Annual Report for Period: 01/2009 - 12/2009
Submitted on: 11/13/2009
Principal Investigator: Fahey, Timothy J.
Award ID: 0423259
Organization: Cornell University State
Submitted By:
Fahey, Timothy - Principal Investigator
Title:
Long-Term Ecological Research (LTER) at Hubbard Brook Experimental Forest (HBR-LTER)

Project Participants

Senior Personnel

Name: Fahey, Timothy
Worked for more than 160 Hours: Yes
Contribution to Project:
Co-PI at Cornell University studying soil and root work.

Name: Driscoll, Charles
Worked for more than 160 Hours: Yes
Contribution to Project:
Co-PI at Syracuse University studying solution chemistry and modelling work.

Name: Groffman, Peter
Worked for more than 160 Hours: Yes
Contribution to Project:
Co-PI at Institute of Ecosystem Studies studying microbial ecology.

Name: Johnson, Christopher
Worked for more than 160 Hours: Yes
Contribution to Project:
Co-PI studying soil chemistry.

Name: Fisk, Melany
Worked for more than 160 Hours: Yes
Contribution to Project:
Co-PI at Appalachian University studying soil fungi.

Name: Ollinger, Scott
Worked for more than 160 Hours: Yes
Contribution to Project:
Co-PI at University of New Hampshire studying remote sensing and ecosystem modeling.

Name: Aber, John
Worked for more than 160 Hours: Yes
Contribution to Project:
Co-PI at University of New Hampshire studying ecosystem modelling.

Name: Martin, Mary
Worked for more than 160 Hours: Yes
Contribution to Project:
Co-PI at University of New Hampshire studying ecosystem modelling.

Name: Likens, Gene
Worked for more than 160 Hours: Yes
Contribution to Project:
Co-PI at Institute of Ecosystem Studies studying watershed dynamics.

Name: Battles, John
Worked for more than 160 Hours: Yes
Contribution to Project:
Co-PI at University of California-Berkeley studying vegetation dynamics.

Name: Joel, Blum
Worked for more than 160 Hours: Yes
Contribution to Project:
Co-PI at University of Michigan studying soil geochemistry.

Name: Lovett, Gary
Worked for more than 160 Hours: Yes
Contribution to Project:
Co-PI at Institute of Ecosystem Studies studying beech bark disease.

Name: Arthur, Mary
Worked for more than 160 Hours: Yes
Contribution to Project:
Co-PI at University of Kentucy studying beech bark disease.

Name: Fitzhugh, Ross
Worked for more than 160 Hours: Yes
Contribution to Project:
Co-PI at University of Illinois studying beech bark disease.

Name: Siccama, Thomas
Worked for more than 160 Hours: Yes
Contribution to Project:
Co-PI at Yale University studying vegetation ecology.

Name: Rodenhouse, Nicholas
Worked for more than 160 Hours: Yes
Contribution to Project:
Senior personnel at Wellesley College studying heterotroph populations.

Name: Mitchell, Myron
Worked for more than 160 Hours: Yes
Contribution to Project:
Co-PI at SUNY-ESF working on biogeochemistry with a particular focus on sulfate isotopes and climate change.

Name: Hamburg, Steven
Worked for more than 160 Hours: Yes
Contribution to Project:
Hamburg is Co-PI at Brown University working on land-use history and biogeochemistry.

Name: Richardson, Andrew
Worked for more than 160 Hours: Yes
Contribution to Project:
Dr. Richardson, University of New Hampshire, is a colleague of Dr. Scott Ollinger, studying carbon cycling and phenology.

Name: Gleason, Jamie
Worked for more than 160 Hours: Yes
Contribution to Project:
Jamie Gleason is a research scientist who worked on Ca isotope and Sr isotope analyses on the project.

Name: Jenkins, Julian
Worked for more than 160 Hours: Yes

Contribution to Project:
Julian Jenkins is a research scientist at University of New Hampshire doing work on ecosystem modeling.

Post-doc

Name: Cleavitt, Natalie
Worked for more than 160 Hours: Yes
Contribution to Project:
Post-doc with Fahey studying bryophytes and lichens.

Name: Wu, Wei
Worked for more than 160 Hours: Yes
Contribution to Project:
Wei Wu is a post-doc with Driscoll at Syracuse University applying the model PnET-BGC to investigate the response of forests and surface waters to changes in air pollution

Name: Lowe, Winsor
Worked for more than 160 Hours: Yes
Contribution to Project:
postdoctoral associate with Likens at IES; worked on salamanders in the HBEF.

Name: Bade, Darren
Worked for more than 160 Hours: Yes
Contribution to Project:
a postdoctoral associate with Likens at IES; worked on the biogeochemistry of Mirror Lake.

Name: Judd, Kristin
Worked for more than 160 Hours: Yes
Contribution to Project:
postdoctoral associate, with Likens at IES; worked on the biogeochemical interface between streams and uplands in the HBEF.

Name: Nezat, Carmen
Worked for more than 160 Hours: Yes
Contribution to Project:
Carmen Nezat moved from graduate student to postdoctoral fellow status in 2006-2007. In Fall 2007, she started as faculty at Eastern Washington University. In 2008, Carmen continued to work on publishing results from HB, but she is no longer receiving financial support on the project.

Name: Betts, Matthew
Worked for more than 160 Hours: Yes
Contribution to Project:
Matt lead the crew, including Adam, Mike and Benjamin, that conducted the valley-wide bird surveys and completed the beech-bark disease survey.

Name: Kiekbusch, Jana
Worked for more than 160 Hours: Yes
Contribution to Project:
Jana Kiekbusch is a post doctoral research associate with Charles Driscoll in the Department of Civil and Environmental Engineering at Syracuse University. She is working on evaluating critical loads of acidic deposition.

Name: Burgin, Amy
Worked for more than 160 Hours: Yes
Contribution to Project:
Amy Burgin work on nitrogen gas fluxes in Hubbard Brook soils, funded by a combination of LTER and other NSF funds.

Graduate Student

Name: Christenson, Lynn

Worked for more than 160 Hours: Yes

Contribution to Project:

Ph.D. student at SUNY-ESF with Groffman and Mitchell studying moose and microbiology.

Name: Kulkarni, Madhura

Worked for more than 160 Hours: Yes

Contribution to Project:

PhD student at Cornell University (with Groffman) studying denitrification.

Name: Cho, Youngil

Worked for more than 160 Hours: Yes

Contribution to Project:

Youngil Cho is a Ph.D student with Johnson in Department of Civil Engineering at Syracuse University. He is evaluating the response of soil, soil solutions and streamwater to the wollastonite treatment.

Name: Fashu-Kanu, Samuel

Worked for more than 160 Hours: Yes

Contribution to Project:

Samuel Fashu-Kanu is a Ph.D student with Driscoll in Dept. of Civil Engineering at Syracuse University. He is evaluating soil solution response to soil freezing events.

Name: Naples, Brendan

Worked for more than 160 Hours: Yes

Contribution to Project:

Naples is a MS student at Appalachian State University. He is characterizing the soil fungal response to variations in local nutrient availability in several mature (70 year-old) and young (30 year-old) hardwood forest stands. He has completed an experiment in which soils amended with nitrogen, phosphorus, or calcium were incubated for one growing season to allow ingrowth of roots and fungi. He is now analyzing the fungal communities using a terminal restriction fragment length polymorphism (TRFLP) approach with the ITS region of the fungal rDNA genes.

Name: Littell, Aaron

Worked for more than 160 Hours: Yes

Contribution to Project:

Littell is a MS student at Appalachian State University. His thesis project tests patterns of fungal colonization and community development on decomposing fine roots. He trenched forest plots in 2003 to kill fine roots and has used TRFLP to analyze the fungal communities on these roots through summer 2005. Aaron is now writing his thesis.

Name: Dasch, Amanda

Worked for more than 160 Hours: Yes

Contribution to Project:

PhD candidate at University of Michigan, working with Blum; BA from Amherst College. PhD research on the uptake of alkaline earth elements by trees and their response to Ca fertilization at Hubbard Brook.

Name: Nezat, Carmen

Worked for more than 160 Hours: Yes

Contribution to Project:

Research assistant and PhD candidate at University of Michigan with Blum; BA from Univ of Lousiana. PhD research on the interaction between mycorrhizae and mineral weathering in soils at Hubbard Brook.

Name: Masters, Mike

Worked for more than 160 Hours: Yes

Contribution to Project:
Graduate research assistant, MS program in Plant Biology at University of Illinois with Fitzhugh

Name: Burke, Joshua

Worked for more than 160 Hours: Yes

Contribution to Project:
Joshua Burke is a Master's student at University of Illinois working on the relationship between soil chemistry and root chemistry in the Hubbard Brook Valley.

Name: Keller, Katy

Worked for more than 160 Hours: Yes

Contribution to Project:
Katy Keller worked on this project as a research assistant, but not as a part of her dissertation research.

Name: Miles, Gretchen

Worked for more than 160 Hours: Yes

Contribution to Project:
M.S. student at SUNY-ESF with Mitchell studying biogeochemistry on sulfur using sulfate isotopes.

Name: Solmonoff, Natalie

Worked for more than 160 Hours: Yes

Contribution to Project:
Natalie is an PhD student and crew leader working with John Battles at UC Berkeley. She has been researching the spatial and temporal changes in forest composition and biomass in Hubbard Brook Valley. This summer she started collecting data for a PhD dissertation, which will in part quantify neighborhood dynamics in Hubbard Brook Valley.

Name: Biasioli, Traynor

Worked for more than 160 Hours: Yes

Contribution to Project:
Tray was primarily responsible for banding male and female Black-throated Blue Warbler for the long-term demographic study.

Name: Kang, Phil-Goo

Worked for more than 160 Hours: Yes

Contribution to Project:
Mr. Kang began work in Fall 2007 working on aspects of sulfur biogeochemistry at Hubbard Brook. Mr. Kang is from Korea.

Name: Pourmokhtarian, Afshin

Worked for more than 160 Hours: Yes

Contribution to Project:
Afshin Pourmokhtarian is a Ph.D. student with Charles Driscoll in the Department of Civil and Environmental Engineering at Syracuse University. He is working on climate change effects on soil and stream chemistry.

Name: Wang, Liang

Worked for more than 160 Hours: Yes

Contribution to Project:
Liang Wang is a M.S. student with Charles Driscoll in the Department of Civil and Environmental Engineering at Syracuse University. He is evaluating soil and stream response to air pollution controls.

Name: Yandik, William

Worked for more than 160 Hours: Yes

Contribution to Project:
Mr. Yandik was a MA student at Brown University with Steve Hamburg. Mr. Yandik studyied the effects of land use history and climate change on bird populations in Grafton County. Yandik completed his degree in 2009.

Name: Riechel, Celia

Worked for more than 160 Hours: Yes

Contribution to Project:

Ms. Riechel was a MA student at Brown University with Steve Hamburg. Ms. Riechel studyied the role of land owner demography in determining land fragmentation in Grafton County. Riechel completed her degree in 2009.

Name: Stange, Erik

Worked for more than 160 Hours: Yes

Contribution to Project:

Erik Stange is a Ph.D. at Wellesley College working on the studies of Lepidoptera population dynamics.

Name: Werner, Samuel

Worked for more than 160 Hours: Yes

Contribution to Project:

Samuel Werner is a M.S. student with Charles Driscoll in the Department of Civil and Environmental Engineering at Syracuse University. He is working on soil-stream atmosphere dynamics.

Name: Fuss, Colin

Worked for more than 160 Hours: Yes

Contribution to Project:

Colin Fuss is studying the long term soil solution and stream chemistry patterns at Syracuse University (2009).

Name: Minick, Kevan

Worked for more than 160 Hours: Yes

Contribution to Project:

Kevan Minick is a graduate student at Miami University studying soil microbial process responses to nutrient availability.

Name: Engelman, Heather

Worked for more than 160 Hours: Yes

Contribution to Project:

Heather is a PhD student in the Department of Forest and Natural Resources at SUNY ESF. She provides administrative support for Ruth Yanai and her students.

Name: Bae, Kikang

Worked for more than 160 Hours: Yes

Contribution to Project:

Kikang is a PhD student in the Department of Forest and Natural Resources at SUNY ESF. She is measuring soil respiration and will be estimating total belowground carbon allocation. She also assisted in collecting tree inventory data.

Name: Quintero, Braulio

Worked for more than 160 Hours: No

Contribution to Project:

Braulio is a PhD student in the Department of Forest and Natural Resources at SUNY ESF. He is studying nutrient retranslocation by comparing summer foliage to fall leaf litter. He also assisted in collecting tree inventory data.

Name: Walter, Matthew

Worked for more than 160 Hours: No

Contribution to Project:

Matthew is a graduate student in the Environmental Studies Department, Antioch University New England. Matthew collected foliage samples.

Name: Fournier, Katherine

Worked for more than 160 Hours: Yes

Contribution to Project:

Studying effects of moose herbivory on understory vegetation and bird populations. Masters of Science, in progress. The Rubenstein School of Environment and Natural Resources, University of Vermont, Burlington, VT.

Name: Frey, Sarah

Worked for more than 160 Hours: Yes

Contribution to Project:

Studying effects of climate, vegetation and conspecifics on the landscape pattern and dynamics of forest birds. Ph.D. Dissertation, in progress. Oregon State University, Corvallis, OR.

Name: Griffith, Benjamin

Worked for more than 160 Hours: Yes

Contribution to Project:

Studying the effects of habitat structure, elevation, climate, and presence of congeners on the distribution Red-eyed and Blue-headed vireos. Masters of Science degree, in progress. The Rubenstein School of Environment and Natural Resources, University of Vermont, Burlington, VT.

Name: Kaiser, Sara

Worked for more than 160 Hours: Yes

Contribution to Project:

Studying trade-offs in male reproductive behaviors: examination of their regulatory mechanism and fitness consequences in response to experimentally manipulated food availability in black-throated blue warblers. Ph.D. Dissertation, in progress. Cornell Univesity, Ithaca, NY.

Name: Lany, Nina

Worked for more than 160 Hours: Yes

Contribution to Project:

Studying biotic and abiotic drivers of Lepidoptera biomass across a climate gradient. Ph.D. Dissertation, in progress, Biological Sciences, Dartmouth College, Hanover, NH.

Undergraduate Student

Name: Sargent, Shavonne

Worked for more than 160 Hours: Yes

Contribution to Project:

Shavonne returned to Hubbard Brook as a field technician working with Tim Fahey at Cornell. She resuveyed Valley plots, mapped trees in the demography plot, collected soil samples and tagged trees in W1. She also helped enter data into a database.

Name: Minick, Kevan

Worked for more than 160 Hours: Yes

Contribution to Project:

Minick is an undergraduate student in the Biology Department at Appalachian State Univeristy. He is developing a sequence database of the ITS region of fungal rDNA genes, needed for our work on soil and fine root fungal communities. He has created clone libraries from soil and fine root DNA extracts and prepared representative clones for sequencing. He has also carried out restriction fragment length polymorphism analyses for our fungal fruitbody collection and is using these to match known fruitbodies with sequences from our database of fungal DNA.

Name: Lide, William

Worked for more than 160 Hours: Yes

Contribution to Project:

Lide is an undergraduate student in the Biology Department at Appalachian State University. He is testing root length and enzyme activity (phosphatases, lignin oxidases) responses to variations in local nutrient availability, as part of the ingrowth experiment carried out by Brendan Naples.

Name: Kies, Antonietta

Worked for more than 160 Hours: Yes

Contribution to Project:

Undergraduate employee assisting with management of environmental and ecological data and distribution via the Hubbard Brook web site.

Name: Nathan, Mayda

Worked for more than 160 Hours: Yes

Contribution to Project:

Mayda Nathan served as a research assistant at Wellesly College and assisted on the studies of Lepidoptera population dynamics.

Name: Eby-Bosler, Devin

Worked for more than 160 Hours: Yes

Contribution to Project:

Devin worked with Rodenhouse at Wellesley College. He conducted point counts of birds and when the point counts were completed, he assisted with the survey of beech bark disease.

Name: Eby-Bosler, Justin

Worked for more than 160 Hours: Yes

Contribution to Project:

Justin worked with Rodenhouse at Wellesley College. He conducted point counts of birds and when the point counts were completed, he assisted with the survey of beech bark disease.

Name: Griffith, Benjamin

Worked for more than 160 Hours: Yes

Contribution to Project:

Benjamin conducted point-counts of birds for half of the period of employment. When the point counts were completed, he assisted with the survey of beech bark disease.

Name: Cosentino, Brad

Worked for more than 160 Hours: Yes

Contribution to Project:

Research Support specialist with Likens at IES; worked on salamanders in the HBEF.

Name: Green, Brian

Worked for more than 160 Hours: Yes

Contribution to Project:

Research Support specialist with Likens at IES also worked on salamanders in the HBEF.

Name: Collins, Andrew

Worked for more than 160 Hours: Yes

Contribution to Project:

Collins worked with Battles at UC Berkley; as field technician revisited 203 plots and collected data pertaining to tree growth, species composition, mortality and recruitment.

Name: Manion, Caitlin

Worked for more than 160 Hours: Yes

Contribution to Project:

Caitlin Manion worked as field technician with Battles at UC Berkeley and revisited 203 plots and collected data pertaining to tree growth, species composition, mortality and recruitment.

Name: Manion, Meghan

Worked for more than 160 Hours: Yes

Contribution to Project:

Meghan Manion, BS student at Cornell University: as field technician at UC Berkeley, revisited 203 plots and collected data pertaining to tree growth, species composition, mortality and recruitment.

Name: Serlen, Rachel

Worked for more than 160 Hours: Yes

Contribution to Project:

Serlen worked with Battles at UC-Berkley as field technician and revisited 203 plots and collected data pertaining to tree growth, species composition, mortality and recruitment.

Name: Yee, Suk-Ann

Worked for more than 160 Hours: Yes

Contribution to Project:

Yee worked as a field technician with Battles at UC Berkely; revisited 203 plots and collected data pertaining to tree growth, species composition, mortality and recruitment.

Name: DeJaegher, Lewis

Worked for more than 160 Hours: Yes

Contribution to Project:

Undergraduate research assistant, BS program in Integrative Biology at University of Illinois with Fitzhugh.

Name: Steinweg, Megan

Worked for more than 160 Hours: Yes

Contribution to Project:

Steinweg received her undergraduate degree from the Biology Department at Appalachian State University in May, 2005. She quantified the effects of soil freezing on soil aggregate size distributions and particulate organic matter for her undergraduate honor's thesis.

Name: Worsham, Sara

Worked for more than 160 Hours: Yes

Contribution to Project:

Sara is working on the project for a senior honors thesis.

Name: Fahey, Cathy

Worked for more than 160 Hours: Yes

Contribution to Project:

Cathy Fahey worked as a field technician with Tim Fahey at Cornell. She surveyed Valley plots, mapped trees in the demography plot, collected soil samples and tagged trees in W1. She also helped enter the Valley data into a database.

Name: Johnson, Sam

Worked for more than 160 Hours: Yes

Contribution to Project:

Sam Johnson worked as a field technician with John battles at Berkeley. He led the W1 tree tagged inventory project and participated in the Valley plot resurveys, mapping project and soil sampling of W1. He also helped enter the W1 data into a database.

Name: Kaczowsky, Debra

Worked for more than 160 Hours: Yes

Contribution to Project:

Debra worked as a field technician with Tom Siccama at Yale. She resurveyed Valley plots, mapped trees in the demography plot, collected soil samples and tagged trees in W1. She helped enter the soil and mapping data into a database.

Name: Kelsen, Sarah

Worked for more than 160 Hours: Yes

Contribution to Project:

Sarah was a Binghamton University undergraduate student (now at SUNY-ESF); she worked as a field technician with Chris Johnson (Syracuse University) at Hubbard Brook in Summer 2006. She resurveyed Valley plots, mapped trees in the demography plot, collected soil samples and tagged trees in W1. In addition, she helped enter the Valley tree data into a database.

Name: Laua, Tami

Worked for more than 160 Hours: Yes

Contribution to Project:

Tami worked as a field technician with John Battles at Berkeley. She resurveyed Valley plots, mapped trees in the demography plot, collected soil samples and tagged trees in W1. She also helped enter W1 data into datbase.

Name: Lavalee, Jocelyn Marie

Worked for more than 160 Hours: Yes

Contribution to Project:

Jocelyn worked as a field technician with Tim Fahey at Cornell. She resurveyed Valley plots, mapped trees in the demography plot, collected soil samples and tagged trees in W1. She also helped enter Valley data into a database.

Name: Danyluk, Casey

Worked for more than 160 Hours: Yes

Contribution to Project:

Casey assisted Ph.D. candidate, Erik Strange, on the studies of Lepidoptera population dynamics.

Name: Harvey, Michael

Worked for more than 160 Hours: Yes

Contribution to Project:

Mike conducted point-counts of birds.

Name: Hausladen, Debra

Worked for more than 160 Hours: Yes

Contribution to Project:

Debra weighed malaise trap samples, entered those data, and organized the malaise trap samples and database.

Name: Bradford, Jonelle

Worked for more than 160 Hours: Yes

Contribution to Project:

Jonelle sorted litter samples to identify and count seeds of mast-bearing trees.

Name: Kelley, Elizabeth

Worked for more than 160 Hours: Yes

Contribution to Project:

Elizabeth assisted with data entry and verification.

Name: Ciurej, Katherine

Worked for more than 160 Hours: Yes

Contribution to Project:

Katherine assisted with sorting litter samples, weighing Malaise trap samples and exmained nests for evidence of botfly ectoparasites.

Name: Wallach, Leah

Worked for more than 160 Hours: Yes

Contribution to Project:

Wallach is an undergraduate student in the Biology Department at Appalachian State University studying soil microbial responses to calcium and phosphorus.

Name: Meyer, Natacha

Worked for more than 160 Hours: Yes

Contribution to Project:

Natacha is a Brown University student who monitored snail populations on W6 and W1.

Name: Feeser, Russell

Worked for more than 160 Hours: Yes

Contribution to Project:

Russell is a Rochester Institute of Technology student who worked on black locust influence on forest structure.

Name: Austin, Kemen

Worked for more than 160 Hours: Yes

Contribution to Project:

Kemen is a Brown University student who examined soil C changes associated with home construction around Hubbard Brook (senior thesis project).

Name: Fuller, Christopher

Worked for more than 160 Hours: Yes

Contribution to Project:

Christopher is a Brown University student who worked on soil carbon changes following abandonment of agricultural lands -- a 25 y retrospective.

Name: Tang, Christina

Worked for more than 160 Hours: Yes

Contribution to Project:

Christina is a Brown University student who assisted with sample processing in the lab.

Name: Anderson, Christa

Worked for more than 160 Hours: Yes

Contribution to Project:

Christa worked on the field crew of PI Thomas Siccama (Yale)in the summer of 2007. Christa graduated from Yale in May 2007 and will return for her Master's in 2008.

Name: O'Neill, William

Worked for more than 160 Hours: Yes

Contribution to Project:

Bill is an undergraduate student in the Environmental and Forest Biology Department at SUNY-ESF. He has been sorting and verifying samples collected by Farrah Fatemi.

Name: Deull, David

Worked for more than 160 Hours: Yes

Contribution to Project:

David served as a summer assistant to Will Yandik, graduate student at Brown University.

Name: Burkhardt, Jennifer

Worked for more than 160 Hours: Yes

Contribution to Project:

Jennifer assisted Ph.D. candidate Erik Stange on the studies of Lepidoptera population dynamics during summer 2007.

Name: Sheridan, Caroline

Worked for more than 160 Hours: Yes

Contribution to Project:

Caroline, under the direction of PI, Nicholas Rodenhouse at Wellesley College, sorted litter samples to identify and count seeds of mast-bearing trees during the academic year.

Name: Wyman, Katherine

Worked for more than 160 Hours: Yes

Contribution to Project:

Katherine worked at Wellesley College under the direction of PI, Nicholas Rodenhouse. She weighed malaise trap samples and entered those data; sorted litter samples to identify and count seeds of mast-bearing trees and assisted with data entry and verification during the academic year.

Name: Schneider, Rachel

Worked for more than 160 Hours: Yes

Contribution to Project:

Rachel worked with PI, N. Rodenhouse, at Wellesley College assisting with data entry and verification during the academic year.

Name: Foley, Catherine

Worked for more than 160 Hours: Yes

Contribution to Project:

Catherine worked with PI, N. Rodenhouse, at Wellesley College weighing malaise trap samples; assisted with data entry and verification during the academic year.

Name: Baumgartner, Alice

Worked for more than 160 Hours: Yes

Contribution to Project:

Alice was hired as a field technician through Tom Siccama at Yale University. She resurveyed the Valley-wide tagged-tree inventory, mapped and cored trees in the demography plot, conducted a moose density survey and tagged trees for the fertilization 'Shoestring' project. In addition, she entered data into a database and completed quality control checks on the entered data.

Name: Rudstam, Per

Worked for more than 160 Hours: Yes

Contribution to Project:

Per Rudstam was hired through Tim Fahey at Cornell University. He helped with the resurvey of the Valley plots. He mapped trees in the demography plot and entered the data into a database. He also completed quality control checks on the entered data.

Name: Tane, Zachary

Worked for more than 160 Hours: Yes

Contribution to Project:

Zachary worked as a field technician for John Battles (UC Berkeley). He resurveyed Valley plots, mapped and cored trees in the demography plot, conducted a moose density survey and tagged trees for the fertilization 'Shoestrong' project. In addition, he entered data into a database and performed quality control checks.

Name: Shafer, Devaja

Worked for more than 160 Hours: Yes

Contribution to Project:

Devaja Shafer sorted litter samples to identify and count seeds of mast-bearing trees, weighed malaise trap samples; assisted with data entry and verification during the academic year.

Name: Mallama, Celeste

Worked for more than 160 Hours: Yes

Contribution to Project:

Celeste Mallama began pilot study of the spatial distribution and abundance of vespid wasps across the elevation gradient within the HBEF.

Name: Stenquist, Asha

Worked for more than 160 Hours: Yes

Contribution to Project:

Asha Stenquist began a pilot study on the use of digitally recorded song as a method of surveying forest bird abundance.

Name: Wright, Charles

Worked for more than 160 Hours: Yes

Contribution to Project:

Mr. Wright conducted point counts of birds and assisted with vegetation sampling during summer 2007.

Name: Syrek, Jonathon

Worked for more than 160 Hours: Yes

Contribution to Project:

Jonathon Syrek, an undergraduate at University of Michigan, works as a lab assistant on sample preparation and chemical analysis.

Name: Negrey, Matt

Worked for more than 160 Hours: Yes

Contribution to Project:

Matt Negrey is an undergraduate at Miami University studying soil enzyme activity.

Name: Reidy, Matt

Worked for more than 160 Hours: Yes

Contribution to Project:

Matt Reidy is an undergraduate at Miami University studying fungal decomposer communities in leaf litter.

Name: Zienkowski, Elise

Worked for more than 160 Hours: Yes

Contribution to Project:

Elise Zienkowski is an undergraduate at Miami University studying fine root community responses to soil nutrients.

Name: Coyne, Brittany

Worked for more than 160 Hours: Yes

Contribution to Project:

Brittany Coyne is an undergraduate at Miami University studying fine root community respones to soil nutrients.

Name: Bailin, Grady

Worked for more than 160 Hours: Yes

Contribution to Project:

Grady sorted litter samples to identify and count seeds of mast-bearing trees, weighed malaise trap samples; assisted with data entry and verification

Technician, Programmer

Name: Martel, Lisa

Worked for more than 160 Hours: Yes

Contribution to Project:

Martel: technician based at Hubbard Brook in summer, IES in winter. Does field and laboratory analysis associated with long-term monitoring of microbial biomass and activity.

Name: Lewis, David

Worked for more than 160 Hours: Yes

Contribution to Project:

Lewis: technician based at Institute of Ecosystem Studies. Does laboratory analysis associated with long-term monitoring of microbial biomass and activity, specializing in gas chromatography.

Name: Koppers, Mary Margaret

Worked for more than 160 Hours: Yes

Contribution to Project:

Mary Margaret Koppers is a technician examining soil chemistry at Syracuse University.

Name: Fuss, Colin

Worked for more than 160 Hours: Yes

Contribution to Project:

Colin Fuss is studying long term soil solution and stream chemistry patterns at Syracuse University.

Name: Montesdeoca, Mario

Worked for more than 160 Hours: Yes

Contribution to Project:

Mario Montesdeoca supervises laboratory activities at Syracuse University, Department of Civil Engineering.

Name: Day, Michelle

Worked for more than 160 Hours: Yes

Contribution to Project:

Research technician at University of New Hampshire working on remote sensing and carbon cycling.

Name: Jessen, Brita

Worked for more than 160 Hours: Yes

Contribution to Project:

Brita (working with Rodenhouse at Wellesley College) weighed malaise trap samples, entered those data, and organized the malaise trap samples and database for the period late 1970s to the present.

Name: Webster, Raymond

Worked for more than 160 Hours: Yes

Contribution to Project:

Ray (working with Rodenhouse at Wellesley College)lead the crew of undergraduates conducting the valley wide bird census and the beech bark disease survey.

Name: Simon, Katherine

Worked for more than 160 Hours: Yes

Contribution to Project:

Kate (working with Rodenhouse at Wellesley College) lead the crew that carried out demographic studies of Black-throated Blue Warbler on the Ridge plot.

Name: Andrikova, Irina

Worked for more than 160 Hours: Yes

Contribution to Project:

Laboratory technician responsible for soil and vegetation extractions and digestions, analysis of soil, vegetation and streamwater for major and trace elements by ICP-OES, and Sr isotope separations and analysis by TIMS.

Name: Mellen, Brent

Worked for more than 160 Hours: Yes

Contribution to Project:

Brent Mellen is a technician at Institute of Ecosystem Studies responsible for the field sampling and chenmical analysis of soils associated with the Hubbard Brook 'valley-wide' watershed analysis project at Hubbard Brook. He has also been managing the dataset on valley-wide stream chemistry and watershed characteristics.

Name: Juice, Stephanie

Worked for more than 160 Hours: Yes

Contribution to Project:

Stephen worked on long-term analysis of microbial biomass and activity and how this responds to calcium additions.

Name: Ward, Margaret

Worked for more than 160 Hours: Yes

Contribution to Project:

Margaret Ward is a technician at IES who is working on the beech bark disease project.

Name: Hoskinson, Sarah

Worked for more than 160 Hours: Yes

Contribution to Project:

Sarah Hoskinson is a temporary project assistant at IES who worked in the summer and fall of 2006 on the beech bark disease project.

Name: Pudner, Rebecca

Worked for more than 160 Hours: Yes

Contribution to Project:

Rebecca Pudner is a project assistant at University of Kentucky who worked during the summer of 2006 on the beech bark disease project.

Name: Prescott, Howard

Worked for more than 160 Hours: Yes

Contribution to Project:

Howard worked as a field technician with Tim Fahey at Cornell. He resurveyed Valley plots, mapped trees in the demography plot, collected soil samples and tagged trees in W1. He also performed quality control checks on data entered into databases.

Name: Hadley, Adam

Worked for more than 160 Hours: Yes

Contribution to Project:

Adam conducted point counts of birds.

Name: Eaton, Derek

Worked for more than 160 Hours: Yes

Contribution to Project:
Derek Eaton collected foliage and litter samples.

Name: Vadeboncoeur, Matthew

Worked for more than 160 Hours: Yes

Contribution to Project:
Matthew is employed through Brown University, under the direction of PI Steven Hamburg, to oversee LAI, snail and soil C field work and data analysis.

Name: Oakley, Clinton

Worked for more than 160 Hours: Yes

Contribution to Project:
Clinton is employed through Brown University, under the direction of PI Steven Hamburg, to process soil samples in the laboratory.

Name: Buso, Donald

Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Minicucci, Brenda

Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Starr, Emily

Worked for more than 160 Hours: Yes

Contribution to Project:
Under the direction of PI, Peter Groffman, Emily did field sampling at HBR, lab work at both HBR and IES.

Name: Schmidt, Robin

Worked for more than 160 Hours: Yes

Contribution to Project:
Under the direction of PI, Peter Groffman, Robin did field sampling at HBR and lab work at both HBR and IES.

Name: Brennan, Peter

Worked for more than 160 Hours: Yes

Contribution to Project:
Mr. Brennan worked as a research assistant at Brown University (part-time).

Name: Wiedman, Toni

Worked for more than 160 Hours: Yes

Contribution to Project:
Under the direction of PI, N. Rodenhouse (Wellesley College), Toni conducted point counts of birds and assisted with vegetation sampling during summer 2007.

Name: Smith, Megan

Worked for more than 160 Hours: Yes

Contribution to Project:
Under the direction of PI, N. Rodenhouse (Wellesley College), Megan conducted point counts of birds and assisted with vegetation sampling during summer 2007.

Name: Whidden, Erin

Worked for more than 160 Hours: Yes

Contribution to Project:
Under the direction of PI, N. Rodenhouse (Wellesley College), Erin conducted point counts of birds and assisted with vegetation sampling during summer 2007.

Name: Wilson, Geoff
Worked for more than 160 Hours: Yes
Contribution to Project:
Geoff Wilson coordinated the undergraduate research program, which included undergraduates supported by an REU site grant administered through Plymouth State University, as well as undergraduates supported by the REU supplements on the LTER grant and undergraduates with Hubbard Brook Consortium support.

Name: McGarry, Mary Ann
Worked for more than 160 Hours: Yes
Contribution to Project:
Mary Ann McGarry is the Education Director for the Hubbard Brook Research Foundation. She worked on school and teacher outreach and curriculum development. Also Director of Hubbard Brook's Environmental Literacy Program (ELP).

Name: Worsham, Sara
Worked for more than 160 Hours: Yes
Contribution to Project:
Sara Worsham finished as an undergraduate thesis student and became a technician on the project conducting geochemical analyses.

Name: Ratliff, Tera
Worked for more than 160 Hours: Yes
Contribution to Project:
Ratliff is a graduate of Miami University currently working as a technician on projects studying nutrient limitation of microbial activity, fine root responses to nutrients, and soil fungal communities.

Name: Brinkley, Jordan
Worked for more than 160 Hours: Yes
Contribution to Project:
Sampling and analysis of soil solution and stream samples.

Name: Bailey, Stephanie
Worked for more than 160 Hours: Yes
Contribution to Project:
Stephanie Bailey is a technician at Miami University working on studies of nutrient limitation of microbial activity and soil fungal communities.

Name: O'Neill, William
Worked for more than 160 Hours: Yes
Contribution to Project:
Bill is a graduate of SUNY ESF currently working there as a Research Analyst preparing and processing samples for analysis.

Name: Lombard, Issac
Worked for more than 160 Hours: No
Contribution to Project:
Issac collected foliage samples.

Name: Adams, Duncan
Worked for more than 160 Hours: Yes
Contribution to Project:
Duncan assisted with collections of mast samples.

Name: Marczi, Kaitlyn
Worked for more than 160 Hours: Yes

Contribution to Project:
Kaitlyn conducted point-counts of birds and assisted with vegetation sampling during summer 2007.

Name: Trutwin, Justin
Worked for more than 160 Hours: Yes
Contribution to Project:
Justin conducted point-counts of birds and assisted with vegetation sampling during summer 2007.

Other Participant

Name: Kaczowski, Debra
Worked for more than 160 Hours: Yes
Contribution to Project:
Debra is a May 2006 graduate from Mass. College of Liberal Arts in Williamstown, Massachusetts. Her work was on the Hubbard Brook field crew which involved several projects specifically related to the work of Thomas Siccama (Yale) -- mainly the collection and preliminary processing (drying) of the quantitative forest floor 5-year sampling from W1- the Ca addition watershed and secondly the measuring and tagging of the ~8000 trees on W1 as part of the 5-year reinventory of the forest.

Name: Likens, Phyllis
Worked for more than 160 Hours: Yes
Contribution to Project:
Phyllis provides administrative support for the programs of Dr. Gene Likens (co-PI) at Institute of Ecosystem Studies.

Name: Wu, Wei
Worked for more than 160 Hours: Yes
Contribution to Project:
Wei Wu is a Research Associate working PI Driscoll at Syracuse University applying the model PnET-BGC to investigate the response of forests and surface waters to changes in air pollution.

Name: Gontarz, Gerald
Worked for more than 160 Hours: Yes
Contribution to Project:
Gerald worked on the Mirror Lake website for elementary and junior high school students.

Name: Shaller, Mirjan
Worked for more than 160 Hours: Yes
Contribution to Project:
Dr. Mirjam Shaller (University of Michigan) worked in soil chemistry data interpretation at no expense to the project.

Research Experience for Undergraduates

Name: Mayack, Christopher
Worked for more than 160 Hours: Yes
Contribution to Project:
Mayack was an IES REU student, who worked on fish parasites in Mirror Lake.

Years of schooling completed: Freshman
Home Institution: Same as Research Site
Home Institution if Other:
Home Institution Highest Degree Granted(in fields supported by NSF): Bachelor's Degree
Fiscal year(s) REU Participant supported: 2005
REU Funding: REU site award

Name: Bouchard, Krystle
Worked for more than 160 Hours: Yes
Contribution to Project:

Bouchard was an IES REU student, who worked on phytoplankton productivity in Mirror Lake.

Years of schooling completed: Freshman

Home Institution: Same as Research Site

Home Institution if Other:

Home Institution Highest Degree Granted(in fields supported by NSF): Bachelor's Degree

Fiscal year(s) REU Participant supported: 2005

REU Funding: REU site award

Name: Dorovskoy, Pavel

Worked for more than 160 Hours: Yes

Contribution to Project:

Pavel Dorovsky is an undergraduate student at the University of New Hampshire majoring in computer science. Pavel did research on wireless sensor networks and helped establish the current network at Hubbard Brook. He also worked on a web interface for displaying real-time data.

Years of schooling completed: Sophomore

Home Institution: Same as Research Site

Home Institution if Other: University of New Hampshire

Home Institution Highest Degree Granted(in fields supported by NSF): Bachelor's Degree

Fiscal year(s) REU Participant supported: 2006

REU Funding: REU supplement

Name: Wollenburg, Stephan

Worked for more than 160 Hours: Yes

Contribution to Project:

Stephan is a Brown University student (hired as an REU through Brown, supplement through SUNY ESF) who helped monitor changes in LAI.

Years of schooling completed: Sophomore

Home Institution: Same as Research Site

Home Institution if Other: Brown University

Home Institution Highest Degree Granted(in fields supported by NSF): Bachelor's Degree

Fiscal year(s) REU Participant supported: 2006

REU Funding: REU supplement

Name: Berwick, Rebecca

Worked for more than 160 Hours: Yes

Contribution to Project:

Rebecca is a Brown University student (hired as an REU through Cornell University supplement)who monitored LAI changes.

Years of schooling completed: Sophomore

Home Institution: Same as Research Site

Home Institution if Other: Brown University

Home Institution Highest Degree Granted(in fields supported by NSF): Bachelor's Degree

Fiscal year(s) REU Participant supported: 2006

REU Funding: REU supplement

Name: Powell, Sylvia

Worked for more than 160 Hours: Yes

Contribution to Project:

Sylvia worked on the stream salamander project in the Hubbard Brook Experimental Forest.

Years of schooling completed: Freshman

Home Institution: Other than Research Site

Home Institution if Other: Institute of Ecosystem Studies

Home Institution Highest Degree Granted(in fields supported by NSF): Bachelor's Degree

Fiscal year(s) REU Participant supported: 2007

REU Funding: REU supplement

Name: Little, Neith

Worked for more than 160 Hours: Yes

Contribution to Project:

Neith worked on the stream salamander project in the Hubbard Brook Expermental Forest.

Years of schooling completed: Freshman

Home Institution: Other than Research Site

Home Institution if Other: Institute of Ecosystem Studies

Home Institution Highest Degree Granted(in fields supported by NSF): Bachelor's Degree

Fiscal year(s) REU Participant supported: 2007

REU Funding: REU supplement

Name: Lide, William

Worked for more than 160 Hours: Yes

Contribution to Project:

Under the direction of PI, Melany Fisk (Appalachian State University), William identified fine roots of trees based on DNA sequence information to contribute to a project comparing root depth distributions of different tree species.

Years of schooling completed: Junior

Home Institution: Same as Research Site

Home Institution if Other:

Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree

Fiscal year(s) REU Participant supported: 2007

REU Funding: REU supplement

Name: Hunter, Erin

Worked for more than 160 Hours: Yes

Contribution to Project:

Erin Hunter is an undergraduate in Environmental Engineering in the Department of Civil and Environmental Engineering at Syracuse University. She is evaluating throughfall and stream chemistry of watershed calcium treatment.

Years of schooling completed: Junior

Home Institution: Same as Research Site

Home Institution if Other: Syracuse University

Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree

Fiscal year(s) REU Participant supported: 2007

REU Funding: REU supplement

Name: Metcalf, Cassidy

Worked for more than 160 Hours: Yes

Contribution to Project:

Cassidy is a summer 2007 REU participant -- worked on characterizing vegetation among differing land-use histories in Grafton County.

Years of schooling completed: Junior

Home Institution: Same as Research Site

Home Institution if Other:

Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree

Fiscal year(s) REU Participant supported: 2007

REU Funding: REU supplement

Name: Wheat, Ian

Worked for more than 160 Hours: Yes

Contribution to Project:

Ian was a participant in the Hubbard Brook Undergraduate Research Program and worked with John Battles and Tim Fahey on Beech Bark disease effects on Beech sprout and seed reproduction. He also partner with the Society for the Protection of New Hampshire Forests, a non-profit, to do an outreach project on carbon sequestration.

Years of schooling completed: Junior

Home Institution: Other than Research Site

Home Institution if Other: Dartmouth College

Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree

Fiscal year(s) REU Participant supported: 2008

REU Funding: REU supplement

Name: Santangelo, Sharon

Worked for more than 160 Hours: Yes

Contribution to Project:

Santangelo is an undergraduate in the Microbiology Department at Miami University. She is studying soil nutrient availability and limitations to soil microbial activity in young and old forests.

Years of schooling completed: Sophomore

Home Institution: Other than Research Site

Home Institution if Other: Miami University

Home Institution Highest Degree Granted(in fields supported by NSF): Bachelor's Degree

Fiscal year(s) REU Participant supported: 2008

REU Funding: REU supplement

Name: Refsland, Tyler

Worked for more than 160 Hours: Yes

Contribution to Project:

Tyler was a participant in the Hubbard Brook Undergraduate Research Program and worked with Ruth Yanai and Tim Fahey investigating the relationships between site fertility and root-shoot ratios. He also partnered with the Margaret and H.A. Rey Center designing a data collection system to be used by high school students investigating forest phenology.

Years of schooling completed: Junior

Home Institution: Other than Research Site

Home Institution if Other: St. Olaf College

Home Institution Highest Degree Granted(in fields supported by NSF): Bachelor's Degree

Fiscal year(s) REU Participant supported: 2009

REU Funding: REU supplement

Name: Gilbert, Kadeem

Worked for more than 160 Hours: Yes

Contribution to Project:

Kadeem was a participant in the Hubbard Brook Undergraduate Research Program and worked with Tim Fahey and John Battles investigating the relationships between moose density and vegetation community composition. He also partnered with the New Hampshire Fish and Game Department designing recommendations for a local elementary school interested in enhancing migratory bird habitat at their school.

Years of schooling completed: Freshman

Home Institution: Other than Research Site

Home Institution if Other: Cornell University

Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree

Fiscal year(s) REU Participant supported: 2009

REU Funding: REU supplement

Name: Salvino, Cayce

Worked for more than 160 Hours: Yes

Contribution to Project:

Cayce was a participant in the Hubbard Brook Undergraduate Research Program and worked with Pam Templer and John Campbell. nvestigating the impacts of soil frost on sugar maple trees. She also partnered with the NH Lakes Association creating an educational video informing young audiences of the role they play in the condition of their home watersheds.

Years of schooling completed: Junior

Home Institution: Other than Research Site

Home Institution if Other: Unity College

Home Institution Highest Degree Granted(in fields supported by NSF): Bachelor's Degree

Fiscal year(s) REU Participant supported: 2009

REU Funding: REU supplement

Name: Zimmer, Maggie

Worked for more than 160 Hours: Yes

Contribution to Project:

Maggie was a participant in the Hubbard Brook Undergraduate Research Program and worked with Scott Bailey and Kevin McGuire investigating groundwater-surface water interactions. She also partnered with the Hubbard Brook Research Foundation developing protocols for high school teachers to measure and interpret soil characteristics in the context of acid deposition.

Years of schooling completed: Junior

Home Institution: Other than Research Site

Home Institution if Other: Oberlin College

Home Institution Highest Degree Granted(in fields supported by NSF): Bachelor's Degree

Fiscal year(s) REU Participant supported: 2009

REU Funding: REU supplement

Name: Harvey, Katie

Worked for more than 160 Hours: Yes

Contribution to Project:

Katie was a participant in the Hubbard Brook Undergraduate Research Program and worked with Scott Bailey and Kevin McGuire investigating whether near-stream soil development could be used to define a riparian zone in streams that do not have obvious vegetation changes in riparian areas. She also partnered with the USDA-Forest Service in creating a brochure used to explain the use and advantages of ecological classifications in resource management.

Years of schooling completed: Junior

Home Institution: Other than Research Site

Home Institution if Other: University of Kentucky

Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree

Fiscal year(s) REU Participant supported: 2009

REU Funding: REU supplement

Name: Reid, Audrey

Worked for more than 160 Hours: Yes

Contribution to Project:

Audrey was a participant in the Hubbard Brook Undergraduate Research Program and worked with Charley Driscoll investigating the changes in acidity over time in ponds of the White Mountain region. She also partnered with Plymouth State University's Center for the Environment in creating a blog site which chronicled the summer REU program.

Years of schooling completed: Junior

Home Institution: Other than Research Site

Home Institution if Other: University of Vermont

Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree

Fiscal year(s) REU Participant supported: 2009

REU Funding: REU supplement

Name: Jessop, Jordan

Worked for more than 160 Hours: Yes

Contribution to Project:

Jordan was a participant in the Hubbard Brook Undergraduate Research Program and worked with Charley Driscoll investigating solute chemistry in ponds of the White Mountains. He also partnered with Plymouth State University's Center for the Environment in a project summarizing the work of their graduate students for publication to general audiences (alumni and the press).

Years of schooling completed: Junior

Home Institution: Other than Research Site

Home Institution if Other: University of New Hampshire

Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree

Fiscal year(s) REU Participant supported: 2009

REU Funding: REU supplement

Name: Dorcey, Cord

Worked for more than 160 Hours: Yes

Contribution to Project:

Cord was a participant in the Hubbard Brook Undergraduate Research Program and worked with Peter Marra characterizing stable isotope ratios in the litter-layer arthropod community in an attempt to elucidate food ?web interactions with ground-foraging birds. He also partnered with the NH Lakes Association in creating an educational video which informed young audiences of the role they play in the condition of their home watersheds.

Years of schooling completed: Junior

Home Institution: Other than Research Site

Home Institution if Other: University of California Santa Barbara

Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree

Fiscal year(s) REU Participant supported: 2009

REU Funding: REU supplement

Name: Friedman, Kaitlin

Worked for more than 160 Hours: Yes

Contribution to Project:

Kaitlin was a Cary IES REU student working with Gene E. Likens on a stream salamander project, evaluating variation in headwater stream chemistry and temperature and its effect on salamander abundance and distribution at the Hubbard Brook Experimental Forest.

Years of schooling completed: Junior

Home Institution: Other than Research Site

Home Institution if Other: University of Vermont

Home Institution Highest Degree Granted(in fields supported by NSF): Bachelor's Degree

Fiscal year(s) REU Participant supported: 2008

REU Funding: REU supplement

Organizational Partners

University of California - Berkeley

Institute of Ecosystem Studies

Wellesley College

University of New Hampshire

Appalachian State University

Syracuse University

University of Michigan

Brown University

University of Kentucky

University of Illinois

SUNY Environmental Science & Forestry

Yale University

Hubbard Brook Research Foundation
This 'Friends' group helps fund and run our facilities, outreach and educational programs.

Other Collaborators or Contacts

Dr. Scott Bailey, USDA Forest Service
Dr. Emily Bernhardt, Duke University
Dr. Daniel Conley, National Environmental Research Institute, Roskilde, Denmark
Dr. Tom Winter, US Geological Survey
Dr. Christine Goodale, Cornell University
Dr. Joseph Yavitt, Cornell University
Dr. Clifford Kraft, Cornell University
Dr. Lars Hedin, Princeton University
Dr. Laura Schneider, Rutgers University
Dr. Jamie Shanley, USGS
Dr. Winsor Lowe, University of Montana
Dr. Mary Arthur, University of Kentucky
Dr. Pam Templer, Boston University

Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)
see attached file.

Findings: (See PDF version submitted by PI at the end of the report)
See attached file.

Training and Development:
TRAINING AND DEVELOPMENT 2009: The senior scientists in our project take very seriously the responsibility and opportunity of training and development for junior colleagues, and we take pride in their professional accomplishments and career advancement. We utilize a variety of formal and informal approaches to accomplish this goal. In particular, training and development at Hubbard Brook relies on the active interactions among PIs and senior scientists, junior researchers, post-docs, graduate students and undergraduates and technicians. These interactions are fostered by frequent formal and informal events that encourage both cross-disciplinary discussions and communication and

learning across the academic hierarchy: the HBES Cooperators' Meeting, weekly science nights at our dormitory, Pleasant View Farm (PVF), weekly potluck dinners at PVF, quarterly LTER planning meetings at the Institute of Ecosystem Studies. We believe that the potentially debilitating separation that comes with the distribution of our project among a dozen institutions actually has proven to stimulate a higher level of interaction among all levels of our project because we must actively promote communication and training. In addition, the remoteness of our site from our academic institutions results in the concentration of intellectual activity while scientists are on-site away from their routine obligations.

In 2008-2009, we continued to develop a new initiative in undergraduate research training, a NSF Research Experiences for Undergraduates site project. This program is providing an exceptional opportunity for interaction between senior scientists, junior scientists and students in the HBR LTER. Our REU project fosters a combination of scientific discovery and public outreach, as described below. The active involvement of a dozen senior scientists as well as post-docs, graduate students and technicians in the REU project has been both a boon to student learning and to scientific interaction within the overall LTER program. We hope to continue this training and development enterprise in the indefinite future.

Outreach Activities:

OUTREACH ACTIVITIES-2009: The Hubbard Brook LTER project continues to support an extremely active program of outreach and public education activities, coordinated through the Hubbard Brook Research Foundation (HBRF). Outlets of these activities include: 1) an undergraduate research program emphasizing science outreach by matching students with management agencies and non-profits engaged with the public on ecosystem-related issues, as well as with researchers for a separate independent research project 2) our Environmental Literacy Program (ELP), which is a cooperative effort with the USDA-Forest Service aimed at supporting secondary science teachers through training events and the development of teaching resources, as well as direct student contact with neighboring schools, 3) posting of related educational-support material on our web page (www.hubbardbrook.org), 4) cooperation with other regional groups engaged in secondary education teacher development, 5) presentations of research findings in formats and at forums for general and professional audiences, 6) conducting field trips at the site for visiting schools and the general public, and 7) discussions of research findings with reporters and policymakers.

Undergraduate Research Program: 2009 was the second year of our new undergraduate research program titled 'Investigating and Communicating Change in Ecosystems.' Twelve undergraduates from around the country were paired with Hubbard Brook researchers and developed and conducted independent research projects on topics representing the range of research at the Hubbard Brook LTER. In addition, the students were matched with government management agencies and non-profits engaged in translating ecosystem concepts to general audiences. Students designed and produced projects such as brochures, articles, videos, and web content at the request of their partner organization with the aim of aiding that organization's mission of public engagement. Partners included: The USDA-Forest Service, the New Hampshire Department of Environmental Services, the New Hampshire Fish and Game Department, The New Hampshire Lakes Association, The Margaret and H.A. Rey Center, Plymouth State University's Center for the Environment, and the Hubbard Brook Research Foundation. A description of the program can be found at: www.hubbardbrookreu.org

Environmental Literacy Program (ELP): ELP is a joint project of the HBRF and the USDA Forest Service Northern Research Station to use ecological knowledge to promote informed decision-making for a sustainable future. ELP focuses on middle- and high school teachers and their students through the following three programs:

Science Links teaching guides: The first Science Links teaching guide, Exploring Acid Rain, was completed in 2007. It is available electronically by request and work is underway to make it web-accessible. The second teaching guide, Mysterious Migratory Birds; Here in the Summer, Where in the Winter? is an outgrowth of our collaboration with the Smithsonian Migratory Bird Center and will be completed by December, 2009. Both are supported by teacher workshops, on-going interactions with HBRF staff, who continuously incorporate feedback from teachers who pilot-test lessons incorporated in the guides.

Teacher training events: We continue to hold teacher workshops and to participate in those organized by other partners, either focusing on Acid Rain and the use of Exploring Acid Rain in the classroom, or showcasing the Mystery Migratory Birds teaching guide. Since last year's report, 45 teachers have attended the acid rain workshops and 70 have attended the migratory birds' workshops. In many cases teachers attended both. All events are aimed at middle- and high school teachers.

School partnerships: We are currently actively involved with six schools in the region, in addition to the schools which visit us for tours (described below). Our regional partner schools are: LinWood School (grades 6-12), Campton Elementary (grades 6-8), Plymouth Elementary (grades 6-8), Profile School (6-12), Littleton High School (9-12), and Plymouth Regional High School (9-12). Together these represent the 4 school districts closest to Hubbard Brook.

Other K-12 support activities:
We are a partner with A Forest For Every Classroom, New Hampshire (FFEC). FFEC is a year-long professional development course conducted in collaboration with HBRF, Project Learning Tree, the USDA Forest Service White Mountain National Forest, USDA Forest Service State and Private Forestry, the National Wildlife Federation, and Plymouth State University. Workshops are held at Hubbard Brook facilities and Hubbard Brook staff give presentations and conduct skill-building sessions. Teachers write curriculum units based on the FFEC program as final projects and these are made available for use by other teachers. Additionally, HBRF and USDA Forest Service staff give elementary and secondary school tours of the site upon request.

Presentation of research findings for general and professional audiences:
In addition to tours conducted at Hubbard Brook (described below), scientists and staff have presented research findings to general and professional audiences throughout 2008-9. Organizations included: The New Hampshire Fisheries Council; The New England Forestry Foundation, The New England-St. Lawrence Valley Geography meeting (Nestval), and a group of regional silvaculturists.

The HBEF provides educational tours of the research site on a frequent basis throughout the academic year. Undergraduate partner schools bring at least once class per year to the site and provide the Hubbard Brook staff with syllabi and written statements describing how the site visit is incorporated into the course curriculum. These schools include: Plymouth State University, the University of New Hampshire, Colby-Sawyer College, Boston University, University of Rhode Island, Cornell University; Wellesley College, and Dartmouth College. Secondary school tours are offered to our ELP partner schools (described above) and other schools where our curriculum guides are being used in the classroom.

Another major public education program in the HBR-LTER is Science Links. Together with experts from other institutions, LTER scientists translate scientific information from the HBES and related research projects for policymakers at regional and national levels. In 2009 we continued to work on the fourth major Science Links project, a regional analysis of carbon sources, sinks, and mitigation strategies. In conjunction with colleagues from the BES, HFR and PIE LTER sites, we are comparing the costs and potential for C emission reductions across several regional settings. In addition, organization of the next major Science Links project, which will focus on long-term migratory bird data, was begun in 2009.

An outgrowth of the Science Links program is Hubbard Brook Roundtable, initiated in 2006. The roundtables incorporate a broad range of stakeholders and utilize an ecosystem perspective to identify and discuss threats and opportunities in the Northern Forest Region. A roundtable discussing the formation of wood-fuel cooperatives was held in September of 2009.

Journal Publications

Rhoads, A.G., S.P. Hamburg, T.J. Fahey, T.G. Siccama and R. Kobe., "Comparing direct and indirect methods of assessing canopy structure in a northern hardwood forest.", Can. J. For. Res., p. 584, vol. 34, (2004). Published,

Fahey, T.J., G.L. Tierney, R.D. Fitzhugh and G.F. Wilson. 2005., "Soil Respiration and Soil Carbon Balance in a Northern Hardwood Forest Ecosystem.", Can. J. For. Res., p. 244, vol. 35, (2005). Published,

Fahey, T.J. and J.B. Yavitt., "An in situ Approach for Measuring Root-Associated Respiration and Nitrate Uptake of Forest Trees.", Plant and Soil, p. 125, vol. 272, (2005). Published,

Phillips, R.P. and T.J. Fahey., "Patterns of rhizosphere carbon flux in sugar maple (Acer saccharum) and yellow birch (Betula allegheniensis) saplings.", Global Change Biology, p. 983, vol. 11, (2005). Published,

Campbell, J.L., J.W. Hornbeck, M.J. Mitchell, M.B. Adams, M.S. Castro, C.T. Driscoll, J.S. Kahl, J.N. Kochenderfer, G.E. Likens, J.A. Lynch, P.S. Murdoch, S.J. Nelson and J.B. Shanley., "Input-output budgets of inorganic nitrogen for 24 forest watersheds in the northeastern United States.", Water Air Soil Pollut., p. 373, vol. 151, (2004). Published,

Groffman, P.M., C.T. Driscoll, G.E. Likens, T.J. Fahey, R.T. Holmes, C. Eagar and J.D. Aber., "Nor gloom of night: a new conceptual model for the Hubbard Brook Ecosystem Study.", BioScience., p. 139, vol. 54, (2004). Published,

Johnson, C.E., R.J. Smernik, T.G. Siccama, D.M. Keimle, Z. Xu, and D.J. Vogt., "Using 13C nuclear magnetic resonance spectroscopy for the study of northern hardwood tissues.", Can. J. For. Res., p. 1821, vol. 35, (2005). Published,

Peters, S., J. Blum, C.T. Driscoll and G.E. Likens., "Dissolution of wollastonite during the experimental manipulation of Hubbard Brook Watershed 1.", Biogeochemistry, p. 309, vol. 67, (2004). Published,

Palmer, S.M., C.T. Driscoll and C.E. Johnson., "Long-term trends in soil solution and stream water chemistry at the Hubbard Brook Experimental Forest: relationship with landscape position.", Biogeochemistry, p. 51, vol. 68, (2004). Published,

Whitall, D., M. Castro and C. Driscoll., "Evaluation of management strategies for reducing nitrogen loadings to four U.S. estuaries.", Sci. Total Environ., p. 25, vol. 333, (2004). Published,

Wellington, B.I. and C.T. Driscoll., "The episodic acidification of a stream with elevated concentrations of dissolved organic carbon.", Hydrol. Proc., p. 2663, vol. 18, (2004). Published,

Palmer, S.M., B.I. Wellington, C.E. Johnson and C.T. Driscoll., "Landscape influences on aluminum and dissolved organic carbon in streams draining the Hubbard Brook valley, New Hampshire, USA.", Hydrol. Proc., p. 1751, vol. 19, (2005). Published,

Warby, R.A.F., C.E. Johnson, and C.T. Driscoll., "Chemical recovery of surface waters across the northeastern U.S. from reduced inputs of acidic deposition: 1984-2001.", Environ. Sci. Technol., p. 6548, vol. 39, (2005). Published,

Ollinger, S.V., "Biodiversity and Ecosystem Function in Forests. Review of: Forest diversity and function: temperate and boreal systems. Scherer-Lorenzen, Michael, Christian K?rner, and Ernst-Detlef Schulze, editors.", Ecology., p. 2256, vol. 86 (8), (2005). Published,

Turner, D.P, S.V. Ollinger and J.S. Kimball., "Integrating Remote Sensing and Ecosystem Process Models for Landscape to Regional Scale Analysis of the Carbon Cycle.", BioScience., p. 573, vol. 54(6), (2004). Published,

Turner, D.P., S.V. Ollinger, M.L. Smith, O. Krankina and M. Gregory., "Scaling net primary production to a MODIS footprint in support of earth observing system product validation.", International Journal of Remote Sensing., p. 1961, vol. 25(10), (2004). Published,

Melany C. Fisk, Will R. Kessler, Ava Goodale, Timothy J. Fahey,
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Web/Internet Site

URL(s):

www.hubbardbrook.org

Description:

An internet home page (HBES website: www.hubbardbrook.org) continued to be provided during 2008-2009, under the supervision of the USDA Forest Service's Data Manager and the HBES IOC. The website was revamped and updated in 2007.

The announcement of registration for the 2009 HBES Annual Cooperator's Meeting and agenda for the meeting has been provided on the HBES website, as is done annually. Personnel CVs and HBES publications are now updated interactively on the web site, and a section devoted to current research for each investigators has been added.

All of the HBES monthly volume-weighted chemical data were updated and submitted to the Data Manager, according to standard HBES policy. The IOC policy for access to HBES chemical data continued to be enforced in order to promote an ethical and professional relationship with serious users of these HBES data.

All of the HBES website chemical data have been updated to the end of water-year or calendar-year 2007. The primary data sets are the monthly volume-weighted average concentration values for deposition and export at all nine watersheds in HBEF. Other data sets added to the

website include: weighted average streamwater concentration values for all nine watersheds for the most recent years, unweighted, weekly chemical concentration data from the Mirror Lake inlets and outlets, seasonal profile chemistry from the lake itself, annual lake ice-cover duration data, and monthly lake profile temperature values.

We have developed a new web site for Mirror Lake to feature a virtual tour of Mirror Lake and its watershed as part of our outreach activities. A sixth-grade teacher, Mr. Gerry Gontarz, in the Plymouth School System, NH worked on this virtual tour project as an NSF-supported Research Experiences for Teachers (RET) in the summer of 2005, and has been updating and perfecting this virtual tour through the 2005-2007 school year with his sixth-grade students. http://www.hubbardbrook.org/ mirrorlake_tour/index.html

Other Specific Products

Product Type:

Physical collection (samples, etc.)

Product Description:

There are now over 32,000 water samples in the Archives Building, located at the USDA Forest Service Headquarters at the Hubbard Brook Experimental Forest. In 2009, through funding from the Hubbard Brook Research Foundation, we purchased and installed a new shelving system designed to hold the W6 stream water and bulk precipitation collections (about 4000 samples total) in a special, temperature-controlled section of the archives. The new system consists of heavy-duty, steel shelving (spaced to maximize efficiency), plastic bins that hold approximately 1-year of samples each, and a rolling step ladder that reaches to the top shelves safely. Examples of additional analyses conducted in the past, include nitrogen and sulfur isotopes, and various trace metals. A HBES document archive continues to be maintained in the library at the Institute of Ecosystem Studies by P.C. Likens.

Sharing Information:

All samples will be handled individually by the scientist who submits them.

Product Type:

Teaching aids

Product Description:

During 2007 we introduced a new website for Mirror Lake to feature a virtual tour of Mirror Lake and its watershed as part of our outreach activities. A sixth-grade teacher, Mr. Gerry Gontarz, in the Plymouth School System, NH worked on this virtual tour project as an NSF-supported Research Experiences for Teachers (RET) and has been updating and perfecting this virtual tour through the 2005-2006 and 2006-2007 school years with his sixth-grade students. http://www.hubbardbrook.org/mirrorlake_tour/index.html

Sharing Information:

As with our website and the Hubbard Brook virtual tour, this new site will be refined on the basis of the past year's experience and then more widely disseminated, first to school groups who visit the HBEF for field trips.

Product Type:

Presentation

Product Description:

Powerpoint presentation by Natalie Solomonoff entitled: "Changes in tree species composition and biomass in Hubbard Brook Valley: 1995-2005"

Sharing Information:

This presentation was presented at the annual HBES Cooperator's meeting.

Product Type:

Data or databases

Product Description:

Three databases: W1 inventory, demography plot, Valley plots.

Sharing Information:

databases are being shared with other researchers at the HB-LTER.

Product Type:

Data or databases

Product Description:

Developed a searchable database making the taxonomic and ecological information on the HBEF Lepidoptera accessible to the general public. This FileMaker database includes images and abundance data for close to 200 species and morphospecies.

Sharing Information:

Via the web:

http://www.hubbardbrook.org/data/dataset_search.php
http://www.dartmouth.edu/~estange/mothbd.htm

Product Type:

website

Product Description:

http://nationalzoo.si.edu/ConservationAndScience/MigratoryBirds/Research/Climate_Change/

Sharing Information:

The effect of climate change on migratory birds.

Product Type:

Teaching Aides

Product Description:

Two teaching guides have been completed by the Hubbard Brook Research Foundation, with extensive involvement of the Hubbard Brook Committee of Scientists. Both rely heavily on Hubbard Brook data and emphasize major themes of research at the site (Acid Rain and Migratory Birds).

Sharing Information:

The teaching guides are supported by HBRF hosted teacher training events, as well as staff attendance and presentation at conventions for secondary science teachers, including the annual meetings of the New Hampshire Science Teachers Association and the New England Environmental Educators Association.

Product Type:

Website

Product Description:

http://www.hubbardbrook.org/research/animals/bird/holmes-intro03.htm

Sharing Information:

The site describes long-term research on birds at the HBEF, including studies at the population, community and ecosystem level. Recent reasearch in avian ecology is highlighted on the Current Research pages.

Product Type:

Data or databases

Product Description:

Database of mapped tree locations in 9 ha forest demography plot in the hemlock-hardwood community in Hubbard Brook Valley (2^nd of 3 demography planned).

Sharing Information:

The mapped demography data is being processed and checked for consistency. The data will be made available to all internal HB collaborators by Summer 2009. Data will be posted on HB LTER network site after the PhD student finishes her dissertation. Expected May 2010

Product Type:

Data or databases

Product Description:

Database of 10-yr remeasurement of the valley-wide forest plots. Will permit landscape scale exploration of spatial patterns in biomass accumulation and tree productivity.

Sharing Information:

Most of the remeasured valley-wide forest plot data is already available to HB collaborators. The full 10-yr data will be posted to the HB LTER network site by Summer 2009.

Product Type:

Data or databases

Product Description:

"Dear Associates" Letter: Hubbard Brook valley-wide survey of moose winter density and browsing impact for 2007/08.

Sharing Information:

We are currently working with the data archivist and web manager to provide a repository of all "Dear Associates" letters that summarize interim results and procedures for the Hubbard Brook Valley vegetation analyses.

Product Type:

Teaching aids

Product Description:

Two teaching guides have been completed by the Hubbard Brook Research Foundation, with extensive involvement of the Hubbard Brook Committee of Scientists. Both rely heavily on Hubbard Brook data and emphasize major themes of research at the site (Acid Rain and Migratory Birds).

Sharing Information:

The teaching guides are supported by HBRF hosted teacher training events, as well as staff attendance and presentation at conventions for secondary science teachers, including the annual meetings of the New Hampshire Science Teachers Association and the New England Environmental Educators Association.

Contributions

Contributions within Discipline:

Research in the Hubbard Brook LTER program seeks a better basic understanding of the discipline of ecosystem biology, especially biogeochemistry and energy flow. Our long-term measurements of a suite of large-scale experiments has contributed to refined understanding of the interactions between ecological processes and biogeochemical cycles, as elucidated in our series of six monographs on particular chemical elements in the Hubbard Brook landscape. Our studies of energy flow through the complex herbivore and detrital food webs integrates knowledge across sub-disciplinary lines including vegetation dynamics, microbial ecology and heterotroph population dynamics.

Contributions to Other Disciplines:

Beyond the core disciplines of ecosystem biology and biogeochemistry, the HBR LTER Program contributes to allied research disciplines in the physical and biological sciences. Our work attracts the interest of geochemists and physical hydrologists as well as that of molecular and cell biologists. The continuity of standardized and well-documented data collection is a hallmark of the HBR LTER; this aspect of the long-term studies at our site provides an internationally recognized benchmark for many disciplines of field-oriented research.

Contributions to Human Resource Development:

The Hubbard Brook LTER Project makes an active effort to develop human resources at many stages of development, from K-12 through post-doctoral. Most recently we have undertaken a REU Site project designed to provide students with both an understanding of basic science research and its application to societal needs. Through our educational and research activities numerous students and technicians have advanced their capacity for addressing the environmental problems that face 21st Century society. A continuous stream of researchers has been nurtured in the HBR LTER, eventually to reach prominent positions in academic, governmental and private sector institutions. We have encouraged the participation of females and minorities in our project through recruitment at our participating Universities and throughout the world.

Contributions to Resources for Research and Education:

Building upon its tradition of contributing to public education and policy development, the Hubbard Brook LTER project has developed two principal outreach and educational programs: the Science Links and Environmental Literacy programs. Science Links is designed to communicate scientific results to policy makers and the general public in areas such as acid rain, nitrogen deposition and mercury pollution. Most recently we have been working on Science Links projects concerning Long-term Environmental Monitoring and Forest Carbon. By providing a politically-neutral scientific appraisals of the state of research on these topics, Science Links performs a public service that is not easily accomplished either by government agencies or by environmental NGO's. The Environmental Literacy program is a cooperative effort with the USDA Forest Service to train K-12 teachers in northeastern states in the fundamentals of forest ecology. The Forest in Every Classroom initiative is achieving this goal through teacher training workshops and curriculum development.

Contributions Beyond Science and Engineering:

Society is confronted with difficult choices about the degree of pollution abatement that is necessary to achieve desirable outcomes in terms of environmental quality. The long-term data sets from HBEF provide among the best objective information available on which to base judgments about the threats of pollution to forest health, soil and water quality, and about the effectiveness of pollution abatement efforts in reducing those threats. Temporal trends can be evaluated against the backdrop of natural variation in reference and manipulated catchments, providing both parameter values and validation data for predictive models. Cost-effective environmental protection depends upon using these models to project the benefits of particular pollution abatement strategies. Hubbard Brook is a cornerstone of such efforts.

Conference Proceedings

Special Requirements

Special reporting requirements: None

Change in Objectives or Scope: None

Animal, Human Subjects, Biohazards: None

Categories for which nothing is reported:

Any Conference

Research Activities: 2009

The HBR LTER program utilizes experiments, surveys and long-term monitoring to improve overall understanding of the structure and function of northern hardwood forests and coupled aquatic ecosystems. During the past year we have continued to pursue a suite of biogeochemical and ecological questions that can be classified into six major areas of study. In the following summary we explain our principal results and insights that have been completed during 2008-2009 in each of these areas.

1. Biogeochemistry

In addition to our long-term biogeochemical monitoring results that have been presented each year in our Annual Report (omitted this year), we have recently completed a suite of process studies, as described below.

a. *Chemical weathering rates*. Constraining the range of chemical weathering rates in soils is important because weathering can have a strong influence on surface and ground water chemistry, soil nutrient release, neutralization of acidity, and preparation of rock for physical erosion. Determination of chemical weathering rates in soils developed from glacial till can be advantageous relative to other soils, because soil ages are more easily determined. To allow measurement of real differences in weathering rates across sites, rigorous exclusion criteria need to be applied to soil profiles to reduce uncertainty that may arise from soil parent material heterogeneity and soil disturbance. Soil profiles used for weathering rate calculations in this study were required to have the following characteristics: a) an overall decreasing concentration of the immobile element (Ti) with depth; b) Ti concentrations of no more than 1 standard deviation lower in the B horizon than in the C horizon; and c) at least three mineral soil samples collected from above the C-horizon. In the White Mountains (New Hampshire), we applied these criteria to data from 39 soil profiles developed in glacial till derived from granitic and high grade metamorphic parent material. Soils were excavated quantitatively, thus eliminating errors associated with measurement of bulk density. The resulting long-term weathering rates for individual soil pits range from 2 to 50 meq m^{-2} yr^{-1}. Average weathering rates for sites with two or three profiles within 50 m of each other range from 10 to 30 meq m^{-2} yr^{-1}. Averaging weathering rates from sites within 5 km of each other results in “local rates” ranging from 13 to 22 meq m^{-2} yr^{-1}. An inverse correlation is observed between site elevation and weathering rate, which may reflect differences in temperature, precipitation or vegetation type. Our best estimate of the regional average long-term weathering rate for the White Mountain is 17 meq m^{-2} yr^{-1}, considerably lower than the 35 meq m^{-2} yr^{-1} previously reported for a 12 ha catchment at the nearby Hubbard Brook Experimental Forest. Weathering rates determined from granitic glacial deposits of similar age elsewhere in the world are of the same order of magnitude (2 to 62 meq m^{-2} yr^{-1}) as the rates determined in this study.

b. *Silica dynamics*. In terrestrial ecosystems the largest pool of amorphous silica (ASi) is stored in soils and is an important reservoir of biologically active Si for the global biogeochemical cycling of Si. Only limited data are available that quantify the size of this

reservoir and often these estimates are made from the physical separation of silt-sized phytoliths, which can underestimate the ASi pool. Soil samples from five watersheds in the Hubbard Brook Experimental Forest were analyzed for ASi using alkaline digestion. Soils from two of the watersheds were analyzed after forest removal. In undisturbed watersheds ASi is concentrated at the surface of the soil profile, similar to organic matter, and then progressively decreases with depth. In watersheds disturbed by forest removal, ASi was lost from the upper soil horizons and was translocated down the soil profile. Although significant decreases in ASi concentrations were observed in the upper soil profile, estimates of the ASi pool before and after harvesting show that the total ASi pool remained essentially unchanged. The ASi pool was estimated to be 17400 Kg/ha prior to harvesting (1983) and 17500 Kg/ha after harvesting (1986). More studies are needed, as significant increases in the transport of dissolved silica by rivers have been observed with deforestation, and the ASi pool in soils may play an important role.

c. *Flow-concentration relationships in small watersheds.* In addition to the routine samples, we continued to collect streamwater samples from HBEF Watersheds 1, 6, 9, the West Inlet of Mirror Lake, and the main Hubbard Brook during periods of unusually high flow. We have observed that flow-concentration relationships in most of our streams have changed over the years, and samples taken at the highest flow rates help to clarify these changes. In addition, the physical, chemical and hydrologic characteristics of these sites represent a spectrum of conditions found across the entire HBEF Valley.

   We installed our four ISCO automated samplers at W8 this past year, in an effort to understand the unusually high variability of stream chemistry in the routine weekly samples collected from that watershed. We activated the ISCOs during hydrologic events to capture at finer temporal scales stream samples from the main sample site at Weir 8, and three sites immediately above that: the east and west forks to the main channel, and a single spring located between those forks.

d. Speciation and d*ynamics of iron.* We constructed a biogeochemical budget for Fe for W6 at the HBEF to better understand the behavior of Fe and its role in the development of Spodosols (podsolization). Fluxes of reduced (ferrous, Fe(II)) and oxidized (ferric, Fe(III)) iron draining through the soil profile were calculated. Soil solution fluxes of Fe and dissolved organic carbon (DOC) decreased from the organic (Oa) horizon down through the mineral (Bh and Bs) horizons, consistent with theories of translocation of organically-complexed Fe and co-precipitation of Fe and C in the spodic horizon. The portion of total Fe as Fe(II) ranged approximately 10-60% in soil solutions, seemingly high for soils that are considered to be well-drained, oxidizing environments. Analysis of total Fe and Fe(II) in hardwood leaf litter extracts identified a source of reduced Fe to solutions draining the forest floor, with approximately 50% of this Fe occurred as Fe(II). Flux calculations showed that inputs of Fe to the forest floor (litterfall + throughfall) were insufficient to account for all Fe in soil solutions. The organic forest floor horizons were a net source of Fe(II) and Fe(III). Dissolved Fe draining the forest floor was either mobilized by organic compounds following organic decomposition or was leached directly from litter. The results indicate that organic complexes likely stabilized Fe(II) in solution under oxidizing conditions that would otherwise promote oxidation to Fe(III). Fe(II) concentrations

remained as a fairly constant fraction of total Fe despite fluctuations in dissolved oxygen concentrations. Concentrations of Fe species and DOC decreased with elevation in soil solutions and stream water. Our study indicates that there are organic matter-derived sources of dissolved Fe(II) as well as substantial mobilization of Fe(II), possibly the result of reduction of Fe soil minerals. The translocation of Fe(II) could have implications for redox chemistry in deeper mineral soils and downstream surface waters.

e. *Uncertainty analysis in ecosystem nutrient budgets*. Ecosystem nutrient budgets often report values for pools and fluxes without any indication of uncertainty, which makes it difficult to evaluate the significance of findings or make comparisons across systems. We used a Monte-Carlo approach to propagate uncertainty in parameter estimates in the calculation of the N content of vegetation at Hubbard Brook, using Excel spreadsheets. The coefficient of variation was 18% of the mean, which was higher than the spatial variation in N content of vegetation assessed across multiple plots (5-10% depending on the size of the plots). In addition to allowing estimation of uncertainty in budget estimates, this approach can be used to assess which measurements should be improved to reduce uncertainty in the calculated values. Note also that it is important to report the error associated with parameters in regression models, so that future users can estimate uncertainty in calculations that depend on them. To our knowledge, the combined uncertainty resulting from the allometric equations describing tree biomass and the uncertainty in tissue concentrations have never before been reported in forest ecosystem budgets.

f. *Forest colimitation by N and P*. Although temperate forests have long been thought to be primarily nitrogen limited, resource optimization theory suggests that ecosystem productivity should be co-limited by multiple nutrients. In northeastern North America, air pollution elevates N availability and contributes to the likelihood of P limitation. Forest harvesting also elevates N availability immediately after the disturbance (i.e. in young stands). That young forests are especially P limited is consistent with the suggestion of enhanced apatite weathering in young forests (Yanai et al 2005) suggested by an early-successional peak in calcium availability (Hamburg et al. 2003).

We extended the Multi-Element Limitation (MEL) model to include P, light, and water (as well as N and carbon), and we simulated resource limitation during secondary succession in northern hardwood forests. We also made field measurements indicating the relative limitation by nitrogen and phosphorus in northern hardwood forest ecosystems of different ages in central New Hampshire, USA. The MEL model suggests that northern hardwood forests are co-limited by N and P, and that the primary nutrient limitation shifts from P to N during secondary succession. Field results are consistent with model predictions, as young forests appear to allocate more effort to obtaining P, as evidenced by fine root foraging, phosphatase enzyme activity, and foliar retranslocation.

2. Forest ecosystems and pollution

a. *Pollution-climate interactions and critical loads*. Changes in climate and atmospheric deposition of base cations can alter the ionic composition of soil and surface waters, and therefore affect the structure and function of sensitive ecosystems. However, these drivers are not generally explicitly considered in the calculation of critical/target loads to evaluate the recovery of ecosystems from elevated acidic deposition. In this study we explored the importance of accounting for these changes in calculating target loads for ecosystems. We developed three-dimension target load surfaces as a function of nitrate, sulfur and base cation deposition under current and future climate change scenarios for the HBEF. This case study indicates that target loads for nitrate and sulfur will be lower under conditions of potential climate change or decreases in base cation deposition. This analysis suggests that greater emission controls may be needed to protect sensitive forest ecosystems from acidic deposition under future climate change or conditions of lower atmospheric deposition of base cations, particularly for watersheds experiencing elevated leaching losses of nitrate. This study should facilitate more informed policy decisions on emission control strategies and assessments of ecosystem restoration.

b. *Nitrogen and canopy albedo.* Remote sensing work at Hubbard Brook and the Bartlett Experimental Forest focuses on assessing patterns of ecosystem composition, structure and function and extending rates of C and N cycling in forests from local to regional scales. In 2008, we reported on an analysis that combined data from Hubbard Brook and several other sites and demonstrated a strong coupling between canopy nitrogen, forest carbon uptake and shortwave canopy albedo. This relationship suggests that variation in N availability may have a dual influence on climate via its effects on reflectance of incident solar energy as well as through its better-known effect on forest growth and carbon gain.

   Most recently, we have extended this study in several ways. First, in the summer of 2009, we conducted a field and aircraft remote sensing campaign that involved collecting hyperspectral imagery over long gradients in N deposition. This involved collection of new imagery of Hubbard Brook as well as several other sites located between West Virginia and Maine. The aim of this analysis is to determine whether regional patterns of N deposition have had an influence on regional patterns of forest albedo. Second, we have been collecting leaf-level reflectance measurements in conjunction with measurements of leaf-level traits that may shed light on the mechanisms underlying the nitrogen-albedo relationship. Finally, we have just begun an analysis of the N-albedo relationships at finer spatial scales, focusing on landscape level variation in both variables at Hubbard Brook and Bartlett.

c. *Stream mercury loss in northern forests*. Mercury (Hg) contamination is widespread in remote areas of the northeastern USA. Terrestrial uplands have accumulated a large reservoir of Hg in soil from decades of elevated anthropogenic deposition that can be released episodically to stream water during high flows. The objective of this study was to evaluate spatial and temporal variations in stream water Hg species and organic matter fractions over a range of hydrologic conditions in three forested upland watersheds, including W6 at the HBEF. Mercury and organic matter concentrations increased with

discharge at all three sites; however the partitioning of Hg fractions (dissolved vs. particulate) differed among sites and seasons. Increased discharge caused a shift in flow paths from mineral soil under base flow to upper soil horizons. As flow paths shifted, greater concentrations of DOC richer in aromatic substances and lignin were flushed from upper soil horizons to stream water. The hydrophobic organic matter associated with humic material from upper soils appears to have had a greater capacity to bind Hg. Due to the strong correlation between Hg and DOC, we hypothesize that there was a concurrent shift in the source of Hg with DOC from lower mineral soil to upper soil horizons. Our results emphasize the importance of monitoring Hg species and organic matter concentrations in stream water during high flow periods. A better understanding of fine temporal scale Hg dynamics is needed to fully quantify ecosystem response to changes in Hg deposition. Our study suggests that stream discharge data are an effective predictor of dissolved THg flux. However, future research into other proxy approaches for measuring Hg fractions in stream water will be needed to fully understand Hg dynamics over short time scales.

d. *Sulfur dynamics and oxygen isotopes of sulfate*. We conducted the first analyses of oxygen isotopes of sulfate in precipitation and drainage waters at Hubbard Brook. These results show the importance of internal cycling of sulfur in forested watersheds and suggest that internal S sources are important contributors to sulfur losses. These internal sulfur sources will delay the recovery of forested watersheds from acidic deposition. We have also analyzed the discrepancies in watershed sulfur budgets and the importance of estimates of dry sulfur deposition and internal sulfur sources in affecting ecosystem recovery from acidification on W6, HBEF.

e. *Nitrogen saturation*. Forty-five years of biogeochemical monitoring at the Hubbard Brook Experimental Forest has revealed multiple surprises, seeming contradictions, and unresolved questions in the long-term nitrogen budget. From 1965 to 1977, more N was accumulating in living biomass (17 kg N ha-1 y-1) than was received in atmospheric N deposition; the "missing" N source was attributed to N fixation. Despite strong plant demand for N, 4 kg N ha-1 y-1 was lost as dissolved inorganic N (DIN) in streamwater export. More recently (1992 – 2007), biomass accumulation has been negligible, but streamwater export of DIN has fallen to ~1 kg N ha-1 y-1 despite chronically elevated atmospheric N deposition (~10 kg N ha-1 y-1), which was expected to lead to N saturation. This budget imbalance indicates that the ecosystem is either now a net sink for ~8 kg N ha-1 y-1, or else excess N is being denitrified to the atmosphere. Repeated sampling over 25 years shows that the forest floor is not detectably accumulating N (+2 ± 22 kg N ha-1 y-1, 95% CI) but the C:N ratio is increasing (p=0.05). Repeated forest floor sampling of mature forests elsewhere in the region yields similar results. The large mineral soil N stock shows no significant increase over the past several decades based on repeat measurements of related sites, though the variability of these measurements prevents detection of a change < ~700 kg N ha-1, even with intensive sampling. Whether excess N is accumulating in detritial material or being denitrified is unclear; denitrification could represent a major source of greenhouse gases (~1 Mg CO2eq ha-1 y-1).

3. Calcium and Watershed 1

a. *Ecosystem responses*. Liming has been used to mitigate effects of acidic deposition in soil and water. The watershed 1 (W1) study was designed to examine the effects of calcium (Ca) supply on the spatial patterns and the relations between soil and soil solution chemistry in a base-poor forest watershed. Watershed 1 at the Hubbard Brook Experimental Forest was experimentally treated with wollastonite ($CaSiO_3$) in October, 1999. Exchangeable Ca (Ex-Ca), pH_s (in 0.01M $CaCl_2$), effective cation exchange capacity (CEC_e), and effective base saturation (BS_e) have increased, while exchangeable acidity (Ex-Acid) decreased in organic soil horizons in 2000 and 2002. Mineral soils experienced either small increases in Ex-Ca, pH_s, CEC_e, BS_e and small decreases in Ex-Acid or no changes. Thus, most of the added Ca remained in the forest floor during the study period. Prior to the treatment the BS_e decreased with increasing elevation in organic and mineral soil horizons. This spatial pattern changed significantly in the forest floor after the treatment suggesting that soils at higher elevations were more responsive to the chemical addition than at lower elevations. Soil solutions draining the forest floor responded to the treatment by increases in concentrations of Ca, dissolved silica, pH, and acid neutralizing capacity (ANC), and a decrease in inorganic monomeric Al (Al_i). Treatment effects diminished with increasing soil depth and decreasing elevation. Positive correlations between Ca/Al_i in soil solution and Ex-Ca/Ex-Al ratios in soil indicated that changes in the chemistry of soils significantly influenced the chemistry of soil water, and that Ca derived from the dissolution of wollastonite mitigated the mobilization of Al within the experimental watershed.

b. *Episodic acidification and stormflow events*. Patterns of storm runoff chemistry from the wollastonite (calcium-silicate mineral, $CaSiO_3$) treated watershed (W1) were compared with a reference watershed (W6) at the HBEF to investigate the role of Ca^{2+} supply in the acid–base status of stream chemistry. In the summer of 2003, six storm events were studied in W1 and W6 to evaluate the effects of the wollastonite treatment on the episodic acidification of stream waters. Although mean values of Ca^{2+} concentrations decreased slightly from 33.8 to 31.7 μmol/L with increasing stream discharge in W1 during the events, the mean value of acid neutralizing capacity (ANC) was positive (1.2 μeq/L) during storm events, compared to negative values (−0.2 μeq/L) in W6. This pattern is presumably due to enhanced Ca^{2+} supply in W1 (20.7 to 29.0% of dissolved Ca^{2+} derived from the added wollastonite) to stream water as a result of interflow along shallow flowpaths. In addition, the application of wollastonite increased pH and dissolved silica (H_4SiO_4) concentrations, and decreased the concentration of inorganic monomeric Al (Ali) in W1 in comparison with W6 during storm events. Despite an increase in SO^{2-}_4 concentration, likely due to desorption of sulfate from soil after the treatment, the watershed showed an increase in ANC compared to the reference watershed, serving to mitigate episodic acidification.

c. *Ca sources to vegetation*. Calcium/strontium and $^{87}Sr/^{86}Sr$ ratios in foliage can be used to determine the relative importance of different soil sources of Ca to vegetation, if the discrimination of Ca/Sr by the plant between nutrient sources and foliage is known. We compared these tracers in the foliage of sugar maple (*Acer saccharum)* to the exchange

fraction and acid leaches of soil horizons at six study sites in the White Mountains of New Hampshire, USA. Based on tracer work in W1 (above), sugar maple was shown to discriminate for Ca compared to Sr in foliage formation by a factor of 1.14 ±0.12. After accounting for the predicted 14% shift in Ca/Sr, foliar Ca/Sr and $^{87}Sr/^{86}Sr$ ratios closely match the values in the Oie horizon at each study site across a 3.6-fold variation in foliar Ca/Sr ratios. Newly weathered cations, for which the Ca/Sr and $^{87}Sr/^{86}Sr$ ratios are estimated from acid leaches of soils, can be ruled out as a major Ca source to current foliage. Within sites, the $^{87}Sr/^{86}Sr$ ratio of the soil exchange pool in the Oa horizon and in the 0-10 cm and 10-20 cm increments of the mineral soil are similar to the Oie horizon and sugar maple foliar values, suggesting a common source of Sr in all of the actively cycling pools, but providing no help in distinguishing among them as sources to foliage. The Ca/Sr ratio in the soil exchange pool, however, decreases significantly with depth, and based on this variation, the exchange pool below the forest floor can be excluded as a major Ca source to the current sugar maple foliage. This study confirms that internal recycling of Ca between litter, organic soil horizons and vegetation dominate annual uptake of Ca in northern hardwood ecosystems. Refinement of our understanding of Ca and Sr uptake and allocation in trees allows improvement in the use of Ca/Sr and $^{87}Sr/^{86}Sr$ ratios to trace Ca sources to plants.

d. *Sugar maple and soil calcium*. Our previous studies demonstrated that increased Ca availability on W1 resulted in striking increases in sugar maple reproduction, apparently reversing the long-term trend of sugar maple decline at HBEF. In continuing studies we found that this result was not explained by maternal effects on seed germination or survival. We observed density-dependent effects on early survivorship of seedlings associated with spread of a key fungal pathogen, *Rhizoctonia* (undescribed).

   Across the entire HB valley, sugar maple survivorship was not explained by spatial variation in soil Ca availability. However, early-season survival was dependent on formation of arbuscular mycorrhizal associations (AMF), protecting seedlings from *Rhizoctonia* infection. Long-term survivorship was strongly dependent upon hypocotyl development in young seedling which was, in turn, strongly correlated with resicle formation by AMF.

4. Studies of disturbance.

a. *Long-term recovery from ice storm disturbance*. Ice storms can cause severe damage to forest canopies, resulting in differential mortality among tree species and size classes and leading to long-lasting changes in the vertical structure and composition of the forest. An intense ice storm in 1998 damaged large areas of the northern hardwood forest, including much of the Hubbard Brook Experimental Forest, New Hampshire (USA). Following up on detailed post storm assessments, we measured changes in the vertical structure of the forest canopy 8 years post storm. We focused on how the presence of disease-induced advance regeneration of American beech (*Fagus grandifolia* Ehrh.) has affected canopy structure in the recovering forest. We measured foliage-height profiles using a point-

quadrat approach and a pole-mounted leaf area index (LAI) sensor. Although the total LAIs of damaged and undamaged areas were similar, areas damaged in 1998 showed an increased proportion of total leaf area between 6 and 10 m above the ground. The foliage at this height is largely (54%) beech. To the extent that this heavily beech-dominated understory layer suppresses regeneration of other species, these findings suggest that rare disturbances of mature northern hardwood forests affected by beech bark disease will increase the importance of damage-prone and economically marginal beech.

b. *Soil climate effects on C and N cycling.* We exploited the natural climate gradient in the northern hardwood forest at the Hubbard Brook Experimental Forest (HBEF) to evaluate the effects of climate variation similar to what is predicted to occur with global warming over the next 50 – 100 years for northeastern North America on soil carbon (C) and nitrogen (N) cycle processes. Our objectives were to 1) characterize differences in soil temperature, moisture and frost associated with elevation at the HBEF and 2) evaluate variation in total soil respiration (TSR) and microbial respiration, N mineralization, nitrification, denitrification, nitrous oxide (N_2O) flux and methane (CH_4) uptake along this gradient. Low elevation sites were consistently warmer (1.5 – 2.5 ^{o}C) and drier than high elevation sites. Despite higher temperatures, low elevation plots had less snow and more soil frost than high elevation plots. Net N mineralization and nitrification were slower in warmer, low elevation plots, in both summer and winter. In summer, this pattern was driven by lower soil moisture in warmer soils and in winter the pattern was linked to less snow and more soil freezing in warmer soils. These data suggest that N cycling and supply to plants in northern hardwood ecosystems will be reduced in a warmer climate due to changes in both winter and summer conditions. TSR was consistently faster in the warmer, low elevation plots. N cycling processes appeared to be more sensitive to variation in soil moisture induced by climate variation, while C cycling processes appeared to be more strongly influenced by temperature.

c. *Vegetation dynamics on W6*. Forest composition and biomass on the biogeochemical reference watershed, W6, has been measured at 5-yr intervals since the mid-1960s. Biomass accumulated rapidly in this largely even-aged forest from age 50-70 yrs. Thereafter biomass accumulation rather suddenly declined, departing markedly from the predicted pattern. During the most recent intervals, age 85-100 yrs, live biomass has been gradually declining. This unexpected observation is associated with declining growth rates in dominant tree species and increased mortality especially of birches and sugar maple. The role of climatic warming and air pollution in driving these trends has been demonstrated, particularly for paper birch and sugar maple, respectively.

5. Dynamics of heterotroph populations

a. *Soil organisms: interdependence with C and N cycling*. The interactions among different components of detrital food webs are likely to influence carbon processing and linkages between C and nutrient cycling. Our objective was to identify potentially important interactions in detrital food webs at the Hubbard Brook by exploring relationships among C resources, microbial biomass, microarthropod abundance, and nitrogen availability as they vary across the landscape. We found significant spatial variation in microarthropod

abundance in the forest floor across elevation zones in two watersheds, with consistently higher abundance in low-elevation hardwoods and upper conifer zones and lower abundance in mid- and high-elevation hardwoods. The same pattern was observed in the Oe horizon for microbial biomass C and respiration but not for N transformations; however, no patterns were observed in the Oa horizon. Microarthropod abundance and microbial biomass C were significantly positively correlated, but neither was related to forest floor mass or to annual aboveground fine litterfall flux. Instead, a positive correlation with fine root biomass suggests that C supply from roots plays a key role in the fungal channel of the detrital food web of these forests. The lack of relationship between patterns of microarthropod abundance and net N mineralization leads us to hypothesize that spatial patterns of nitrogen availability are not closely linked to variation in carbon flow through the detrital food web, within this forested landscape. In contrast, microarthropod abundance and net N mineralization did exhibit similar interannual variation and may respond to the same temporal controls.

b. *Valley-wide patterns of heterotrophic abundance*. The 3000ha HBEF spans a range of environment and habitat conditions across which heterotroph populations exhibit complex patterns of variation. For example, we are examining the effects of habitat structure, elevation and climate on the distribution of congeneric species of vireos to test ecological theory about niche partitioning in relation to climate change. We have also quantified spatial patterns of abundance of a keystone herbivore, the moose, and its role in regulating tree regeneration and animal habitat structure. Moose profoundly influence shrub layer vegetation with consequences for populations of *Lepidoptera* and their predators, several species of songbirds. The results indicate that moose play a key role in regulating heterotrophic biodiversity in the northern hardwood forest. Valley-wide surveys of bird abundance have continued for 12 years, resulting in a database capable of addressing critical questions at the landscape scale. We are using these data to test and validate assumptions of bioclimatic envelope models that are now commonly being used to project species responses to climate change. We will use the vegetation, climate and bird data available from Hubbard Brook to test hypotheses about which suite of variables most effectively predicts bird distributions over time. This approach provides a test of the niche conservatism assumption made by bioclimatic envelope models by comparing the prediction accuracy of different predictor variables across time.

c. *Community dynamics of Lepidoptera*. In the past year we completed studies of controls on spatio-temporal fluctuations in the abundance of *Lepidoptera* in our intensive plot at the HBEF. Building on those results we are examining the paradox that *Lepidoptera* larvae are more abundant in cooler habitats at the HBEF despite annual fluctuations that indicate warmer weather favors higher population growth rates. A combination of bottom up (e.g., soil N availability) and top-down (e.g., parasitoids) controls appears to contribute to these patterns, and the combination of climate change and pollution deposition would be expected to alter these dynamics.

d. *Bird habitat sensed with Lidar*. A recent new collaboration with Goetz and co-workers is allowing us to include Lidar measures of vegetation structure in our spatial models of bird abundance. Lidar is a remote sensing technology that directly measures the three-

dimensional distribution of plant canopies. Lidar data have been collected for the HBEF in both 1999 and 2006. These data have been processed to provide information at a relatively fine resolution (2 m) and large spatial extent (valley-wide). We will be using a variety of multivariate statistical techniques (e.g., CART, GLM, GAM) to develop models that predict bird distribution. In a later stage of this research, these models will be applied and tested in other regions of the Northeast where relevant data have been collected.

e. *Beech bark disease*. Beech bark disease is a major pest/pathogen complex that has been spreading through populations of American beech in eastern North America. At Hubbard Brook, most beech trees are affected by the disease and many have died. In some cases the canopy space liberated by the dying beech is taken up by other species, while in other cases the space is re-occupied by prolific beech regeneration. We have been sampling former canopy gaps created by dead beech trees to determine what factors determine the course of vegetation dynamics following beech mortality from the disease. We have sampled throughout the Hubbard Brook valley, in several other locations in the White Mountains, and in the Catskill Mountains of New York for comparison. We found that sugar maple is more likely to replace beech on sites with higher soil calcium availability, whereas beech regeneration is more likely on lower-calcium sites. Where the canopy dominance shifted from beech to maple, we observed higher extractable nitrate concentrations and lower C:N ratios in the soils beneath the trees. These data suggest that the geological substrate sets the template for the forest response to this introduced disease, and that the forest response determines patterns of carbon storage and nitrate production in the soil.

6. Studies of aquatic ecosystems

a. *N and P colimitation of Mirror Lake*. Mirror Lake, a small clearwater oligotrophic lake at the base of the HBEF was shown to be co-limited by both nitrogen and phosphorus in the early 1970s. Because of continued interest in limits to ecosystem productivity, cultural eutrophication and issues related to atmospheric nitrogen pollution, we repeated a similar study to determine if limits to algal productivity had changed during the subsequent 30 years. We used in situ mesocosms to study the response of algae to nitrogen and phosphorus additions. We hypothesized that after 30 years of increased atmospheric nitrogen input that Mirror Lake would no longer be limited by nitrogen, but would be solely limited by phosphorus. Our results, however, were remarkably similar to the original experiment and clearly showed continued limitation by both nitrogen and phosphorus. It also appears that another undetermined factor may be limiting phytoplankton productivity, as Chl-a concentrations in the enclosure with added nitrogen and phosphorus only increased to about 6 µg/L, similar to the results in the original experiment.

b. *Salinization of Mirror Lake*. The salinization of Mirror Lake has been ongoing steadily since Interstate 93 (I-93) was built through the NE subcatchment of the lake in the fall and winter of 1969-1970. Salt added to I-93 during winter as a deicer has been transported to the lake by different quantified, hydrologic pathways, but primarily from the Northeast Tributary, which was intersected by I-93. Now, surprisingly after the New Hampshire Department of Transportation has spent more than $500,000 on recent structural

modifications to divert salt from I-93 away from the Northeast subcatchment of Mirror Lake, applications of salt to a small, town road traversing the other two subcatchments for the lake and servicing a new housing development, have become the major source of salt to the lake. Streamflow from these two subcatchments currently provides more than 3× as much salt to the lake as from I-93, and the salt concentration in the lake continues to rise.

c. *Rising stream and river temperatures*. Water temperatures are increasing in many streams and rivers throughout the US. We analyzed historical records from 40 sites and found that 20 major streams and rivers have shown statistically significant, long-term warming. Annual mean water temperatures increased by 0.009–0.077 °C yr^{-1}, and rates of warming were most rapid in, but not confined to, urbanizing areas. Long-term increases in stream water temperatures were typically correlated with increases in air temperatures. If stream temperatures were to continue to increase at current rates due to global warming and urbanization, this could have important effects on eutrophication, ecosystem processes such as biological productivity and stream metabolism, contaminant toxicity, and loss of aquatic biodiversity.

Major Research and Education Activities: 2009

The goal of the Hubbard Brook Ecosystem Study is to advance basic understanding of biotic community composition, energy flow and biogeochemical cycling in northern hardwood forests and linked aquatic ecosystems. This knowledge contributes towards designing policy and management activities to protect and improve these natural resources. We approach these goals through an integrated suite of research activities: 1) long-term monitoring of carefully selected ecosystem attributes, 2) experimental manipulations of ecosystem components to test hypothesis about cause-effect relationships in ecosystem composition, structure and function, and 3) development, parameterization, testing and application of quantitative ecosystem simulation models. We continue the development of archival systems for long-term storage and easy access to data sets and physical samples. Increasingly, our research has expanded to include the scale of the whole Hubbard Brook Valley as well as the regional forested landscape. The long-term records from our site provide a basis for interpreting regional and global observations of ecosystem dynamics, and we are contributing to interpretation of these observations by synthesizing the state of knowledge for lay audiences. In the following report we highlight several prominent recent results and new initiatives funded primarily by the LTER program in the past year.