Summer Research Program in Ecology

22nd Annual Student Symposium
August 7, 2014

22nd Annual Harvard Forest Summer Research Program Symposium

August 7, 2014
Harvard Forest Fisher Museum
Petersham, Massachusetts

Photographs by Grace Barber, Samuel Knapp, Harvard Forest Staff, and 2014 Summer Program Participants
Drawings by Heather Clendenin

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 approximately 3,650 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 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 four-member Facilities Crew undertakes forest management and physical plant activities.

ABOUT THE 2014 SUMMER RESEARCH PROGRAM IN ECOLOGY

The 2014 Harvard Forest Summer Student Research program, coordinated by Manisha Patel with assistance from Grace Barber and Samuel Knapp, 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, career and graduate panels, and field excursions on navigation and land-use history. The summer included an annual trip to Harvard University's Museum of Comparative Zoology and Herbaria in Cambridge, MA, for a tour of the collections. The Harvard Forest Summer Research Program in Ecology culminates in the Student Research Symposium held on August 7th, 2014, where students present their research findings to an audience of scientists, peers, and family.

2014 Summer Program Students and Mentors

2014 SUMMER PROGRAM SEMINARS AND WORKSHOPS

Thurs., May 29	Talking ecology with the public – *Clarisse Hart, Harvard Forest*
Wed., June 4	Forest Walk – *David Foster, Harvard Forest*
Mon., June 9	Navigation Workshop – *Audrey Barker-Plotkin, Harvard Forest*
Wed., June 11	Behind the scenes in a radio newsroom: Lessons for telling compelling stories about science – *Marissa Weiss, Science Policy Exchange*
Tues., June 17	Tour of the Harvard Museum of Comparative Zoology and Herbaria
Wed., June 18	Can payments for environment services support sustainable forest management: Lessons from a Randomized Control Trial (RCT) – *Nigel Asquith, Natura Bolivia*
Thurs., June 19	Photoassimilate distribution in large trees and vines – *Michael Knoblauch, Washington State University*
Mon., June 23	Digging into the DIRT Experiment: Soil Carbon Dynamics and Storage in Forest Ecosystems – *Richard Bowden, Allegheny College*
Wed., July 2	The PEcAn Project: Putting ecosystem model-data fusion in your pocket – *Michael Dietze, Boston University*
Mon., July 7	Scientific Poster Workshop – *Aaron Ellison, Harvard Forest*
Wed., July 9	Career Panel – *Jeremy Barker-Plotkin, North Amherst Community Farm; Bryan Connolly, Massachusetts Natural Heritage and Endangered Species Program; Deborah Rocque, U.S. Fish and Wildlife Service; Paul Sokoloff, Battelle; Alan VanArsdale, U.S. Environmental Protection Agency*
Mon., July 14	Graduate School Panel – *Donald Aubrecht, Harvard University; Allyson Degrassi, University of Vermont; Danielle Ignace, Smith College; David Kittredge, University of Massachusetts Amherst*
Wed., July 16	Nature Sketching – *Elizabeth Farnsworth, New England Wild Flower Society*
Mon., July 21	Scientific Presentation Workshop – *David Orwig, Harvard Forest*
Wed., July 23	Scientific Abstract Writing Workshop – *Allyson Degrassi, University of Vermont*
Mon., July 28	Biodiversity of Sudan: Status, conservation challenges and urgent research needs – *Ahmed Hassabelkreem, University of Massachusetts Amherst*
Wed., July 30	Natural dynamics and management of black ash forests threatened by emerald ash borer – *Anthony D'Amato, University of Minnesota*
June 2014: 5 Sessions	R Workshop – *Elizabeth Nicoll, Harvard Forest; Emery Boose, Harvard Forest; Barbara Lerner, Mount Holyoke College*

FUNDING FOR THE 2014 SUMMER RESEARCH PROGRAM IN ECOLOGY

The Harvard Forest Summer Research Program in Ecology in 2014 was supported by the following organizations:

National Science Foundation

REU Site IV: Harvard Forest Summer Research Program in Forest Ecology 2010-2014: Ecological data-model fusion and environmental forecasting for the 21st Century (DBI-1003938)

Collaborative Research: Interacting influences of climate, land use, and other disturbances on regime shifts in forest ecosystems: Holocene dynamics in the northeastern US (REU Supplement to DEB-1146207)

DIMENSIONS: 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)

FSML: Walk-up towers for research, education, communication, and outreach at the Harvard Forest (REU Supplement to DBI-1224437)

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

National Aeronautics and Space Administration

NASA Innovations in Climate Education (NICE): Data-model fusion and forecasting 21st-Century environmental change in northeastern North America (NNX10AT52A)

Bowling Green University

Mount Holyoke College

Miller Worley Center for the Environment Summer Leadership Fellowship

Smith College

Summer Research Fellows (SURF) Program

Harvard University, The Faculty of Arts and Sciences and Harvard Forest

Department of Organismal and Evolutionary Biology

G. Peabody "Peabo" Gardner Memorial Fund

Harvard Forest Living Diorama/Bliss

22nd ANNUAL HARVARD FOREST SUMMER PROGRAM SYMPOSIUM

THURSDAY, AUGUST 7th FISHER MUSEUM

Aaron Ellison		Welcome
9:00 A.M. Session I: Big Data		
Luis Perez *Boose and Lerner*	Harvard College	Accessible and efficient data provenance in the R scripting environment
Nicole Hoffler *Boose and Lerner*	Mount Holyoke College	The aesthetics of data derivation
Sofie McComb *Duveneck and Thompson*	University of Texas at Austin	A snapshot in time: 1830 land-use legacy on present-day Massachusetts forest composition
Jessica Asirwatham *Wehr and Saleska*	Case Western Reserve University	Multi-leaf isotopic partitioning of net ecosystem-atmosphere CO_2 exchange
Sidni Frederick *Klosterman and Richardson*	Harvard College	Monitoring spring phenophase transitions with UAV imagery
	~ Break ~	
10:30 A.M. Session II: Plant Dynamics		
Bruce McAlister *VanScoy and Siqueira*	University of Massachusetts Amherst	Simplicity and robustness: keys to designing an aerial tram for autonomous, above-canopy data collection
Joshua Alaniz *MacLean and Williams*	University of North Texas	Measuring changes in phenology with Landsat
Alayna Johnson *MacLean and Williams*	University of Minnesota Morris	Nitrogen availability impacts productivity and carbon storage at three recently cleared sites at Harvard Forest
Kyle Boyd *Ignace*	Smith College	Assessing seasonal photosynthetic function of dominant species post-clearcut
Ivonne Trujillo *Aubrecht, Hufkens, and Richardson*	University of Texas at Brownsville	Impacts of climate change on the rhythm of the spring in northeast deciduous forests
Katherine Bennet *Hufkens and Richardson*	J. R. Briggs Elementary School	Teacher's Page – The Phenocam Project
	~ Lunch ~	

Mentor names italicized under presenters' names.

22nd ANNUAL HARVARD FOREST SUMMER PROGRAM SYMPOSIUM

THURSDAY, AUGUST 7th FISHER MUSEUM

1:00 P.M. Session III: Hemlock Forests

Emily Keenan *VanScoy and Orwig*	University of Michigan	Meteorological changes in declining hemlock forests
Jessica Robinson *Barker-Plotkin and Ellison*	Knox College	Beneath the canopy: understanding the effects of light availability on understory vegetation in *T. canadensis* forests after logging and simulated *A. tsugae* infestation
Claudia Villar-Leeman *Barker-Plotkin and Ellison*	Bowdoin College	Life under a log: how is the eastern red-backed salamander (*Plethodon cinereus*) affected by the abundance of deadwood in hemlock and hardwood forests?
Alison Ochs *Hassabelkreem and Ellison*	Mount Holyoke College	Red-backed salamanders as indicators of hemlock forest health
Simone Johnson *Hassabelkreem and Ellison*	Lincoln University	The effects of local climate conditions on salamanders and newts in a hemlock dominated forest
Joel van de Sande *Degrassi and Ellison*	City College of San Francisco	Hemlock woolly adelgid impacts rodent ranging behavior in a New England forest
Jefferson França *Degrassi and Ellison*	Saint Michael's College	Hemlock woolly adelgid affects microhabitat association of small mammals
Ariel da Cruz Reis *Degrassi and Ellison*	Saint Michael's College	How far does an ant travel? A study case of *Aphaenogaster picea* in western Massachusetts, U.S.A.

~ Break ~

3:00 P.M. Session IV: Soil Surface and Below

Maria Orbay-Cerrato *Oswald*	Brown University	Coprophilous fungi spores as an indicator of grazing in New England during the past few centuries
Ada Vilches *Blanchard and DeAngelis*	University of Puerto Rico at Mayagüez	Microbial community composition at the Barre Woods warming plots
Marisa Houlahan *Goldman and Munger*	Harvard College	The effect of tree species on soil carbon content and variability
Laura Figueroa *Maran and Pelini*	University of Oklahoma Norman	Decomposition in a warmer world
Heather Clendenin *Maran and Pelini*	Bowling Green State University	Spiders, springtails, and soil respiration: top-down effects within the soil food web

4:15 P.M.

Aaron Ellison		Tick Study

Joshua Alaniz

University of North Texas

Mentors: Richard MacLean and Christopher Williams

Group Project: Monitoring ecosystem physiology and vegetation structure in recent clearings within Harvard Forest and its surrounds

Measuring changes in phenology with Landsat

Human disturbance of forests is increasingly prolific across the U.S. In studying how an ecosystem regrows after human disturbance, changes in phenology can act as a proxy for other ecosystem characteristics, like leaf area or productivity. This study investigates changes in phenology at a 2008 clear-cut at Harvard Forest by determining the date of peak and fastest increase in vegetation for the growing season, estimated by the Normalized Difference Vegetation Index (NDVI). Greater NDVI values indicate greater vegetative cover. By comparing seasonal NDVI curves, the timing of maximum vegetative cover and fastest growing period within the year can be compared over time. This study attempts to test if NDVI derived from Landsat imagery can be used to characterize changes in phenology, given limitations in spatial, spectral, and temporal resolution of Landsat. Images were gathered from USGS Earth Explorer from March through November of 2009, 2011, and 2013. Cloud-free imagery from Landsat 5, 7, and 8 were used, and each image was atmospherically corrected with the COST model. NDVI and Tasseled Cap (Kauth-Thomas) transformations were calculated with ESRI's ArcGIS raster calculator. Given the regrowth of vegetation after clear-cut, we predicted that NDVI will start from a higher value each year than the previous and that the peak of NDVI will occur earlier and reach a greater value than the year before. This is inferred by vegetation having more structure and resources available each year increasing the rate and magnitude of leaf area.

Jessica Asirwatham

Case Western University
Mentors: Rick Wehr and Scott Saleska
Project: Isotopic carbon and water cycling in a temperate forest

Multi-leaf isotopic partitioning of net ecosystem-atmosphere CO_2 exchange

Measurements of the forest-atmosphere exchange of carbon isotopes can be used to partition the net total carbon exchange (measured by standard eddy covariance) into its photosynthetic and respiratory components. This partitioning requires an estimate of the isotopic signature of canopy-scale photosynthesis, which has been obtained to date by assuming that the canopy behaves like a single 'big leaf'. This assumption neglects the heterogeneity of the canopy both vertically and with respect to leaf angles. Leaves at various heights in the canopy and at various angles to the sun experience different sunlight, temperature, and wind. Our research goal was to quantify the relevant characteristics of a range of leaves in the canopy sufficiently to constrain a multi-leaf isotopic partitioning analysis, and to use that analysis to assess errors associated with the usual big leaf approach. Carbon dioxide and water vapor exchange were measured in leaves of the site-dominant deciduous species *Quercus rubra* and *Acer rubrum* using a Li-Cor 6400XT portable photosynthesis system. In order to characterize canopy heterogeneity, we carried out spot measurements, CO_2 response curves, and light response curves at the top (fully sunlit), middle, and bottom (shaded) part of the canopy. A walk-up tower and bucket lift allowed us to take intact gas exchange measurements from terminal leaves of trees in the surrounding area. A multi-leaf isotopic partitioning analysis more accurately models photosynthesis in the canopy and can be used to assess the errors associated with the big leaf assumption.

From left to right: mentor Rick Wehr and Jessica Asirwatham

Kyle Boyd

Smith College

Mentor: Danielle Ignace

Group Project: Monitoring ecosystem physiology and vegetation structure in recent clearings within Harvard Forest and its surrounds

Assessing seasonal photosynthetic function of dominant species post-clearcut

Large-scale forest disturbance affects the exchange of carbon, water and energy between the ecosystem and the atmosphere. Clearcutting is one of the most dramatic disturbances due to the impacts on ecosystem processes and vegetation structure. Due to the complexity in these processes, it is not well understood how the physiology and vegetation structure will change post-clearcut. In the fall of 2008 Christopher Williams' lab commercially clearcut an eight-hectare area in Harvard Forest to study the forest recovery. We studied photosynthetic function and nutrient content in six of the most common species located at the clearcut study site. During June and July a portable photosynthesis system (LI-6400XT) was used to measure leaf-level CO_2-response curves and light-response curves of *Prunus pensylvanica, Prunus serotina, Acer rubrum, Quercus rubra, Rubus idaeus and Dennstaedtia punctilobula*. Additionally, leaf tissue samples were analyzed for carbon and nitrogen content. Previous work from the Williams lab during the summer of 2012 provided the basis for comparing changes in photosynthetic capacity. Taken together, this allowed us to measure the photosynthetic capacity, understand potential limitations to photosynthetic capacity, and determine how these change over time. The data suggested similar photosynthetic rates for most species over the past two years. However, preliminary results showed that *Prunus pensylvanica* appeared to be the most efficient in both years, while *Acer rubrum* had the highest C:N ratios. Results from this work will allow us to understand changes in photosynthetic capacity of the most dominant species and how they play a role in ecosystem productivity.

From left to right: mentor Danielle Ignace and Kyle Boyd

Heather Clendenin

Bowling Green State University
Mentors: Audrey Maran and Shannon Pelini
Project: Predators link above- and belowground carbon responses to warming

Spiders, springtails, and soil respiration: top-down effects within the soil food web

The respiration of soil microbes releases ten times the amount of CO_2 as anthropogenic inputs. Changes in the activity and biomass of soil microbes, which both affect respiration, can be linked to the presence and density of springtails (arthropods in the subclass Collembola). Additionally, predation by spiders alters the density and activity of Collembola, and may subsequently affect soil respiration. This study addresses the top-down control wolf spiders (genus *Pardosa*) may have upon soil respiration through their interactions with Collembola. It aims to differentiate between changes caused by predation and those caused by trait-mediated interactions, specifically behavioral changes due to predator presence. In step with other studies examining predators' net effects, we hypothesized that trait-mediated interactions would be of the same magnitude as the lethal effects of predation. To examine this, we set up mesocosms with three treatment types: Collembola present and spiders absent; Collembola present with spiders modified to prevent predation; Collembola present with unmodified spiders. Soil efflux was recorded over a 5 week period using a LiCor 6400XT and analyzed using a one-way ANOVA in R. We expected efflux rates to vary significantly between the control and both treatments with predators present, indicating that trait-mediated interactions are as significant as the lethal effects of predation. Examining the role of predators in the soil ecosystem should shed light on top-down effects upon soil respiration. As issues associated with global climate change are addressed, carbon efflux in the soil ecosystem, including the role played by invertebrates, should bear consideration.

Laura Figueroa

University of Oklahoma Norman Campus

Mentors: Audrey Maran and Shannon Pelini

Project: Predators link above- and belowground carbon responses to warming

Decomposition in a warmer world

Decomposition is the process by which organic matter is broken down into pieces that are more easily used by living organisms. In this way nutrients and elements can cycle through the food web over time. Invertebrates affect decomposition either directly by digesting material or indirectly by altering the habitat favorably for bacteria and fungi. Because invertebrates are ectotherms they are more active in warmer temperatures, particularly if moisture levels are not limiting. Climate change is expected to increase global temperatures. Due to the warmer climate, invertebrates may be more active, decompose more material, and consequently contribute more CO_2 emissions. In order to gain a greater understanding of the relationship between warming, invertebrate presence and decomposition, we made three-dimensional decomposition bags that either excluded invertebrates, included those smaller than 2.5 mm^2 (many macro-invertebrates), or included those under 1 cm^2 (control) and deployed them in warming chambers at Harvard Forest, Massachusetts. The warming chambers mimic all environmental conditions of the forest with the exception of temperature which is made to simulate different warming scenarios. To measure decomposition, we collected and dried leaves from a red maple tree (*Acer rubrum*) and placed them within the bags for each of the three treatments (no invertebrates, macro-invertebrates, and control) and re-weighed after a five week period. We expect that warmer temperatures and greater numbers of invertebrates and/or their activity will increase decomposition. Understanding the intricate relationships between invertebrates, decomposition, and climate change may provide scientists necessary tools for facing potential obstacles in the future.

From left to right: Laura Figueroa and mentor Shannon Pelini

Jefferson França

Saint Michael's College

Mentors: Allyson Degrassi and Aaron Ellison

Group Project: Declining hemlock forests affects diversity of arthropods, salamanders, and small mammals

Hemlock woolly adelgid affects microhabitat association of small mammals

The eastern hemlock is a foundation species in New England that stabilizes microclimate and supports wildlife. The loss of eastern hemlocks can alter microclimate and microhabitat that can potentially influence the structure of animal communities by changing animal microhabitat associations. Unfortunately, eastern hemlock abundance is declining within its range from the effects of the invasive hemlock woolly adelgid. The loss of eastern hemlocks in New England forests may impact ecologically important forest-dwelling rodents. Due to their role in the food-web, a reduction in their population may generate future cascading effects on biodiversity. In order to determine if rodent microhabitat associations differ among insect-invaded hemlock forests and healthy hemlock forests, we have examined microhabitat factors that are known to influence rodent presence, such as vegetation, coarse woody debris, and leaf litter percent cover at Harvard Forest's Hemlock Removal Experiment in Petersham, Massachusetts. It was hypothesized that changes in microhabitat caused by simulated effects of the hemlock woolly adelgid influence rodent species. Percent cover of microhabitat variables (rock, woody debris, vegetation, leaf litter, and fungi) was calculated using digital photos of rodent trap locations (n = 196). To date, results indicate that vegetation cover differs among hemlock treatments and may be positively correlated with the white-footed mice, southern red-backed voles, and eastern chipmunks, but negatively correlated with deer mice and southern flying squirrels. These data suggest that vegetation ground cover change by the hemlock woolly adelgid may affect rodent microhabitat associations.

Sidni Frederick

Harvard College

Mentors: Stephen Klosterman and Andrew Richardson

Project: Impacts of climate change on the rhythm of the seasons

Monitoring spring phenophase transitions with UAV imagery

Recent warming trends associated with climate change have extended the growing season in temperate forests, pushing spring earlier and autumn later in the year. Monitoring arboreal seasonal transitions under these circumstances will help us to understand how forest ecosystem services are being impacted. UAVs, or unmanned aerial vehicles, have emerged as a helpful tool in the scientific community, and previous studies have documented their capacity to monitor changes in the forest canopy over time with digital photography. However, the question remains as to how phenological events determined from digital photography correlate to canopy physiology. I hypothesized that spring transition dates calculated from changes in the greenness of UAV-based imagery time series would correlate positively with observed transitions in leaf growth and development. I worked with time series imagery of a portion of the Harvard Forest canopy taken using a digital camera mounted to a UAV with a pre-programmed flight path. I used Matlab scripts to calculate Green Chromatic Coordinate values for individual trees on different dates, and to calculate dates for the beginning, middle and end of spring based on thresholding and curve-fitting methods. I then compared these dates with spring transition dates from ground-level observations of leaf development. From my analysis, I expect to see a significant relationship between phenophase transitions calculated from UAV imagery and the progression of leaf growth relative to final size. With an understanding of the physiological events that UAV-based canopy imagery captures, we can better employ UAVs as ecological monitoring tools.

From left to right: Sidni Frederick and mentor Andrew Richardson

Nicole Hoffler

Mount Holyoke College

Mentors: Emery Boose and Barbara Lerner

Group Project: Retracing our steps in the analysis of data

The aesthetics of data derivation

To help scientists ensure that data analyses lead to accurate and reproducible results, our team designed DDG Explorer, a Java program that can show a visual representation of data analysis using a Data Derivation Graph, or DDG. When a scientist writes an R script with RDataTracker enabled, DDG Explorer pulls in information about the data manipulations that the user can store, search, or visualize as a DDG. Our software must be easy to employ so that our future users will incorporate it into their routines. To encourage scientists to embrace our software, I focused on refining our user interface. I streamlined the program's existing features by merging DDG Explorer's many windows into a single home window for seamless navigation. I also added a toolbar that lets the user zoom into a graph to check individual variables and their values throughout the execution of a script. Data analysis can become very complex, so I enhanced DDG navigation through an Overview tool, which serves as a map that can quickly reorient a user who has zoomed into a small, specific section of a Data Derivation Graph. By adding and streamlining features in DDG Explorer, I expect the software to be a more intuitive and effective tool for interpreting data analysis. When our team releases DDG Explorer to scientists, we will learn whether our software can truly increase the reproducibility and reliability of scientific discoveries.

Marisa Houlahan

Harvard College

Mentors: Evan Goldman and William Munger

Project: Long-term trends and spatial patterns of soil carbon storage

The effect of tree species on soil carbon content and variability

As atmospheric CO_2 levels continue to rise, research has increasingly focused on the ecosystemic impact and allocation of surplus carbon. Though forest soil organic matter (SOM) stores more carbon than any other terrestrial source and contains roughly twice as much carbon as the atmosphere, relatively little is understood about belowground carbon cycling or its relationship to forest composition. New England forests in particular have been identified as potential carbon reservoirs, so it is crucial to understand soil carbon and tree species interactions in the context of New England's land use history and species composition. In this study, we sampled the organic layer across a mixed deciduous forest in Massachusetts using a cordless drill and steel coring cylinder. For each of 214 soil cores, we recorded data on leaf litter and canopy species composition as well as tree species associated with the core. We dried, sieved, root picked, ground, and ashed each core to determine SOM content and further analyzed 33 cores to determine carbon and nitrogen content. Across coring sites we found a significant correlation ($p < 2.2 \times 10^{-16}$) between percent SOM and percent carbon content, where approximately 52% of SOM is made up of carbon. We expect to find that sites dominated by conifers will have lower percent carbon than sites dominated by hardwoods. This study provides a snapshot of New England soil carbon content and variability, and we plan to repeat this experiment in 3 to 4 years to examine how soil carbon storage changes over time.

Alayna Johnson

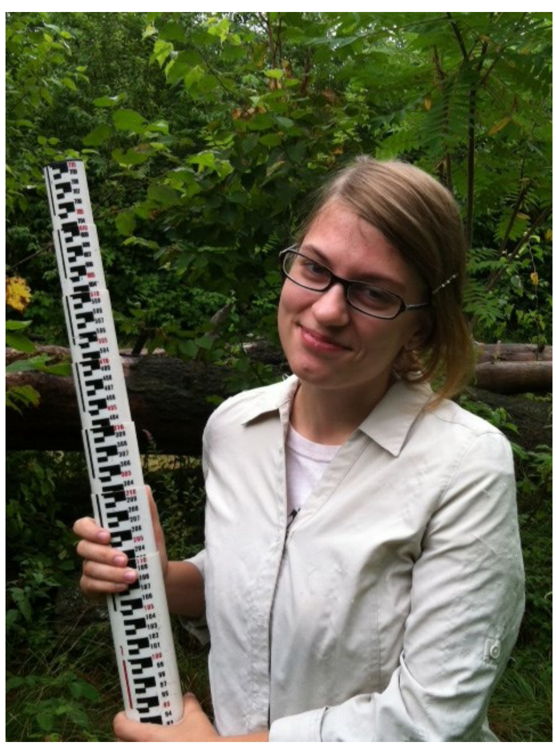
University of Minnesota Morris

Mentors: Richard MacLean and Christopher Williams

Group Project: Monitoring ecosystem physiology and vegetation structure in recent clearings within Harvard Forest and its surrounds

Nitrogen availability impacts productivity and carbon storage at three recently cleared sites at Harvard Forest

Assessing the productivity of a forest ecosystem is crucial for understanding the total amount of carbon being stored as biomass within a forest and, therefore, what role a forest has in broader discussions of climate change. However, site-specific variables should be considered such as the effect of nutrient availability on productivity. Since the productivity of temperate and boreal forests is often limited by nitrogen availability, examining this factor is important for more accurately understanding the carbon balance of forests. To test the hypothesis that greater nitrogen availability correlates with greater productivity across recently cleared sites at Harvard Forest, bulk organic and mineral soil samples were collected and analyzed for total carbon and nitrogen percentage. Productivity at each site was determined through woody biomass vegetation surveys and allometry. Preliminary data also suggests that there is an inverse exponential trend between above-ground sapling biomass and mean C:N ratios, suggesting that sites with low C:N ratios correlate with increases in productivity. Greater productivity at these sites may suggest that larger amounts of carbon are being stored in the biomass of regenerating forests that are less restricted by nitrogen availability. Thus, the role of nutrient-limitation is shown to be an important factor for accurate analysis of the overall carbon storage in similar regenerating New England forests.



Simone Johnson

Lincoln University

Mentors: Ahmed Hassabelkreem and Aaron Ellison

Group Project: Declining hemlock forests affects diversity of arthropods, salamanders, and small mammals

The effects of local climate conditions on salamanders and newts in a hemlock dominated forest

Eastern hemlock (*Tsuga canadensis*) is a foundation tree species in New England forests that has declined in the past due to infestations of invasive insects. Hemlock habitat is particularly suitable for many salamander populations, as it provides a complex and dense canopy that creates a dark, cool, and moist microenvironment. For instance, red-backed salamanders (*Plethodon cinereus*) are not just one of the abundant, stable, and ecologically important species on New England forest floors, but also are sensitive to forest disturbances and are therefore thought to be good indicators for such ecosystem changes. The objective of this study was to investigate the effects of local climate conditions on the occurrences of red-backed salamanders (*Plethodon cinereus*) and eastern red spotted newt (*Notophthalmus viridescens*). This study was conducted in Simes tract of Harvard Forest, Massachusetts between May 1 and August 1, 2014. During this period climate data were collected from Harvard Forest archive and meteorological stations, and salamander data were collected using artificial cover boards and visual encounter surveys along transects. Data were analyzed using analysis of covariance (ANCOVA) and generalized linear models (GLM) applied in R. The results showed that red-backed salamander (*Plethodon cinereus*) occurrence was affected by the season; there were more occurrences during the cooler spring than during the warmer summer. Using the cover board method for red-spotted newt occurrence was not as successful as visual encounters along transects; it was more of a serendipitous encounter when there was a visual of newts along transects and on/under cover boards.

From left to right: Jessica Robinson and Simone Johnson

Emily Keenan
University of Michigan
Mentors: Mark VanScoy and David Orwig
Project: Changes in Hemlock forest decline associated with the hemlock woolly adelgid infestation

Meteorological changes in declining hemlock forests

Since its appearance in Virginia in the 1950's, the hemlock woolly adelgid (HWA; *Adelges tsugae*) has spread to infest eastern hemlocks (*Tsuga canadensis*) along the eastern coast of the United States. These trees are a foundation species throughout many East Coast forests, and their decline dramatically alters the forest structure. The study site at the Prospect Hill tract at the Harvard Forest in Petersham, Massachusetts, is dominated by *T. canadensis* and is the subject of long-term research. In anticipation of an *A. tsugae* infestation of the stand more than five years ago, meteorological parameters and fluxes of carbon and water were closely monitored. I expected to see increased levels of photosynthetically active radiation (PAR) in the understory because of the decline in growth of needles and decreasing canopy thickness. This is supported by an increase in PAR at the understory level and a decrease in percentage of light intercepted by the canopy in 2013. Overall these changes will become more dramatic with time, as this is the beginning of the decline. Other factors examined were soil moisture, soil temperature and air temperature, but no significant change was found in any as of 2013. Decline of *T. canadensis* will not only directly affect species composition but also other forest processes in the area. Analyzing the changes that are already occurring can lead to a greater understanding of the problem and what can be expected in the future.

Bruce McAlister

University of Massachusetts Amherst
Mentors: Mark VanScoy and Paul Siqueira
Group Project: Monitoring ecosystem physiology and vegetation structure in recent clearings within Harvard Forest and its surrounds

Simplicity and robustness: keys to designing an aerial tram for autonomous, above-canopy data collection

In collecting data above forest canopies, either data can be collected frequently at a single location by sensors mounted on a tower, or infrequently measured by hand across transects. The Harvard Forest aerial tram combines both the frequency of data collection from a tower and the mobility of people to measure daily and seasonal variations. The base station computer for the tram system uses python scripts running on Windows to send commands to the tram and control motion via a stepper motor. Onboard the tram a BeagleBoard XM running python scripts in Linux communicates over a wireless IEEE 802.11n link to relay data and commands between a Campbell Scientific CR1000 datalogger and the base station computer. Because of the need for the system to run continuously and without monitoring, we aimed to achieve simplicity and robustness in our designs. To this end a virtual router was implemented in the control computer to host the communication network without the need for a separate router; a simple two-pronged charging interface for the tram's internal battery was fabricated, and the motor drive sheave was redesigned to provide location control via the motor. Parts were fabricated from common materials to make modification and repair of the tram simple and fast. The project is ongoing and will continually receive improvements to both its hardware and software. The refinements implemented this summer have added robustness and adapted the tram to operating at its field site in the Harvard Forest.

From left to right: mentor Paul Siqueira and Bruce McAlister

Sofie McComb

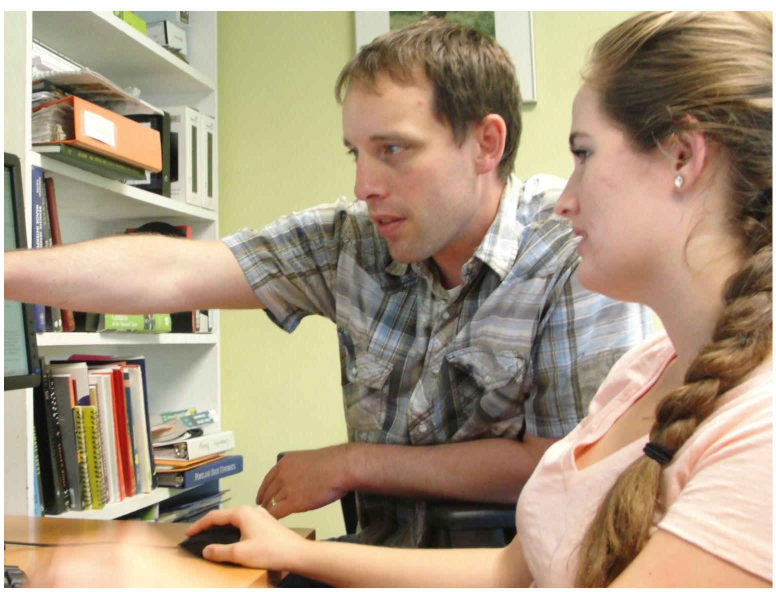
University of Texas at Austin

Mentors: Matthew Duveneck and Jonathan Thompson

Project: Mapping New England forest composition and structure using remote sensing and field data

A snapshot in time: 1830 land-use legacy on present-day Massachusetts forest composition

European settlement led to clearing of three-quarters of New England forests for agriculture, while the remaining forests were intensively logged. Peak agricultural landcover in Massachusetts occurred in approximately 1830; after which, farmland abandonment led to reforestation. An 1830 Massachusetts statute required towns to create landcover maps depicting cultural and ecological features. Using the archived maps, I analyzed the long-term land-use legacy of forest clearing on current forest composition. Specifically, I assessed whether sites that were forested in 1830 had a different contemporary species composition than areas that were cleared. I analyzed current inventory data from the USFS Forest Inventory and Analysis database aggregated within 1830 land-use legacy categories and described the difference in species composition and functional traits between areas that were forested versus cleared in 1830. At the state scale, there were few differences in tree species composition between sites that were cleared versus forested in 1830 ($A < 0.01$ based on Multi-response Permutation Procedure). Mid-successional eastern white pine (*Pinus strobus*) and red maple (*Acer rubrum*) account for half of the basal area in both areas. Stratifying and focusing on data-rich parts of the state revealed moderate compositional differences ($0.01 < A < 0.1$) in 5 of 9 ecoregions. These differences are largely attributable to greater late-successional eastern hemlock (*Tsuga canadensis*) abundance within historically forested sites. Overall, this analysis suggests that more than 180 years of natural and anthropogenic processes have largely erased the legacy of colonial land use on modern forest composition.



From left to right: mentor Matthew Duveneck and Sofie McComb

Alison Ochs

Mount Holyoke College

Mentors: Ahmed Hassabelkreem and Aaron Ellison

Group Project: Declining hemlock forests affects diversity of arthropods, salamanders, and small mammals

Red-backed salamanders as indicators of hemlock forest health

Species that react quickly to ecological changes are useful indicators for assessing forest health. Red-backed salamanders (*Plethodontid cinereus*) may be used as an indicator species in declining hemlock forests, allowing for assessment of soil quality and forest health. We hypothesized that decline of hemlock stands due to the effect of hemlock woolly adelgid would negatively impact the abundance of red-backed salamanders by altering soil quality. In the Hemlock Removal Experiment at Harvard Forest, eight 0.8-ha plots were treated either with girdling to simulate adelgid invasion, logging to simulate preemptive logging strategies, no treatment in hemlock areas, or no treatment in hardwood areas. Within these treatments in June and July of 2014, *P. cinereus* relative abundance was determined from coverboard surveys. Soil quality was determined from core samples. Bulk density, pH, carbon-nitrogen ratio, moisture, soil temperature, and litter depth were measured, and ordination was used to create an index of soil quality from these. There was a significant correlation between plot treatment and soil quality ($p < 0.05$). Temperature, C:N ratio, and pH influenced a strong significant negative correlation between soil quality and salamander abundance ($p < 0.05$). Soil quality affected by hemlock decline influenced salamander abundance. These data suggest that we could gain an understanding of forest health and soil quality by examining salamander abundance. Assessing adelgid invasion can be difficult and objective, whereas salamander abundances are easily measured; therefore, we suggest that salamander abundances could be useful in assessing the health of hemlock forest ecosystems.

From left to right: Alison Ochs and mentor Ahmed Hassabelkreem

Maria Orbay-Cerrato

Brown University
Mentor: Wyatt Oswald
Project: Long-term history of vegetation in New England

Coprophilous fungi spores as an indicator of grazing in New England during the past few centuries

By converting forests into agricultural lands, European settlers drastically changed the New England landscape. This disturbance left its mark in lake-sediment pollen records, with elevated abundances of grass, weeds, and agricultural plants during the settlement era. While pollen evidence for the shift from forests to fields has been widely documented, little attention has been paid to the paleoecological record of other agricultural practices, including grazing. In this study, we investigated the possibility of reconstructing the presence of grazers in post-settlement New England via the analysis of spores of coprophilous fungi. We hypothesized that dung-fungi spores would be present and most abundant during the height of European settlement, when thousands of sheep and cows grazed the pastures of New England. To explore this hypothesis, we collected a sediment core from Ware Pond, located in Marblehead, Massachusetts, a town that saw heavy grazing in the 19th century. We analyzed pollen using standard methods, with 300 grains counted at 400x magnification at each level. Our analyses revealed that pre-settlement forests featured oak, hickory, and beech. Pollen assemblages from the beginning of the settlement period featured grass, sorrel, and ragweed, with declining sorrel, increasing ragweed, and maximum values of grass and weedy taxa higher in the core. Spores of *Sordaria*, a coprophilous fungus, peaked at the same depth as the agricultural indicators. These findings suggest that the spores of dung fungi do reflect grazing, such that future studies should be able to use this approach to explore the patterns and impacts of grazing across New England.

Luis Perez
Harvard College
Mentors: Emery Boose and Barbara Lerner
Group Project: Retracing our steps in the analysis of data

Accessible and efficient data provenance in the R scripting environment

Scientific progress relies on the reproducibility of experiments and data analyses. However, as scientists explore increasingly complex problems, they often require the use of large data sets, complicated data-filling models, and complex analysis methods. Subsequently, the data's provenance — the transformation performed to achieve the reported results — becomes increasingly difficult to record and access, even by expert peers. A Data Derivation Graph (DDG), a structured record of the data manipulation process, is one solution for the problem of accessibility. However, the creation of complete DDGs often involves unfamiliar tools, additional data recording steps, and longer computation time, hindering wide scientific adoption. In our project, our team worked to improve the accessibility, correctness, and efficiency of RDataTracker, a provenance collection package for R. In order to maintain correctness throughout the development process, we created and utilized an automated system for software testing and performance data collection (using Apache Ant). We worked on features to facilitate and reduce the number of annotations needed for the creation of DDGs. Furthermore, we reduced annotation time by improving the effectiveness and correctness of RDataTracker's automatic DDG creation capabilities. We expect this additional ease of data collection to decrease computational performance; however, improvements in saving intermediate data to disk should counteract this performance hit. Through the above improvements in data collection and automation, we expect RDataTracker to become a more useful and accessible tool for scientists, making provenance collection second nature, an important first step in dealing with the increasing complexity inherent to scientific research.

Ariel da Cruz Reis

Saint Michael's College

Mentors: Allyson Degrassi and Aaron Ellison

Group Project: Declining hemlock forests affects diversity of arthropods, salamanders, and small mammals

How far does an ant travel? A study case of *Aphaenogaster picea* in western Massachusetts, U.S.A.

Ants (Hymenoptera: Formicidae) occur worldwide, and have many ecological roles. Although ant foraging behavior has been well-studied, there are scant data on how far ants will actually forage, even though these data are needed to define sampling scales (e.g., spacing between adjacent pitfall traps). In order to determine an appropriate sampling distance, I examined foraging distances of the ant *Aphaenogaster picea* in a hemlock-dominated forest in Petersham, Massachusetts. I used cookie baits to attract *A. picea* and measured distances traveled from nest to baits, time taken for a scout to find the bait, mean number of ants per bait, and quantity of bait removed. Ten of 11 nests located baits placed 2 meters from nests, but none located baits placed three meters from nests. Grids of baits attracted ants from nests 0.65 - 3.15 m from the closest bait. Most nests located the baits within 30 minutes, but some were not located for 3 hours. The distance of the nest from the food resource explained 0.6% of the variance in recruitment to the bait and 12% of the variance in the amount of food carried back to the nest. Based on these results, a minimum of 3-m spacing between pitfall traps seems adequate for sampling *A. picea* and perhaps other small-bodied ants. In addition, baits should remain available for up to three hours to increase probability of attraction and capture of these forest ants.

Jessica Robinson

Knox College

Mentors: Audrey Barker-Plotkin and Aaron Ellison

Group Project: Declining hemlock forests affects diversity of arthropods, salamanders, and small mammals

Beneath the canopy: understanding the effects of light availability on understory vegetation in *T. canadensis* forests after logging and simulated *A. tsugae* infestation

Eastern hemlock (*Tsuga canadensis*), a foundation species, is declining due to infestation by the invasive hemlock woolly adelgid (*Adelges tsugae*). Due to this the once heavily shaded understory of hemlock forests are experiencing increased light availability as all sizes of *T. canadensis* trees lose their needles and die. Understanding how light availability affects forest understory vegetation composition will help us to predict how these forests may regenerate after this major disturbance. I hypothesized that understory vegetation and tree sapling species richness and abundance is positively correlated with light availability, regardless of whether hemlocks died standing or were removed by logging. In 2004, a large experiment was established to study hemlock decline; treatments included girdling, mimicking the slow death of *T. canadensis* due to *A. tsugae* infestation, logging, mimicking a common human response to hemlock decline, and a control. Every year, canopy photos are taken within a 15 m grid to document light availability in each of the 90 x 90 m plots. I sampled understory vegetation composition and sapling abundance at the grid posts where photos were taken. Higher 2013 global site factor (GSF; proportion of reflected and absorbed light that reaches the camera) doesn't necessarily cause increased response in species richness and abundance. The absence of correlation suggests that treatment, rather than GSF, has a greater effect on vegetation response variables. Understory vegetation responds to girdling versus logging loss of *T. canadensis* in a more complex way than a simple response to light availability.

From left to right: Claudia Villar-Leeman and Jessica Robinson

Ivonne Trujillo

University of Texas at Brownsville

Mentors: Donald Aubrecht, Koen Hufkens, and Andrew Richardson

Project: Impacts of climate change on the rhythm of the seasons

Impacts of climate change on the rhythm of the spring in northeast deciduous forests

Climate change has impacted the rhythm of the spring in northeast deciduous forests, including Harvard Forest. However, vital knowledge gaps exist in our understanding of the responses between climate change and seasonal cycles. My project this summer aimed to address some of those gaps by focusing on leaf development for the red maple (*Acer rubrum*), red oak (*Quercus ruba*), and the paper birch (*Betula papyrifera*), three common species in the northeastern United States. To characterize leaf development through the season, I sampled leaves from the canopy and measured leaf color, chlorophyll fluorescence, water content, and stomatal conductance. I was particularly focused on leaf color and used data from scanned leaves and digital repeat photographs of the canopy to compare vegetation greenness at the leaf level and canopy scale. This data was modified to include a calculation of the green chromatic coordinate (GCC) over the growing season. My prediction is that the trend with the GCC values calculated from the flatbed scanner and PhenoCam images will be very similar. This is a reasonable prediction because no major changes in green color or canopy structure have occurred, therefore trends will be similar. Tracking vegetation greenness through time at a canopy scale and the physiology at a leaf level will allow us to accurately model phenology on both scales. The results of this study will help create a model to better predict how ecosystems like Harvard Forest respond to changes in climate.

From left to right: Ivonne Trujillo and mentor Andrew Richardson

Joel van de Sande

City College of San Francisco
Mentors: Allyson Degrassi and Aaron Ellison
Group Project: Declining hemlock forests affects diversity of arthropods, salamanders, and small mammals

Hemlock woolly adelgid impacts rodent ranging behavior in a New England forest

Hemlock woolly adelgid (HWA, *Adelges tsugae*) is killing eastern hemlocks (*Tsuga canadensis*) in New England. Hemlock decline is altering forest biodiversity and may be impacting rodent ranging behavior. Rodents play important roles in forest ecosystem functions by dispersing seed and mycorrhizal fungi. We hypothesized that rodents would have shorter ranges in HWA-infested forests compared to their ranges in intact forests. We examined the ranging behavior of mice (*Peromyscus maniculatus* and *Peromyscus leucopus*) and voles (*Myodes gapperi*) at Harvard Forest's Hemlock Removal Experiment in Petersham, Massachusetts. We used four replicated experimental hemlock canopy treatments that are 90 x 90 m: 1) hemlock control, 2) unmanipulated hardwood control, 3) girdled treatment, which simulates HWA invasion, and 4) logged treatment, which simulates preemptive forest management. Rodents were captured in Sherman live traps within a 7 x 7 array (0.49 ha) from June-July 2014 (> 3000 trapping nights). Captured animals (n = 119) were identified, marked with Passive Integrated Transponders, and released. The range of each animal was mapped and the mean distance squared was calculated. We found that *P. leucopus* (~25 m), *P. maniculatus* (~20 m), and *M. gapperi* (~30 m) travel further in the hemlock control than all other canopy treatments. *M. gaperi* showed the greatest decrease in ranging behavior within the logged treatment. These data suggest that preemptive logging to prevent HWA spread restricts rodent ranges. Understanding how rodents respond to hemlock decline will allow us to predict changes in their behavior and attendant patterns of forest succession.

Ada Vilches

University of Puerto Rico at Mayagüez
Mentors: Jeffery Blanchard and Kristen DeAngelis
Project: Global warming and forest soil microbiomes

Microbial community composition at the Barre Woods warming plots

Earth's climate is changing, and an important factor in this process is the carbon cycle. Soil microbes are key components of soil carbon cycling, but it's not fully understood how temperature changes will affect soil microbial community composition and activity overtime. To test how a long-term temperature increase would affect soil microbial community dynamics we used soil DNA and RNA extraction to determine the total community structure and function at the Harvard Forest Barre Woods (2003) warming plots. This experiment consists of two 30 m x 30 m plots; the heated plots are kept at 5°C above ambient temperature year round. Samples from two layers in the heated and control plots were collected in October 2011. DNA and RNA was extracted and sent to the Joint Genome Institute for metagenomic and metatranscriptomic sequencing. The metagenomics analysis showed bacteria at the domain level and its phylum Proteobacteria had the highest relative mRNA abundance overall in amino acid transport and metabolism function. In the metatranscriptomics analysis the highest abundance was in translation, ribosomal structure and biogenesis function for Proteobacteria. In the metagenomic data through the use of statistical analysis it was observed that the heated treatment had an effect on genes related to carbohydrates, protein metabolism, respiration, and vitamins functions. For the metatranscriptomic data the functions for the affected genes were protein metabolism, carbohydrates, and amino acids and derivatives. This suggests that the microbial community structure and activity could be influenced by the temperature increments occurring in the warming plots.

From left to right: mentor Kristen DeAngelis and Ada Vilches

Claudia Villar-Leeman
Bowdoin College
Mentors: Audrey Barker-Plotkin and Aaron Ellison
Group Project: Declining hemlock forests affects diversity of arthropods, salamanders, and small mammals

Life under a log: how is the eastern red-backed salamander (*Plethodon cinereus*) affected by the abundance of deadwood in hemlock and hardwood forests?

The abundant eastern red-backed salamander (*Plethodon cinereus*; RBS) is critical to nutrient cycling in North American hemlock forests. Eastern hemlock (*Tsuga canadensis*) forests have recently been fatally colonized by the invasive woolly adelgid (*Adelges tsugae*), prompting many landowners to pre-emptively harvest their hemlocks. This practice may have consequences on RBS abundance and distribution, as RBS abundance is associated with high densities of cover objects such as downed woody debris (DWD). This study analyzed RBS abundance in relation to volume, size, and decay of DWD across disturbed and non-disturbed hemlock and hardwood plots. We expected to find more RBS under bigger pieces of DWD and in transects with greater volumes of DWD. RBS abundances under artificial cover objects (ACOs) in 2005, 2013 and 2014 were analyzed with DWD data from corresponding years across Harvard Forest Hemlock Removal Experiment (HF-HeRE) logged, girdled and control plots in the Simes Tract. To directly evaluate RBS use of DWD, two hardwood and two hemlock forest plots were established nearby. Along three 30 m line transects in each plot, deadwood was measured and RBS use of DWD cover evaluated with biweekly surveys of RBS presence, size, life stage and sex. Statistical analyses were carried out in R. Surprisingly, trends suggest that RBS presence does not depend on DWD size, and that RBS abundance is lower in HF-HeRE plots with higher DWD volume. These data shed light on RBS habitat association and suggest further investigation is needed regarding the use of ACOs as an unbiased survey method.

Katherine Bennet
J. R. Briggs Elementary School
Mentors: Koen Hufkens and Andrew Richardson
Project: Impacts of climate change on the rhythm of the seasons

Teacher's Page – 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. The images are computer analyzed for color resulting in a numerical measure of relative greenness – a green chromatic coordinate. 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. This summer a Teacher's Page has been added to the Phenocam website, giving K-12 students and teachers access to images and data from all the sites on the network. The Teacher's Page includes screencasts on navigating the Phenocam website and downloading data. An introduction to the Phenocam project as well as ideas for using the images and graphing the data are provided. These growing data sets can be used to observe seasonal patterns and compare growing seasons from year to year and along longitudinal gradients. This project will greatly enhance STEM education, giving students the opportunity to be a part of real and important research concerning the critical environmental issue of climate change.

PERSONNEL AT THE HARVARD FOREST - 2014

Grace Barber	Proctor
Audrey Barker-Plotkin	Research Coordinator
Emery Boose	Information Manager
Jeannette Bowlen	Accountant
Laurie Chiasson	Administrative Assistant
Betsy 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
Clarisse Hart	Outreach and Development Manager
Ahmed Hassabelkreem	Graduate Student - University of Massachusetts
Jenny Hobson	Secretary
David Kittredge	Forest Policy Analyst
Samuel Knapp	Proctor
Oscar Lacwasan	Woods Crew
Matthew Lau	Post-Doc
Ronald May	Woods Crew
Roland Meunier	Woods Crew
Alisha Morin	Accounting Assistant
Luca Morreale	Research Assistant
Elizabeth Nicoll	Data Analyst
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
Sky-Maelene Santiago	Summer Program Assistant Cook
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
Tim Zima	Summer Program Cook

Harvard University Affiliates

Richard Forman	Graduate School of Design
Noel Michele Holbrook	Organismic and Evolutionary Biology
William Munger	School of Engineering and Applied Sciences
Andrew Richardson	Organismic and Evolutionary Biology
Steven Wofsy	School of Engineering and Applied Sciences

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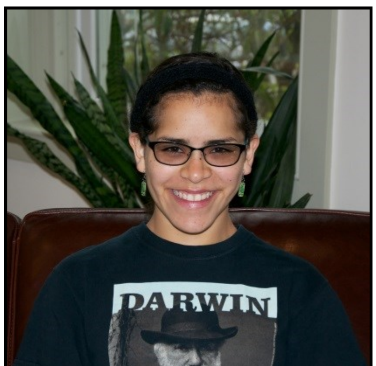
Jessica Asirwatham
Case Western Reserve Univ.

Kyle Boyd
Smith College

Heather Clendenin
Bowling Green State University



Laura Figueroa
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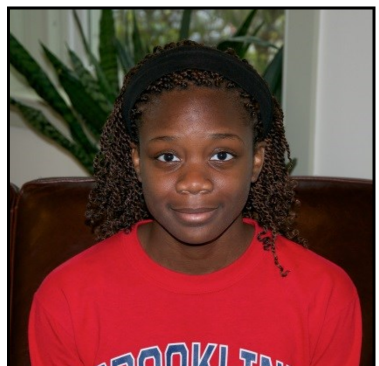

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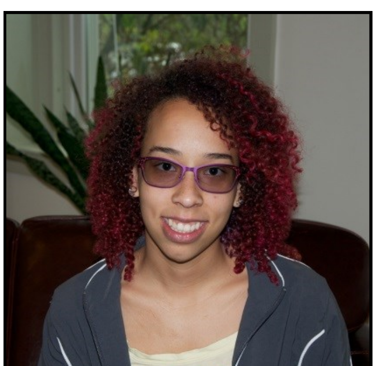

Nicole Hoffler
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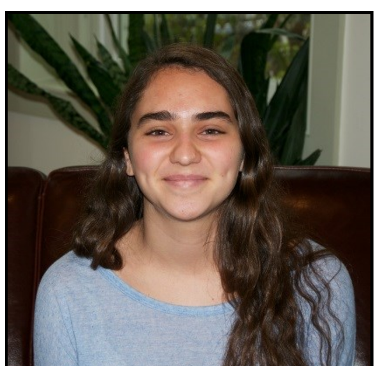

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Simone Johnson
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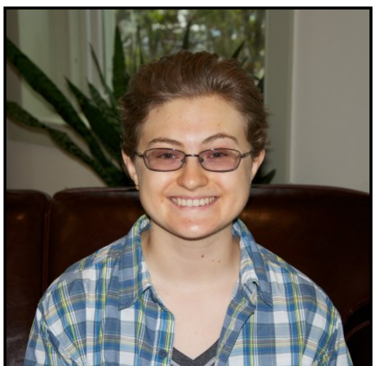

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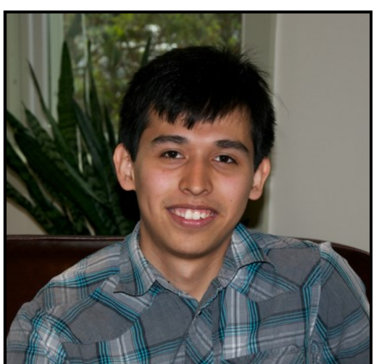

Luis Perez
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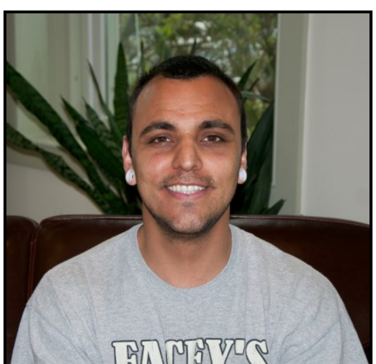
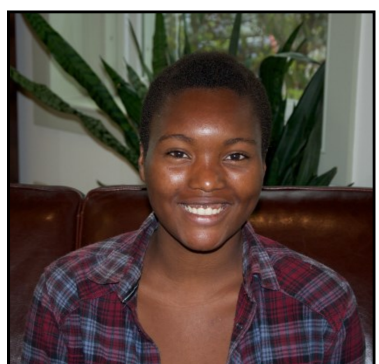


Ariel da Cruz Reis
Saint Michael's College



Jessica Robinson
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2014 SUMMER RESEARCH PROGRAM STUDENTS

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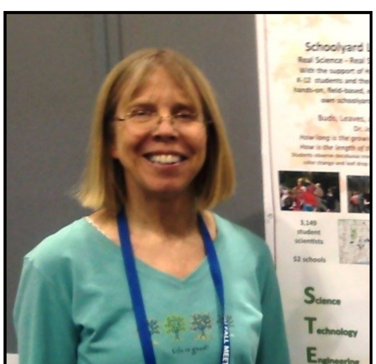

Katherine Bennet
J. R. Briggs Elementary School

Grace Barber
Summer Program Proctor

Samuel Knapp
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