM data and collaborated on the synthesis.

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### **US Geological Survey**

**Organization Type:** Other Organizations (foreign or domestic)

**Organization Location:** Augusta, Maine

**Partner's Contribution to the Project:**

In-Kind Support

Facilities

Personnel Exchanges



**More Detail on Partner and Contribution:** The US Geological Survey has been a partner in the development and monitoring of hydrology in both East and West Bear streams since the beginning of the project. This activity is cost-shared between the BBWM program and the USGS, with their personnel actively involved in operations at the site. Through this collaboration, real-time hydrologic data are continuously available through the USGS web site and data archiving is provided.

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### USDA Forest Service

**Organization Type:** Other Organizations (foreign or domestic)

**Organization Location:** Durham, New Hampshire

**Partner's Contribution to the Project:**

Collaborative Research

Personnel Exchanges

**More Detail on Partner and Contribution:** There are ongoing interactions with members for the USDA Forest Service regarding the BBWM project. Of particular note is Dr. Lindsey Rustad, a USDA Forest Service scientist, who has been part of the BBWM scientific team since the beginning of the project and whose collaboration continues to today. Recently we have also begun a dialogue about collaborations on hydrology with Dr. Mark Green of Plymouth State University, New Hampshire and the USDA Forest Service. Dr. Green is collaborating with us to explore the relationship between experimental manipulations and water balance using the long-term BBWM data set.

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### University of Colorado at Boulder

**Organization Type:** Academic Institution

**Organization Location:** Boulder, Colorado

**Partner's Contribution to the Project:**

In-Kind Support

Collaborative Research

**More Detail on Partner and Contribution:** Dr. Michael SanClements, who earned his doctoral degree at the University of Maine and is now a research scientist at the University of Colorado and recently also was hired in the National Ecological Observatory Network in Boulder, and continues to collaborate on BBWM research. There is an ongoing collaborative grant that builds on the existing watershed hydrogeochemical mass balance by using cutting edge techniques to characterize the movement of dissolved organic matter through the Bear Brook ecosystems.

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### University of Michigan

**Organization Type:** Academic Institution

**Organization Location:** Ann Arbor, Michigan

**Partner's Contribution to the Project:**

In-Kind Support

Collaborative Research

**More Detail on Partner and Contribution:** We have been interacting with Dr. Lucas Nave regarding the development of a carbon database for the National Soil Carbon Network affiliated with the University of Michigan and others. We have begun the process of carbon data entry into their databank.

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## University of New Hampshire

**Organization Type:** Academic Institution

**Organization Location:** Durham, New Hampshire

**Partner's Contribution to the Project:**

In-Kind Support

**More Detail on Partner and Contribution:** Dr. J.S. Kahl of the University of New Hampshire has been affiliated with the Bear Brook Watershed in Maine project for geochemical stream dynamics in monitoring the reference stream chemistry (East Bear) over time, as part of the US Environmental Protection Agency's long-term monitoring program.

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## University of Strasbourg

**Organization Type:** Academic Institution

**Organization Location:** Strasbourg, France

**Partner's Contribution to the Project:**

In-Kind Support

Collaborative Research

Personnel Exchanges

**More Detail on Partner and Contribution:** We have been involved with a project funded by other NSF support collaborating with scientists at the University of Strasbourg in France (Bertrand Fritz, Marie-Claire Pierret-Neboit, Gaetana Quaranta-Millet) and conducting research at their Strengbach watershed collaboratively with our own BBWM project. There has been an exchange of scientists and sampling in both directions. This exchange continues in the development of data dependent on measurements being made in this NSF LTREB project. Dr. Marie-Claire Pierret-Neboit was on a Fulbright Fellowship during 2009-2010 from France working with the PIs and project staff at the University of Maine and on BBWM data. These collaborations continue.

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## University of Western Ontario

**Organization Type:** Academic Institution

**Organization Location:** London, Ontario, Canada

**Partner's Contribution to the Project:**

In-Kind Support

Collaborative Research

**More Detail on Partner and Contribution:** We collaborated with Dr. Irena Creed and colleagues on a meta-analysis of C, N, and P export patterns from forests to surface waters across continental-scale climatic gradients. The project collaborators met during the 2011 Gordon Conference.

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## What other collaborators or contacts have been involved?

NO

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## Impacts

**What is the impact on the development of the principal discipline(s) of the project?**

The ongoing record of whole ecosystem function at BBWM becomes increasingly important, and rare, with each passing year. Few experiments exist in the world with these kinds of data which is reflected in the many examples where BBWM is one of a handful of key sites sought to study ecological processes.

**What is the impact on other disciplines?**

Because of the intensive, ecosystem-scale science at BBWM, any discipline involved in ecosystem services from the forested northern New England landscape is likely to draw on BBWM data and findings. As an example, considerable attention has been paid to the sustainability of forests in light of pending increased utilization for renewable energy technologies. The intensive nutrient cycling data available from the BBWM project is a unique data source to draw upon for research and modeling of these concerns by foresters and engineers.

**What is the impact on the development of human resources?**

See entry for training and professional development and outreach.

**What is the impact on physical resources that form infrastructure?**

This project allows the Bear Brook Watershed in Maine to be an ongoing, long-term research site that supports numerous research objectives and training opportunities.

**What is the impact on institutional resources that form infrastructure?**

No new impacts on the infrastructure in the past year. This NSF LTREB, however, is responsible for supporting this project for the past year. Without this support, the long-term BBWM project would not have been able to continue.

**What is the impact on information resources that form infrastructure?**

As noted, this past year the Bear Brook Watershed in Maine resulted in two unique contributions to data and information dissemination. First, the BIOGEMON international conference series on ecosystem biogeochemistry was hosted in Maine in 2012 in large part because of the international reputation of the Bear Brook Watershed in Maine project and the research cohort associated with this project. This was the 7th conference in the series spanning a quarter of a century. Second, the project formed the framework for K-12 instructional materials and programs during the 2012-2013 school year. Third, the BBWM continues to be widely recognized as a key resource and is available to contribute to emerging programs such as the regional Smart Forests (<http://smartforests.org/>) initiative.

**What is the impact on technology transfer?**

Nothing to report.

**What is the impact on society beyond science and technology?**

The BBWM project continues to provide information about ecosystem function that informs management (e.g., foresters, conservation professionals) and policy (e.g., Clean Air Act, state regulations). The BBWM project offers examples of how ecosystems respond on the long-term, multi-decadal scale, as well as on the short-term such as biogeochemical responses to the ice storm of 1998 or hurricane Irene in 2011.

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**Changes/Problems****Changes in approach and reason for change**

Nothing to report.

**Actual or Anticipated problems or delays and actions or plans to resolve them**

Nothing to report.

**Changes that have a significant impact on expenditures**

Nothing to report.

**Significant changes in use or care of human subjects**

Nothing to report.

**Significant changes in use or care of vertebrate animals**

Nothing to report.

**Significant changes in use or care of biohazards**

Nothing to report.