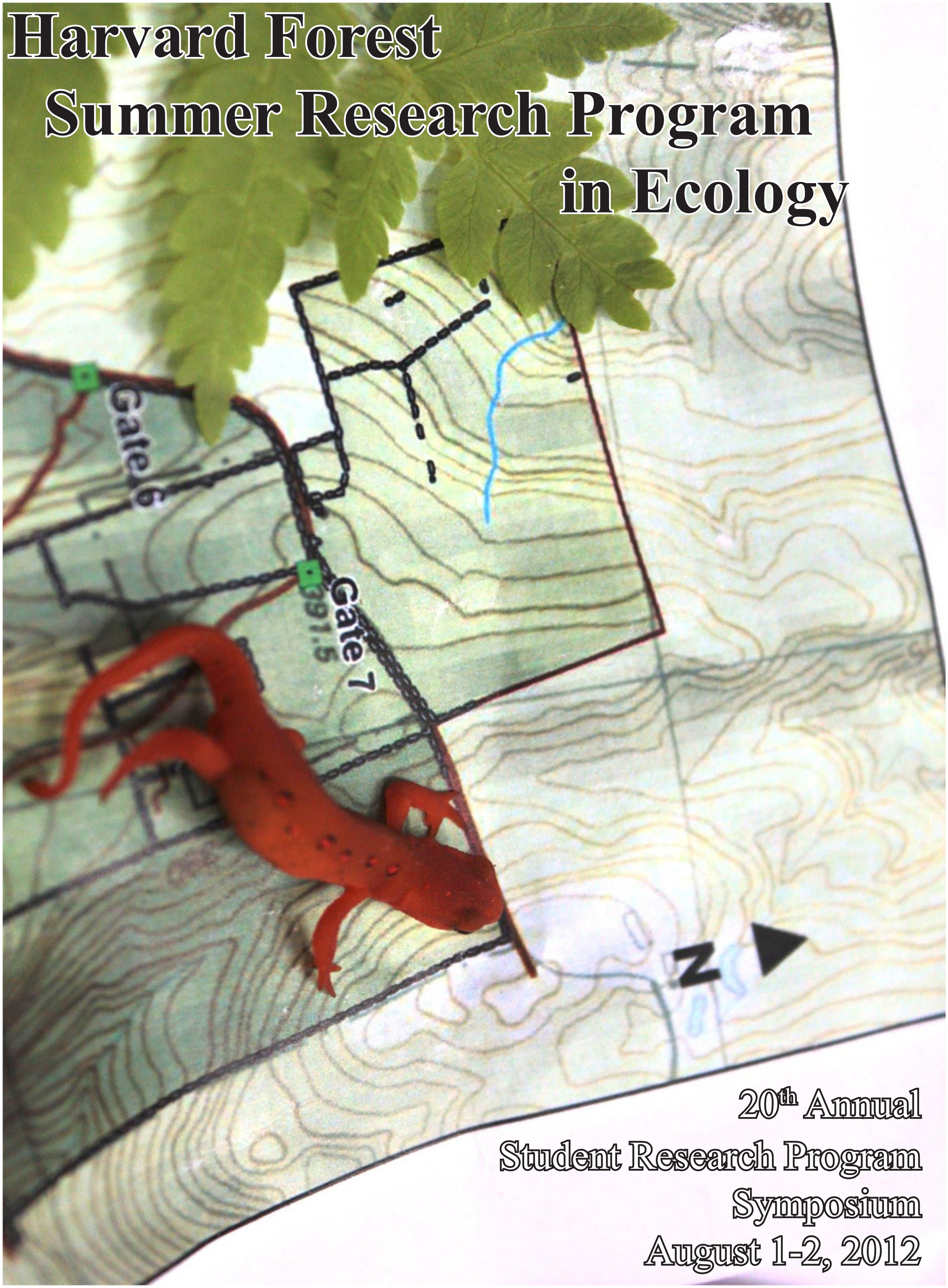
Harvard Forest
Summer Research Program
in Ecology



20th Annual
Student Research Program
Symposium
August 1-2, 2012

20th Annual Harvard Forest Summer Research Program Symposium

August 1-2, 2012
Harvard Forest Fisher Museum
Petersham, Massachusetts

Photography by Lindsay Day, Ross Heinemann, Harvard Forest Staff, and 2012 Summer Program Participants

Introduction to The Harvard Forest

Since its establishment in 1907, the Harvard Forest has served as Harvard University's rural laboratory and classroom for research and education in forest biology and ecology. Through the years, researchers have focused on forest management, soils and the development of forest site concepts, the biology of temperate and tropical trees, plant ecology, forest economics, landscape history, conservation biology, and ecosystem dynamics. Today, this legacy of activities is continued as faculty, staff, and students seek to understand historcal and modern changes in the forests of New England and beyond resulting from human and natural disturbance processes, and to apply this information to the conservation, management, and appreciation of natural ecosystems. This activity is epitomized by the Harvard Forest Long Term Ecological Research (HF LTER) program, which was established in 1988 through funding by the National Science Foundation (NSF).

Physically, the Harvard Forest is comprised of approximately 5,000 acres of land in the north-central Massachusetts town of Petersham. These acres include mixed hardwood and conifer forests, ponds, streams, extensive spruce and maple swamps, fields, and diverse plantations. Additional land holdings include the 25-acre Pisgah Forest in southwestern New Hampshire (located in the 5,000-acre Pisgah State Park), a virgin forest of white pine and hemlock that was 300 years old when it blew down in the 1938 Hurricane; the 100-acre Matthews Plantation in Hamilton, Massachusetts, which is largely comprised of plantations and upland forest; and the 90-acre Tall Timbers Forest in Royalston, Massachusetts. In Petersham, a complex of buildings that includes Shaler Hall, the Fisher Museum, and the John G. Torrey Laboratories provide office and experimental space, computer and greenhouse facilities, and lecture room for seminars and conferences. Nine colonial-style houses provide accommodations for staff, visiting researchers, and students. Extensive records, including long-term data sets, historical information, original field notes, maps, photographic collections, and electronic data are maintained in the Harvard Forest Archives.

Administratively, the Harvard Forest is a department of the Faculty of Arts and Sciences (FAS) of Harvard University. Faculty associated with the Forest offer courses through the Department of Organismic and Evolutionary Biology (OEB), the Harvard Kennedy School (HKS), and the Freshman Seminar Program. Close association is also maintained with the Department of Earth and Planetary Sciences (EPS), the School of Engineering and Applied Science (SEAS), the School of Public Health (SPH), and the Graduate School of Design (GSD) at Harvard and with the Departments of Biology, Natural Resource Conservation, and Computer Science at the University of Massachusetts, the Ecosystems Center of the Marine Biological Laboratory and the Complex Systems Research Center at the University of New Hampshire.

The staff and visiting faculty of approximately fifty work collaboratively to achieve the research, educational, and management objectives of the Harvard Forest. A management group meets monthly to discuss current activities and to plan future programs. Regular meetings with the HF-LTER science team, weekly research seminars and lab discussions, and an annual ecology symposium provide for an infusion of outside perspectives. The six-member Facilities Crew under take forest management and physical plant activities. Funding for Harvard Forest operations is derived from endowments, whereas major research support comes primarily from federal and state agencies (e.g., National Science Foundation, Department of Energy, Commonwealth of Massachusetts Department of Conservation and Recreation), private foundations, and individuals.

About The 2012 Summer Research Program

In 2012, the Harvard Forest Summer Student Research Program, coordinated by Manisha Patel and assisted by Lindsay Day and Ross Heinemann, attracted a diverse group of 31 students to receive training in scientific investigations and to gain experience in long-term ecological research. All students worked closely with researchers while many conducted their own independent studies. The program included weekly seminars from resident and visiting scientists, discussions on career paths in science, and field exercises on navigation, land-use history, and nature sketching. Students presented major results of their work at the Annual Summer Student Research Symposium in early-August.

Summer Student Researchers 2012

2012 Student Seminars and Programs

Wed., May 23	Using Data and Models in Ecology - Trevor Keenan, Harvard University, OEB
Wed., May 30	Science Check-in – Manisha Patel, Summer Program Coordinator
Mon., June 4	Navigation Workshop – Sydne Record and Audrey Barker Plotkin, Harvard Forest
Wed., June 6	Forest Walk – David Foster (6pm START TIME. 2 hours)
Mon., June 11	Warm Ants: Community and Thermal Ecology of Ants of Harvard Forest – Israel Del Toro, University of Massachusetts
Thurs., June 21	Harvard Museum of Natural History Behind-the-Scenes Tour
Wed., June 13	Talking Ecology with the Public – Clarisse Hart, Harvard Forest
Mon., June 18	Students present elevator speeches, I
Wed., June 20	Students present elevator speeches, II and Science Check-in – Manisha Patel, Summer Program Coordinator
Mon., June 25	Graduate School Panel
Wed., June 27	Literary Routes: A Birds Eye View of the Forest – Rosalinda Ruiz, University of Alcalá
Mon., July 2	Nature Sketching – Elizabeth Farnsworth (6pm START TIME. 1.5-2 hours)
Mon., July 9	Career Panel
Wed., July 11	Scientific Presentation Workshop – Dave Orwig, Harvard Forest
Mon., July 16	Conservation Decision-Making – Elizabeth Crone, Harvard Forest
Wed., July 18	Scientific Abstract Writing Workshop – Allyson Degrassi and Ross Heinemann
Mon., July 23	Seeing the Forest for the Trees – Observing and Modeling Phenology across Multiple Scales – Mark Friedl, Boston University
Wed., July 25	Science Check-in – Manisha Patel, Summer Program Coordinator

Funding for the Summer Research Program

The Harvard Forest Summer Research Program in Ecology in 2012 was supported by the following organizations:

National Science Foundation
1. LTER IV: Integrated Studies of the Drivers, Dynamics, and Consequences of Landscape Change in New England (DEB-0620443)
2. REU Site: Harvard Forest Summer Research Program in Forest Ecology 2010-2014: Ecological data-model fusion and environmental forecasting for the 21st Century (DBI-1003938)
3. FSML: Infrastructure for molecular and microbial ecology at the Harvard Forest (DBI-0930516)
3. How Important Is 'Colored' Stochastiticy for Plant Population Dynamics (DEB-1020889)

US Department of Energy and University of North Carolina - Impacts of elevated temperature on ant species, communities and ecological roles at two temperate forests in eastern North America (DE-FG02-08ER64510)

United State Department of Agriculture (USDA) and University of Rhode Island,
A Foodweb Approach to Native Plant Protection in a Forest (2011-67013-30142)

US Environmental Protection Agency, Predicting Regional Allergy Hotspots in Future Climate Sce-narios (RD-83435901-0)

National Aeronautics and Space Administration, Langley Research Center, Data-model fusion and forecasting 21st-Century environmental change in northeastern North America (NNX10AT52A)

Other Funders

Ecological Society of America – Strategies for Ecology Education, Diversity and Sustainability: Diverse People for a Diverse Science Program

Grinnell College Internship Program

Mount Holyoke College – Center for the Environment Summer Leadership Fellowship

Harvard University, the Faculty of Arts and Sciences and Harvard Forest endowment gift funds including the G. Peabody "**Peabo**" Gardner Memorial Fund.

20TH ANNUAL HARVARD FOREST SUMMER RESEARCH PROGRAM SYMPOSIUM

AUGUST 1-2, 2012 FISHER MUSEUM

Wednesday, August 1st, 10:00 a.m. - 3:45 p.m

10:00	Aaron Ellison	Harvard Forest		Welcome
Session I: Water				
10:15	Tefiro Serunjogi	Grinnell College	Colburn	What is the Response of Turbidity and Pathogen Levels to Variations in Sand Depths in Filters?
10:30	Yujia Zhou	Dickinson College	Boose & Lerner	Quality Control of Sensor Data and Data Provenance Tracking
10:45	Miruna Oprescu	Harvard College	Boose & Lerner	Visualization Tools for Digital Dataset Derivation Graphs
			~15 Minute Break ~	
Session II: Insect and Plant Dynamics				
11:15	Jennie Sirota	North Dakota State University	Ellison & Baiser	Identifying Indicators of Tipping Points within Aquatic Micro-Ecosystem of the Pitcher Plant
11:30	Aubrie James	Iowa State University	Crone & Breed	New Host, New You! How a Butterfly's Change in Hostplant Enlightens Our Understanding of Developmental Resource Partitioning and Sexual Selection
11:45	Kelsey McKenna	Harvard College	Crone, Crall & Donnelly	Does Bumblebee Body Size Affect Foraging Distance or Flight Maneuverability?
			~ Lunch Break ~	
Session III: Forest Dynamics				
1:00	Alexander Kappel	Clark University	Williams, Vanderhoof & Khomik	Post Disturbance Soil Respiration Dynamics in a Clear Cut Temperate Forest
1:15	Paul Quackenbush	Middlebury College	Williams, Vanderhoof & Khomik	The Leaf Level Relationship Between Temperature, Leaf Nitrogen and Photosynthetic Parameters in Five C3 Species
1:30	Anne Cervas	Harvard College	Barker Plotkin	Changing Vegetation Structure in Current and Former Plantations at the Harvard Forest
			~ 15 Minute Break ~	
Session IV: Urban to Rural Gradients				
2:00	Erin Frick	Mount Holyoke College	Friedl, Melaas & Gray	Determining the Reliability of MODIS Vegetation Indices to Assess Vegetative Phenological Trends Across Regional Scales
2:15	Jose Luis Rugelio	Lincoln University	Friedl, Melaas & Gray	Phenology: An Urban to Rural Gradient
2:30	Tiffany Carey	University of Michigan	Stinson	Determining How Climate Change Affects the Growth and Distribution of Ragweed Plants Across the New England Gradient
	Courtney Maloney	University of California, Berkeley	Stinson	Examining the Influence of Ragweed Regional Ecotypes on Reproductive Investment and Pollen Output Under Increasing Atmospheric CO_2 Concentrations
			~ 15 Minute Break ~	
Session V: Research and Teaching				
3:15	Katherine Bennett	Ashburnham-Westminster Reg. School District	Richardson, Toomey & Klosterman	K-12 Phenology Lessons for the *Phenocam* Project
3:30	Bill Van Valkenburg	Gardner High School	Stinson	Effect of Elevated CO_2 on Ragweed Morphology and Response of Varying Ecotypes

20TH ANNUAL HARVARD FOREST SUMMER RESEARCH PROGRAM SYMPOSIUM

AUGUST 1-2, 2012 FISHER MUSEUM

Thursday, August 2nd, 10:00 a.m. - 4:45 p.m.

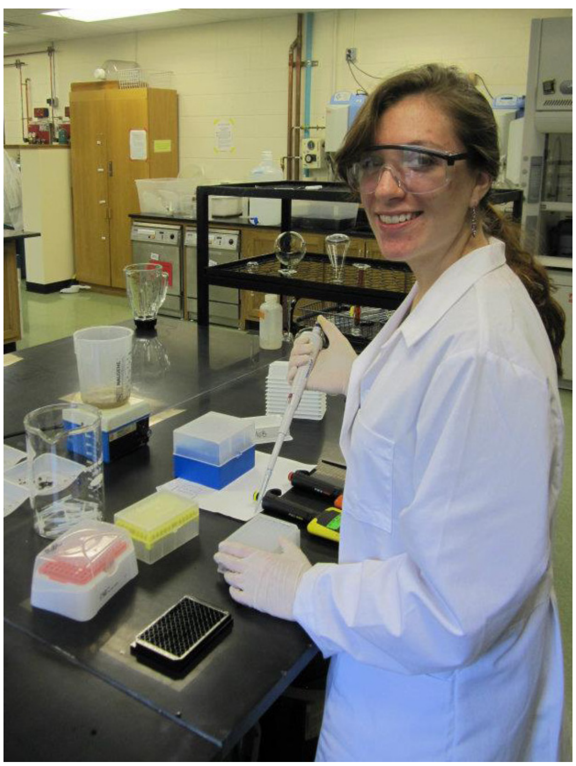
Session VI: Forest Ecosystems				
10:00	Lauren Alteio	SUNY, ESF	Melillo, Scott Baldino, & Werner	Soil Microbial Enzyme Potential in Response to Forest Soil Warming
10:15	Samuel Knapp	University of Wisconsin, Stevens Point	Abramoff	Seasonality of Fine Root Growth, Mortality, and Carbon Allocation in Temperate Forest Trees: Underground Observations with a Minirhizotron
10:30	Julia Brokaw	Cornell University	Orwig	Effects of Hemlock Woolly Adelgid and Elongate Hemlock Scale Interactions on Eastern Hemlock
	Vincent Waquiu	Southwestern Indian Polytechnic Institute	Orwig	The Impact of Co-occurring Invasive Insects on Eastern Hemlock Branch Growth and Chemistry
		~15 Minute Break ~		
Session VII: Soil Carbon Dynamics				
11:15	Margaret Garcia	Villanova University	Tang, Yu & Savas	Bird's Eye View: Using GIS for Plot Level Data
	Candice Hilliard	Cornell University	Tang, Yu & Savas	Soil Carbon Dynamics at Harvard Forest
	Adalyn Naka	Brown University	Tang, Yu & Savas	Factors Affecting Carbon Efflux at Harvard Forest
		~ Lunch Break ~		
Session VIII: Animal Dynamics				
1:00	Yvan Delgado de la Flor	Humboldt State University	Ellison & Ribbons	Eastern Hemlock Forests Provide Habitat to a Greater Vareity of Spiders
	Elizabeth Kennett	University of Vermont	Ellison & Degrassi	A Mark-Recapture Study of the Rodent and Shrew Populations Within a Declining Hemlock Stand
	Andrew Moe	Vermilion Community College	Ellison & Faison	Ungulate Response to Simulated Hemlock Woolly Adelgid and Salvage Logging Disturbance
		~ 15 Minute Break ~		
Session IX: Global Climate Change				
2:00	Matthew Combs	Hamilton College	Ellison, Pelini & Del Toro	Hot Eggs: An Exploration of Ant Nests and Temperature Change
2:15	Katherine Davis	Duke University	Ellison, Pelini & Del Toro	Effects of Warming on Slugs and Decomposition in Harvard Forest, MA
2:30	Sonia Filipczak	Essex County College	Blanchard	Global Warming and its Effects on Forest Soil Micro Bioomes
		~ 15 Minute Break ~		
Session X: Phenology				
3:00	Dmitri Ilushin	Harvard College	Richardson, Toomey & Klosterman	Alternatives to Remote Sensing of Phenology Using Public Outdoor Webcams
	Sascha Perry	Lincoln University	Richardson, Toomey & Klosterman	Tracking Seasonal and Climatic Changes through Webcam Imagery
	Hannah Skolnik	John Hopkins University	Richardson, Toomey & Klosterman	Using Webcam Imagery to Study Forest Phenology on a Global Scale
		~ 15 Minute Break ~		
Session XI: Conservation Awareness				
4:00	Emma Schnur	Cornell University	Kittredge	Assessing Land Owner Conservation Awareness Along Urban-to-Rural Gradients
4:15	Laura Bartock	University of Maryland, Baltimore County	Kittredge	Clearing Up the Fog: An Analysis of Knowledge and Uncertainty in Conservation Awareness Data
Closing				
4:30	Aaron Ellison	Harvard Forest		Tick Study and Remarks

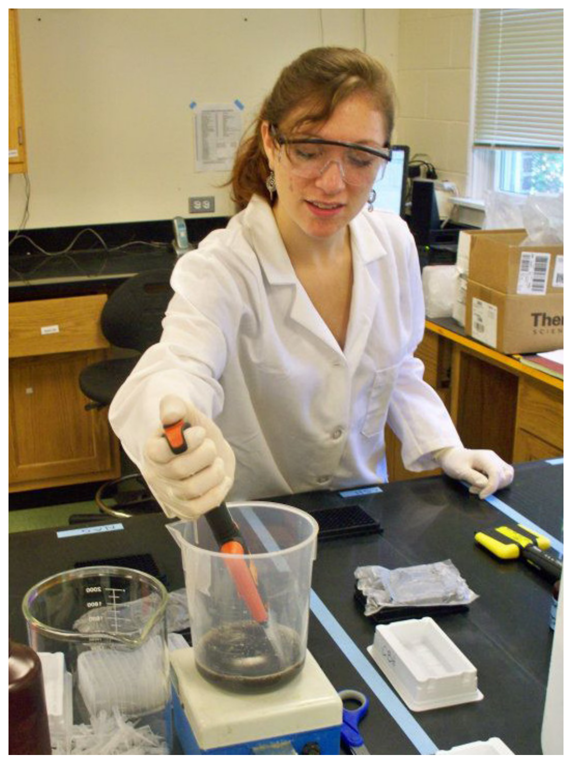
Lauren Alteio

State University of New York, College of Environmental Science and Forestry
Mentors: Jerry Melillo, Lindsay Scott, Chelsea Baldino, and William Werner

Soil Microbial Enzyme Potential in Response to Forest Soil Warming

Global climate change is impacting the function and health of our forest ecosystems. Soil plots at Prospect Hill have been heated five degrees Celsius above ambient temperature for twenty-one years to mimic the effects that rising global temperatures may have on northeastern hardwood forests. Over the past 21 years, the difference in the amount of CO_2 respired from heated and control plots has changed: initially, the amount was greater in the heated plots than in the control. Between years ten and fifteen of the study, there was a negligible difference in CO_2 respired, but this difference is now increasing again. Our hypothesis states that this change is due to microbial community shifts, allowing soil microbes to produce enzymes to break down alternative carbon sources. This summer, I explored the possible reasons for this increase in CO_2 respired by examining microbial enzyme potential through enzyme assays. This methodology allows us to view potential microbial activity and metabolic mechanisms in the lab, and apply the findings to *in situ* activity. I expected the level of hydrolytic activity of β-1,4-Glucosidase, β-D-1,4-Cellobiosidase, and β-N-Acetylglucosaminidase to be greater in the control plots where simpler, labile compounds are more readily available. I also projected that the activity of the oxidative enzymes, Phenol Oxidase and Phenol Peroxidase, would be greater in the heated plots where labile compounds have largely been depleted and more recalcitrant compounds remain. I conducted three rounds of enzyme assays using organic horizon soil from the heated and disturbance control plots at Prospect Hill. I plated the twelve soil slurry samples, and read the fluorescence and absorbance using a microplate reader. I found that there was a significant difference in enzyme activities between months, but not between heated and disturbance control treatments. For some enzyme activity potentials, I found the percent soil moisture affected enzyme activity.





Laura Bartock

University of Maryland, Baltimore County
Mentor: David Kittredge

Clearing Up the Fog: An Analysis of Knowledge and Uncertainty in Conservation Awareness Data

Families privately own the overwhelming majority of Massachusetts' woodland. For this reason, it is important to understand the conservation awareness and decision-making processes of these families in order to understand the way the forests of Massachusetts may change in the coming years. The Conservation Awareness Index (CAI) has been used in multiple studies to assess general awareness of conservation options among landowners in Massachusetts. In this study, survey data from CAI 1.0 (2010), 2.0 (2011), and 3.0 (2012) are used to determine which questions are answered correctly most frequently, as well as which questions are answered as "don't know" or left unanswered most frequently. Additionally, through an exploratory interview format, qualitative data from CAI 4.0 (2012) is examined to determine on which questions participants experience "fog," a term for expression of uncertainty or hesitation, most often. Both quantitative and qualitative data were also analyzed to determine differences in knowledge and differences in uncertainty by generation.

Across several measures, conservation restrictions ranked most uncertain among the true/false questions. Among the true/false questions, the first generation more frequently responded with "don't know" or no answer more often than the second generation. However, when the first generation responded with either true or false, they were more likely to answer correctly than the second generation. When examining qualitative "fog" data from the interviews, the estate planning subsection had the highest degree of uncertainty of the four subsections. However the overwhelming majority of the uncertainty was focused on one question, whereas, in other sections, uncertainty was spread across all questions. There is no significant difference in uncertainty between the generations. These findings suggest that long-term conservation strategies, conservation restrictions and estate planning, should be clarified in conservation outreach and education. Furthermore, generational differences are slight enough that no significant change can be predicted for the future.

Julia Brokaw

Cornell University
Mentor: David Orwig

Effects of Hemlock Woolly Adelgid and Elongate Hemlock Scale Interactions on Eastern Hemlock Growth and Foliar, Fine Branch, and Litter Chemistry

Heavy infestations of herbivorous insects can contribute to rapid changes in forest ecosystems. Currently in the northeastern U.S., two co-occurring invasive pests, the hemlock woolly adelgid, *Adelges tsugae*, and the elongate hemlock scale, *Fiorinia externa*, both feed on the eastern hemlock, *Tsuga canadensis*. While they share a native host plant, their feeding mechanisms differ. *A. tsugae* feed on the ray parenchyma cells on the undersides of twigs and *F. externa* feed on the mesophyll cells on the undersides of the needles. *Fiorinia externa* is not considered to be as destructive as *A. tsugae*, but understanding individual tree responses to the combined impacts of these insects is especially important as these insects may interact in unpredictable ways. In order to document the impact of these pests on hemlock health, new branch growth was measured and the percentages of branches producing new shoots were documented in twelve hemlock stands differing in insect densities across southern New England. Four treatments were examined in these stands: high *A. tsugae*, high *F. externa*, both *A. tsugae* and *F. externa*, and no infestation. Foliar, twig, and fallen litter chemistry was also examined. Additionally, we analyzed the chemistry of scale covers and adelgid wool. Our results showed that the percentage of branches with new growth was significantly reduced in stands infested with *A. tsugae* or both insects (40-50%) compared to *F. externa*-infested and uninfested trees (75% and 60%, respectively). The length of new growth was significantly lower on trees with both *A. tsugae* and *F. externa* (1.5 cm) compared to uninfested branches (> 3 cm). New shoot growth declined significantly with increasing *A. tsugae* density but not with increasing *F. externa* density. We also found that these insects influence foliar and fine twig chemistry, as foliar nitrogen content (%N) increased significantly in infested versus uninfested needles, but did not differ among insect treatments. Fine twig %N was significantly higher in sites with high *A. tsugae* and the presence of both insects (~1-1.2%N). The %N in hemlock litter collected from the forest floor under each tree was not significantly different across stand/insect site types but contained more N (1.11-2.78%) than living needles. The percent carbon (%C) did not differ across treatments in any parameter. The scale covers had a high nitrogen content (5.75%-9.16%) and adelgid wool had lower values (0.78%-2.57%). *T. canadensis* are not resistant to *A. tsugae* or *F. externa*, however the higher %N in fine twigs suggests a defensive response to *A. tsugae* infestation. The feeding of both insects led to significant changes in growth and chemical changes within needles and twigs compared to uninfested forests, but did differ substantially from impacts by *A. tsugae* alone. Our findings of pest-induced changes in twig and foliar chemistry and their by-products will likely affect subsequent ecosystem processes like decomposition, and should be examined further.


Photo Credit: Brokaw Photography

Tiffany Carey

University of Michigan
Mentor: Kristina Stinson

Determining How Climate Change Affects the Growth and Distribution of Ragweed Plants Across the New England Gradient

One of the many signs of spring is the United States' report on pollen counts across the country. These pollen counts are essential, due to the 35 million Americans who get hay fever every year from pollen. In this project, we investigated whether allergenic pollen concentrations from three ecotypes of common ragweed (Ambrosia artemisiifolia) produce more pollen in response to rising CO_2 concentrations. Ragweed seeds were taken from several sites in different states(Massachusetts, Vermont and New York) and grown in hoop houses with CO_2 concentrations of 400, 600 and 800 ppm in the year 2011. The three levels represented the current carbon dioxide concentrations and predicted concentrations over the next 100 years. Our objective was to test for differences in pollen production by ecotypes from these climatically distinct parts of New England. In order to predict when and where pollen allergies are most likely to increase in response to climate change, we have to determine its impact in different places.

There were two components we focused on within our project this year. We analyzed the amount of pollen produced by each ecotype, and in each of the three CO_2 concentrations. To do this we created a stratified random subset of approximately 90 plans out of the full experimental design. The pollen was collected and frozen from the three to five flowering spikes per plant by covering the spikes with polyethelene bags at the time of flowering until pollen was completely released and then placed in a sub-80C freezer. To extract the pollen from each ragweed plant we constructed a solution of 12mL, of distilled water and pollen from one ragweed spike. Using a Hemocytometer, we counted the amount of pollen grains that were present in 10 uL of the solution to assess the amount of pollen produced by each ragweed plant. We also measured the length and weighed the dry biomass of each ragweed plant to examine the growth under these three conditions.

With this data we predict a high degree of spatial heterogeneity in pollen concentrations across the New England gradient. This corroborates our observations that there is statistical significance between ecotypes and growth and production of ragweed plants. This project has potential for an increase in public health management to help identify health risks associated with different regions of New England. The importance of these results will only increase over the next several decades, as climate change increases the quantity and allergenicity of pollen in certain area via rises in CO_2 concentrations and temperatures.

Anne Cervas

Harvard College
Mentor: Audrey Barker Plotkin

Changing Vegetation Structure in Current and Former Plantations at the Harvard Forest

While pine and spruce plantations were an important component of forestry in New England over the first half of the 20th century, plantation activity ceased in the 1950s due to extensive tree damage and mixed results in plantation growth. In 2007, about 55 hectares of plantations remained at Harvard Forest, in stands ranging from 0.4 to 15 hectares. Twenty-two 20 by 20 meter permanent plots were established in these plantations and the vegetation in these plots was surveyed in summer 2007. In 2008 and 2009, about half of the remaining plantation area was clear-cut to create a young forest cohort. This summer, I examined how vegetation structure and diversity have changed over the past five years, in order to determine the variation among the harvested sites, as well as examine the differences between harvested and forested sites. I compared vegetation measurements among sites to see the magnitude of changes in harvested versus control plots and to see if control sites have started the process of succession to native forest on their own accord. I expected that basal area would be higher in control sites, since they contain mature trees, but that all other measurements would be higher in the harvested plots, which should have more species diversity and tree regeneration as they grow back. I hypothesized that control plots may vary based on which planted tree species dominates, but I did not expect to see major differences between harvested plots on the same basis. My mentor and I revisited all twenty-two plots and recorded the species and diameter of all trees, stumps, snags, and coarse woody debris (CWD), the number and species of saplings, the presence of seedling species, and the composition and cover of understory vegetation. From my field measurements, I calculated and compared the differences in the overstory, in terms of basal area and stem density; regeneration, as measured by sapling density; the understory, in terms of understory species richness and community composition; and dead wood, as measured by the volume of CWD. Preliminary results suggest considerable variation among harvested and control sites, but little difference between the two types of sites as stem density, CWD, and species richness are not considerably higher in harvested sites. While basal area appears to be much higher in control sites than harvested sites, basal area is declining in control sites, which suggests that plantation stands may be ceding to native forest. Finally, neither control nor harvested sites seem to exhibit extensive variation on the basis of dominant planted tree species. My results have important implications for future research and forest management at the Harvard Forest, as extensive variation among harvested or control sites may limit application of research in sites across the Harvard Forest. In addition, evidence of the natural break up of plantations or variation across sites based on current or former plantation species can inform decisions about forest management.

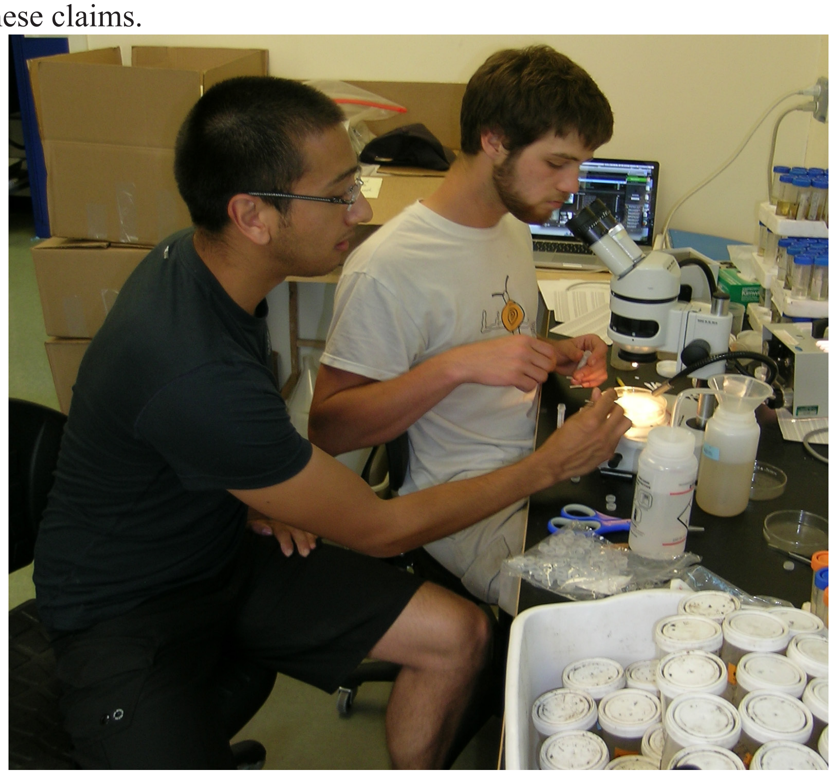
Matthew Combs

Hamilton College

Mentors: Aaron Ellison, Shannon Pelini, and Israel Del Toro

Hot Eggs: An Exploration of Ant Nests and Temperature Change

The ant *Formica subsericea* is a widespread and abundant species, known to drive ecosystem function through soil turnover, seed dispersal, and nitrogen movement. While these above-ground activities are well documented and fairly easy to observe, little is known about the way *F. subsericea* colonies behave within their subterranean nests. I describe the distribution of adult ants and their brood in *F. subsericea* nests and determine whether they are significantly affected by the soil temperature as it shifts throughout the day. At a field site in Montague, Massachusetts I extracted nine nest casts by pouring molten wax down the surface entrances at particular times of the day, essentially freezing them in time. The casts were excavating once the wax solidified. In the laboratory these nests were weighed, photographed, and melted down, providing accurate counts of adults ants and various stages of brood development at known depths. A bimodal trend was recorded for the distribution of nest volume as described by depth, with a large peak around 15cm and a minor peak around 30cm. Similar patterns were found to exist in the distribution of both ants as well as brood in the early morning hours, when temperatures are cooler. During the hottest hours of the day, the bimodal trend was absent. These ants and brood were found at deeper temperatures, with very few remaining above 15cm in depth. Temperature gradients from the field site show that below 15cm temperatures become fairly steady at 25°C. Between 0 and 15cm, temperatures are known to change upwards of 20°C throughout the day. These results support previous conclusions that some ant species move their brood throughout the day in order to optimize temperature for brood development (Roces, 1989). We can now say that the ideal temperature for *F. subsericea* is about 25°C. These results also mean that further temperature increases, as predicted by global climate change models, would drive the ants deeper in order to reach the same optimum temperature. This would mean more colony energy would be spent on digging and brood movement, leaving less colony energy for above-ground activities and a potential loss of ecosystem fitness. More research into energy allocation and brood development is required to be certain of these claims.



Katherine Davis
Duke University
Mentors: Aaron Ellison, Shannon Pelini, and Israel Del Toro

Effects of Warming on Slugs and Decomposition in Harvard Forest, MA

Slugs are well known as garden and agricultural pests, but also play important roles in forest ecosystems. Slugs can influence decomposition by consuming dead organic material, and ultimately make nutrients available to plants. Studies have also shown that fecal material from slugs, as well as the mucus they produce for movement, creates favorable conditions for bacteria, further contributing to decomposition. As the climate warms, it is important to understand how invertebrates and the ecosystem processes mediated by them will be affected. I investigated the response of *Arion lusitanicus*, a non-native slug common in central Massachusetts and their influence on decomposition under different warming treatments by placing slugs in heated open-top chambers at Harvard Forest, Massachusetts. Hot water was used to increase the air in each chamber, resulting in a temperature range of 0 to 5.5°C above ambient. I used two enclosures, one with three slugs and the other with no slugs, in each chamber. Each container had the same amounts of potting soil, leaf litter, and bran flakes (food for the slugs). Over the course of four weeks, I monitored slug mortality and the amount of food consumed in each chamber. I also weighed the leaf litter to determine decomposition rates and the slug weight at the beginning and end of the experiment in order and whether the slugs gained or lost weight. I expected to see an increase in slug food consumption due to higher metabolic rates in the warm chambers, and higher slug mortality in the warm chambers because of desiccation.

Neither slug mortality rates nor slug weight changed across temperature treatments, but the slugs in warmer chambers consumed significantly less food than those in cooler chambers. This may be due to slugs' preference for moist food items; if the food dried out faster in the warmer chambers, the slugs may have stopped eating it. Decomposition occurred at a faster rate in the warmer chambers, but was not affected by the presence or absence of slugs. More research is needed to understand how these slugs function in the forest and how that might change in the future.

Yvan Delgado de la Flor

Humboldt State University
Mentors: Aaron Ellison and Relena Ribbons

Eastern Hemlock Forests Provide Habitat to a Greater Variety of Spiders Compared to Non-Hemlock Forests

Eastern hemlock (*Tsuga canadensis*) is a foundation species in eastern North America and plays a critical role in the local biota. Hemlock forests deeply shade the soil and create a unique microclimate for some species. Currently, hemlocks are dying rapidly due to the invasive hemlock woolly adelgid (*Adelges tsugae*), a nonnative phloem-feeding insect. Hemlocks are being replaced slowly by hardwood forests and this may cause alterations to the understory microclimates. All of these changes affect the entire ecosystem and result in the local extinction of some arthropods; for example, some spiders are very sensitive to changes in temperatures and any increase in temperature may have a direct impact in their habitat. In this study I measured the impact of hemlock loss on spider communities in hemlock stands and contrasted spider assemblages in hemlock and hardwood stands. I hypothesized that the loss of eastern hemlock and associated increase in forest-floor temperature would result in the extirpation of some spider genera. The effect of the adelgid was mimicked with four 30x30m canopy-manipulation treatments: 1) hemlock control, which is a forest dominated by hemlocks, 2) girdled hemlock, simulating tree mortality due to the hemlock woolly adelgid, 3) logged hemlock, mimicking the impact of the lumber companies and 4) hardwood control, in which the forest are dominated by non-hemlock trees simulating the succession event after the dead of the hemlock trees. Pitfall traps were sampled approximately every two weeks to set up and collect pitfalls. Pitfalls are small plastic cups that are placed at ground level and filled up with one-inch of soapy water. I picked up the pitfalls two days after I set them. Then, I brought them to the laboratory to proceed with the identification. I sorted all the pitfalls into three small tubes: ants, spiders and beetles. I identified spiders to genus, whereas ants and beetles were archived for future investigations. Initial results suggested little differences among the treatments, but sample size remained small because I am currently working on the spiders' identification from the pitfall traps collected recently. Eastern hemlocks occupy large area of late successional forests in eastern North America and the effect and impact will be better observed in 20 or more years, when hemlocks will be locally extinct, potentially leading to the extirpation of spiders and other species, and the alteration of local food webs and ecosystems.

Photo Credit: Brokaw Photography

Sonia Filipczak

Essex County College

Mentor: Jeff Blanchard

Global Warming and Its Effect on Forest Soil Micro Biomes

Global Warming has had a significant affect on our planet through the continual rise in green house gases mostly emitted through anthropogenic means. Since soil feedback has the potential to dramatically impact our climate system, Jerry Melillo started an experimental study here at Harvard Forest to observe these theories. In doing so, we would be able to determine the long-term response of soil organic matter (SOM) decomposition to higher temperatures. What I am looking to understand is the impact of increased soil temperature on forest soil microbial species and the rate of SOM decomposition as a result of this warming. Since microbes are infinitely small, we use DNA sequences to identify the microbes in the soil and their specific functions. To do this we process the soil, break open cells, then through a series of extractions and washing, get a pure DNA sample for sequencing. In parallel with my laboratory studies, I analyzed sequenced data derived from the National Ecological Observatory Network (NEON) prototype study that included a sampling site near the warming experiment on Prospect Hill. I downloaded 1.56 million protein sequences taken from 16 different soil locations across the US and then used RSP-BLAST to query the proteins against local versions of the Argonne National Lab (SEED), National Center for Biotechnology Center (COG) and Sanger Institute (Pfam) motif databases to infer gene function. In doing so I was able to determine differences between Grassland and Forest microbial communities and identify genes involved in biogeochemical cycling.

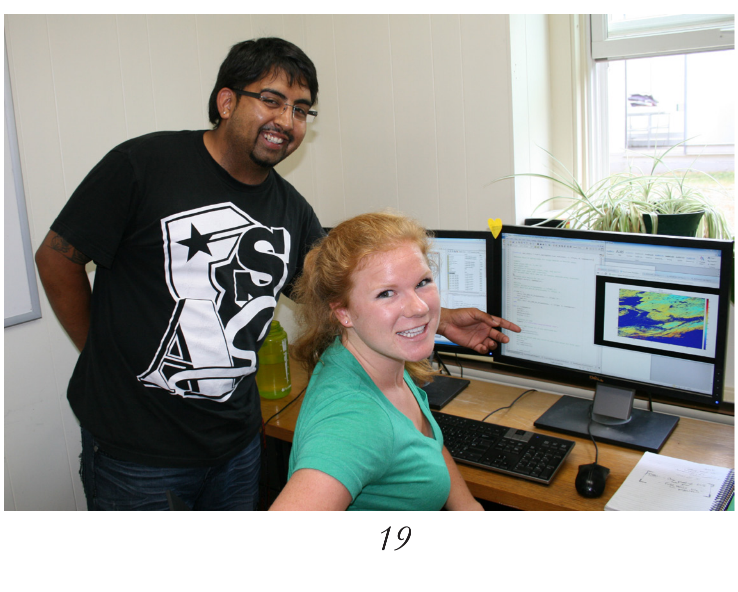
Erin Frick
Mount Holyoke College
Mentors: Mark Friedl, Eli Melaas, and Josh Gray

Determining the Reliability of MODIS Vegetation Indices to Assess Vegetative Phenological Trends Across Regional Scales

Phenology is the study of recurring biological events such as vegetation growth cycles and animal migration. As plant growth is correlated to land surface temperature, these measures are indicative of climate change trends. The heterogeneity of phenological patterns prevents field observations, which have been implemented to study phenology for centuries, from serving as an optimal method for phenological assessment across regional to continental scales. Alternatively, remote sensing devices such as the Moderate Resolution Imaging Spectroradiometer (MODIS), may be used to estimate phenological trends using measures of vegetation greenness inferred from wavelengths of reflected solar radiation. A compelling question that is frequently addressed using these data is where and how vegetation phenology is shifting in response to climate change.

Several datasets within the MODIS archive provide time series of vegetation greenness. It is necessary to determine which of these products provides the greatest quantity of reliable data to estimate the timing of phenological events with confidence. We investigated the Nadir BRDF-Adjusted Reflectance (MCD43A4) product which accounts for the effect of sun-illumination geometry and the Vegetation Indices (MOD13A1) product which is not BRDF-adjusted. A key question is whether or not MOD13A1 contains enough high-quality information to accurately calculate phenophase transition dates compared to data provided by MCD43A4. MODIS datasets, including these products, differ as a result of unique processing nuances involving compositing procedures, algorithmic manipulation and incorporation of ancillary data. To assess the differences between, and overall ‘usefulness’ of these products, we produced various plots and maps based on vegetation greenness data spanning a decade. These results include comparisons of the mean date of spring onset and assessment of the length of high-quality EVI time series across MODIS products and forested land cover types.

Our results suggest that the usefulness of the MOD13A1 product is limited by quality control filtering. If this filtering is too exclusive, insufficient data are available to derive accurate phenophase transition dates. With respect to the reliability of spring onset dates derived from these products, the MOD13A1 product consistently returns substantially later spring onset dates than both MCD products. This result is counterintuitive: we would expect these dates to be similar as they use the same EVI values to determine spring onset. By adjusting this quality threshold to balance the competing needs for quality and quantity, we expect the MOD13A1 product to become a more reliable source of data for phenophase transition date calculations. These estimations may then be used to model future vegetative response to changing climatic conditions on a global scale.



Margaret Garcia

Villanova University
Mentors: Jim Tang, Quian Yu, and Tim Savas

Bird's-Eye View: Using GIS for Plot Level Data

Soil carbon respiration (SCR) is an important indicator of global climate change. Spatial analysis is necessary in order to obtain a clear view of the varying characteristics that affect SCR. Varying temperatures and levels of moisture may cause an increase or decrease in the production of carbon dioxide. We studied these changes at the Harvard Forest long-term ecological research site. A Li-Cor 6400XT was used to obtain average carbon dioxide efflux values and temperature on a 48 plots scattered throughout the forest. In addition, soil moisture measurements were taken with a moisture sensor probe. We found that carbon dioxide increased with increasing temperature. Moisture also increased with increasing moisture. We used Geographic Informational Systems (GIS) techniques to display the trends at the forest level from data collected at a plot level. From the GIS maps, we found that areas with higher temperature released higher concentrations of carbon dioxide. Similarly, regions with lower moisture exhibited less emanation of carbon dioxide. The use of maps is relevant to better understand soil respiration and its effects throughout the forest. Based on the findings of our study, we could conclude that a decrease in temperature could lead a decrease in carbon dioxide emissions and moisture. These relationships could evolve over time, depending on various factors. Alterations to the land use, such as decreased forest area, changes in plant community structure, or soil drainage can have an impact on carbon dioxide, moisture, and temperature regimes.


Photo Credit: Brokaw Photography

Candice Hilliard

Cornell University
Mentors: Jim Tang, Qian Yu, and Tim Savas

Soil Carbon Dynamics at Harvard Forest

Soil contains one of the largest carbon stocks in the world; a stock significantly greater than that of the atmosphere or terrestrial vegetation. A dynamic exchange occurs between the carbon stock and the atmosphere known as the soil carbon flux. This carbon flux is sensitive to human disturbance, changes in climate, and ecosystem transformations. These changes may alter the flux dynamics by either increasing the ability of soil to store carbon or allowing it to more readily release carbon dioxide into the atmosphere. To better understand these processes and how soil carbon dynamics will function in the future, this research explores the relationship between ecosystems and rates of soil carbon respiration. Respiration rates, which determine how much carbon dioxide is released from the soil, are measured using a Li-Cor 6400XT portable photosynthesis machine. Every two weeks over the course of Summer 2012, three respiration measurements were taken at forty-eight natural gradient plots located throughout Harvard Forest. These plots were not altered by any treatments, but instead varied depending on dominant stand vegetation and soil drainage. These variables were used to determine what affect, if any, natural ecosystem differences have on soil carbon respiration. Two measurements for determining stand density, DBH and LAI, and a measurement of the carbon stock of each plot were also taken to reveal any relationships they may have with carbon dioxide efflux. ANOVA was used to determine the significance of these relationships. Preliminary results show that carbon efflux is not affected by dominant tree species alone, and that soils which are excessively drained exhibit a much lower rate of respiration. The study of how these natural differences in ecosystem type, specifically dominant vegetation and soil drainage, affect the soil carbon flux can help to determine how soil carbon dynamics will react to a changing world.

Dmitri Ilushin

Harvard College

Mentors: Andrew Richardson, Michael Toomey, and Stephen Klosterman

Alternatives to Remote Sensing of Phenology Using Public Outdoor Webcams

Currently, there are hopes of expanding tree phenology tracking to a global scale, but established methods of phenology tracking are limited now by their low temporal granularity or their prohibitive costs in terms of manpower. With the growth of the internet, publicly available webcams have become more and more available, providing a set of data that covers all areas of the world with high temporal and spatial granularity. This summer our goal was to analyze the utility of public webcams in studying local phenological trends on a global scale. We used a repository of publicly available webcam images from AMOS (the Archive of Many Outdoor Scenes, administered by Washington University in St. Louis). Through visual inspection, we classified a subset of 1879 geolocated sites based on camera stability and overall image quality for the series of photos into one of three categories: stable locations with few FOV (Field Of View) shifts, consistently changing FOV sites, and poor locations. Of these, sets of images from cameras both marked as stable and containing vegetation were put into a program to create ROI (Region Of Interest) masks around vegetation and then processed to extract a time series of GCC (Greenness Chromatic Coordinate), the percentage of greenness to overall brightness, within an image's vegetated area. The resulting time series can then be compared with established phenological observation methods and help corroborate the utility of webcam imagery as an alternative method for studying tree phenology. By better understanding how trees respond to climactic events, we can further understand yearly NPP (Net Primary Productivity, a measure of overall carbon intake of trees) responses to increased carbon concentrations in the atmosphere. AMOS provides a new frontier to explore tree phenology and will help allow us to understand better how forests respond to climate change.

Aubrie James

Iowa State University
Mentors: Elizabeth Crone and Greg Breed

New Host, New You! How a Butterfly's Change in Host Plant Enlightens Our Understanding of Developmental Resource Partitioning and Sexual Selection

Though sexual size dimorphism (SSD) is widespread in the Lepidoptera, with females typically larger than males, the developmental (proximate) and evolutionary (ultimate) mechanisms that cause it are difficult to tease apart. The butterfly *Euphydryas phaeton* (the Baltimore Checkerspot) has historically been a specialist on the host plant *Chelone glabra*, but has recently adopted an exotic species, *Plantago lanceolata*, as a secondary larval host. In an attempt to understand the mechanisms of SSD, I exploit the dietary expansion of *E. phaeton* to investigate the effects of host plant on male and female allometry. 24 outdoor enclosures were set up in two fields in Massachusetts known to sustain *E. phaeton* populations in the spring of 2012. At one site (Harvard, MA) the population uses both *P. lanceolata* and *C. glabra*. The second population (Ashfield, MA) uses *P. lanceolata* almost exclusively. Enclosures were inoculated with *E. phaeton* larvae in early May. Upon enclosure, butterflies were weighed to the nearest milligram, body length was measured, and wings photographed and later digitized to calculate wing area. Individuals were then marked and released.

I analyzed the data collected for allometric differences between sexes and host plant treatments using mixed-effect models and confirmed SSD in *E. phaeton*. I found that the significant allometric difference between host plant treatments in males was expressed as variation in wing size: males using *C. glabra* had up to 37% larger wing areas than males using *P. lanceolata*. Male weight did not differ between treatments, and there was no relationship between male weight and wing area ($R^2 = 0.03046$). In females, neither weight nor wing area was significantly different among host plant treatments, but the data indicate a relationship between female weight and wing area ($R^2 = 0.23601$).

My results suggest an interesting proximate mechanism for the prioritization of growth in butterflies: where males prioritize their developmental resources to wing area, females prioritize massiveness, only increasing wing area in lock-step with mass. Ultimately, this pattern suggests females increase mass (and probably also fecundity) and wing together to ensure enough lift to move the increased mass, whereas males might gain a competitive advantage in defending territories and attracting mates with larger wings to drive more powerful flight.

Alexander Kappel

Clark University

Mentors: Chris Williams, Melanie Vanderhoof, Myroslava Khomik, and Marcus Pasay

Post-Disturbance Soil Respiration Dynamics in a Clear Cut Temperate Forest

The balance of carbon dioxide (CO_2) exchange for different land types and environmental settings is a key determinant of the global carbon budget. Along with photosynthetic CO_2 uptake, respiratory CO_2 release from the land to the atmosphere is one of the major gross fluxes in the carbon balance. Many studies have shown soil respiration to be responsive to temperature, with underlying reaction rates approximately doubling per 10 degree Celsius increase. With the ongoing rise in temperatures ensuing with global climate change, soil respiration is expected to increase, and with it the amount of CO_2 that is being released into the atmosphere. The potential for this phenomenon to support a positive feedback fueling further warming is high. Therefore, a thorough understanding of the respiration-temperature relationship and its many components, characteristics, and trends is important for both the understanding and mitigation of global climate change. For this study, soil respiration measurements were made at Harvard Forest's Prospect Hill clear cut site using a portable LI-6200 Infrared Gas Analyzer over the course of 8 weeks in a variety of temperature conditions as well as between control plots and treatment plots. The treatment plots, excluding roots and therefore autotrophic respiration, provided data allowing the quantitative partitioning of total soil respiration into autotrophic and heterotrophic source origins. Following analysis it was determined that an average respiration rate of 6.175 µmol m-2 s-1 characterized the study site, a value roughly 16 percent higher than the 2011 rate. When comparing control plots to treatment plots it was found that roughly 66 percent of total respiration could be attributed to heterotrophic sources with the remaining 35 percent attributed to autotrophic sources. Looking at these results it appears that soil respiration rates at the clear cut site are increasing temporally, an observation which implies that disturbance events such as clear cutting can have long lasting impacts on carbon dynamics.

Elizabeth Kennett

University of Vermont

Mentors: Aaron Ellison and Allyson Degrassi

A Mark- Recapture Study of the Rodent and Shrew Populations Within a Declining Hemlock Stand

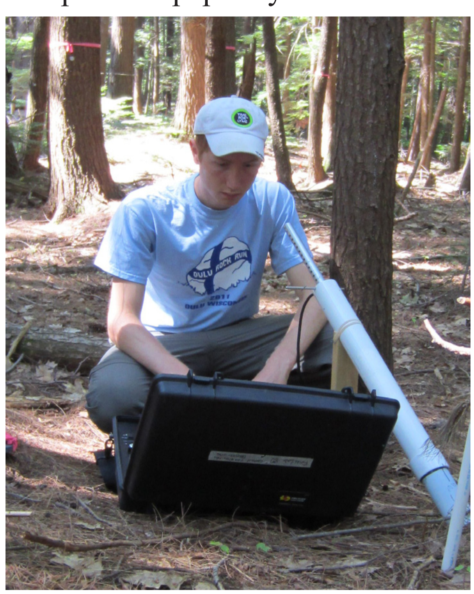
Eastern Hemlocks (*Tsuga canadensis*) are foundation species, which are known to have a large influence on species composition and ecosystem dynamics of a forest ecosystem. The purpose of this study was to understand how rodent species richness and composition differed among different hemlock treatments consisting of intact forest, logged forest, and invaded hemlock stands in the Harvard Forest of Petersham, MA. Sherman live traps were arranged on 7x7m grids covering .49ha in four different hemlock treatments that were established in 2003; 1) the logged treatment, where commercial trees were removed 2) the girdled treatment, where the hemlocks were girdled using a chainsaw, thus killing the trees, and mimicking the affects of the woolly adelgid, an invasive insect 3) the hemlock control which is where hardwoods are at least 70% hemlocks, and 4) the hardwood control, where other hardwood species are dominate. Animals were marked and recaptured from June-July. Using Schnabel methods for population estimate, there appeared to be a shift in the population from more abundant Gapper's Red-backed vole, *Clethrionomys gapperi* in the logged and girdled treatments to white footed and deer mice (*Peromyscus spp*) in the hemlock and hardwood control plots. This shift in population may indicate that hemlocks support *Peromyscus spp* over voles. The species richness and overall population dynamic of these rodents surveyed may lead to a greater understanding as to the potential affect they may have on the seed dispersal in these plots and could account for many interactions between the vegetation and the animals also present.

Samuel Knapp

University of Wisconsin, Stevens Point
Mentor: Rose Abramoff

Seasonality of Fine Root Growth, Mortality, and Carbon Allocation in Temperate Forest Trees: Underground Observations with a Minirhizotron Camera

Above ground phenology has been extensively studied in temperate forests; however, due to the difficulties of studying below ground systems, seasonal changes in root growth and death are relatively unknown. Many climate models incorrectly assume that above and below ground processes are in sync and use things like air temperature or remote sensing data to infer root production. Studies have shown, however, that root phenologies vary widely relative to aboveground in woody and herbaceous species. To understand carbon flux in temperate forests, it is therefore necessary to study root phenologies at the species level. This study investigated fine root production and mortality in two prevalent temperate tree species, *Quercus rubra* and *Tsuga candadensis.* Using a minirhizotron camera, fine root systems were photographed in situ weekly to determine seasonal growth and death patterns. In both species, leaf flushes were not in synchrony with root flushes. Differences between the species mirrored known aboveground physiologies—*Q. rubra* roots were observed growing in pulses, while *T. canadensis* roots were observed to grow at relatively stable rates. Heterogeneity of soils, moisture, and individual organisms likely accounted for observed differences in root growth and death within species. This study also investigated an alternative method of scaling to forest level carbon flux. Allometric relationships between diameter and linear mass density were determined for fine roots of five temperate tree species: *Q. rubra, T. canadensis, Fagus grandifolia, Acer saccharum,* and *Fraxinus americana*. All species displayed quadratic relationships between root diameter and linear mass density, and there appeared to be little species level variation in the densities of roots under ~ 0.5 mm. Rather than assuming percentage length production and percentage mass production were equal in fine roots, the density relationships were used to calculate actual percentage mass production and, using data from soil cores and known carbon percentages in fine roots, carbon allocation rates. This method of scaling from 2-dimensional minirhizotron photographs to 3-dimensional ecosystems may be superior to those making questionable assumptions regarding viewing depth into soil and equality between length and mass production percentages. Data from this study will be incorporated in the Ph D. thesis of Rose Abramoff, of the Finzi Lab at Boston University, investigating the biotic and abiotic drivers of root phenology, as well as a cooperative paper by Sam and Rose on fine root morphology.



Courtney Maloney

University of California, Berkeley

Mentor: Kristina Stinson

Examining the Influence of Ragweed Regional Ecotypes on Reproductive Investment and Pollen Output Under Increasing Atmospheric CO_2 Concentrations

Global temperatures and atmospheric concentrations of CO_2 are predicted to rise throughout the next 100 years. These abiotic changes are likely to have profound changes on Earth's vegetation. 10-20% of Americans suffer from ragweed-induced hay fever. Ragweed, (*Ambrosia artemisiifolia*) is a highly allergenic plant which grows throughout the United States, and is primarily concentrated in the Midwest and East. Ragweed pollen contains the protein Amb a 1; which is responsible for inducing an allergenic response in those sensitive to ragweed. We hypothesized that the predicted climate change conditions of elevated atmospheric CO_2 will increase ragweed growth and pollen output. Different areas possess varying temperature and CO_2 norms, leading to unique ecotypes in each region. Our aim is to understand how high atmospheric CO_2 concentrations will affect ragweed growth among different ragweed ecotypes of the New England area. We subsampled 1/16 of a total of 1248 ragweed individuals drawn from 24 different populations from New York, Vermont, and Massachusetts at varying CO_2 concentrations; 400 (ambient,) 600, and 800 ppm corresponding to present CO_2 levels and those predicted for the next 100 years. We bagged the flowering spikes to capture pollen and harvested the spikes and the pollen after pollen release. After harvesting the spikes, we measured the length of spikes, determined the dry biomass of the spike, and quantified the amount of pollen from the different regional ecotypes in the three CO_2 concentrations.

We tested for differences in flower spike size and pollen production using ANOVA in which CO_2 and ecotype were the main effects in the model. We also performed regressions to test for correlations between the continuous variables related to spike size and pollen output. In this preliminary analysis, ecotypes differed significantly in the length of the inflorescence. Inflorescence weight and pollen output per inflorescence were nearly significantly different between ecotypes. Initial analysis has suggested that there may be a relationship between inflorescence length and pollen output per inflorescence, as well as inflorescence weight and pollen output per inflorescence. These relationships can help develop estimators of pollen output, simplifying the data collection procedure for the larger experiment. Ragweed-induced hay fever poses major public health risks. Predicting how increased CO_2 affects ragweed growth and pollen output and achieving greater understanding of how different local ecotypes respond to such changes, will better inform decisions regarding ragweed and allergenic plant policy and management.

Kelsey McKenna

Harvard College

Mentors: Elizabeth Crone, James Crall, and Dash Donnelly

Does Bumblebee Body Size Affect Foraging Distance or Flight Maneuverability?

Bumblebee worker size can vary considerably within the same colony and even within the same brood. Larger workers are thought to be better physically suited to flying larger distances, but likely to be less maneuverable. It is not known how movement distance relates to intra-colony body size variation. I investigated whether body size variation within colonies relates to worker foraging range and maneuverability. I measured mass [0.08 g – 0.25 g], intertegular span (the distance between wing base joints on the bee's thorax) [1.5 cm – 5.2 cm], thorax width [3.6 cm – 7.1 cm], and body length [10.2 cm – 15.9 cm] of 28 *Bombus impatiens* workers from three colonies in order to compare these body size indices to foraging range through pollen load. In favor of a conservation estimate, in this study "maximum foraging distance" is defined as the distance from the bee colonies to the nearest patch of the farthest species of plant identified after swabbing each bee. Each bee was measured and swabbed for pollen after returning to the hive and slides of the pollen loads were examined for flower species. I searched the local landscape and mapped the locations of potential pollen sources. Maximum foraging distance did not appear to relate to any indicator of body size. Pollen species richness was weakly positively correlated with mass (R2=0.12295), and moderately positively correlated with body length (R2=0.21418), thorax width (R2=0.25457), and IT Span (R2=0.22748). Factors other than bee body size, like distribution of resources, are potentially important in determining bee foraging patterns. In order to investigate bee maneuverability, foam tunnels varying in circumference from 5 to 12 cm were serially attached to the entrance of a *B. impatiens* hive, and workers were filmed with a high-speed camera upon return to the hive through the tunnel. Wing motion was identified through analysis of these videos. Although analysis has not yet been completed, preliminary observations show that sampled bees respond to the tunnel obstacles similarly, but potentially in proportion to their body size.

Andrew Moe

Vermilion Community College

Mentors: Aaron Ellison and Ed Faison

Ungulate Response to Simulated Hemlock Woolly Adelgid and Salvage Logging Disturbance

Declines in Eastern Hemlock (*Tsuga canadensis*) forests resulting from infestation of Hemlock Woolly Adelgid (HWA; *Adelges tsugae*) and associated salvage logging operations are expected to result in widespread transition to hardwood-dominated forest communities in the Northeast. Moose (*Alces alces*) and deer (*Odocoileus virginianus*) are large herbivores that utilize hemlock and surrounding hardwood stands, and are often associated with recently disturbed habitat . Still—little is known about how these herbivores will interact with HWA to shape regenerating hardwood stands or whether these animals will forage differently in logged vs. insect-killed stands.

Ungulate activity—browsing, pellet groups, and camera traps—was assessed at the Harvard Forest Hemlock Removal Experiment, which consists of two blocks of four replicate treatments: girdled hemlocks, simulating HWA outbreak, salvage logging, hemlock control, and hardwood control. In addition, understory woody vegetation—stem density, stem height, diameter, and composition—was sampled in recently constructed (November 2011) 15x30m exclosures and paired control plots at each of the treatments.

Browsing intensity (proportion of stems browsed) and pellet group density were strongly correlated, and browsing was more intense in the logged than in the girdled and undisturbed plots. Images recorded from the camera traps (number of individuals, duration of visit, and activity during visit) did not differ among treatments and were uncorrelated with browsing intensity and pellet groupds. As expected, no significant differences in stem density, stem height, or browsing intensity had emerged yet between the fenced and control plots after only 8 months. Overstory treatments, were, however, significant predictors of stem height and stem density.

As stem height was greatest in the logged plots, and stem density was highest in the girdled plots, this apparent preference of ungulates for the logged plots over the girdled plots suggests that stem vigor (i.e. growth rate) may be a more important factor than stem density in attracting ungulates to disturbed sites. These results suggest that preemptively logged hemlock stands may yield superior foraging habitat to HWA killed stands. Ungulates, in turn, may have greater browsing impacts in salvage logged areas than in HWA-infested areas.

Adalyn Naka

Brown University

Mentors: Jim Tang, Qian Yu, and Tim Savas

Factors Affecting Carbon Efflux at Harvard Forest

Soil is both the largest terrestrial carbon sink and the second largest terrestrial emitter of carbon; however, little is known about the factors that affect the exchange of carbon between soil and the atmosphere. This study seeks to determine how temperature, root respiration, leaf litter, and nitrogen addition influence soil respiration (carbon dioxide efflux). A portable gas analyzer (Licor 6400 XT) was used to measure soil respiration at four different treatment plots in Harvard Forest three times over the course of eight weeks. In addition, stem respiration of nine trees was measured to determine how carbon efflux varies across species, allowing for a more holistic understanding of forest carbon emissions. One-way ANOVAs were used to analyze differences between carbon efflux of treatment and control plots. Removal of leaf litter and exclusion of roots appear to have significant (p-value <0.05) positive correlations with soil carbon emissions. Temperature and nitrogen were not significantly correlated with soil respiration. Additionally, stem respiration varies significantly across species. A better understanding of the way these factors affect soil respiration can help to more accurately predict and prepare for the effects of climate change; thus, more research regarding these driving factors of carbon flux should be pursued in the future.

Photo Credit: Brokaw Photography

Miruna Oprescu

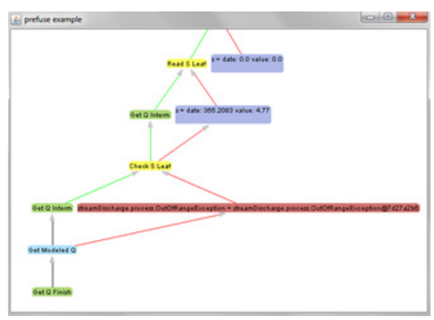
Harvard College

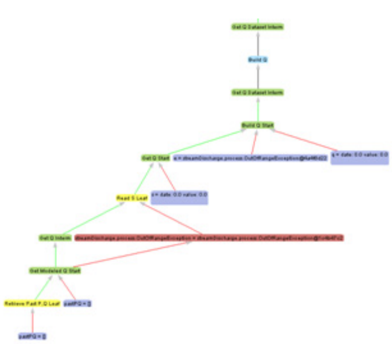
Mentors: Emery Boose and Barbara Lerner

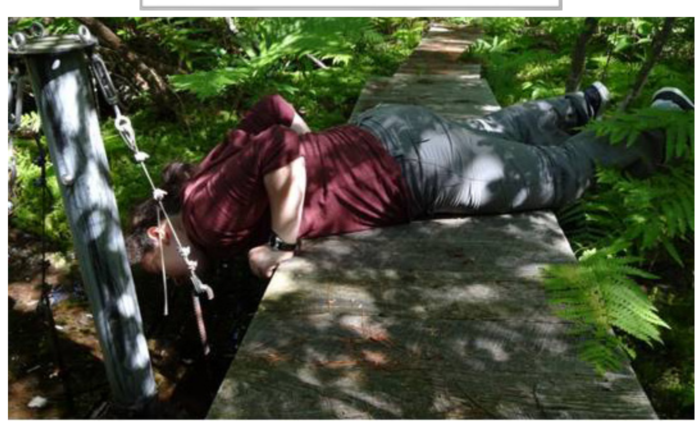
Visualization Tools for Digital Dataset Derivation Graphs

The ability to provide proper documentation on how research data was collected and processed is essential for ensuring reproducible results in any research project. We use the term data provenance to define the practice of recording all the processes the data has undergone from its collection to its output as a final result. While it is common to record data provenance in the form of narrative description, the increasing complexity of processes applied to large datasets requires software tools for automatically capturing and storing provenance data in a digital format. To make data provenance easier to understand, we developed a way to represent it graphically through powerful interactive visualizations.

We applied these concepts to the needs expressed by the community of scientists at Harvard Forest. The motivation comes from the necessity of these scientists to constantly process 15 min data from a meteorological station and six stream and wetland gauges on the Prospect Hill Tract for the study of the ecology of forest watersheds. Checking for equipment malfunction, sensor drift and modeling or replacing corrupted data are some of the problems scientists at Harvard Forest are faced with on a day-to-day basis. To respond to these issues, we used Little-JIL, a graphical programming language for defining processes developed at the University of Massachusetts, Amherst, and results from previous research to produce a visual implementation of an abstract mathematical object, a Dataset Derivation Graph (DDG), which documents how every piece of data in a dataset was turned into information. Extending Prefuse, a graphical platform written in Java which supports visualizations of data structures such as graphs and trees, we turned the information provided by the DDG into easy-to-read, easy-to-follow visual graphs built and displayed in real time as the process runs on the computer. Furthermore, this interactive visual program collapses or expands parts of the graph, allowing the user to focus on certain parts of the process and manage large DDGs. To address other concerns expressed by the scientific community, future research will seek to implement this tool to make queries on data processes available to scientists in a visual form.







Sascha Perry

Lincoln University

Mentors: Andrew Richardson, Michael Toomey, and Stephen Klosterman

Tracking Seasonal and Climatic Changes through Webcam Imagery

Tracking seasonal variability in ecosystems has been an ongoing study, used to better understand how climate change will affect organisms. This field, better known as phenology, looks at the changes in the timing of organismal activities (e.g. flowering, migration) throughout the year. Specifically for our project, tree phenology was analyzed using webcam imagery. Webcam imagery has provided the science community with a new and optimal way, versus the traditional ways of human observation and large spatial coverage with limited temporal availability. We analyzed imagery from 1879 geo-located locations around the globe using the Archive of Many Outdoor Scenes (AMOS). All sites were classified based on their stability and amounts/presence of vegetation, which was shown through images taken over time spans of up to 5 years. Stable sites were then visually inspected for changes in view to extract the greenness chromatic coordinate (GCC), the percentage of green brightness to overall image brightness, within the vegetated area. Along with tracking the GCC, we were able to track the overall time series of these changes, specifically the spring green-up period and the brown-down of autumn. Performing this research will ultimately provide an alternative methodology of studying tree phenology, to better understand how various organisms may respond to these warming trends, and assist in the prediction of ecosystem responses to ongoing changes in climate.

Paul Quackenbush

Middlebury College

Mentors: Chris Williams, Melanie Vanderhoof, Myroslava Khomik, and Marcus Pasay

The Leaf Level Relationship Between Temperature, Leaf Nitrogen and Photosynthetic Parameters in Five C3 Species

Theoretical and empirical analyses have suggested that among the major terrestrial biomes, temperate forest ecosystems are an important global sink for atmospheric carbon dioxide (Tans *et al*., 1990; Ciais *et al*., 1995; Tans *et al.*, 1995), storing up to a quarter of the CO_2 added to the atmosphere annually by fossil fuel burning (http://www.lternet.edu/vignettes/hfr.html). Photosynthesis, which is governed by photosynthetic parameters including light saturated assimilation (A_{max}) and maximum carboxylation velocity (V_{cmax}), is the primary mechanism through which carbon enters ecosystems for possible storage by this important global sink (Sellers *et al*. 1997, Sellers *et al.* 1986). It is also a process that governs the fluxes of energy, mass and momentum between vegetated land surfaces and the atmosphere, with profound impacts on climatic conditions on earth's surface (Sato *et al*. 1989, Margolis & Ryan 1997). Thus, understanding the factors and processes influencing seasonal variation in photosynthetic parameters is critical for accurate modeling of carbon dioxide exchange between vegetation and the atmosphere (Dang *et al*. 1998, Wilson *et al*. 2001,Tanaka *et al*. 2002, Kosugi *et al*. 2003, Misson *et al*. 2005), including important feedbacks to climate change (Woodwell & Mackenzie 1995). However, most forest carbon cycle models do not adequately consider how tree species contribute differently to carbon-cycle processes and how changing environmental conditions may differentially affect species (Bassow & Bazzaz 1998). This fits into a larger call for more plant- and species-level estimates of photosynthetic parameters under varying environmental conditions in order to tailor, refine, and improve popular models of photosynthesis such as the Farquhar model (Patrick *et al*. 2009). In light of this need for species level photosynthesis data, this study investigates the influence of two factors, nitrogen and temperature, on the photosynthetic parameters A_{max} and V_{cmax} in five temperate early successional species. These parameters are derived from light and CO_2 assimilation curves taken over a 10 week period in a highly dynamic post-clearcut environment at the Harvard Forest Long Term Ecological Research Site (HF LTER) in Petersham, MA with the use of a Li-6400XT Portable Photosynthesis System. Preliminary results indicate a positive correlation between nitrogen content and V_{cmax} among the species studied. However, further experimentation is needed to confirm this trend. In addition to its applicability to forest carbon models, this work, when paired with vegetation and soil data for the HF LTER clearcut site, has the potential to be upscaled to the ecosystem for comparison with gross ecosystem productivity estimated with the eddy covariance method. This may provide a more holistic understanding of carbon, water, and energy fluxes in post-disturbance forest environments.

Jose Luis Rugelio

Lincoln University
Mentors: Mark Friedl, Eli Melaas, and Josh Gray

Phenology: An Urban to Rural Gradient

Urban land use represents a significant disturbance of the natural landscape. The presence of humans and complex networks of buildings, roads, and structures have a direct impact on biogeochemical, carbon, and water cycles. One of the most observable environmental changes in urban areas is an effective increase in air and surface temperature relative to surrounding rural areas called an urban heat island. Since air temperature is a first order control of the timing of spring onset of vegetation, it is assumed that spring will occur earlier in urban areas. To test this hypothesis, we used time series of moderate resolution satellite data collected by the Moderate Resolution Imaging Spectroradiometer (MODIS) to analyze interannual variation in the timing of spring onset across the Boston Metropolitan area. Specifically, we produced plots showing patterns in the timing of spring onset in buffer zones along the urban to rural gradient for each of 10 years (2001-2010), and then analyzed patterns in phenology to see if any trends were present. Results from this analysis show that the standard deviation decreases in all the buffer zones as distance from the city increases and the land cover becomes dominated by rural areas and stable forests. In buffer zones closer to the urban areas, the data shows that green-up occurs earlier and brown-down occurs later than vegetation in rural areas. The main reason for this occurrence is because of the “heat island effect” in Boston, which leads to earlier springs and later falls. By studying urban heat islands we may be able to relate what is happening at local scales to processes at regional-to-global scales arising from climate change.

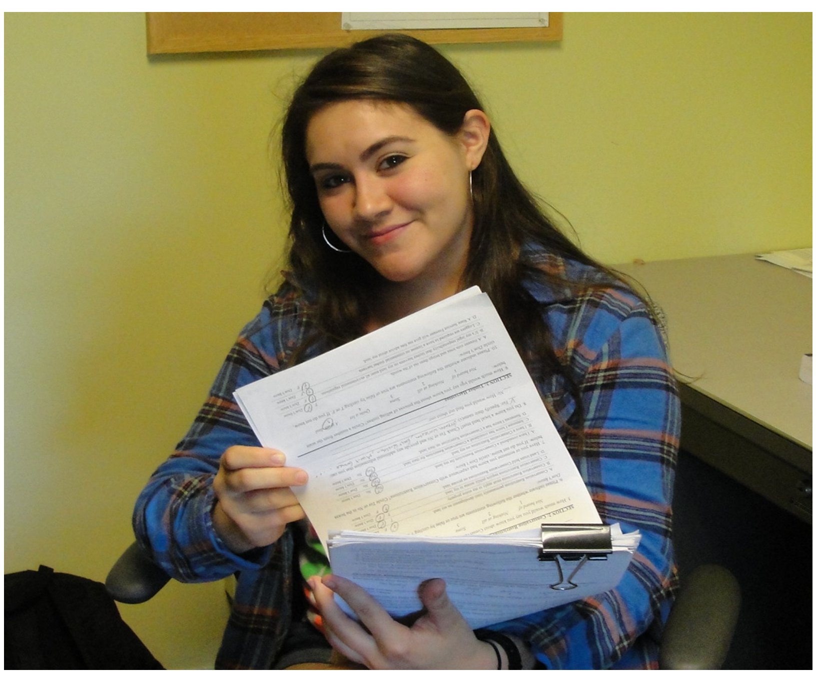
Emma Schnur

Cornell University

Mentor: David Kittredge

Assessing Land Owner Conservation Along Urban-to-Rural Gradients in Massachusetts

Massachusetts is both the eighth most forested state and the third most densely populated state in the United States. These somewhat conflicting characteristics are due to the heavy clustering of people in and around Boston coupled with the relative lack of population density as one travels west of the city. Though the changes in the physical characteristics of the land are clear along an urban-to-rural gradient away from Boston, what is less clear is how people along the gradient perceive conservation and management for this land. This project examines how landowner conservation awareness varies along two urban-to-rural transects in Massachusetts, the northern transect extending from Boston to Petersham and the southern transect from Boston through Worcester to Palmer. Analyses are based on results from the Conservation Awareness Index (CAI) survey instrument. Administered to over 1,000 randomly selected forest landowners in 21 towns along the transects, the survey questions respondents about their experience with and knowledge of land management practices such as conservation restrictions, timber harvesting, and estate planning. Upon their return, surveys are then scored on a scale of 0 to 64. A GIS analysis reveals that there is no apparent pattern of increasing or decreasing conservation awareness among towns as one travels west along the transects away from Boston. Further, investigating other urban indicators such as percent impervious surface area and percent forested land of respondents' surrounding property shows that there is little correlation between these indicators and conservation awareness. Though there is not a direct urban-to-rural trend in conservation awareness among towns, analysis reveals that social capital at the town level does matter in terms of influencing conservation awareness. Social capital refers to the collective benefits derived from the cooperation and communication of individuals and groups through social networks. As it pertains to conservation, social capital includes factors such as how active a town's conservation commission is, the presence of a land trust in that town, and others. This "Conservation Social Capital" has a very strong positive correlation with average conservation awareness of respondents in each town. Overall, social factors seem to play a larger role than physical indicators of "urban-ness" in affecting forest landowner conservation awareness.



Tefiro Serunjogi

Grinnell College

Mentor: Betsy Colburn

What is the Response of Turbidity and Pathogen Levels to Variations in Sand Depths in Filters?

My project this summer considered ways in which safe water could be made available to people in areas like my village that lack access to safe water sources. It encompassed aspects pertaining to community water supply, household filtration, and the development of hand-held sand filters. After realizing that research into household sized filters was quite comprehensive, I switched my focus to the development of hand-held filters. My interest was in using locally available materials like sand and gravel for the filtration process and then coupling it with chlorination using regular bleach (sodium hypochlorite).

Chlorination as a means of water disinfection has been on the rise in Uganda in recent years but its effectiveness is greatly reduced by the turbidity that is often present in the water sources. Therefore, I focused on a three step process (settling, filtration, and chlorination) that aimed to rid the water of as much turbidity as possible (by settling & filtration) and so allow for the chlorination process to be as effective as possible.

I designed a range of bottle-sized sand filters with varying sand depths: 3inches, 4inches, 5inches, and 6inches. My first test involved one replicate of filters that I tested with a very dirty source-water from a tub that I artificially contaminated with dirt and cow waste-which I later discontinued, given the considerable amount of biological matter that had developed in the source over time. The second test tested 5 replicates of all 4 sand depths using turbid water from a local river with more natural pathogen levels (I spiked it with more coliform-containing water). A sub-sample of each filtrate was chlorinated. I tested source water, blanks, filtrates, and chlorinated filtrate for pathogen indicators (Total Coliforms and *Escherichia coli* (*E. coli*)) using membrane filtration and the m-coli blue24 method (Hach Company). I also tested for the turbidity of the samples using the Non-Filterable Residue technique (formerly known as the Total Suspended Solids (TSS) technique) by filtration through a glass fiber filter. My third experiment looked at the effectiveness of filters over time by pouring source water through one 6 inch filter on a daily basis and observing pathogen removal and TSS.

The investigation showed; a) that the hand-held filters were up to 88% effective in pathogen removal provided pathogen levels were not too high, b) that the filters removed a considerable amount of suspended solids, c) that chlorination after filtration was effective, d) that increased sand depth gave the filters greater effectiveness in the removal of pathogens (ANOVA, p. = 0.08) as well as the removal of suspended solids, and e) that filters could reduce pathogen levels for at least 3 days. However, more tests would need to be run to provide a greater understanding of the effect of the varying sand depths on the pathogen counts and the statistical significance of the relationship between the two variables.

This study's conclusions may eventually help improve access to safe water for people where developed water sources are not available. My hope is that these results will help to better the lives of people in my community and, possibly, around the world.

Jennie Sirota

North Dakota State University
Mentors: Aaron Ellison and Ben Baiser

Identifying Indicators of Tipping Points Within the Aquatic Micro-Ecosystem of the Pitcher Plant, *Sarracenia purpurea*

A gradual or rapid disruption to a natural system can lead to a tipping point, after which the system undergoes a potentially irreversible and undesirable state change. State changes are challenging to predict but hold great importance in the management of ecosystems and maintenance of biodiversity. Tipping points are often observed in aquatic ecosystems in which an overabundance of nutrients can push the system from an aerobic state to an anaerobic one, greatly altering community composition and structure. Here, we aim to determine if tipping points can occur within the aquatic micro-ecosystem of the carnivorous pitcher plant, *Sarracenia purpurea*, and to identify nutrient concentrations that drive the system to shift states from aerobic to anaerobic. Six replicate greenhouse experiments were conducted; each consisted of five treatments that included one control and four levels of nutrient enrichment (prey addition). One leaf on each plant was filled with filtered pitcher fluid containing only bacteria and introduced daily aliquots of ground dried vespid wasp to test state change dynamics. In addition, five individuals of the pitcher plant mosquito, *Wyeomyia smithii*, were placed into three of the replicates to test the influence of oxygen levels on the top predator in this aquatic food web. Dissolved oxygen and temperature were measured in each pitcher, and photosynthetically active radiation (PAR) was measured at the level of the pitcher plant leaves. The addition of 0.5-1.0 mg ml-1d-1 of prey (ground wasps) shifted the *Sarracenia* micro-ecosystem from aerobic to anaerobic within five days. The pitcher plant mosquito showed no difference in a range of oxygen levels, suggesting that the top predator isn't immediately affected by a state change. By having a clearer understanding of tipping points in the *Sarracenia* ecosystem, we can learn more about predicting and managing state changes in a variety of other systems.

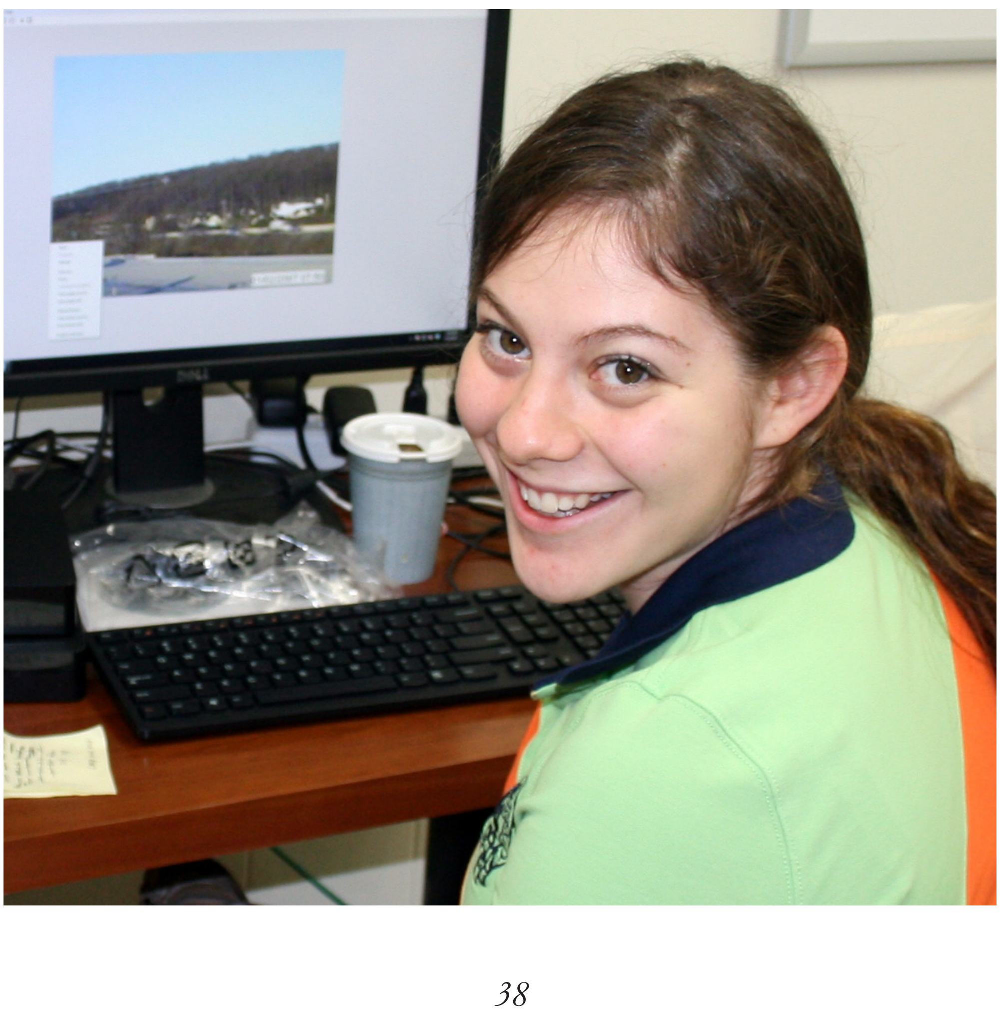
Hannah Skolnik

John Hopkins University

Mentors: Andrew Richardson, Michael Toomey, and Stephen Klosterman

Using Webcam Imagery to Study Forest Phenology on a Global Scale

The earth's climate has been changing steadily getting warmer. There is no evidence that this will cease and as such, it is most important to study the ramifications of this heating trend. Growing season length can be a good indicator for how the earth's natural systems are responding to global warming. There are two traditional ways to track growing season length, however these options either require significant methodological improvement (e.g. satellite remote sensing) or are subjective (e.g. human observations of when leaves begin to grow and die). The goal of this summer's project has been to explore a more innovative method to track tree phenology. We have been using the technique of near-surface remote sensing, using freely available webcam images pulled off the Internet. The photos have all come from the AMOS (Archive of Many Outdoor Scenes) archive, a collection of many thousands of outdoor webcams compiled by Washington University in St. Louis. We had the opportunity to use 90 million images from over 1,800 geolocated webcams around the world. We analyzed the data by classifying the utility of the sites, based on how much the camera moves and how much/ what type of vegetation is in the view. We then calculated the relative greenness values, or Green Chromatic Coordinate (GCC). This is graphed to show how the leaves are responding temporally over a season so we can then estimate the onset of Spring and the onset of Autumn. By monitoring phenology in ecosystems, we can quantify the effect of climate change on the natural world which brings us one step closer to understanding how humans are altering their environment.



Vincent Waquiu

Southwestern Indian Polytechnic Institute
Mentor: David Orwig

The Impact of Co-occurring Invasive Insects on Eastern Hemlock Branch Growth and Chemistry

Throughout most of eastern New England, eastern hemlock (*Tsuga canadensis*) has been experiencing widespread decline due to the invasion of two invasive insects, the hemlock woolly adelgid (HWA; *Adelges tsugae*) and the elongate hemlock scale (EHS; *Fiorinia externa*). Hemlock is a foundation species that creates distinctive biogeochemical, habitat, and microclimatic conditions. The HWA causes foliar damage, crown loss and mortality, while the EHS usually causes needle discoloration but rarely leads to hemlock mortality. Our objective was to investigate how the presence of these two invasive insects affects twig, needle, and fallen litter chemistry (nitrogen) and new branch growth across sites varying in insect densities: high HWA, high EHS, HWA and EHS, and no infestation (control). Three hemlock stands of each treatment were selected from a large set of stands examined across southern New England over the last 15 years. Within each site we examined 3 small hemlock trees to conduct foliar and litter analysis, and insect density, and branch growth determination. Based on earlier studies, we hypothesized that insect feeding would lead to elevated nitrogen content in twigs and needles compared to uninfested trees.

Results suggest that uninfested trees had significantly higher new growth (> 3cm) compared to trees with both HWA and EHS (1.5 cm). The percentages of branches that produced new growth was significantly lower (40-50%) on HWA infested trees compared to EHS infested and uninfested trees (75 and 80%, respectively). Branch growth and percent of branches producing new growth declined with increasing HWA density but not EHS density. Foliar nitrogen was significantly higher in infested compared to uninfested trees, but did not differ among insect treatments. Twigs that were fed on by HWA alone or in combination with had significantly higher nitrogen content than EHS-infested or uninfested trees. Nitrogen content of litter collected from the forest floor did not differ among treatment types but contained higher N content than live, intact needles. Carbon content of twigs, needles, and litter was not significantly different among insect treatment; lastly, the nitrogen content of the insect by-products differed greatly, as EHS wax covers contained just over 6% nitrogen and HWA wool just under 2%. These results warrant future work on how these byproducts influence subsequent decomposition. Continued feeding by both insects in these forests will likely lead to continued hemlock deterioration and associated twig and needle chemical changes, along with altered ecosystem function.

Yujia Zhou

Dickinson College
Mentors: Emery Boose and Barbara Lerner

Quality Control of Sensor Data and Data Provenance Tracking

Scientists often rely on sensors to obtain data. Sometimes, sensors may go wrong, thus the raw data needs to be processed before it can be used. This process of quality control includes but is not limited to calibration adjustment, detection of irregular values, and gap filling of missing data. In this research, we used the 15-minute real-time data from the meteorological station at the Harvard Forest and studied the quality control methods that might be applied to this dataset. We developed R programs to detect and fix quality control problems. This process will be performed multiple times in the future due to improvements of quality control techniques and hence will generate different versions of datasets. However, as the datasets grow larger and time passes, it becomes difficult to know how a particular version of the dataset was derived from the raw data, because we will lose track of which activities have been done to obtain a specific version of the processed data. As a result, recording the data provenance, or the history of data, is necessary for scientists to understand data derivation. Data Derivation Graphs (DDG) can record the full provenance of how each data point is derived from the raw data, allowing scientists to keep track of their data. To accomplish this goal, we built a process simulating scientists' initial processing of the raw data and the reprocessing after some of the quality control techniques are updated. We implemented this process in both Kepler and Little-JIL to compare the data provenance graphs they produce from identical processes. We found that while Kepler is easier to use for scientists with no programming background, Little-JIL has a much stronger visualization tool for drawing comprehensive DDGs and stores more information in them.

Katherine Bennett

Ashburnham-Westminster Regional School District
Mentors: Andrew Richardson, Michael Toomey, and Stephen Klosterman

K-12 Phenology Lessons for the *Phenocam* Project

In the fall of 2011, the Ashburnham- Westminster Regional School District became the first of five schools to join Dr. Andrew Richardson's *Phenocam* Network with the installation of a digital phenocam on the roof of Overlook Middle School in Ashburnham, Massachusetts. Our school district is now part of a network of near surface remote sensing digital cameras that send images of forest, shrub, and grassland vegetation cover at more than 130 diverse sites in North America to the digital archives at the University of New Hampshire. Our phenocam provides a digital image every half hour of the mixed deciduous/ coniferous forest canopy due north from the school. As a part of the *Phenocam* project, students at the K-12 level have expanded the scope of phenological monitoring that is part of the Harvard Forest Schoolyard Ecology Program protocol, *Buds, Leaves, and Global Warming*. In this protocol, students work with Dr. John O'Keefe to monitor buds and leaves on schoolyard trees to determine the length of the growing season, giving them the opportunity to be a part of real and important research concerning the critical environmental issue of climate change. Students involved in the *Buds, Leaves, and Global Warming* study have the opportunity to compare their ground data on budburst, color change, and leaf drop to the webcam images, as well as to similar forested sites in locations throughout the United States. Lessons are being developed for comparing student data to phenocam images, GCC (Green Chromatic Coordinate- relative greenness) graphs extracted from the images, and satellite data. Lessons addressing map scale and Urban Heat Island effect will also be available for teachers. This project will greatly enhance the district science and mathematics curriculum and further our goal of educating ecologically literate and concerned citizens.

Bill Van Valkenburg

Garnder High School

Mentor: Kristina Stinson

Effect of Elevated CO^2 on Ragweed Morphology and Response of Varying Ecotypes

Additional available atmospheric CO2 is expected to increase the rate of photosynthetic activity, therefore increasing total plant biomass and reproductive capacity of *Ambrosia artemisiifolia*. more commonly known as ragweed. Since ragweed produces allergenic pollen, increased pollen production is expected increase the impact on human allergenic responses. This study subjected equal populations of ragweed from three distinct regions differing in latitude within the northeastern United States to CO2 levels of 400 ppm, 600 ppm and 800 ppm . The design of the experiment exposed 128 plants of each ecotype to CO2 levels of 400 ppm, reflecting ambient conditions, including 4 replicated plants from 16 populations from each ecotype in a controlled setting in which plants were placed equidistant for each other and provided equal exposures of sunlight, nutrients, water and climate conditions. The same conditions and allocation of ragweed ecotypes were repeated at each CO2 exposures of 600 ppm and 800 ppm. Collected data analyzes the vegetative biomass response including responses to change in plant reproductive structures and pollen production in terms of quantity and potency based on protein assay analysis. The analysis also compares biomass and pollen production response of each varying ecotype. Demographic data collected across a climate gradient in Massachusetts will serve as a field dataset to help interpret differences among genotypes. Data and methods in this study will be incorporated into an Environmental Science high school curriculum. Students will make observations, collect and analyze data to compare ragweed demographics based on varying environmental conditions and disturbance. Additionally, the experience gained from my participation in this study will be used to help reinforce the role of CO2 in photosynthesis as well as reinforce students understanding of scientific method of investigation and scientific design within a high school Biology lesson related to photosynthesis.

Personnel at the Harvard Forest - 2012

Audrey Barker Plotkin	Site and Research Coordinator
Andrew Bennett	Bullard Fellow
Emery Boose	Information & Computer System Manager
Jeannette Bowlen	Accountant
Laurie Chiasson	Financial Assistant/Receptionist
Elizabeth Colburn	Aquatic Ecologist
Elizabeth Crone	Senior Ecologist
Lindsay Day	Summer Program Assistant
Dash Donnelly	Research Assistant
Elaine Doughty	Research Assistant
Israel Del Toro	Graduate Student
Edythe Ellin	Director of Administration
Aaron Ellison	Senior Ecologist
Kathy Fallon Lambert	Science & Policy Integration Project Director
David Foster	Director
Lucas Griffith	Maintenance Technician
Brian Hall	Research Assistant
Linda Hampson	Staff Assistant
Clarisse Hart	Outreach and Development Director
Ross Heinemann	Summer Program Assistant
David Kittredge	Forest Policy Analyst
Oscar Lacwasan	Maintenance Technician
James Levitt	Director, Program on Conservation Innovation
Stephen Long	Bullard Fellow
Ron May	Maintenance Technician
Liza Nicoll	Research Assistant
John O'Keefe	Museum Coordinator
David Orwig	Forest Ecologist
Wyatt Oswald	Paeloecology Lab Coordinator
Julie Pallant	System and Web Administrator
Manisha Patel	Lab Manager and Summer Program Coordinator
Michael Pelini	Research Assistant
Shannon Pelini	Post Doctoral Fellow
Sydne Record	Postdoctoral Researcher
Lisa Richardson	Accounting Assistant
Pamela Snow	Environmental Educator
Kristina Stinson	Staff Scientist/Population Ecologist
Jessica Taylor	Lab Assistant
Jonathan Thompson	Post Doctoral Fellow
Mark VanScoy	Research Assistant
Scot Wiinikka	Maintenance Technician
John Wisnewski	Maintenance Technician
Rui Zhang	Postdoctoral Fellow
Tim Zima	Summer Cook

Harvard University Affiliates

Peter del Tredici	Arnold Arboretum
Richard T.T. Forman	Graduate School of Design
Charles H.W. Foster	Harvard Kennedy School
N. Michelle Holbrook	Organismic & Evolutionary Biology
Paul Moorcroft	Organismic & Evolutionary Biology
William Munger	Div. Engineering & Applied Sciences
Steven Wofsy	Div. Engineering & Applied Sciences

2012 Summer Research Program Students

Lauren Alteio
State University of New York - ESF

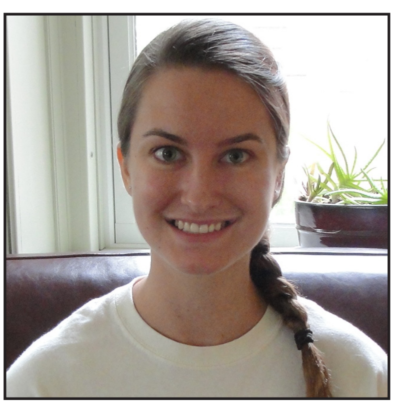
Laura Bartock
University of Maryland, Baltimore County

Julia Brokaw
Cornell University

Tiffany Carey
University of Michigan

Anne Cervas
Harvard College

Matthew Combs
Hamilton College



Katherine Davis
Duke University

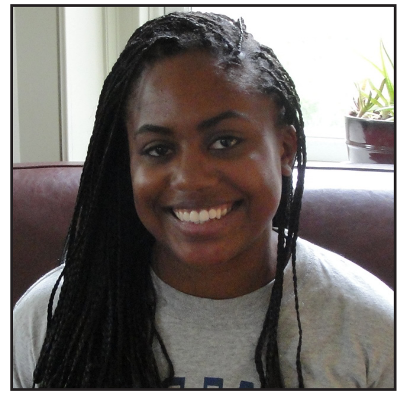
Yvan Delgado de la Flor
Humboldt State University

Sonia Filipczak
Essex County College

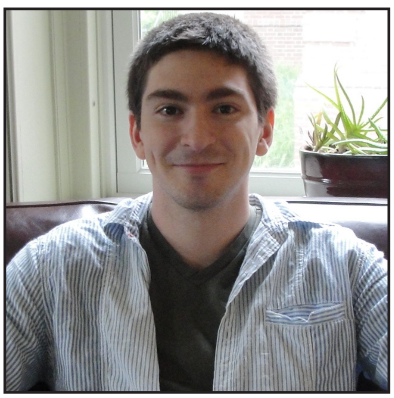
2012 Summer Research Program Students

Erin Frick
Mount Holyoke College

Margaret Garcia
Villanova University

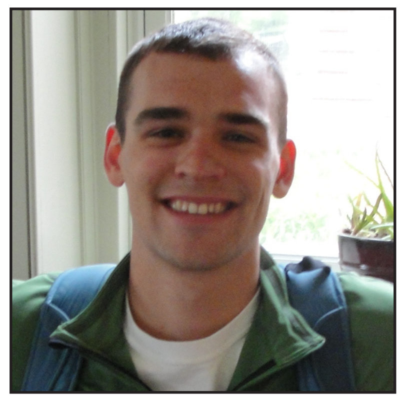


Candice Hilliard
Cornell University



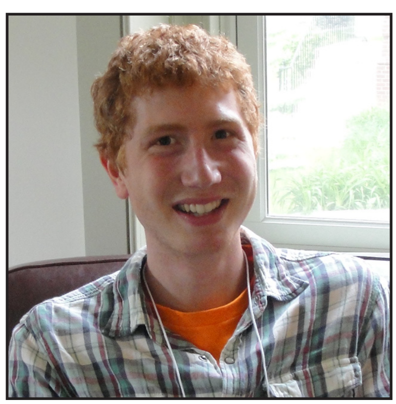
Dmitri Ilushin
Harvard College

Aubrie James
Iowa State University



Alexander Kappel
Clark University

Elizabeth Kennett
University of Vermont



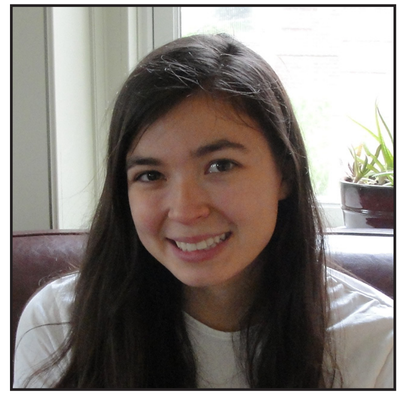
Samuel Knapp
University of Wisconsin, Stevens Point

Courtney Maloney
University of California, Berkeley

2012 Summer Research Program Students

Kelsey McKenna
Harvard College

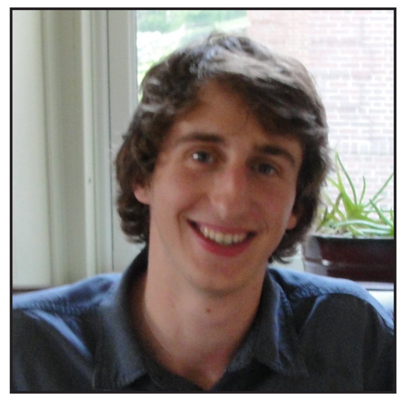
Andrew Moe
Vermilion Community College



Adalyn Naka
Brown University

Miruna Oprescu
Harvard College

Sascha Perry
Lincoln University



Paul Quackenbush
Middlebury College

Jose Luis Rugelio
Lincoln University

Emma Schnur
Cornell University

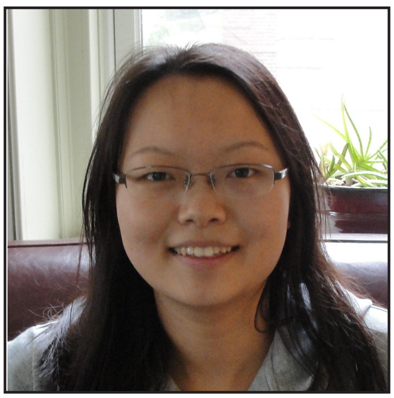
Tefiro Serunjogi
Grinnell College

2012 Summer Research Program Students

Jennie Sirota
North Dakota State University

Sofiya Taskova
John Hopkins University

Vincent Waquiu
Southwestern Indian Polytechnic Institute



Yujia Zhou
Dickinson College

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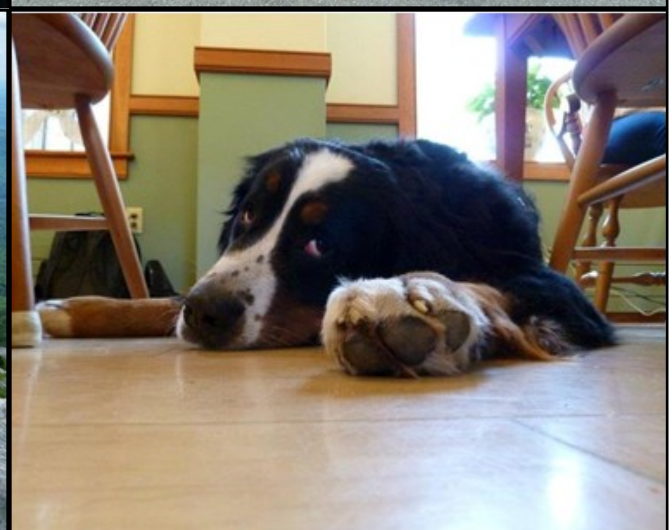
Ashburnham-Westminster Reg. School District

Bill Van Valkenburg
Gardner High School

Lindsay Day
Fisher House Proctor

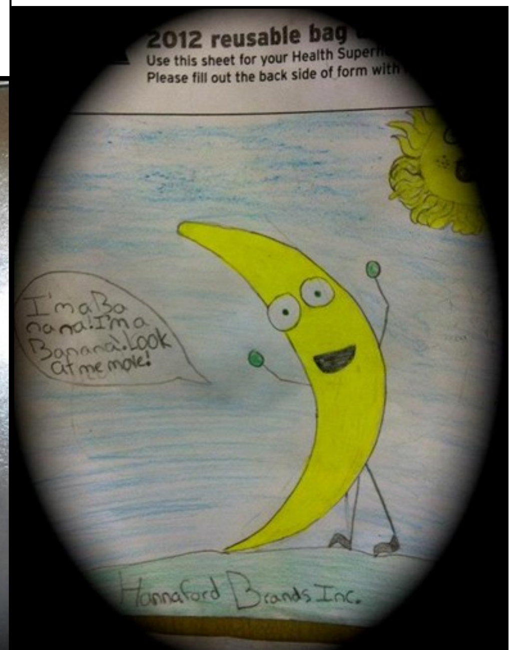
Ross Heinemann
Raup House Proctor

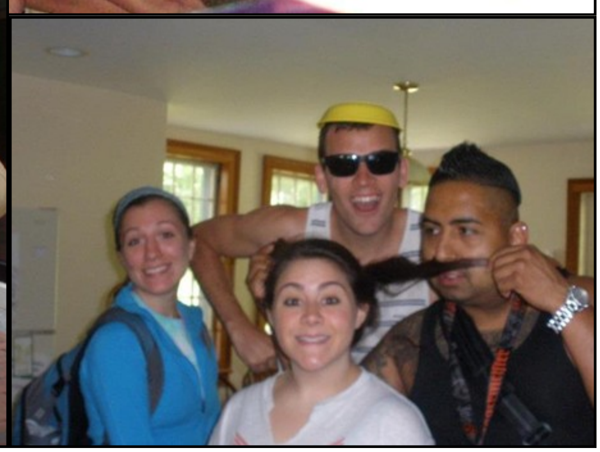


The Beautiful Times...

The Silly Times...





And All the in Between.
Harvard Forest 2012