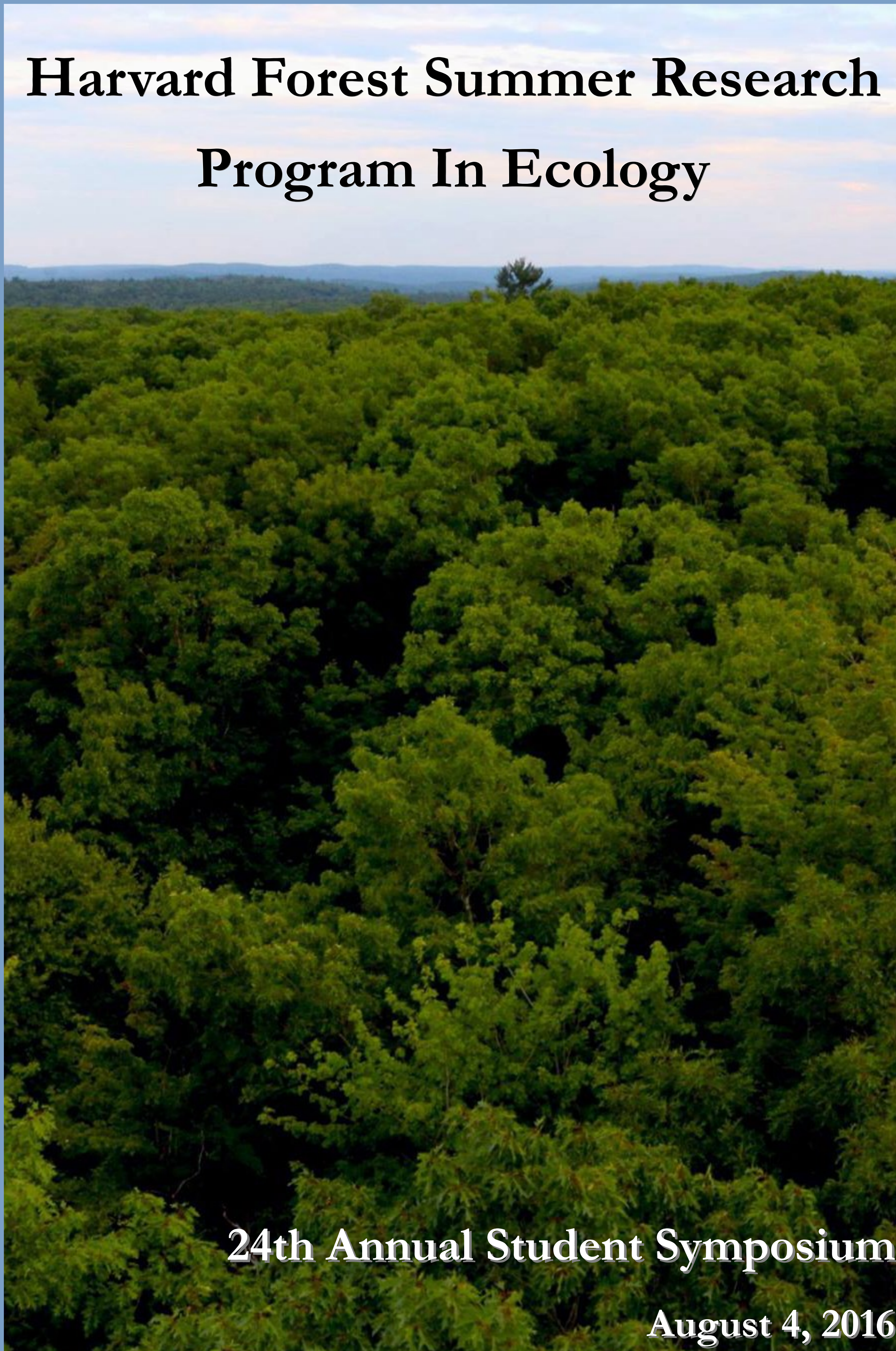
Harvard Forest Summer Research Program In Ecology



24th Annual Student Symposium

August 4, 2016

24th Annual Harvard Forest Student Symposium

August 4, 2016
Harvard Forest Fisher Museum
Petersham, Massachusetts

Photographs by Andrew McDevitt, Dev Harrington, Jenny Hobson
and 2016 Summer Research Program students

INTRODUCTION TO THE HARVARD FOREST

Since its establishment in 1907, the Harvard Forest has served as Harvard University's outdoor classroom and laboratory focused on forest biology and ecology. Through the years, researchers at the Harvard Forest have concentrated on forest management, the development of forest site concepts, the biology of trees, plant ecology, soil processes, forest economics, landscape history, conservation biology, and ecosystem dynamics.

Today, this legacy is continued by faculty, staff, and students who seek to understand historical and modern changes in the forests of New England and beyond. Their research has informed conservation and management as well as enhanced appreciation of forest ecosystems and their histories. This activity is epitomized by the Harvard Forest Long Term Ecological Research (HF LTER) program, which was established in 1988 with funding from the National Science Foundation (NSF).

Physically, the Harvard Forest is comprised of more than 3,750 acres of land in the north-central Massachusetts town of Petersham and surrounding areas. These acres include mixed hardwood and conifer forests, ponds, streams, extensive spruce and maple swamps, fields, and diverse plantations. Additional land holdings include the 20-acre Pisgah Forest in southwestern New Hampshire (located in the Pisgah State Park), which had been a 300 year -old forest of white pine and hemlock when it was blown 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 library space, laboratory and greenhouse facilities, and a lecture room for seminars and conferences. Ten 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 Harvard University's Department of Earth and Planetary Sciences (EPS), School of Engineering and Applied Science (SEAS), School of Public Health (SPH), and Graduate School of Design (GSD). The Harvard Forest's affiliations outside of Harvard University include close ties with the University of Massachusetts departments of Biology, Natural Resource Conservation, and Computer Science; the Marine Biological Laboratory's Ecosystems Center; and the University of New Hampshire's Complex Systems Research Center.

The staff and visiting faculty 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 seven-member Facilities Crew undertakes forest management and physical plant activities.

ABOUT THE 2016 SUMMER RESEARCH PROGRAM

The 2016 Harvard Forest Summer Research Program in Ecology, directed by Aaron Ellison, with assistance from Manisha Patel (coordinator), Andrew McDevitt (proctor) and Dev Harrington (proctor), attracted a diverse group of students to receive training in scientific investigations and experience in long-term ecological research. All students worked closely with mentors on various research projects from field and laboratory experiments to computer based software and hardware development. The program included weekly seminars from scientists, a career panel, and a field excursion on land-use history. The summer included an annual trip to the Harvard Museum of Natural History in Cambridge, MA, for a tour of the collections. The Harvard Forest Summer Research Program in Ecology culminates in the Annual Student Symposium held on August 4th, 2016, where students present their research findings to an audience of scientists, peers, and family.

2016 Summer Research Program Students

2016 SUMMER RESEARCH PROGRAM SEMINARS AND WORKSHOPS

Seminars

Wed., May 25	Forest Walk – *David Foster, Harvard Forest*
Tues., May 31	Science Check-in — *Manisha Patel, Harvard Forest*
Wed., June 1	Hybrid Vigor: Science X Design X Art – *David Buckley Borden, Harvard Forest Bullard Fellow*
Wed., June 15	Visit to Harvard Museum of Natural History, Harvard University Herbaria, and Museum of Comparative Zoology
Wed., June 22	Tardigrades – *William Randy Miller, Baker University*
Wed., June 29	Dying White Oaks: CSI– *Rose Marie Muzika, University of Missouri & Harvard Forest Bullard Fellow*
Wed., July 6	The PEcAn Project: Putting ecosystem model-data fusion in your pocket - *Mike Dietze, Boston University*
Wed., July 20	Career Panel – *Mollie Freilicher, Massachusetts Department of Conservation and Recreation; Tamara Hillman, National Ecological Observatory Network (NEON); Marcela Maldonado, Mount Grace Land Conservation Trust*
Wed., July 27	Nature Sketching – *Elizabeth Farnsworth, New England Wild Flower Society*

Workshops

	Ecological analytics with R – *Matthew Lau & Luca Morreale, Harvard Forest*
Thurs., June 2	Part 1, Why R and getting setup
Thurs., June 9	Part 2, Coding Basics
Fri., June 17	Part 3, Stats and science
	Talking Science with the Public
Mon., June 6	Part 1 – *Marissa Weiss, Science Policy Exchange*
Wed., June 8	*Part 2 – Clarisse Hart, Harvard Forest*
Wed., July 13	Scientific Presentation and Poster Workshop – *Matthew Duveneck, Harvard Forest*

FUNDING FOR THE 2016 SUMMER RESEARCH PROGRAM

The Harvard Forest Summer Research Program in Ecology in 2016 was supported by the following organizations:

National Science Foundation

REU Site: A Forest full of Big Data: the Harvard Forest Summer Research Program in Ecology 2015-2019 (DBI-1459519)

Collaborative Research: The climate cascade: functional and evolutionary consequences of climatic change on species, trait, and genetic diversity in a temperate ant community (DEB-1136646)

HFR LTER V: New Science, Synthesis, and Strategic Vision for Society (DEB-1237491)

SI2-SSI: Collaborative Research: Bringing End-to-End Provenance to Scientists (ACI-1450277)

Collaborative Research and NEON: MSB Category 2: PalEON - a PaleoEcological Observatory Network to access terrestrial ecosystem models (EF-1535623)

Collaborative Research: Structure and Function of Whole-tree 3D Xylem Networks in Response to Past, Present, and Future Drought (IOS-1557917)

Mount Holyoke College

Miller Worley Center for the Environment Summer Leadership Fellowship

Harvard University

Department of Organismic and Evolutionary Biology
G. Peabody "Peabo" Gardner Memorial Fund
Faculty of Arts and Sciences
Martin H. Zimmerman Memorial Fund

24th ANNUAL HARVARD FOREST STUDENT SYMPOSIUM SCHEDULE

THURSDAY, AUGUST 4th FISHER MUSEUM

Audrey Barker Plotkin — Welcome

9:00 A.M. Session I: Data Provenance and its Ecological Applications

Siqing Liu *Amherst College*	Improving RDataTracker accessibility and functionality	16
Moe Pwint Phyu *Mount Holyoke College*	Accessible data provenance with debugging feature in R	20
Anna Calderon *University of California*	Effects of incorporating genetic differentiation and competition on species distribution models under climate change	11

9:45 A.M. Session II: Plant Dynamics with Conservation Applications

Anna Mayrand *Emory University*	Utilizing effective grazing practices to conserve grassland biodiversity	17
Sydney-Alyce Bourget *University of Georgia*	A comparison of functional and fitness traits of *Alliaria petiolata* along a forest gradient	10
Alexandra Salinas *St. Mary's University*	Effects of climate change and invasive species on red maple growth	23

~ Break ~

10:45 A.M. Session III: Carbon Dynamics

Tirsa Rebeca Bonilla *University of Massachusetts Boston*	Determining the effects of deuterium on active soil microbial communities	9
Catherine Polik *Harvard University*	Explaining thermal acclimation of soil respiration in response to prolonged soil warming	21
Megan Wilcots *Columbia University*	Assessing manganese dynamics throughout a moisture gradient in a temperate forest	29
Sarah Goldsmith *Rochester Institute of Technology*	Measuring soil respiration in an infested hemlock stand	13
Rebecca Sparks *Boston University*	Carbon storage dynamics of coarse woody debris	25

~ Lunch ~

24th ANNUAL HARVARD FOREST STUDENT SYMPOSIUM SCHEDULE

THURSDAY, AUGUST 4th FISHER MUSEUM

1:00 P.M. Session IV: Forests Through Time and Space

Anna Guerrero *Arizona State University*	Forest growth and change over time	14
Molly Wieringa *Harvard University*	From the ground up: Defining hemlock undergrowth on Prospect Hill	28
Melinda Paduani *University of Central Florida*	Evaluating disturbance history in red oak growth patterns along a disturbance gradient	19
Alice Linder *Harvard University*	Community composition of woody species at their range limits in eastern North America	15
Ian Smith *Boston University*	Edge effects on forest structure and productivity	24

~ Break ~

2:30 P.M. Session V: Plant Hydraulics

Lauren Ebels *Calvin College*	Augmenting an aerial tram through code for optimized independent data collection above a forest canopy	12
Alexandra Widstrand *Smith College*	Coding among the trees: Automating sap flow measurements	27
Katherine Anstreicher *Yale University*	Characterizing drought resistance of New England saplings by species and tissue type	8
Nathan Stephansky *Bates College*	Vulnerability to cavitation in xylem across and within growth rings in four hardwood species	26

~ Break ~

3:45 P.M. Session VI: New England Forest Landscapes

Kathryn Rawson *Mount Holyoke College*	PING2.0: Utilizing ecological momentary assessment to investigate how private woodland owners engage with their land	22
Karina Agbisit *University of Portland*	Vermont landowners, climate change, and the Green Mountain National Forest	7
Patrick McKenzie *University of Tennessee at Knoxville*	Quantifying uncertainties in forest landscape model outputs using a variance-based global sensitivity analysis	18

4:30 P.M. Ticks

Audrey Barker-Plotkin	Tick study	

Karina Agbisit
University of Portland
Mentors: Emily Silver Huff & David Kittredge
Group Project: Improving our understanding of the ways private woodland owners consider their land

Vermont landowners, climate change, and the Green Mountain National Forest

Over the phone and in person, fourteen southern Vermont landowners were interviewed about their views on climate change, their own land, and the nearby Green Mountain National Forest. Each interviewee brought to the table her or his own views on the subjects; however, twelve major themes emerged from the interviews. Additionally, analysis of the interviews involved categorizing interviewees into the Six Americas (2015, *Climate Change in the American Mind*, Leiserowitz, Maibach, and Light). The Six Americas categorization looks at the behaviors and beliefs of Americans in relation to climate change, placing Americans in easy to understand groupings. Lastly, the interviews serve to answer the research question "how do perceptions of past and current noticed effects of climate change influence private woodland owner attitudes toward climate change?"

Katherine Anstreicher

Yale University

Mentors: Jay Wason, Craig Brodersen & Brett Huggett

Group Project: Structure and function of New England forest trees: Predicting future forest composition by looking back in time

Characterizing drought resistance of New England saplings by species and tissue type

Many scientists project that the New England forest system will adapt as climate change renders atmospheric conditions drier and warmer on average. To gain insight as to which species may fare best in future conditions, I conducted drought resistance research on dominant hardwood species in the Harvard Forest (Petersham, MA). I sampled three saplings from each of the following four species: *Quercus rubra, Acer rubrum, Fraxinus americana,* and *Fagus grandifolia.* In lab, I tested the drought resistance of six distinct tissue types per sapling. Drought resistance was measured using air -seeding pressure (ASP), which indicates the pressure value at which air effectively interrupts flow of water in a given tissue. ASP measurements were compared using ANOVA, TukeyHSD, Shapiro Wilk, and Kruskal Wallis tests. There was no significant difference in ASP value by tissue type; that is to say, no one tissue demonstrated significantly higher drought resistance than another. However, there were significant differences ($p < 0.05$) in ASP values when comparing species within a single tissue type. I found that *A. rubrum* has a significantly higher ASP value (and thus, resistance to drought) in leaf petioles than do all three other species. In addition, *A. rubrum* is more resilient than *F. americana* across all tissue types. My results suggest that *A. rubrum* saplings will survive at a higher rate than *F. americana* saplings in future New England forests. On a broader level, the species *A. rubrum* may perform better as a whole than *F. americana* as droughts become more frequent and severe due to climate change.

Tirsa Rebeca Bonilla

University of Massachusetts – Boston

Mentors: Lauren Alteio & Jeffrey Blanchard

Project: Global warming impacts on soil microbiomes

Determining the effects of deuterium on active soil microbial communities

As simple as the soil may appear, it consists of a whole world of varying microscopic organisms. In the long-term soil warming experiments at Harvard Forest, respiration has increased in the warmed plots as compared to the control. Many microorganisms are found within the soil making it difficult to identify those contributing most to these changes in respiration. This summer, we used stable isotope probing to isolate the active microorganisms in the soil community. The stable isotope used was deuterium (D2O), a form of hydrogen that contains one additional neutron, which is also known as heavy water. Water is linked to the respiration pathway in all organisms because the oxygen in water is used as the final electron acceptor in respiration. Similarly, the oxygen in deuterium oxide will be used to complete respiration. The organisms that take up the isotope are responsible for higher respiration because they comprise the active component of the soil community. Organic and mineral horizon soil samples were collected off-plot at Harvard Forest's Prospect Hill. Data shows that samples treated with 100% deuterium and samples treated with only water have no statistically significant difference in respiration, but have a distinct difference in respiration between homogenized and intact soils. Through the data acquired, it seems that the difference in soil moisture levels affects respiration in homogenized and intact soil samples. Further experimentation must be done to test these hypotheses.

Sydney-Alyce Bourget
University of Georgia
Mentors: Laura Hancock, Julia Wheeler & Kristina Stinson
Group Project: Biological invasions, and plant and soil community responses under global climate change

A comparison of functional and fitness traits of *Alliaria petiolata* along a forest gradient

Alliaria petiolata, commonly known as garlic mustard, is an invasive herb that has been spreading throughout the United States for over 150 years. In recent decades, garlic mustard has begun to invade the intact forest understory communities of eastern North America. The expansion of garlic mustard's invasive range into novel habitats is a great concern as garlic mustard exudes a chemical compound that inhibits the growth of essential soil fungi. The objective of this study was to determine whether garlic mustard populations located along a forest gradient exhibited different functional and fitness traits. We also sought to determine the average height and fruit body yield between these populations over time. To conduct this study an observational field experiment was set up in which the traits of garlic mustard populations located within the edge of a forest, intermediate forest, and forest understory were measured. These traits include height, number of leaf nodes, and reproductive siliques. Based upon preliminary data analyses, garlic mustard populations found within the edge habitats exhibited, on average, greater heights, leaf nodes, and reproductive siliques than any of the other microhabitats observed. Garlic mustard populations in the intermediate sites exhibited the next greatest heights, leaf nodes, and reproductive siliques, while the forest population produced the shortest plants with the fewest siliques on average. This data along with previous data collected would suggest that a source-sink dynamic is occurring in which edge populations are sourcing propagules into the forest understory.

Anna Calderon

University of California

Mentor: Matthew K. Lau

Project: Improving predictions of ecosystem responses to climate: Intraspecific variation and species distribution models

Effects of incorporating genetic differentiation and competition on species distribution models under climate change

Habitat range shifts for a variety of species are predicted to occur in response to climate change. Environmental niche models (ENM) are commonly used to model habitat suitability or probability of occurrence. However, most species distribution models do not consider intraspecific genetic variation. Previous research suggests that including population differentiation may increase the accuracy of ENMs. In this study, we used published presence locations for *Aphaenogaster rudis*, a common New England forest ant and seed disperser, to explore the effects of including local adaptation on ENMs. Studies have found that rising minimum temperatures allow *A. rudis'* expansion into northern and higher elevation habitats. Although our conventional ENM agrees with this "upward" trend, it does not consider intraspecific genetic variation. Using *kmeans* clustering methods to produce genetic clusters, which simulate maximal local adaptation to minimum daily temperature, we ran an environmental niche model for each cluster for three years. We show that when intraspecific variation is included and dispersal is unlimited, habitat suitability expansion is greater than when compared to our conventional ENM. Although, our "genetically" informed ENMs assume unlimited dispersal, optimal local adaptation, and no panmixis, our simulations suggest that including population differentiation could result in more optimistic ENMs. As genetic information becomes more accurate, available, and cheaper, it is beneficial to include genetic information in species distribution models.

Lauren Ebels

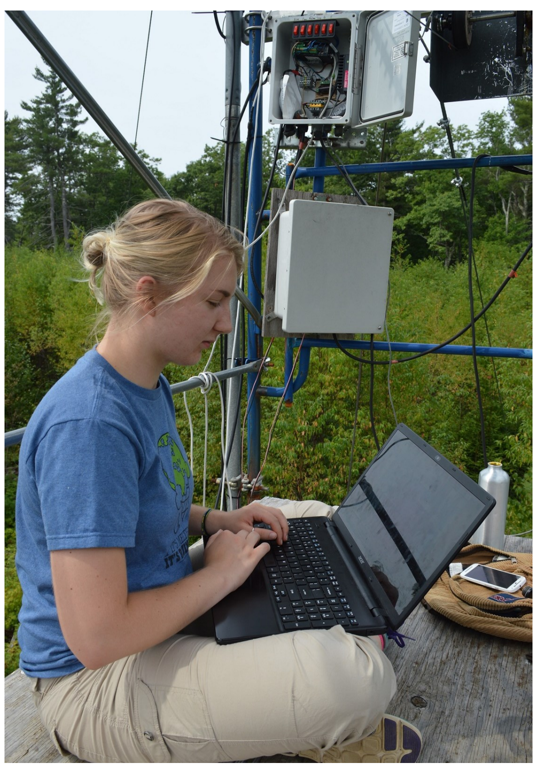
Calvin College

Mentors: Xingjian Chen & Paul Siqueira

Project: Forest stand dynamics measured by an above-canopy automated robotic system

Augmenting an aerial tram through code for optimized independent data collection above a forest canopy

Data collection is essential for an accurate evaluation of climate change and other environmental progressions. An automated tram system which traverses a re-growing clear-cut area in the Harvard Forest provides a minimally invasive and user friendly design for collecting atmospheric data and analyzing long term forest health. The tram, guided by Python code, transfers data files wirelessly from a BeagleBone single-board computer contained within the main tram shell to a base station computer. The tram website also provides a more publicly available platform for researchers to stay updated on the tram's development and its findings. Since the ultimate goal of this project is to maintain a system that is as self-sufficient and durable as possible, the primary focus of this summer's work was to alleviate some commonly occurring technical hindrances. As the tram chassis is frequently exposed to the elements, harsh weather was initially a likely cause for harm. A Python add-on called PyOWM was implemented to help the tram identify potentially hazardous conditions and alert project managers via email. Another portion of the tram code now recognizes when the tram has been attempting measurements for greater than 1 hour, indicating an operation error. The code displays a message that the tram has been away for too long and returns it to the charging station until the next indicated departure time. Through Heroku and Django, two tools used for web application development, the tram data have also started to become more structured and interpretable through graphs displayed on the website.



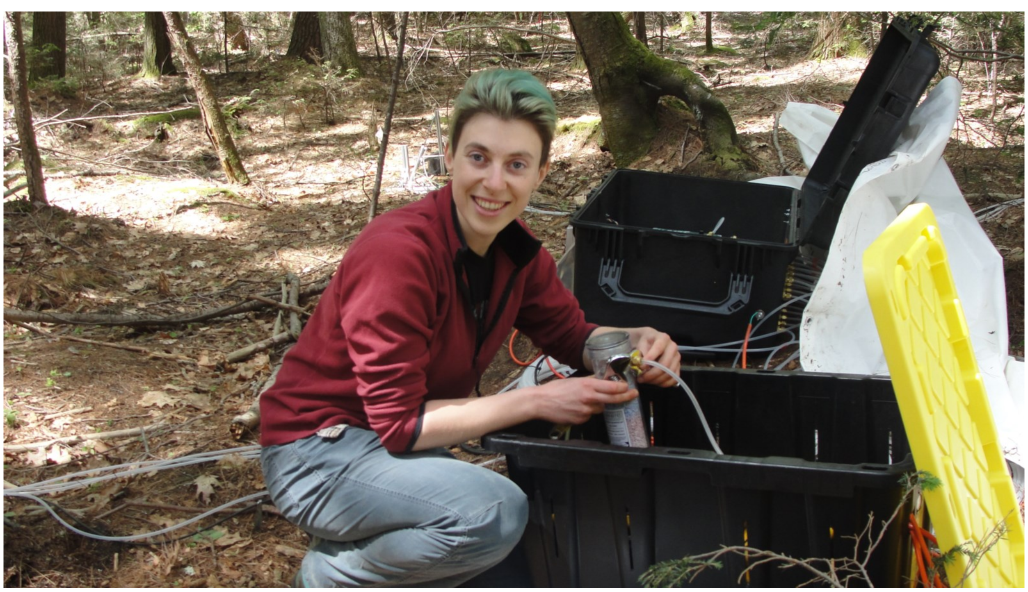
Sarah Goldsmith

Rochester Institute of Technology
Mentors: Marc-Andre Giasson & Adrien Finzi

Project: Measuring soil respiration in a hemlock stand under infestation

Measuring soil respiration in an infested hemlock stand

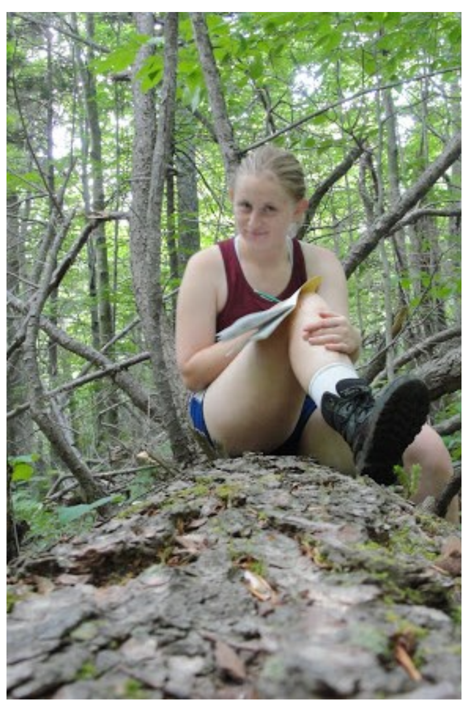
Eastern Hemlock (*Tsuga canadensis*) stands are in decline throughout the eastern United States due the Hemlock Woolly Adelgid (HWA, *Adelges tsugae*) and due to their significance to carbon cycling, there is particular interest in understanding how their deterioration will influence soil respiration and carbon storage. The intent of this project was to determine how soil respiration differs between infested and relatively healthy stands of hemlock forest. Automated chamber systems were installed in two hemlock stands-- one where HWA has caused significant damage (damaged stand) and one where the forest is still fairly intact (intact stand). Each system consists of six automated chambers that measure CO2 concentration, six soil temperature probes, and two soil water content probes in the mineral layer. The rate of soil respiration was determined by a linear regression of CO2 concentration over time. Despite higher temperatures at the damaged stand than the intact stand and similar soil moisture contents between stands, rates of respiration were lower at the damaged stand. This result indicates that, accordant with estimations by Raymer et al. (2013), rates of respiration in damaged hemlock stands will initially decrease following HWA invasion due to the decrease in autotrophic respiration. It was also observed that while soil water content appears to have less of an impact on overall respiration than temperature, rapid increases in soil moisture following rain events tended to correspond with spikes in soil respiration, likely due to the stimulation of heterotrophic respiration.



Anna Guerrero
Arizona State University
Mentors: Clarisse Hart & Neil Pederson
Group Project: Forest Time

Forest growth and change over time

Time can be overlooked as a factor in the development of forest ecosystems, but it is an essential component of forest evolution. The human lifespan— which is relatively short compared to that of a single tree, and strikingly short in relation to an entire forest or landscape— makes it difficult for people to conceptualize the timescale on which trees and forest ecosystems are living and changing. This conceptualization is critical as it will inform and enrich individual experience and insight, scientific study, forest management, and conversations about advocacy and preservation. The temporal element of forests is often considered in detailed study of forestry and ecology, but this concept is integral to the development and wellbeing of forests, and must therefore be translated to a clear and captivating medium for the utilization by all people who depend on trees. In order to personally engage viewers, but still convey useful scientific information, six illustrations were created to trace the development of forest ecosystems and human experience through periods of time that would be significant in both a tree's ring record and a human's memory. By examining and connecting the experiences of people and trees and forests in parallel developmental periods, viewers may participate in an emotionally compelling story in which they may use their own human experiences to gain a more intimate and accurate understanding of forest dynamics and development through time, and conversely, to use the experience of trees and forests to enhance their relationships with time, age, and the environment.



Alice Linder
Harvard University
Mentors: Dan Flynn & Elizabeth Wolkovich
Group Project: Agroecology and invasion ecology at Harvard Farm

Community composition of woody species at their range limits in eastern North America

Plant species' ranges are determined through biotic and abiotic factors such as competition and stressful environments. Tree species in broadleaf temperate forests in the Northeast face changes to these ecological limitations due to shifting temperatures across their range. The effect of this shift is predicted to be most apparent at the species' range limits, where such a change in conditions that previously halted population expansion can cause a range shift. By examining species at their range limits, we can predict their future responses to climate change and the implications for their distribution and success. The goal of this study was to determine how species richness and composition of competitive neighborhoods change across a latitudinal gradient in the Northeast. We examined whether focal deciduous tree species face a competitive disadvantage at their range extremes, which will in turn provide insight into how the species will respond to changing temperatures. We recorded the size and community composition of seven deciduous tree species at their range limits, varying from the northeastern United States to southeastern Quebec. Higher relative basal area, as well as taller individuals, indicates a competitive advantage. Results show a trend towards lower competitive ability for *Betula papyrifera* at its southern range extreme at Harvard Forest. For the other five species we examined, we saw very little change across the gradient. We also analyzed understory and over-story composition and plant functional traits.

Siqing Liu

Amherst College

Mentors: Emery Boose & Barbara Lerner

Group Project: Data Provenance in R

Improving RDataTracker accessibility and functionality

Scientists, in order to turn raw data into usable information, may perform complex manipulations using statistical and other software. Without proper documentation of these manipulations, other scientists can often find it impossible to reproduce and verify results. My mentors Barbara Lerner and Emery Boose are tackling this issue by developing a set of tools that can capture data transformation and history, or as it is more officially termed, data provenance. RDataTracker, our current tool for the R programming language, can automatically execute a R script (a program that can automate tasks) and generate a line-by-line visual representation of what the code does in a Data Derivation Graph, or DDG. Our main goals are extending the functionality of RDataTracker and making it more accessible to scientists. We extended RDataTracker to allow it to work directly with RMarkdown files, a file format that allows for easy formatting and publication of scripts. We also implemented a caching system. This is to save time for scientists who are changing or re-running a program, by saving data that is already calculated and only recalculating parts that have been edited. Overall, we hope to make RDataTracker an easy and useful tool for scientists, so that capturing data provenance is not a burden but an asset.

Anna Mayrand

Emory University

Mentors: Dan Flynn, Martha Hoopes & Elizabeth Wolkovich

Group Project: Agroecology and invasion ecology at Harvard Farm

Utilizing effective grazing practices to conserve grassland biodiversity

Grasslands and pastoral fields have become scarce in the New England area. Introduced in the 1800s by settlers, these open habitats have become a unique part of the region providing habitat for rare and threatened species. However, these habitats are still being lost to continually expanding forests and usually require maintenance, and conservation techniques supportive of increasing demands for local agriculture need to be further developed. Utilizing the Petersham Country Club, we studied the effects that different grazing practices had on grassland biodiversity. 27 10m x 10m permanent plots were set up in three different maintenance areas (traditional grazing, rotational/intensive, and a grazing-free hay field) each containing 4 repurposed fairway, 3 grassy, and 3 brush-covered plots. We sampled all plots in mid- summer 2016, before the application of grazing treatments identifying the community composition within each plot. Compared with 2015's survey there have been no changes in species richness between grazing treatments over time, the overall composition of the plots that received no grazing became more complex as those that received rotational grazing became more simplified. We also analyzed the changes between pre- and post- grazing compositions and post-grazing compositions between years.

Patrick McKenzie

University of Tennessee at Knoxville

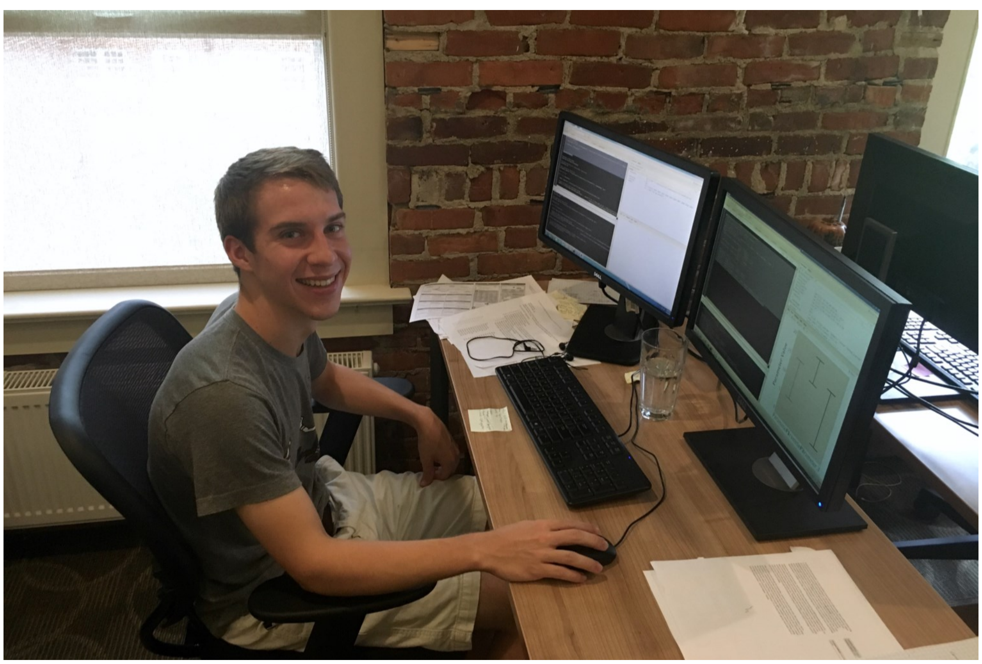
Mentors: Luca Morreale, Matthew Duveneck, Yu Liang & Jonathan Thompson

Project: New England Landscape Simulation Model Sensitivity Analysis

Quantifying uncertainties in forest landscape model outputs using a variance-based global sensitivity analysis

LANDIS-II is a popular forest landscape model that simulates tree cohort colonization, photosynthesis, and succession in response to climatic conditions. It integrates these processes with stochastic disturbances to make spatiotemporal predictions of forest biomass and composition. The model is structured as a core program with a series of extensions that can be activated to simulate different succession and disturbance processes. The new PnET-Succession extension is the most mechanistic of the LANDIS-II succession extensions; it uses equations from the PnET-II physiological model to predict changes in species biomass and spatial distribution as the result of competition for photosynthetic resources. The extension integrates many parameters, so knowing how parameters influence model outputs is necessary for interpretation of model results. I applied the Fourier Amplitude Sensitivity Test (FAST), a popular global sensitivity analysis method, to describe which PnET-Succession parameters contribute most to variation in LANDIS-II outputs. Using indices generated by FAST, sixteen PnET-Succession input parameters were ranked by their contributions to uncertainty in LANDIS outputs.

Total biomass outputs of PnET-Succession are best explained by variation in precipitation loss fraction, maintenance respiration, and climate parameters. In contrast, the biomass of an individual species is influenced primarily by foliar nitrogen for that species. Understanding the relative importance of these parameters in determining model outputs will improve interpretation of model outputs and prioritization of data collection. The analysis also identifies a challenge in that the most influential parameters are difficult to measure empirically. Future steps involve using the extended FAST method to examine interactions between parameters.



Melinda Paduani

University of Central Florida

Mentors: Daniel Bishop, David Orwig & Neil Pederson

Group Project: Evaluating disturbance dynamics in hemlock and oak forests in southern New England

Evaluating disturbance history in red oak growth patterns along a disturbance gradient

Forests in New England that are formally considered "old growth" are rare. Living, old growth trees delineate a more extensive history than those at second growth sites. To investigate these differences, I examined four sites that exhibited a gradient of past human and natural disturbance: two old growth forests, one with mixed human and natural impacts, and the human-dominated Prospect Hill tract here at Harvard Forest. The objectives are to determine if disturbance history (1) influences the rate of initial growth or (2) affects the ability of red oak to persist suppressed. Cores taken at approximately breast height (1.3 m) and at ground level were sanded and annual ring widths were measured. Periods of suppression and releases were used to quantify time to reach breast height and to examine growth response to disturbance. Tree ages ranged from 64 to 346 years old; the old growth sites averaged 192 years, the mixed site averaged 196 years, and Prospect Hill averaged 119 years. Time to reach breast height ranged from 1 to 16 years. Sites varied in past disturbance history and no synchrony of disturbance signals was observed across sites. Surprisingly, oak displayed an ability to persist in the understory of dense forests, growing at <0.5 mm yr----1 for up to 8 decades in some trees. Understanding long-term response to disturbances among various ages of living red oaks gives insight to how they may respond in the future.

Moe Pwint Phyu
Mount Holyoke College
Mentors: Emery Boose & Barbara Lerner
Group Project: Data Provenance in R

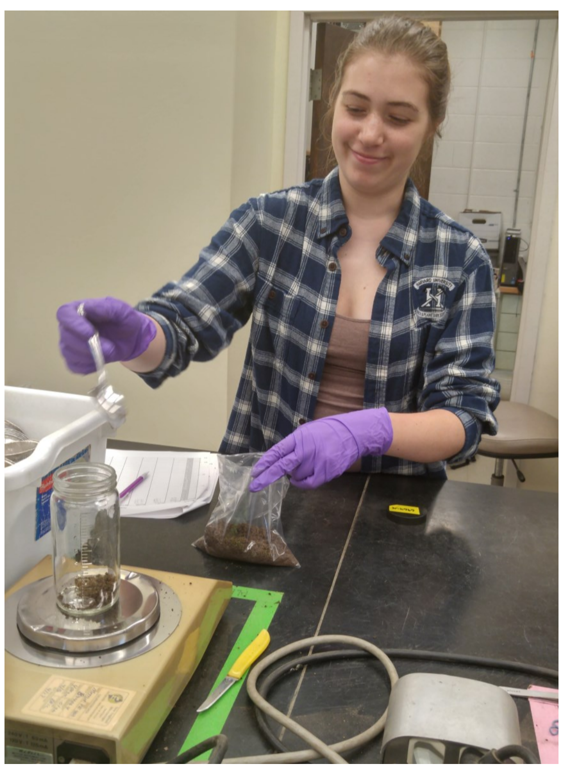
Accessible data provenance with debugging feature in R

Data analysis, a fundamental activity of nearly every scientific experiment, is critical to support hypotheses and report findings. In preparation for data analysis, raw data are transformed and manipulated to find useful information that will answer the scientist's questions. Therefore, recording the transformation of raw data (also known as data provenance) is important not only for the legitimacy of experiments but also for reproducibility by other scientists. To encourage scientists to record data provenance, this project previously produced RDataTracker, an R package that captures data provenance and DDG Explorer, a Java program that uses RDataTracker's provenance documentation, to visualize and query the data manipulation process. Before this summer, the two tools needed to be employed separately: after running RDataTracker, scientists needed to run the DDG Explorer program and select the correct data provenance file to see the visualization. To reduce the steps, I integrated DDG Explorer into the RDataTracker package, allowing scientists to see the visualization from within their R environment. In addition to viewing data provenance when the script is completed, I implemented a feature to incrementally draw as the script executes so that scientists can debug their R scripts better by visualizing what was done at each step. With these new features added to the software, we hope that data provenance will be a more accessible and useful resource for scientists.

Catherine Polik
Harvard University
Mentors: Michael Bernard, William Werner & Jerry Melillo
Project: Thermal acclimation of soil respiration in response to prolonged soil warming

Explaining thermal acclimation of soil respiration in response to prolonged soil warming

Soil organic matter (SOM) is the largest organic carbon reservoir in land ecosystems. The warming climate has the potential to accelerate SOM decay through increased microbial respiration, releasing more carbon dioxide into the atmosphere. At the Prospect Hill Soil Warming Experiment, plots have been heated to 5° C above ambient soil temperature for the last 25 years. Despite increases in annual carbon fluxes from the soil, at any given temperature the heated soils were respiring less than the control soils. This response has been termed thermal acclimation. To explore this further we incubated soils by horizon (surface organic and upper mineral) from the heated and control plots at a range of temperatures and measured how this affected heterotrophic respiration rates. The respiration patterns seen in the incubation matched the field data. Heated soils respired less, but also had less SOM and lower microbial biomass than control soils. When scaled by SOM, the acclimation response disappeared in the organic horizon, but remained in the mineral horizon. Scaling microbial biomass by SOM also provided similar values across treatments in the organic horizon, but lower values in the heated plot for the mineral horizon. Thus, scaling respiration by biomass removed the acclimation response in both horizons. We later added sucrose to release the microbes from substrate limitation, but the acclimation response persisted. Therefore, microbial biomass is the key to explaining the acclimation. These results are integral to modeling the response of soil carbon to warming and potential self-reinforcing feedbacks to the climate system.



Kathryn Rawson
Mount Holyoke College
Mentors: Emily Silver Huff & David Kittredge
Group Project: Improving our understanding of the ways private woodland owners consider their land

PING2.0: Utilizing ecological momentary assessment to investigate how private woodland owners engage with their land

Private woodland owners are a unique group because the decisions they make about their land have the potential to determine the future of forests in New England and the rest of the nation. We are interested in studying how private woodland owners engage with their land because of the important impact their activities and decision-making related to their woods may have on larger scales. Past research on private woodland owners has primarily utilized survey methods that rely on participants to retrospectively recall acts and decisions that may have occurred years in the past. Retrospective recall studies (such as the National Woodland Owner Survey) may introduce biases and limitations simply because of the nature of human memory. Our project this summer (PING2.0) tested a method of surveying woodland owners that would minimize these biases and provide a more accurate snapshot of how participants are engaging with their land. This method is based on the approach of Ecological Momentary Analysis (EMA) that is typically used in psychological research and involves frequent short contact with participants in their natural environment. We sent out a series of surveys via the Qualtrics platform over the course of 5 weeks to woodland owners recruited in various ways. Ping 2.0 is a continuation and development of our mentors' previous Ping 1.0 study and serves as a proof of concept for using EMA as a way to reach woodland owners. Our results provide a clearer direction for future applications of EMA in ecological social science.

Alexandra Salinas

St. Mary's University

Mentors: Julia Wheeler & Kristina Stinson

Group Project: Biological invasions, and plant and soil community responses under global climate change

Effects of climate change and invasive species on red maple growth

Acer rubrum (red maple) is a common canopy tree in northeastern American forests and is increasingly dominating the understory and mid-canopy of this region. However, changing climate conditions and invasion by *Alliaria petiolata* (garlic mustard) potentially threaten the future success of red maple recruitment. Our objectives were thus to examine the interacting effects of soil warming, nitrogen fertilization, and garlic mustard invasion on red maple seedling growth and leaf production. First-year red maple seedlings were planted in 20 plots on the Harvard Forest property under 8 treatments (control, control-invasion, heated, heated-invasion, nitrogen addition, nitrogen-invasion, heated-nitrogen, and heated-nitrogen-invasion) in October 2015. We monitored seedling growth from May to August 2016. Preliminary results suggest that soil warming alone has a strong positive effect on aboveground seedling growth, but in conjunction with nitrogen addition, the positive effects of warming are decreased. Furthermore, seedlings on heated-invasion and heated-nitrogen-invasion treatments had fewer survivors compared to other treatments, suggesting a negative effect of soil warming in conjunction with garlic mustard invasion on early survival. Additionally, garlic mustard invasion on its own appears to positively affect leaf count (though these leaves have smaller surface areas), and in conjunction with nitrogen addition, appears to have a positive effect on stem height compared to nitrogen addition alone. Though growth responses to soil warming are positive, warming is only a single factor of climate change, and our results suggest potential positive growth effects in red maple seedlings from soil warming may be reduced in combination with other climate change factors.

Ian Smith

Boston University

Mentors: Andrew Reinmann, Lucy Hutyra & Jonathan Thompson

Project: Effects of Forest Fragmentation on Carbon Sequestration

Edge effects on forest structure and productivity

Forests play an important role in the global carbon cycle by removing atmospheric carbon and storing it in their biomass and soils. Land use change and deforestation reduce forest carbon pools and fragment the forest. Globally, 70% of forests are estimated to be within 1km of an edge. Fragmentation is known to alter microclimate of the remaining forest, this study characterizes how forest structure and productivity change from the forest edge to the interior in Central Massachusetts. Within the research plots, trees are cored and the biomass is mapped; in addition, the microenvironment is characterized by continuously measuring air temperature, soil temperature, soil moisture, relative humidity and light. Our results show that there is higher biomass density within 20m of a forest edge than the interior of the forest, suggesting that biomass density is greater along the forest edge. Despite air temperature gradients of up to 1.5°C, we observed no differences in soil respiration rates from the edge to the interior. Taken as a whole, these data suggest that the forest edge is a larger carbon sink than the forest interior. Given the highly fragmented nature of our forests, these edge effects should be integrated into ecosystem models to better capture carbon balance across heterogeneous landscapes.

Rebecca Sparks

Boston University

Mentors: Evan Goldman & J. William Munger

Project: The dynamics of woody debris turnover and its contribution to the carbon budget of a temperate, mixed-deciduous forest; impact of disturbance events

Carbon storage dynamics of coarse woody debris

Coarse Woody Debris (CWD) refers to dead wood with a diameter > 7.5cm. CWD plays an important role in forest ecosystems, limiting erosion, providing habitat, and serving as a source of nutrients. Carbon is stored in the structure of CWD and CO2 is released during decomposition (Harmon and Sexton, 1996; Evans and Ducey, 2010). For a comprehensive understanding of carbon storage in a forest, CWD must be taken into account. In my research CWD carbon storage was determined from volume and biomass measurements obtained using the FIA line transect sampling method, as opposed to fixed area sampling (Woodall and Monleon, 2007; Evans and Ducey, 2010). Input was determined by isolating new CWD measurements from the transect sampling. Decay rate was determined by measuring change in CWD density over time. In 2016, CWD stored 7.265 MgCha-1. In 2013 this value was 8.266 MgCha-1. This indicates a 12.1% decrease in overall CWD carbon storage. Input of CWD has been an average 0.716 MgCha-1year-1 over the past three years. The long term decay rate of CWD is 1.025 MgCha-1year-1. With decay rates higher than average annual input, we expect to see a decline in the CWD carbon pool. This may be due to increasing decomposition rates, a decline in tree mortality, or some additional factor. Comparison of new measurements to long term data should acknowledge differences in sampling methods. The analysis of carbon storage dynamics of CWD should continue in order to improve our understanding of carbon in the forest as a whole.

Nathan Stephansky

Bates College

Mentors: Jay Wason, Craig Brodersen & Brett Huggett

Group Project: Structure and function of New England forest trees: Predicting future forest composition by looking back in time

Vulnerability to cavitation in xylem across and within growth rings in four hardwood species

Vulnerability to cavitation within xylem vessels is an important characteristic when predicting how a tree will respond to drought. The objective of this study was to determine how the vulnerability to cavitation differs in the xylem of growth rings ranging from current year through one and two year old rings, as well as within a growth ring from the earlywood to latewood. Measuring the air seeding pressure (ASP) in multiyear stem and trunk segments was used to quantify the vulnerability to cavitation in xylem of four hardwood species; red oak (*Quercus rubra*), white ash (*Fraxinus americana*), red maple (*Acer rubrum*), and American beech (*Fagus grandifolia*). Branch and trunk samples from sapling and mature trees for each species were collected at Harvard Forest, Petersham, MA and assessed for differences in ASP across species, growth ring, and earlywood versus latewood. Using ANOVA and Tukey's HSD, there was no significant difference in ASP across growth rings for red oak, white ash, red maple, and American beech. Further investigation of the data suggested no difference in ASP within a growth ring from the earlywood to latewood. These results suggest that the vulnerability to cavitation is independent of xylem vessel age, whether it be across or within growth rings. If vulnerability to cavitation is independent of vessel age, then water transport within trees may not be as severely effected by drought as previous studies have indicated.

Alexandra Widstrand

Smith College

Mentors: Xingjian Chen & Paul Siqueira

Project: Forest stand dynamics measured by an above-canopy automated robotic system

Coding among the trees: Automating sap flow measurements

The water cycle in a forested environment is an important mechanism for plant respiration and the transport of nutrients through trees. Quantifying the presence of water in a forest is a complex undertaking with several possible approaches. Two such methods are being investigated and developed for use in the Prospect Hill clear-cut stand at the Harvard Forest. One approach will use a radar transceiver to send and receive signal pulses to measure trees' water content remotely; the other will allow researchers to measure the rate of sap flow using pairs of probes inserted directly into tree trunks. Implementing these measurement systems simultaneously will enable comparison of the results and more insight into forest dynamics. While the radar will be incorporated into the robotic tram that operates over the clear-cut, the sap flow system functions separately because the probes must be physically attached to the trees of interest. The focus of this project has been to develop a standalone system that can measure diurnal sap flow in multiple trees at the same time. A single-board computer was programmed to continuously gather and store the data. The system is battery-powered and can be charged using a solar panel. The system has been tested in the field, running successfully for several days off-grid with two sets of probes. Development is ongoing for enabling remote access to the system through the Harvard Forest's wireless network.

Molly Wieringa

Harvard University

Mentors: Daniel Bishop, David Orwig & Neil Pederson

Group Project: Evaluating disturbance dynamics in hemlock and oak forests in southern New England

From the ground up: Defining hemlock undergrowth on Prospect Hill

Eastern hemlock (*Tsuga canadensis*) is an integral component of New England forests, fulfilling a unique niche in the temperate forest environment. This study continues previous investigation into the post-regenerative processes of hemlock, which is currently under attack from the invasive pest, hemlock woolly adelgid (*Adelges tsugae*). While hemlock is a species extensively studied in the scientific literature, we endeavor to widen the scope of study regarding its earlier life stages. Given hemlock's shade-tolerance and longevity, and observation of seedling growth on the Prospect Hill mega-plot, we hypothesized that eastern hemlock is capable of employing a competitive regenerative mechanism known as a seedling bank. Within the mega-plot, we aged 100 seedlings (< 1 cm DBH) from subplots where 48 overstory hemlocks had been cored in 2015. Each core and seedling was visually cross-dated, and used to create growth chronologies for Prospect Hill's seedling, understory, and overstory strata. Results suggest that seedlings from the mega-plot ranged in age from 16 to 85 with an average of 38 years, established primarily between 1960 and 1985, remained under 200 cm in height for that time, and have responded to disturbance with release numerous times. Seedlings did not show a release during the last decade, as proposed, most likely due to indiscriminate adelgid infestation. Regardless, these data suggest that eastern hemlock is capable of exhibiting the behavior of a seedling bank, allowing the species to maintain dominance within a forest.

Megan Wilcots

Columbia University in the City of New York

Mentors: Morris Jones & Marco Keiluweit

Project: Assessing metal redox dynamics controlling greenhouse gas emissions and carbon storage in forest soils

Assessing manganese dynamics throughout a moisture gradient in a temperate forest

Soils are an important carbon sink, holding up to three times more carbon than vegetation and atmosphere combined. Changes to this vast carbon reservoir could thus have larger ramifications on the global carbon cycle. Previous studies have shown that manganese (Mn) content of litter is positively correlated with litter decomposition rates. What remains elusive is the extent decomposition rates depend on Mn redox cycling, which (re)generates bioavailable and reactive forms of Mn^{3+} and Mn^{4+}, both of which act as oxidizers in decomposition. Here, we examined Mn redox cycling across a moisture gradient in a temperate, deciduous forest soil, and related our findings to decomposition rates. We determined total Mn content, bioavailability, and $Mn^{3+, 4+}$ content using chemical extractions on four soil horizons (litter, organic, A, and C horizons). We find that Mn^{3+} content, as a ratio of Mn_{total}, is positively correlated with soil moisture. This indicates that Mn redox cycling is more prominent in wetter soils, particularly in the organic and mineral layers. In a laboratory incubation study, we assessed the impact of redox cycles on decomposition by measuring respiration on soil cores amended with manganese oxides and subjected to wetting and drying cycles. The cores undergoing the wet/dry cycles had significantly larger decomposition rates than the continuously incubated cores. Current climate projections predict more intense precipitation events in the Northeast United States, rendering future soil moisture more variable. We would expect an increase in soil decomposition and a decrease in soil carbon storage with these precipitation changes.

PERSONNEL AT THE HARVARD FOREST - 2016

Jay Aylward	Research Assistant
Audrey Barker-Plotkin	Site and Research Manager
Daniel Bishop	Research Assistant
Emery Boose	Information Manager
Jeannette Bowlen	Accountant
Laurie Chiasson	Administrative Assistant
Elizabeth Colburn	Aquatic Ecologist
Elaine Doughty	Research Assistant
Matthew Duveneck	Post-Doc
Edythe Ellin	Director of Administration
Aaron Ellison	Senior Ecologist/Community Ecologist
Kathy Fallon Lambert	Director of Science and Policy Exchange
David Foster	Director of Harvard Forest
Lucas Griffith	Woods Crew
Brian Hall	GIS Specialist
Julie Hall	Assistant Data Manager
Clarisse Hart	Outreach and Development Manager
Jenny Hobson	Secretary
David Kittredge	Forest Policy Analyst
Oscar Lacwasan	Woods Crew
Matthew Lau	Post-Doc
Ronald May	Woods Crew
Marissa McBride	Post-Doc
Roland Meunier	Woods Crew
Alisha Morin	Accounting Assistant
Luca Morreale	Research Assistant
John O'Keefe	Museum Coordinator (Emeritus)
David Orwig	Senior Ecologist/Forest Ecologist
Julie Pallant	Information Technology and Archives Administrator
Manisha Patel	Lab Manager and Summer Program Coordinator
Neil Pederson	Senior Ecologist/Forest Ecologist
Joshua Plisinski	Research Technician
Lisa Richardson	Accounting Assistant
Matthew Robinson	Woods Crew
Thomas Russo	Woods Crew
Pep Serra Diaz	Post-Doc
Pamela Snow	Schoolyard Program Coordinator
Jonathan Thompson	Senior Ecologist/Landscape Ecologist
Greta VanScoy	Museum Coordinator
Mark VanScoy	Field Instrument Specialist
Marissa Weiss	Science Policy Exchange Coordinator
John Wisnewski	Woods Crew Supervisor
Peter Yesmentes	Summer Program Assistant Cook
Tim Zima	Summer Program Cook

Harvard University Affiliates

Richard Forman	Graduate School of Design
Noel Michele Holbrook	Organismic and Evolutionary Biology
J. William Munger	School of Engineering and Applied Sciences
Andrew Richardson	Organismic and Evolutionary Biology
Steven Wofsy	School of Engineering and Applied Sciences
Elizabeth Wolkovich	OEB and Arnold Arboretum

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Sydney-Alyce Bourget
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Lauren Ebels
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Rochester Institute of Technology

Anna Guerrero
Arizona State University

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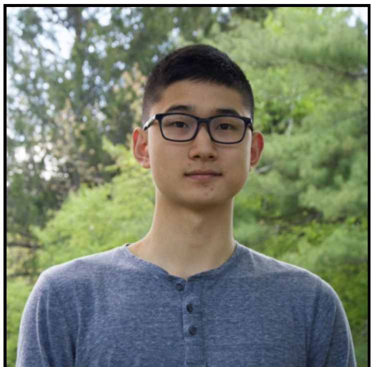
Harvard University

2016 SUMMER RESEARCH PROGRAM STUDENTS



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Moe Pwint Phyu
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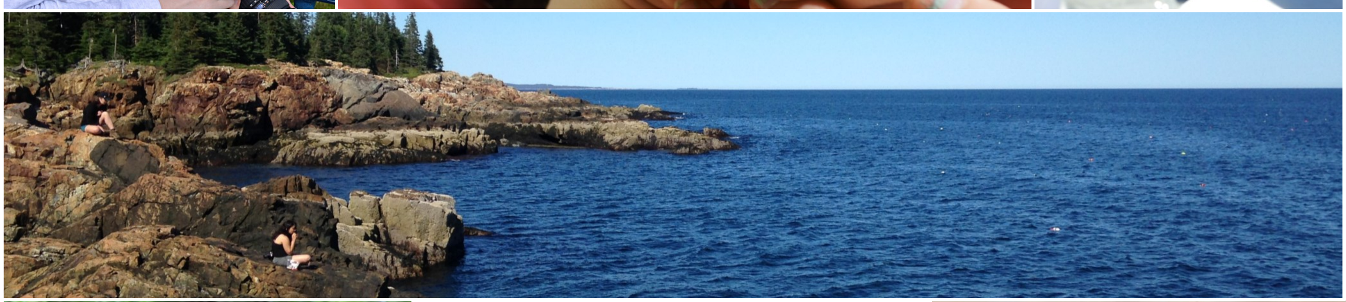






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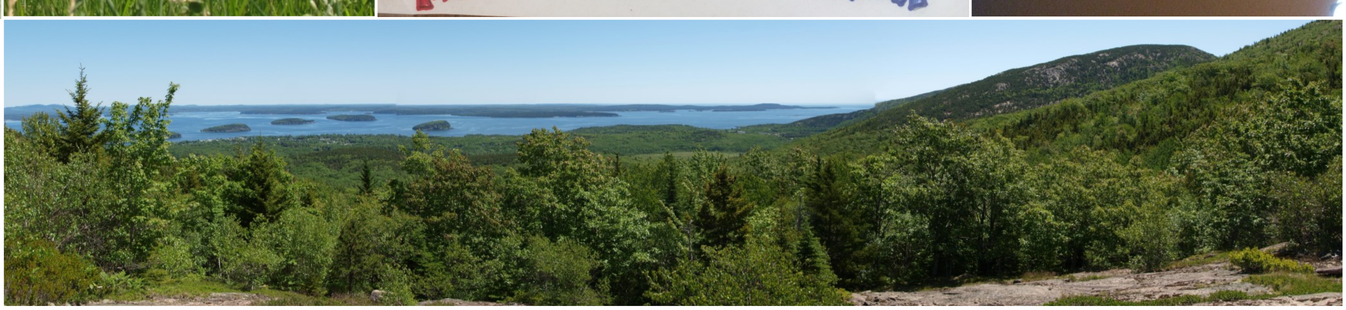


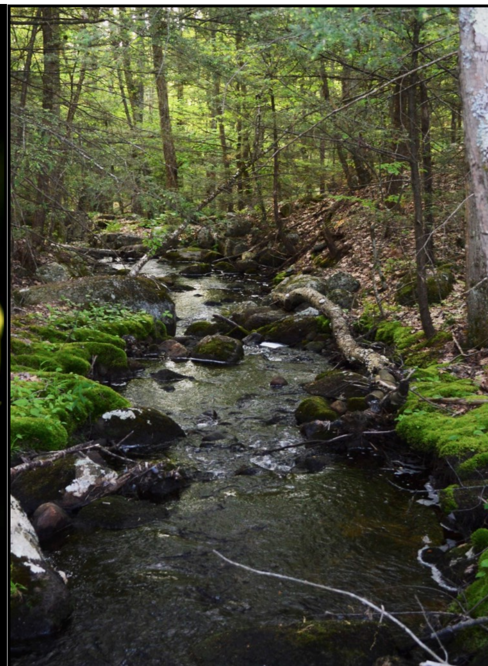
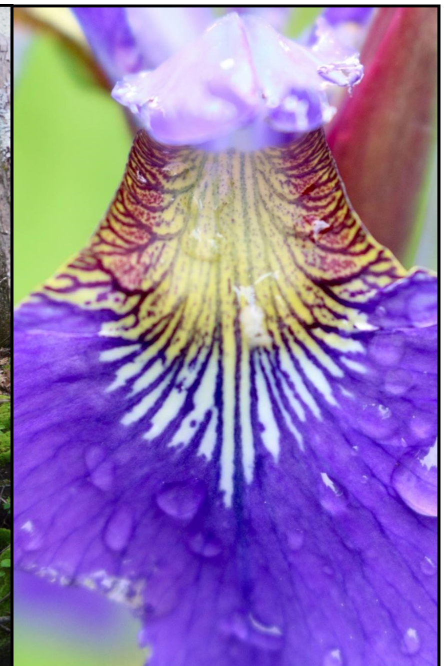

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