Assessing the Role of Tree Species and Nitrogen Deposition in Mediating Carbon Storage in Northern Hardwood Forests.

Principal Investigator:

Gary M. Lovett

Cary Institute of Ecosystem Studies, Millbrook, NY 12545 USA

Email lovettg@caryinstitute.org

Co-PIs:

Mary A. Arthur, University of Kentucky, *Email* mary.arthur@uky.edu

Christine L. Goodale, Cornell University, *Email* clg33@cornell.edu

Pamela H. Templer, Boston University, *Email* ptempler@bu.edu

Kathleen C. Weathers, Cary Institute of Ecosystem Studies, *Email* weathersk@caryinstitute.org

Collaborators:

Alexandra Rodriguez, Fulbright Postdoctoral Fellow from Spain

Lynn M. Christenson, Vassar College

Completion date: September 30, 2013

In this long-term study of the response of different tree species to nitrogen addition:

- the extra nitrogen produced only a moderate response in foliar nitrogen concentration, and
- the added nitrogen inhibited soil microbial processes.

Funding support for this project was provided by the Northeastern States Research Cooperative (NSRC), a partnership of Northern Forest states (New Hampshire, Vermont, Maine, and New York), in coordination with the USDA Forest Service.
http://www.nsrcforest.org

Project Summary

The effect on forests of excess nitrogen from air pollution is complicated because nitrogen is an essential nutrient for trees, but excessive amounts can be toxic. In this study we re-sampled the trees and soil in research plots that had been receiving added nitrogen for 13 years. The study included six replicate plots dominated by each of 5 species, located in the Catskill Mountains of NY State. Nitrogen was added in a granular form at a rate of 50 kg N/hectare/year; for each fertilized plot there was a paired control plot that received only ambient nitrogen deposition. Even though nitrogen is often considered a limiting element for forests in this region, we found that the trees had only a moderate uptake of the extra nitrogen, as reflected in the nitrogen concentration in their foliage. We also found that soil microbial processes such as soil respiration and nitrogen mineralization were inhibited by the added nitrogen. While the decrease in microbial action should eventually lead to a greater buildup of the forest floor, we did not observe an increase in forest floor mass in this study. All of these responses varied individualistically among the different tree species. We conclude that in the Catskill region the trees are probably less limited by nitrogen than is commonly assumed, but that nitrogen deposition can alter key microbial processes that may eventually lead to increased mass and carbon storage in the forest floor. Policy and management decisions regarding nitrogen pollution should factor in the varying responses of different tree species, and simulation models that predict the effect of nitrogen deposition on the Northern Forest should take individual tree species into account in order to make accurate predictions.

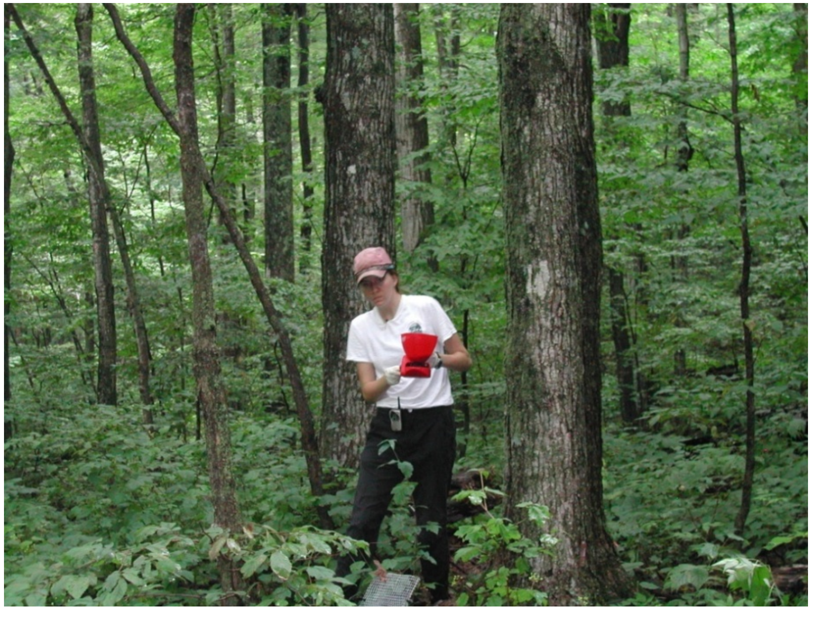
Background and Justification

- The atmosphere is polluted with nitrogen (N), primarily from fossil fuel combustion
- The effects of this excess N deposition on forests is complicated
  - Forests need N as a critical nutrient, and their growth is thought to be limited by it.
  - However, too much N can cause nutrient imbalances and soil acidification, slowing the growth of, or even killing, trees.
- The balance of positive and negative effects is likely to depend on the tree species, age and soil type.
- N addition experiments help to sort out the different effects, and can provide data to simulation models that predict long-term consequences of air pollution

Methods-Study Design

- We sampled 60 single-species forest plots in the Catskill Mountains of NY State that had been receiving added N for 13 years.
- There were 6 replicate pairs of plots of each of 5 tree species as listed in the table below.
- One plot of each pair was fertilized with granular ammonium nitrate (50 kg N/ha/y), and the other served as a control and received only ambient N deposition (~9 kg N/ha/y).

Fertilizing a plot



Tree species used

Common Name	Latin name
Sugar Maple	*Acer saccharum*
American Beech	*Fagus grandifolia*
Eastern Hemlock	*Tsuga canadensis*
Northern Red Oak	*Quercus rubra*
Yellow Birch	*Betula alleghaniensis*

Field Methods

- Forest floor was sampled with a hand corer, and the deeper soils were sampled either with a hand corer or with a power corer (see photo below). Foliage from the trees was collected with a shotgun, using steel shot. The soil and plant samples were brought to the Cary Institute for processing and analyzed at either the Cary Institute, Boston University, or the University of Kentucky.
- Soil samples were incubated in the laboratory for 12 days to determine rates of nitrogen mineralization and nitrification, and were incubated for one year to determine respiration rates

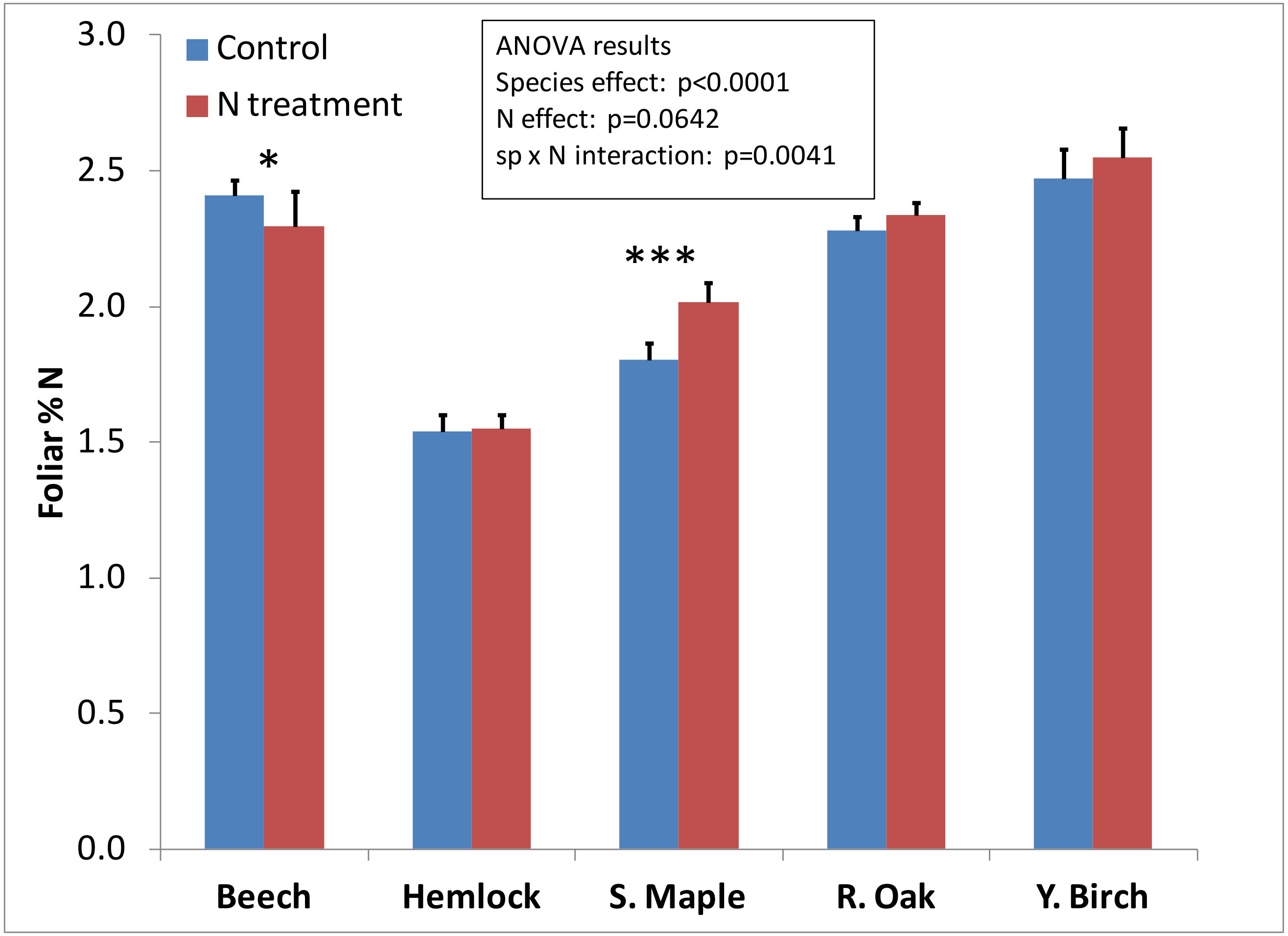
Sampling foliage →

← Sampling soil with the power corer

Results/Project Outcomes 1

- Fertilization only increased foliar nitrogen concentration significantly in sugar maple plots. There was a decline in N concentration in the fertilized beech plots, perhaps because the plots were affected by beech bark disease. This indicates that the trees (except for maples) were not particularly responsive to N fertilization, perhaps because they already receive enough N from the atmosphere.

Foliar N concentration in different species plots, shown as the mean of the 6 plots per species with error bars showing the standard error of the mean. Blue bars are control plots and red bars are the N treated plots.

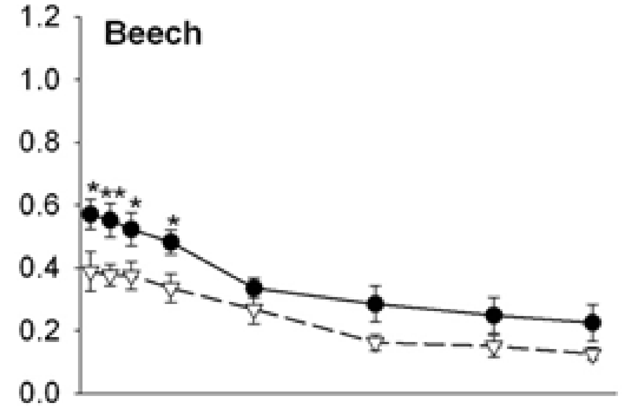


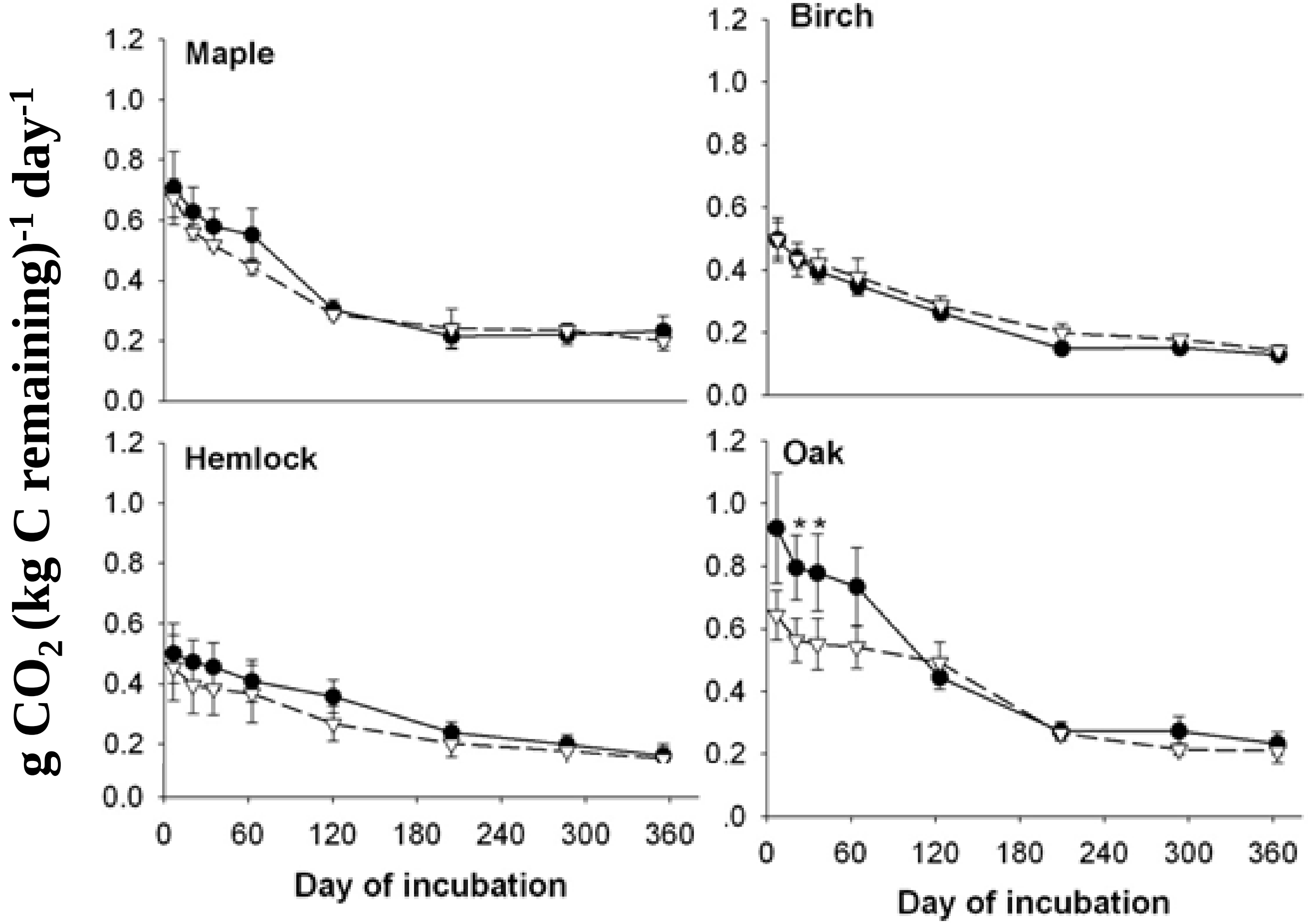
Results/Project Outcomes 2

- In the lab assay, we found that the nitrogen addition generally decreased soil respiration, an indicator of microbial activity. The result is seen in the first several weeks of the incubations , and is strongest for beech and oak plots. This decreased respiration may be a result of N inhibition of decomposition enzymes produced by microbes.

Sampling CO2 during the lab incubation

(Rodriguez et al. in review)

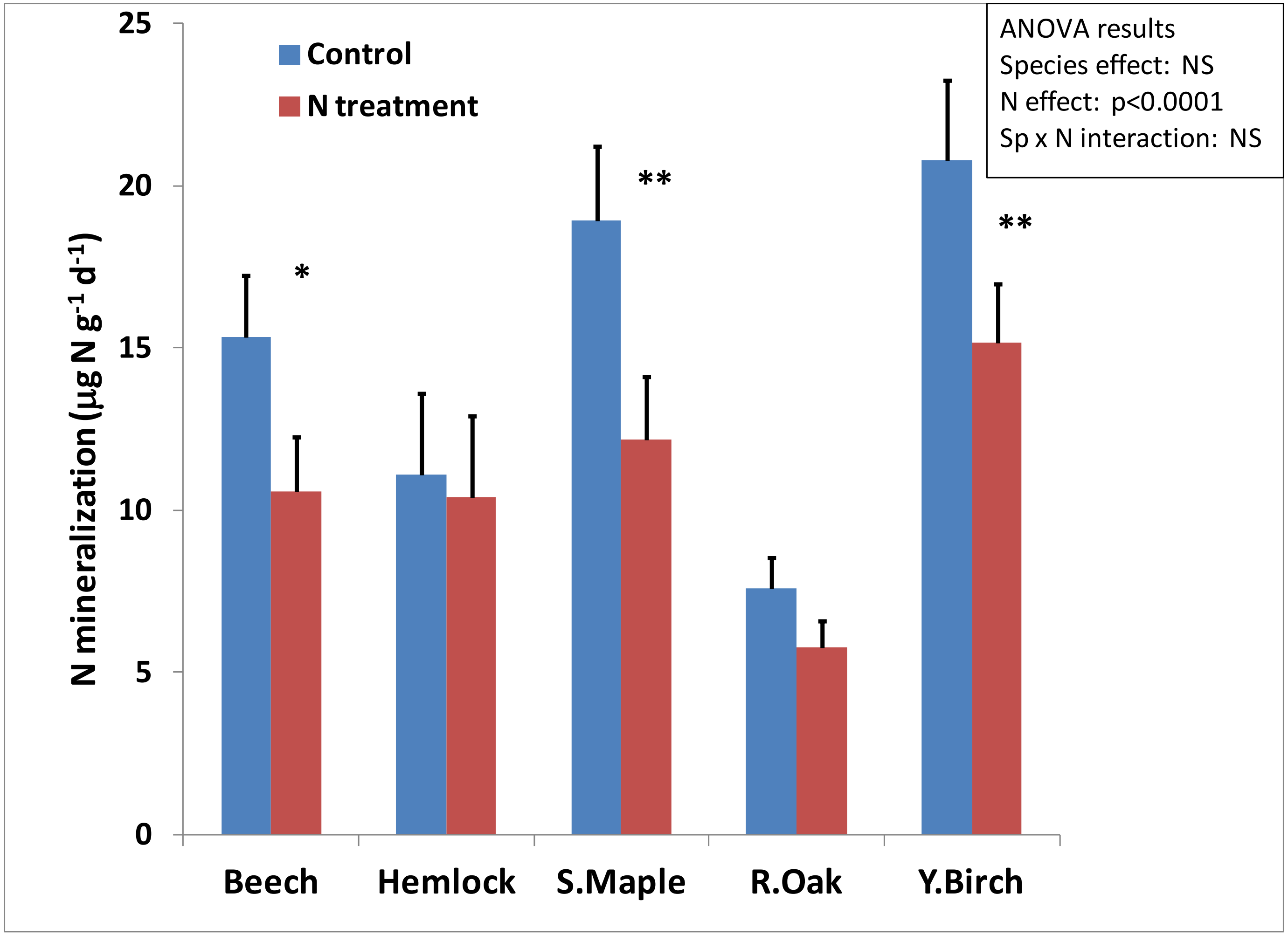




Results/Project Outcomes 3

- We also found that the rate of nitrogen mineralization in the soil was decreased in the fertilized plots compared to the control plots. This is another indication of reduced microbial activity.
- There was no significant difference among the species in rates of N mineralization.

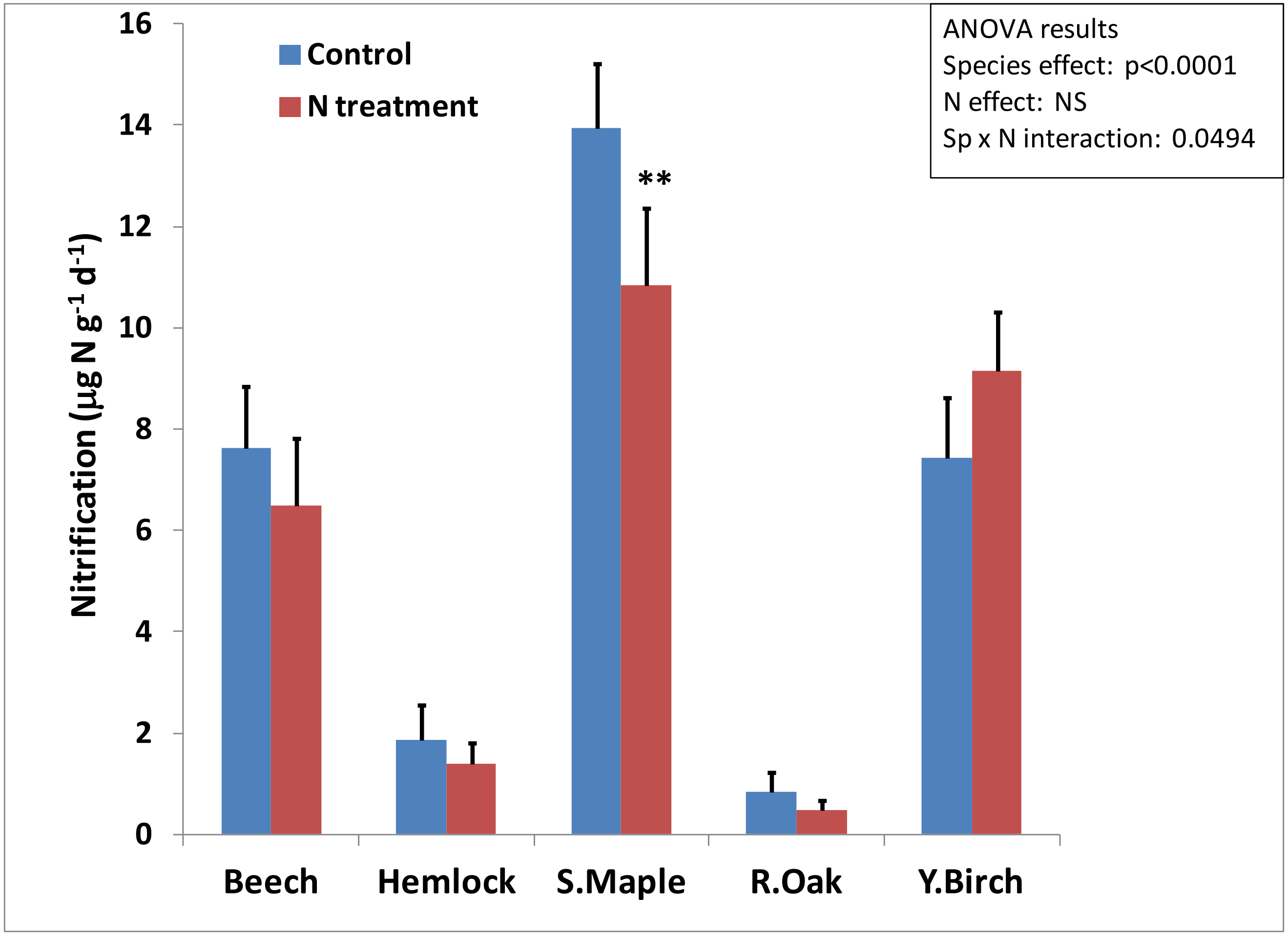
Rate of N mineralization in different species plots, shown as the mean of the 6 plots per species with error bars showing the standard error of the mean. Blue bars are control plots and red bars are the N treated plots.



Results/Project Outcomes 4

- Most of the species showed a decline in nitrification rate as a result of fertilization, but this effect was only significant in maple plots.
- There were strong species differences, with sugar maple having the highest nitrification rates and red oak the lowest.
- Nitrification is important because it produces nitrate, the mobile form of N than can leach from soil into surface waters.

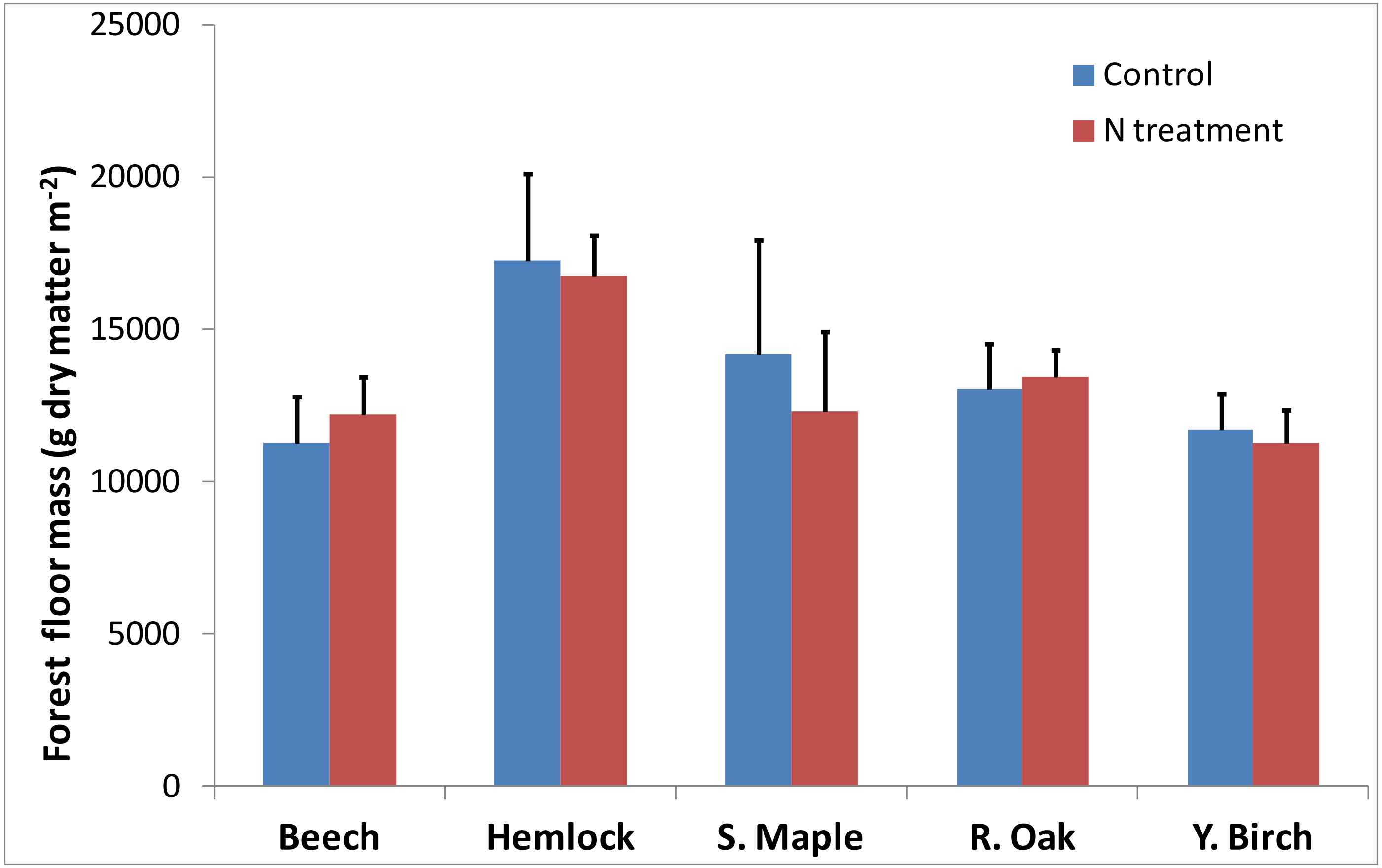
Rate of nitrification in different species plots, shown as the mean of the 6 plots per species with error bars showing the standard error of the mean. Blue bars are control plots and red bars are the N treated plots.



Results/Project Outcomes 5

- Despite the change in rates of soil microbial activity, our preliminary analysis has not found a significant difference in forest floor mass resulting from fertilization. There is a very high spatial variation in forest floor mass, making it difficult to observe an effect. Statistical analysis of these data is continuing.
- In general, hemlock stands had the highest forest floor mass.

Preliminary estimate of the mass of the forest floor in different species plots, shown as the mean of the 6 plots per species with error bars showing the standard error of the mean. Blue bars are control plots and red bars are the N treated plots.



Implications and applications in the Northern Forest region

- This study showed that addition of nitrogen, as occurs through nitrogen pollution of the atmosphere, can affect Northern Hardwood forests in unexpected ways. The expected fertilization effect on trees was not very strong, and there appeared to be an inhibitory effect on soil microbial activity, resulting in decreased decomposition rate. The decreased decomposition could lead eventually to increased forest floor mass.

- Tree species differed strongly in most of the attributes we measured. This suggests that models that predict future ecosystem processes in response to such stresses as air pollution and climate change should take into account potential future changes in tree species composition. In addition, management and policy decisions should consider that species vary in their susceptibility to N saturation.

Future directions

The results of this work suggest several avenues of future research:

- Examination of soil microbial processes and soil C storage across a gradient of N deposition in the Northeast. Gradient studies can complement experimental studies (like this one) to give the clearest picture of the effects of N deposition.
- Development of a computer model of forest ecosystem processes that includes the ability to change tree species composition. Tree species are changing because of several drivers including climate change and the introduction of new insects and pathogens, but current ecosystem models do not include the ability to change species composition.
- Experimental studies and models on the process of “de-saturation,” i.e., what happens when N deposition is decreased and the N stored in the ecosystem is released over time.
- Experimental studies to determine the factors that limit the growth of trees under conditions of chronically high N deposition.

List of products-1

Peer reviewed papers- published:

Lovett, G.M., M.A. Arthur, K.C. Weathers, R.D. Fitzhugh, and P.M. Templer. 2013. Nitrogen addition increases carbon storage in soils, but not in trees, in an eastern U.S. deciduous forest. *Ecosystems* 16: 980-1001.

Crowley, K.F., B.E. McNeil, G.M. Lovett, C.D. Canham, C.T. Driscoll, L.E. Rustad, E. Denny, R.A. Hallett, M.A. Arthur, J.L. Boggs, C.L. Goodale, J.S. Kahl, S.G. McNulty, S.V. Ollinger, L.H. Pardo, P.G. Schaberg, J.L. Stoddard, M.P. Weand, and K.C. Weathers. Do nutrient limitation patterns shift from nitrogen toward phosphorus with increasing nitrogen deposition across the northeastern United States? *Ecosystems* 15:940-957.

Peer-reviewed papers- in review:

Rodriguez, A., G.M. Lovett, K.C. Weathers, M.A. Arthur, P.H. Templer, C. L. Goodale and L.M. Christenson Stabilization of carbon in forest soils: Assessing the role of nitrogen deposition and tree species composition. Global Change Biology, in review (submitted October 2013)

Peer-reviewed papers- in preparation (titles and order of authorship are approximate):

Rodriguez A., G.M. Lovett, K.C. Weathers, M.A. Arthur, P.H. Templer, C. L. Goodale and L.M. Christenson. Soil nitrogen stabilization in a nitrogen-fertilized northern hardwood forest. In preparation for submission February 2014.

Lovett, G.M., A. Rodriguez, M.A. Arthur, K.C. Weathers, P.H. Templer, C. L. Goodale and L.M. Christenson. Effects of 13 years of N addition on a Northern Hardwood forest. In preparation for submission in spring 2014.

Templer, P.H., G.M. Lovett, Rodriguez, A., M.A. Arthur, K.C. Weathers, C. L. Goodale and L.M. Christenson. Fate of 15N 11 years after its addition to a northern hardwood forest. In preparation for submission in summer 2014.

List of products-2

Conference presentations:

Lovett, G.M., M.A. Arthur, K.C. Weathers, R.D. Fitzhugh and P.H. Templer. Nitrogen fertilization increases carbon storage in soil, but not in trees, in a Northeastern US forest. Ecological Society of America Meeting, Minneapolis, MN, August 2013 (Abstract published electronically)

Rodriguez, A., Lovett, G., Weathers, K., Arthur, M., Templer, P., Goodale, C., Christenson, L. Heterotrophic respiration in northern hardwood forest soils after 14 years of N addition. Ecological Society of America Annual Meeting, Portland, Oregon, August 2012 (Abstract published electronically)

Lovett, G.M., Arthur, M.A., Weathers, K.C., Fitzhugh, R.D., Templer, P.H. Nitrogen addition increases carbon storage in soils, but not in trees, in forests of the Catskill Mountains, New York, USA. BIOGEOMON Conference, Point Lookout, Maine, July 2012 (Abstract published electronically)

Lovett, G.M., M.A. Arthur, K.C. Weathers, R.D. Fitzhugh, and P.H. Templer. Nitrogen Fertilization Increases Carbon Storage in Soil, but Not in Trees, in a Northeastern US Forest, INTERFACE/ CLIMMANI Workshop on Nutrient Limitations to Carbon Cycling, Keflavik, Iceland, June 2011

Seminars and invited presentations:

Lovett, G. Nitrogen Saturation, Tree Species, and Carbon Storage in Northeastern Forests. University of New Hampshire seminar, September 2013.

Lovett, G. Nitrogen Saturation, Tree Species, and Carbon Storage in Catskill Forests. Cornell University seminar, September 2013.

Lovett, G. Carbon and Forests. Cornell Cooperative Extension Dutchess County, Teacher Training Workshop, Millbrook, NY, July 2013.