Harvard Forest

Summer Research Program in Ecology

31st Annual Student Symposium

August 1, 2024

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cover photo: Teressa Alexander

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, ecology, and conservation. Through the years, researchers at the Harvard Forest have concentrated on forest management, tree biology and physiology, community ecology and biodiversity, soil processes, watershed studies, forest economics, landscape history, conservation biology, and long-term ecosystem change.

Today, this legacy is continued by faculty, staff, and students who seek to understand historical, modern, and future changes in the New England landscape. Their research has informed conservation and land management policy as well as enhanced appreciation of forest ecosystems, their histories, and the many ways they sustain communities. 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) and now supports some of the world's oldest studies of global change in forest ecosystems and hosts year-round science education programs for learners of all ages.

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 wetlands, and farm pastures. Additional land holdings include the 20-acre Pisgah Forest in southwestern New Hampshire (located in the Pisgah State Park); the 100-acre Matthews Plantation in Hamilton, MA; and the 90-acre Tall Timbers Forest in Royalston, MA. The Facilities Crew undertakes forest management, supports research infrastructure, and maintains facilities.

In Petersham, a complex of buildings provide office and library space, laboratory and greenhouse facilities, experimental gardens, and lecture rooms 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 of Harvard University. Faculty associated with the Forest offer courses through the Department of Organismic and Evolutionary Biology, the Harvard Kennedy School, and the Freshman Seminar Program. Close associations are also maintained with Harvard University's Department of Earth and Planetary Sciences, Paulson School of Engineering and Applied Sciences, Chan School of Public Health, and Graduate School of Design; as well as many Harvard centers, including the Arnold Arboretum, Office for Sustainability, Center for the Environment, Herbaria, Museum of Comparative Zoology, and Museums of Science and Culture. The Harvard Forest's affiliations outside of Harvard University include research collaborations with faculty and students from dozens of institutions– in particular, the University of Massachusetts, Boston University, the University of New Hampshire, the Marine Biological Laboratory's Ecosystems Center, Hubbard Brook Ecosystem Study and other LTER research sites, and regional environmental organizations, including Highstead and the New England Forestry Foundation.

About the 2024 Summer Research Program

The Harvard Forest Summer Research Program in Ecology gathered a diverse group of students to receive training in scientific investigation and experience in long-term ecological research. Audrey Barker Plotkin directed the 2024 program with the help of program coordinator Ben Goulet-Scott and program assistant (proctor) Teressa Alexander. Students worked with mentors on a variety of research projects from field and laboratory experiments to computational science. The program included weekly seminars from scientists, workshops, a career panel, and many field excursions. The Harvard Forest Summer Research Program in Ecology culminated in the Annual Student Symposium held on August 1, 2024, where students presented their research findings to an audience of scientists, peers, and family.

Funding for the 2024 Summer Research Program

In 2024, the Harvard Forest Summer Research Program in Ecology was supported by the following organizations:

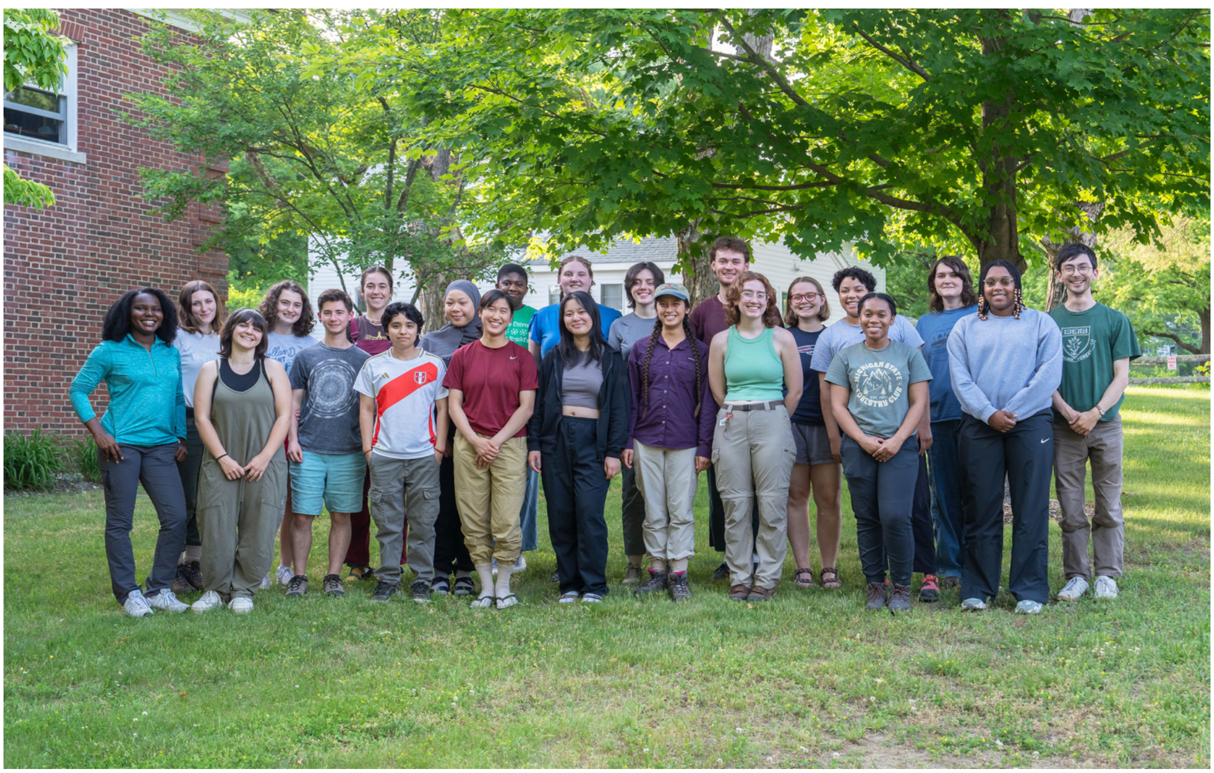
National Science Foundation
REU Site: Exploring Dynamic Ecosystems across Space and Time at the Harvard Forest (DBI-2348924)
REU Site: Summer Research Program in Ecology at the Harvard Forest: Diverse data networks for diverse data scientists (DBI-1950364)
LTER: From Microbes to Macrosystems: Understanding the response of ecological systems to global change drivers and their interactions (DEB-1832210)

National Aeronautics and Space Administration
MUREP Inclusion Across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science: Partners Aligned to Heighten Broad Participation in STEM

Harvard University
Faculty of Arts and Sciences
G. Peabody "Peabo" Gardner Memorial Fund
Reuben Tom Patton Scholarship Fund
The Living Diorama Scholarship Fund
Martin H. Zimmermann Memorial Fund

Mount Holyoke College
Lynk Summer Funding Program

2024 Summer Research Program Students and Mentors



2024 Summer Research Program Proctor, Students, and Coordinator

2024 Summer Research Program Seminar Speakers

May 30	Banu Subramaniam, *Wellesley College*
June 20	Ashley Helton, *University of Connecticut*
June 27	Jess Gersony, *Smith College*
July 11	Lucy Hutyra, *Boston University*
July 18	Sparkle Malone, *Yale University*
July 25	Keshia De Freece Lawrence, *Harvard Forest*

2024 Summer Research Program Workshops & Activities

May 20	Field Tour: Long-term Research Sites at Harvard Forest. *Katharine Hinkle & Emery Boose, Harvard Forest*
May 21	Gender Equity & Diversity in Community. *Caysie Harvey, Harvard University*
May 21	General Lab Safety Training. *Mary Lindstrom, Harvard Forest*
May 28	Best Practices with Data. *Jackie Matthes & Emery Boose, Harvard Forest*
June 4	Writing and Reviewing Research Proposals. *Ben Goulet-Scott, Harvard Forest*
June 6	Day of Service at Pequoig Farm and visit to Mishoon Burn. *Keely Curliss & Cheryll Holley*
June 11	Using R in Ecology. *Jackie Matthes & Xiaojie Gao, Harvard Forest*
June 13	Cambridge visit with Harvard Environmental Summer Programs & Responsible Conduct of Research. *Logan McCarty, Harvard University*
June 18	EcoCareer Compass: Preparing for Ecology Careers. *Sparkle Malone, Yale University & Melissa McCartney, University at Buffalo*
June 22	Visit from Harvard Environmental Summer Programs
June 25	Introduction to GitHub and Open Science. *Xiaojie Gao, Harvard Forest*
July 9	Art & Science. *Teressa Alexander, Harvard Forest*
July 13	Arnold Arboretum visit with Harvard Environmental Summer Programs
July 16	Presenting Your Research. *Savanna Brown, University of Connecticut*
July 17	Graduate School Discussion. *Jon Gewirtzman, Yale University; Marissa Hanley, University of Massachusetts Amherst; Sam Jurado & Ben Goulet-Scott, Harvard Forest*
July 23	Career Panel. *Mushtaaq Ali, American Forests; Erika Bucior, USDA Agricultural Research Service; Cam Mosely, University of Minnesota*

31st Annual Harvard Forest Student Symposium Schedule
August 1, 2024

9:00am **Opening Remarks**

9:15am **Student Talks - Session I**

Olivia Walker *Kennesaw State University*	The Role of Root Exudates in Eastern Hemlock Decline	25
Annabelle Rayson *Harvard University*	From the Woods to the Waters: A Comparison of Macroinvertebrate Communities in Hemlock and Deciduous Streams in Response to the Hemlock Woolly Adelgid	22
Kiley Chen *University of Maine*	Seedling Saga: Investigating the Impacts of Conspecific Negative Density Dependence In a Hemlock Forest	9
Casey Helton *University of North Georgia*	Investigating Trends in Tree Leaf Seasonality and its Impact on Carbon Storage in New England Forests	14
Lauren Hollinger *Ohio Wesleyan University*	Development for a Climate Smart Future: Using Geospatial Analysis to Assess Surface Temperature Dynamics of Ground-Mounted Solar Arrays in Massachusetts	15

BREAK

10:45am **Student Talks - Session II**

Devon Ford *Ohio State University*	Illumination and Regeneration: Investigating Canopy Gaps and Tree Seedling Survival	13
Willow Rhimyr *Tuskegee University*	Impact of Hemlock Woolly Adelgid on Tree Growth Rates	23
Peggy Chen *Mount Holyoke College*	Assessing Microclimate Impact on Decay of HWA-infested Eastern Hemlock (*Tsuga canadensis*)	10
Alejandro Asencio *CUNY Hunter College*	The Temporal Response of Aboveground Biomass to Forest Fragmentation– 2023 to 2024	7
Andra Benson *Harvard University*	An Investigation of Carbon Storage and Sequestration in the Presence of Ecological Disturbance	8

12:00pm **LUNCH**

1:00pm **Student Talks - Session III**

Kamyah Hugee *Tuskegee University*	Looking at Forest Ecosystem Changes Through the Lens of the Terrestrial Amphibians of Harvard Forest	16

	Student Talks - Session III (cont.)		
Ashley Dawn *Harvard University*		Methane Dynamics in Aquatic-Terrestrial Interfaces: Insights from Harvard Forest Wetlands	11
Sónia McCollum *Mount Holyoke College*		Impact of Rain Events on Gas Dynamics in Forest Wetlands: Contrasting Effects in Young and Mature Ecosystems	20
Masako Yang *Harvard University*		Investigating Sources of Methane Flux from Trees: Insights Across Wetlands and Uplands	26
Bethany Duncan *Columbia University*		Applications of the Diffusion Equation: Predicting a Vertical Gas Profile for Soil in Harvard Forest	12
	BREAK		
2:30pm	**Student Talks - Session IV**		
Julia Marquis *Emory University*		Long Term Influences of Hurricane Disturbances on Soil Carbon Cycles	19
Naturi Scott *Emory University*		Terrain Dynamics: Greenhouse Gas Flux in New England Temperate Forests after a Simulated Hurricane	24
Dyllan Nelson *Michigan State University*		Investigating the Effects Forest Edges on Soil Invertebrate Communities and Decomposition of Organic Material	21
Sky Hulse *Columbus State Community College*		Digging Deeper: Edge Effect Impacts on Root Distribution in a Fragmented Northeastern Temperate Forest	17
Blake Logan *Oberlin College*		Can Differences in Hemlock Health Response to Wooly Adelgid Infestation be Explained by Variation in Mycorrhizal Abundance?	18
Research Experience for Teachers			
*Danielle Mazur *The Bement School* *Karen Murphy *Summit Academy*		Storm Stories: Tree's Tales of Growth Following Wind Storms	27
4:00pm	**Closing Remarks**		
5:30pm	**Community BBQ**		

*co-presenting

Alejandro Asencio
CUNY Hunter College

Mentors: Evonne Aguirre, John Paul Hellenbrand, and Andrew Reinmann

The Temporal Response of Aboveground Biomass to Forest Fragmentation– 2023 to 2024

Globally, forests remove about 30% of anthropogenic carbon emissions each year and store it in soils and biomass. However, the future of this carbon sink is jeopardized by climate change and other anthropogenic activities like forest fragmentation – a universal feature of landscapes worldwide with estimates placing 20% of global forests within 100 meters of a forest edge. Between edge and interior, there are gradients in air temperature, soil moisture, and vapor pressure deficit impacting differences in growth depending on a tree's proximity to an edge. Temperate forests have demonstrated increased growth close to forest edges (edge enhancements), partially offsetting the carbon losses from fragmentation. Little is known about how soon these enhancements occur and how climate change might alter their significance. To better understand forest tree growth response to the creation of an edge, a 180-by-45-meter section of Harvard Forest was cleared in the winter of 2023 and 6 plots, 15-by-30m, were created along the south-facing edge of this clearing. Of all trees in the plots, the 101 trees >20 cm DBH were instrumented with dendrometer bands to quantify weekly growth rates during the growing season and 46 of those trees were instrumented with point dendrometers to monitor tree growth. They are primarily *Quercus rubra* (Red oak), *Acer rubrum* (Red maple), and *Pinus strobus* (Eastern white pine). I compared tree growth between 2023 and 2024 and explored microclimate controls on tree growth. In 2023, tree growth rate at the edge lagged behind growth rates for interior trees, but by 2024, edge growth rates accelerated and are similar to the interior, indicating that it can take at least 1 year for trees along the edge to benefit from enhanced light conditions. Precipitation events appear to exert the largest control on temporal patterns of tree growth. In particular, tree growth spurts typically followed precipitation events and spikes in soil moisture, highlighting the importance of precipitation events even in mesic forests. My work shows that the timing of tree growth response is an uncertainty that constrains biomass accumulation at forest edges.

Andra Benson

Harvard University

Mentors: Audrey Barker Plotkin and Greta VanScoy

An Investigation of Carbon Storage and Sequestration in the Presence of Ecological Disturbance

Historically, New England and New York were carbon sources due to extensive forest clearing for development and agriculture. More carbon dioxide was released into the atmosphere than was captured by the landscape. Over the past 150 years, however, these regions have become carbon sinks as abandoned lands return to forest. This means the forest is now storing more carbon than it is releasing. The Harvard Forest Hemlock Removal Experiment (HF-HeRe), initiated in 2003 in response to the invasive insect pest Hemlock Woolly Adelgid (HWA) threatening eastern U.S. hemlock forests, aims to study the long-term effects of hemlock tree loss on carbon storage in New England forests. This long-term study consists of four treatments: girdled trees mimicking HWA-induced mortality, hemlock and hardwood controls, and a logging treatment that emulates timber harvest that many landowners conduct when faced with HWA. I expect the logged plots to have the highest rate of sequestration because the rapid clearing of trees allows for fast growing, early successional trees to grow more quickly than in the girdled treatments. The girdled treatments with standing, dead trees likely shade out seedlings until the trees fall. I also expect that slow growing tree species, that typically grow to larger diameters, will store the most carbon. I tested these hypotheses with data collected through the fieldwork involving tree diameter measurements and applying allometric equations to estimate carbon storage of the trees. I analyzed data from tree censuses, conducted every five years from 2004-2024, and explored spatial mapping. This long term research is important because it allows investigation into the recovery of carbon sinks following a disturbance, and demonstrates how a forest's capacity to sequester and store carbon changes over time. Research on forest carbon sinks provides valuable insight into how the land should be managed before, during, and after a disturbance event if a primary goal is increasing carbon storage and protecting carbon sinks.

Kiley Chen

University of Maine

Mentors: Marcos Rodriguez and Sydne Record

Seedling Saga: Investigating the Impacts of Conspecific Negative Density Dependence In a Hemlock Forest

Forest ecosystem services are integral to human activity and forest-dependent organisms. However, the arrival of the hemlock woolly adelgid (HWA; *Adelges tsugae*), an aphid-like insect, to New England in the 1980s has led to the mortality of hemlock trees of all size classes and could alter ecosystem services in hemlock-dominated forests, necessitating research on how these forests will change. The tree seedling stage is a critical bottleneck stage for tree populations, but their role in forest responses to disturbance is understudied. To understand how hemlock-dominated forests will change, it is necessary to consider factors of current seedling survival. Studies have found that when some seedlings of the same species are closer together, they are more susceptible to host-specific pathogens and predators, negatively impacting their survival. This pattern is known as conspecific negative density dependence (CNDD). To investigate how conspecific density and heterospecific density relate to the seedling survival of different tree species in New England, we collected and analyzed data on seedling survival and species type within $1m^2$ plots in the Harvard Forest MegaPlot, a 35-hectare plot in which every stem over 1cm in diameter is identified and mapped. We predicted seedling survival to be greater with lower seedling density but that the effect size of conspecific density on survival would be greater than for heterospecific density. Surprisingly, we found a significant positive correlation between Betula spp. survival and conspecific density and a significant negative correlation between Pinus strobus survival and heterospecific density. Understanding the relative impact of CNDD on different seedling species can set a foundation for more research to model future tree populations and provide insight into which species will dominate current hemlock stands.

Peggy Chen

Mount Holyoke College

Mentors: Taylor Lucey and Meg Graham MacLean

Assessing Microclimate Impact on Decay of HWA-infested Eastern Hemlock (*Tsuga canadensis*)

Eastern hemlock (*Tsuga canadensis*) is a shade-tolerant foundation species that has dominated the composition of North American forests for thousands of years. Hemlock stands create damp microclimates and are known to be found in riparian areas, suggesting that they may also prefer moist microclimates. Eastern hemlock faces ongoing decline due to hemlock woolly adelgid (HWA), a non-native sap-sucking pest that may be the largest threat to hemlock forests in eastern North America. Our work aims to better understand the relationship between site characteristics and the impact of HWA on Eastern hemlock. The internal decay and decline of Eastern hemlock may be expedited in microclimates that are more moist due to the proliferation of anaerobic conditions. Using acoustic wave technology (Fakopp 1D Microsecond Timer) and internal moisture content calculated from the dry density of tree cores, I compared the moisture and decay characteristics of hemlock stands in Harvard Forest across an upland, riparian, and sloped site. I also used data collected from a healthy, uninfested stand on a sloped site in Hanover, New Hampshire. Initial analysis shows slower acoustic velocity in the healthier New Hampshire stand, which may be due to the higher internal moisture content compared to the three stands sampled at Harvard Forest. Hemlocks in the drier upland site have experienced greater foliage loss than hemlocks in both the stream and sloped sites. Further assessment of the variables that affect decay within HWA-infested hemlock stands will better inform forest management services on how Eastern hemlocks will be impacted by climate and moisture variables.

Ashley Dawn
Harvard University

Mentors: Sam Jurado and Jackie Matthes

Methane Dynamics in Aquatic-Terrestrial Interfaces: Insights from Harvard Forest Wetlands

Wetlands are unique in their ability to store vast amounts of carbon-rich organic matter, making them critical environments in constructing global greenhouse gas budgets. While wetlands are often a sink of carbon dioxide, the waterlogged, anoxic condition of their soils facilitates microbial conversion of stored carbon into methane, a potent greenhouse gas with 28 times the warming potential of carbon dioxide. Globally, wetlands contribute roughly one-third of total natural and anthropogenic methane emissions. Anthropogenic disturbances, including more extreme and varied precipitation caused by climate change, disproportionately impact gas cycling in wetlands due to microbial feedback loops and exposure of previously stored carbon. Wetland methane dynamics are poorly understood, inhibiting our ability to model climate change and accurately achieve global emissions cutting goals. My project quantifies methane gas dynamics in aquatic-terrestrial interfaces at Harvard Forest and works to understand the biotic and abiotic factors that influence methane emissions in wetlands and uplands. We measured the amount of methane and carbon dioxide being absorbed or emitted (net flux) from soils over 10 weeks in wetland and upland conditions, including the first measurement of methane flux in the Beaver and Black Gum Swamps at Harvard Forest. We expected wetland soils to emit more methane than upland soils due to anoxic soil conditions, however, factors like tree species identity and soil moisture fluctuations might also influence rates of methane flux. By examining factors like the species of adjacent trees, soil moisture, precipitation, and stream gas concentrations, we will be better able to account for methane emissions in temperate forests, as well as understand the role of methane in net forest flux. Quantifying methane and carbon dioxide dynamics will help determine how wetlands should be managed, how restoration practices impact gas fluxes, and how methane emissions will need to be offset to achieve global emissions goals.

Bethany Duncan

Columbia University

Mentors: Jonathan Gewirtzman and Jackie Matthes

Applications of the Diffusion Equation: Predicting a Vertical Gas Profile for Soil in Harvard Forest

Methane absorbs and re-emits longwave radiation from the Earth's surface, trapping 80 times more heat than carbon dioxide over a 20-year timescale. Methane is responsible for 25% of anthropogenic warming to date even in its relatively small atmospheric concentration. Methane emissions originate from both anthropogenic sources (e.g., fossil fuel and agriculture) and natural sources (e.g., wetlands and trees). However, the causes, magnitude, and feedback systems of methane fluxes from soil and tree stems are not well understood, leading to problems understanding and modeling forests' roles in the climate system and in predicting how they will affect and/or be affected by a warming world. Understanding the vertical profile of gas concentration, production, and consumption in forest soils can allow us to contextualize the net atmospheric gas exchange from soils and trees by discretizing gas transport and efflux into segments with their own distinct behavior. For example, below a certain depth, soil becomes functionally anoxic because biological demand for oxygen exceeds its rate of diffusion from the atmosphere. We can estimate this boundary between the soil's anoxic layer, where methane-producing microbes (methanogens) proliferate, and the oxic layer, where methane-consuming microbes (methanotrophs) proliferate, and find drivers of temporal or spatial variations in this boundary's depth more accurately than we can by looking at the net flux at the surface. In order to model the gas profile for the soil at Harvard Forest, I created a simple numerical optimization model to find best fit values for soil activity and diffusion coefficients of the analytical solution to the diffusion equation in order to best fit methane and carbon dioxide concentration data from wells at varying depths up to 50cm across Harvard Forest. Comparing these data to entire ecosystem changes (e.g. precipitation, temperature) could be a helpful way to parametrize the forest as a whole and validate estimates on net greenhouse gas flux.

Devon Ford

Ohio State University

Mentors: Marcos Rodriguez and Sydne Record

Illumination and Regeneration: Investigating Canopy Gaps and Tree Seedling Survival

Canopy gaps are an important mechanism for the maintenance of tree diversity in mature forests. The opening and closing of canopies across a landscape provides a range of light conditions in which species, depending on their shade tolerance, can experience a window of competitive advantage. However, the rate of gap formation may be increasing in temperate forests due to novel stressors such as hemlock woolly adelgid affecting common overstory trees. Thus, I investigated the niche in light availability tree species as seedlings occupy to illuminate how their regeneration may be differentially affected by opening canopies. In Harvard Forest in Central Massachusetts, 96 1m by 1m quadrats are located in the ForestGEO plot, which provides more spatial coverage and variation than most studies of seedlings. I tagged new recruits and recorded the status (live or dead) of old recruits of woody species as replicated through previous years. With 2 years of data, I analyzed survival across time and space of individual seedlings of the following overstory trees: red maple (*Acer rubrum*), eastern white pine (*Pinus strobus*), northern red oak (*Quercus rubra*), eastern hemlock (*Tsuga canadensis*), and birch (*Betula* spp.). To quantify the amount of light entering the understory, I took hemispherical photos of the canopies above quadrats using a fish-eye lens camera then used software to analyze the number of light versus dark pixels. Under novel stressors and a changing environment, certain tree species will display greater survivorship than others. I expect the advantage of hemlock seedlings, known to be shade-tolerant, will diminish with greater light, leading to replacement by more shade-intolerant species. Changes in light availability to the seedling layer has the potential to either release or constrain species, ultimately changing the future composition of temperate northeastern forests.

Casey Helton

University of North Georgia

Mentors: Xiaojie Gao and Danelle Laflower

Investigating Trends in Tree Leaf Seasonality and its Impact on Carbon Storage in New England Forests

The phenological events of trees, such as leaf emergence and senescence, are sensitive to the temperature and precipitation changes associated with climate change, thus they serve as an important indicator of a forested ecosystem's response to climatic shifts. Research at Harvard Forest performed a decade ago indicated trends of earlier emergence and later senescence; this is expected due to increasing temperatures triggering photosynthetic changes. This increase in growing season length could have substantial implications in carbon sequestration, as the leaves have more time to perform photosynthesis. However, a shorter study period limits this research, and two anomalous years with very early leaf emergence implies an advancing spring beyond what has been recently observed. We hypothesize that by extending the study years, spring advancement will be less pronounced. In this study, we analyze 33 years of ground data and 39 years of satellite imagery, using linear regression to assess if these trends have continued. We utilize ground observation data of leaf phenology, which researchers have collected at Harvard Forest since 1990. We also process 30-meter Landsat satellite data using a Bayesian phenology model. We use this data to assess long-term phenological trends, compare results by the acquisition method, and quantify the sensitivity of tree phenology to temperature and precipitation. Finally, we explore potential implications on forest carbon storage via the LANDIS-II landscape change model and its PnET-Succession extension. We model species cohorts in a simulated environment of the study area over a range of climatic conditions to quantify changes in aboveground biomass. Our results indicate that most individuals studied do not indicate significant vernal advancement; however, nearly half of the individuals indicate slight autumnal delay. Model simulation results indicated correlation in some species between growing season length and foliage dry weight - a potentially promising result for projecting carbon sequestration based on phenological observation.

Lauren Hollinger
Ohio Wesleyan University

Mentors: Lucy Lee and Josh Plisinski

Development for a Climate Smart Future: Using Geospatial Analysis to Assess Surface Temperature Dynamics of Ground-Mounted Solar Arrays in Massachusetts

Around the world, government entities have enacted legislation encouraging the reduction of greenhouse gas emissions to combat climate change. The state of Massachusetts' Clean Energy and Climate Plan for 2050 intends to achieve net-zero emissions. Solar energy is pivotal to realizing the state's climate goals, yet relatively little is known about the array's impacts of thermal forcing on the surrounding environment. To better understand the potential consequences of solar installation, I conducted a thermal assessment of surface temperatures using remote sensing data for ground-mounted solar array sites across Massachusetts using a buffer technique. Through a regression approach between buffers, I determined that at 200-300 meters from the array, the surface temperature was no longer affected by the arrays. By comparing mean surface temperature difference between the array and the unaffected area before and after the array was developed, I found that post-development arrays displayed significantly higher mean differences in surface temperature. Previously forested sites had a significantly higher difference than the arrays that had other previous land cover. Compared to a sample of non-solar development sites, which was selected based on its similar patch size distribution and mean area, solar sites had a smaller extent of mean temperature difference from pre to post-development years. However, when comparing the samples in terms of land cover, forested sites had a larger mean temperature difference from pre to post-development years, for both solar and non-solar development. Solar sites had a smaller extent of mean temperature difference from pre to post-development years for non-forested sites, but there was no significant difference between solar and non-solar development for forested sites. Understanding the thermal properties of solar sites is vital to understanding how green technology can simulate similar problems to the climate warming they aim to combat.

Kamyah Hugee
Tuskegee University

Mentor: Ahmed Siddig

Looking at Forest Ecosystem Changes Through the Lens of the Terrestrial Amphibians of Harvard Forest

Amphibians are declining worldwide mainly due to habitat loss and destruction and climate change. Loss of the Eastern Hemlock forests in the USA by Hemlock Woolly Adelgid is a live example of such a threat to biodiversity in general and amphibians in particular which makes the need for research and assessments essential. This study aims to assess the status and trend of terrestrial amphibians (i.e. salamanders & newts) in response to the decline in the Eastern Hemlock forest taking advantage of the current and historical assessments that took place in The Hemlock Removal Experiment (HeRE) of Harvard Forest. Two species of terrestrial salamanders (i.e. red-backed salamander and red-spotted newt) were considered in this study as they are considered important indicators for monitoring changes in forested ecosystems for their abundance, position in the forest food web, and sensitivity to changes in their surrounding environment. In each of the eight plots of the HeRE treatment, two transects were laid out and 5 cover boards were located in each transect to assess the presence, abundance, and growth stage of red-backed salamanders. Likewise, four 15m strips were created in the same transects to observe the red efts following the visual encounter survey method. On the other hand, for comparing temporal trends, historical data on both focal species from the years 2004 and 2014 have been extracted from the data archive of the Harvard Forest's Long-Term Ecological Research (HF-LTER) site. The total number of redbacks counted in 2014, 72, and 50 in 2024 which implies a decline of approximately 30% in its abundance. In contrast, the efts' abundance increased by about 17% from 104 in 2014 to 122 in 2024. In terms of the growth stages for Red-backed salamanders, most individuals detected were mature in 44% of the encounters, followed by pre-mature at 34 % and the remaining 21% were juveniles. According to ANOVA analysis, the abundance of both species was notably higher in Hemlock control plots compared to logged, girdled, and Hardwood control plots. Red-backed salamanders and red-spotted newts are both witnessing some decline due to habitat destruction. Given the low abundance observed in Hardwood habitats compared to Hemlock, the future of both species appears challenging. More follow-up studies on demographic characteristics and effective sampling methods for both species are recommended.

Sky Hulse

Columbus State Community College

Mentor: S. Joseph Tumber-Dávila

Collaborator: Lara Roelofs

Digging Deeper: Edge Effect Impacts on Root Distribution in a Fragmented Northeastern Temperate Forest

Forest fragmentation is ubiquitous throughout the temperate forest biome of the Northeastern United States, making it the most fragmented forest biome in the world. In this region, 23% of forests lie within 30 meters of an edge. The creation of edges exposes trees to more solar radiation, leading to surface heating and drier edaphic conditions. Edges are also characterized by greater wind disruption and nutrient availability. Limited studies have been conducted on how this introduced suite of environmental conditions impacts belowground dynamics. Creation of a new forest edge may prompt trees on the edge to shift their resource acquisition strategies towards newly available resources in the deforested area. By observing vertical distribution of root biomass and necromass at newly created forest edges, we sought to gain a more developed understanding of the impacts of fragmentation on root system dynamics, specifically for oaks (the dominant species in our site), maples, and pines. We predict that vertical distribution of fine roots along soil profile will be impacted by edge creation as competition is reduced for resources, water and nutrients in this newly cleared forest edge. To observe this, we sought to compare the vertical distribution of fine root biomass and necromass along three transects of soil cores spanning from the harvested clearcut to the forest interior where roots were identified by their species grouping and sorted into live and dead roots. Assessing fine root biomass and necromass density, depth, and architecture may help determine different tree species' resilience to environmental factors introduced through forest fragmentation, particularly in post-harvest landscapes. By digging deeper into fine root distribution at a created forest edge, this research offers valuable insights towards understanding and managing ecosystem resilience in the face of environmental changes.

Blake Logan
Oberlin College

Mentors: Raydaliz Cancel Vázquez and Ashley Keiser

Can Differences in Hemlock Health Response to Wooly Adelgid Infestation be Explained by Variation in Mycorrhizal Abundance?

After its introduction to the eastern United States in the 1950s, the invasive insect Hemlock Wooly Adelgid (HWA; *Adelges tsugae*) has devastated eastern hemlock (*Tsuga canadensis*) populations. This sap-feeding insect has no natural predators in the Eastern US, allowing it to consume hemlock leaves uncontrollably, killing the tree. Like 80% of plant species, hemlocks form an obligate symbiosis with (ecto)mycorrhizal fungi, a type of fungus that forages for nitrogen (N) and phosphorous (P), which it provides to the tree in exchange for carbon compounds. The tree cannot survive without these fungi, as mycorrhizae's fine hyphal networks access nutrient pools much more effectively than tree roots can, and the fungi cannot survive without the tree's supply of carbon compounds. Previous studies have shown that ectomycorrhizal abundance in eastern hemlocks is strongly correlated to severity of HWA infestation, with infested trees having significantly less fungal biomass associated with their roots than healthy trees. At Harvard Forest, hemlock trees have been infested with HWA since the early 2000's, but some are doing better than others. The cause of this differential response is unknown. Could soil biogeochemistry and/or mycorrhizal productivity account for these differences in hemlock health? Here, we used soil analyses, mycorrhizal ingrowth bags, and root exudates to test for differences in subterranean factors between healthy and unhealthy hemlock sites. We found differences in soil pH between the sites, but no mycorrhizae were collected from either site, as in-growth bags were not left underground long enough for significant amounts of hyphae to colonize them. Learning from this, we provide more specific recommendations for how fungal in-growth bags might be deployed more successfully in future studies. This study identifies promising areas of further research at the intersection of invasive ecology and plant-soil feedbacks and details specific ways to continue researching the potential subterranean mechanisms of hemlock resistance to HWA.

Julia Marquis

Emory University

Mentors: Marissa Hanley and Hannah Naughton

Long Term Influences of Hurricane Disturbances on Soil Carbon Cycles

In the global carbon cycle, greenhouse gasses such as carbon dioxide (CO_2) and methane (CH_4) interact with soils through photosynthesis, decomposition, and soil respiration, creating gas fluxes between the soil and the atmosphere. Temperate forest soils keep these fluxes in balance by acting as carbon sinks, storing carbon as soil organic carbon (SOC). These nutrient cycles are dependent on soil qualities such as moisture, texture, and pH, which can affect SOC storage in soils. Natural disturbances, such as hurricanes, can affect soil qualities and microbiota which in turn can disrupt soil respiration over time. An earlier study examined the effect of hurricane events on temperate forest soils by measuring gas fluxes before and after a simulated hurricane event at the Harvard Forest in Petersham, Massachusetts. Results from this study found that there were no changes in CO_2 and CH_4 fluxes before and after the hurricane event. Here, we follow up on the original study 30 years later to assess how gas fluxes may correlate with SOC stored between the simulated and control plots, and how this differs from the initial simulated blowdown. As time has passed, the forest has recovered so that the two plots have similar forest cover, but the simulation plot has had an increased carbon input due to the decomposing blowdown trees. We hypothesize that the felled trees in the simulation plot added additional carbon inputs into the soil as they decompose, resulting in a higher concentration of SOC compared to the control plot. Understanding carbon content in these two plots will give insight into how temperate forest soils are able to absorb and retain organic carbon for long periods of time, and how the temperate forests' role as a carbon sink might be impacted with the increasing frequency and intensity of disturbance events due to climate change.

Sónia McCollum

Mount Holyoke College

Mentors: Sam Jurado and Jackie Matthes

Impact of Rain Events on Gas Dynamics in Forest Wetlands: Contrasting Effects in Young and Mature Ecosystems

While wetlands are only approximately 6% of Earth's land cover, they provide crucial ecosystem services that support both wildlife and humans alike. Dense and waterlogged peat soils sequester carbon for extended periods of time without releasing it back into the atmosphere, a key function of wetlands. In this study, I researched how rain events impacted two forested wetlands of different ages by measuring how stream flow through wetlands carry gases laterally across landscapes and how rain events impact gas concentrations in the water. I studied Nelson Brook and Arthur Brook, two streams at the Harvard Forest moving through the Black Gum Swamp and the Beaver Swamp, respectively. I measured the temperature and CH_4, CO_2, and dissolved oxygen concentrations in the streams at six different sampling locations each week from early June to late July 2024. Due to the young (~25 yr) age of the Beaver Swamp, it has a more unstable ecosystem than the Black Gum Swamp because there are higher amounts of labile carbon in the soils leading to more active microbes. The microbes in the much older Black Gum Swamp (~14,000 years old) have already processed the fresher organic matter and are now left with recalcitrant carbon which doesn't provide as many nutrients. I expect the gas concentrations in the water exiting the Black Gum Swamp to be lower than that of the water exiting the Beaver Swamp. After periods of increased rainfall, I expect the dissolved oxygen in the water exiting the Black Gum Swamp to be higher than that of the Beaver Swamp. Measuring these processes can help us to better understand the relationship between wetland age and carbon cycling.

Dyllan Nelson

Michigan State University

Mentor: Laura Figueroa

Investigating the Effects Forest Edges on Soil Invertebrate Communities and Decomposition of Organic Material

Forest fragmentation is a widespread issue affecting nearly all global forests. Over 70% of the world's forests are within 1 kilometer of a non-forested edge. These forest edges create microclimate gradients within meters of each other, often resulting in inhospitable conditions for many organisms. Increased exposure to sunlight, wind, and precipitation at forest edges can lead to higher soil temperatures, elevated erosion rates, and drier conditions compared to the forest interior. Despite these significant effects, the impact of forest edges on leaf litter decomposition and invertebrate presence remains underexplored. Decomposition and soil invertebrates are fundamental to nutrient recycling processes in order to maintain healthy, nutrient-rich soil. Decomposition of organic material such as leaf litter provides 90% of nitrogen and phosphorus, and over half of other necessary mineral elements. Soil invertebrates facilitate this process by chemically degrading dead plant material, subsequently enhancing the amount of plant available nutrients. Our research aims to investigate how forest edges affect leaf litter decomposition and soil invertebrate abundance. To study decomposition, I created leaf litter bags using metal and fiberglass mesh, filled with red maple leaves. Litter bags were deployed in the interior of a forest, edge, and clearing. I weighed leaves before and after deployment to observe how much mass was lost in the decomposition process. For the invertebrate experiment, I collected a standard amount of leaf litter from interior, edge, and clearing plots and deployed the samples in Berlese funnels to extract soil invertebrates present. The main goals were to analyze species richness, abundance, composition, and evenness to gain a comprehensive understanding of how soil invertebrate communities are affected by forest edges. We hypothesize that soil invertebrate communities will be less abundant and more even in forest clearings and edges, while being more abundant and diverse in forest interiors. Additionally, we expect that decomposition will occur more slowly at forest edges and in clearings compared to forest interiors. This research is vital for understanding the global impacts of widespread forest fragmentation on ecosystems.

Annabelle Rayson
Harvard University

Mentors: Betsy Colburn and Diana Sharpe

From the Woods to the Waters: A Comparison of Macroinvertebrate Communities in Hemlock and Deciduous Streams in Response to the Hemlock Woolly Adelgid

Eastern Hemlock, *Tsuga canadensis*, is a foundational forest tree species of New England; however, New England is now facing drastic Hemlock loss as Hemlock trees are falling prey to the invasive insect Hemlock Woolly Adelgid (HWA), *Adelges tsugae*. HWA does not have a major predator in the New England ecosystem and there has yet to be an effective method to treat and prevent HWA across broad scales. Thus, it is important to understand how the HWA will impact Hemlock forests and the ecosystems they support. While there has been some research focused on the consequences of Hemlock loss on forest composition, there has been relatively little work to date examining the possible cascading impacts on aquatic ecosystems. Twenty years ago, Willacker and colleagues (2009) performed a study at the Harvard Forest (HF) to investigate the potential impact of Hemlock loss on stream macroinvertebrate communities; however, this study was done before the HWA reached HF and caused any Hemlock damage. In this project, we sampled two streams at HF used in Willacker's study, one surrounded by deciduous trees and one surrounded by Hemlock trees, for benthic macroinvertebrate and water quality metrics. We identified macroinvertebrates to family and compared richness and abundances across streams. We found that the Hemlock stream was found to have tendencies for colder waters, higher pH, and less light availability than the deciduous stream. Both streams had high volumes of EPT taxa (pollution-intolerant species) indicating clean and healthy waters. Both streams had similar levels of richness and total abundance, but there were some differences in community structure. This study provides valuable baseline data for continued monitoring over the next years and decades at the Harvard Forest and further study is needed to better understand the effects of HWA-induced Hemlock loss on streams.

Willow Rhimyr
Tuskegee University

Mentors: Audrey Barker Plotkin and Greta VanScoy

Impact of Hemlock Woolly Adelgid on Tree Growth Rates

Significant loss of eastern hemlock (*Tsuga canadensis*) dominated forest is occurring in the eastern United States due to hemlock woolly adelgid (HWA; *Adelges tsugae*), an aphid-like insect pest. Responding to HWA infestation, many landowners log their hemlock forests. Logged forest experiences more sudden disturbance than infested hemlock forest. This may impact non-hemlock tree growth. Growth of recruited trees versus established trees could vary due to light changes. Hemlocks' growth is expected to change as they experience canopy loss due to HWA. We measured these growth rates in a long-term ecological experiment established in 2004. Eight 90x90m forest plots were established in Harvard Forest's Simes tract near the Quabbin watershed. Four plots are untreated hemlock or deciduous forest. Two plots are girdled hemlock forest, emulating standing death from HWA. Two plots are logged hemlock forest, emulating timber harvest patterns by landowners facing HWA infestation. Diameter at breast height is measured every 5 years for all living trees with a diameter above 5 cm. An estimation of tree vigor based on canopy health is assigned to all hemlock trees. Growth rates from the past 20 years are analyzed with R to create graphs of basal area varied on species, treatment, and time. Hemlocks show decreased basal area growth since infestation with HWA. Data on the loss of foundation species is important as previous functional extinctions such as the American chestnut (*Castanea dentata*) were not properly documented. These data help increase knowledge of forest growth after pest disturbance. Differences in forest recovery between logging and natural death could influence management practices.

Naturi Scott

Emory University

Mentors: Marissa Hanley and Hannah Naughton

Terrain Dynamics: Greenhouse Gas Flux in New England Temperate Forests after a Simulated Hurricane

A forest's microtopography (small-scale, physical landscape features) can shift after a hurricane or similar storm disturbance. Pits spot the forest floor as a result of felled trees creating low points that have the potential to exacerbate anaerobic soil processes and in turn produce two potent greenhouse gasses (GHGs): methane (CH_4), and nitrous oxide (N_20). In addition, downed trees add soil organic matter (SOM) to the forest floor, providing microbes access to fuel for respiration. The key question is whether a disturbance in microtopography to temperate forests causes a significant change in forest soil GHG flux. At the Harvard Forest LTER (Long-Term Ecological Research) Site in Petersham, Massachusetts, a hurricane event was simulated in 1990. Approximately 2/3 of the trees were felled resulting in a pattern of pits and mounds persisting along the forest floor. This study follows up on the study published by Bowden et al. in 1993 where results showed N_2O emissions to be significantly lower in the pulldown plot, and conversely, CH_4 uptake rates were routinely greater in the control plot than pulldown. To assess the effects nearly 35 years later, weekly, soil samples and gas measurements were taken from an untouched control plot and the pulldown plot to assess soil GHG flux and soil characteristics (i.e. moisture, texture, organic matter, redox chemistry). The pulldown plot is expected to have more potential anoxic microsites due to waterlogging, therefore, producing more methane and nitrous oxide emissions than the control plot. Alternatively, due to moist conditions and the passage of time, accessible carbon may be less available to microbes/used up, limiting the production of GHGs in the pulldown plot and signaling a recovery of forest and soil dynamics to what they once were. As the climate changes, the earth warms, and hurricane events become more frequent, the microtopography of temperate forests will be disturbed more often, creating conditions that favor the production of GHGs. Measuring soil respiration in response to microtopography alterations is crucial to understanding forest disturbance effects and resilience. Additionally, soil anoxic microsites and their contribution to GHG production are an understudied area of soil ecology, and understanding the contributing factors of GHG emissions in forests is essential to improving climate modeling.

Olivia Walker

Kennesaw State University

Mentors: Raydaliz Cancel Vázquez and Ashley Keiser

The Role of Root Exudates in Eastern Hemlock Decline

Eastern hemlock, *Tsuga canadensis*, is a keystone species native to eastern North America. However, since 2013 it has faced a significant decline at Harvard Forest due to the invasive insect, hemlock woolly adelgid, *Adelges tsugae*. Hemlock decline is associated with canopy loss, which thus alters its cool, damp microclimate. This leads to increased soil temperature which can affect soil decomposition rates, soil moisture, and rhizosphere dynamics. At Harvard Forest, a healthy and unhealthy stand has been identified on the Prospect Hill tract. One potential driver of different eastern hemlock health statuses is the role of root exudate quantities within the different hemlock stands. Root exudates are active compounds that help recruit beneficial microbiota. The stands also have differing bedrock, which could have weathered and developed into different soil types. Soil type influences the movement of ions in the soil. Therefore, the differences in soil type can lead to a difference in exudation and thus health response at the stands. Four mature and four young eastern hemlock trees were selected from both stands. Exudate samples were collected from the fine roots of each tree and were analyzed using total organic carbon analysis. Results from this data were analyzed in RStudio alongside other soil health measures. We hypothesized: (1) The healthy hemlocks will have more total exudates because the healthier hemlocks have a thick canopy which will result in greater photosynthesis and more photosynthetic carbon inputs to the soil through exudation. (2) The healthy stand will have a higher percentage of clay and with it, greater total exudates to potentially access cations and metals stored on the clay surfaces. (3) The younger eastern hemlock have fewer total exudates than mature eastern hemlock due to higher previously reported mortality rates.

Masako Yang

Harvard University

Mentors: Jonathan Gewirtzman and Jackie Matthes

Investigating Sources of Methane Flux from Trees: Insights Across Wetlands and Uplands

Methane is a potent greenhouse gas, responsible for one-third of climate warming since industrialization. Up to half of annual global methane emissions originate from natural sources including trees and wetland soils; yet, the sources and transport pathways of tree methane emission remain largely unknown and understudied. Potential processes for tree methane emission include within-tree production by methanogens, primarily in the anaerobic heartwood of trees, as well as pressurized flow, transpiration, and/or passive diffusion of soil-originating methane through tree roots, vasculature, or other porous tissues. This research contributes further study on the source of tree methane emissions by analyzing the relationship between tree-stem methane flux, soil methane flux, and environmental conditions. Wetlands are known as net methane sources and uplands as net methane sinks; we therefore hypothesize positive correlations between the two fluxes in the wetland and no significant correlation in the uplands. We used portable trace gas analyzers to measure the stem fluxes of 30 upland and 30 wetland tree, as well as their co-located soil chambers, all located across Prospect Hill of Harvard Forest. Tree fluxes were measured for three minutes using a standard chamber flux technique and soil flux data were collected by a complementary project. Tree methane fluxes were plotted against soil fluxes, as well as soil moisture and temperature, precipitation, vapor pressure deficit, and other environmental variables. The strengths of correlation were determined by the Kendall rank correlation test. Preliminary data support greater correlation between the tree flux and soil flux in the wetland. This research will contribute to greater understanding of the production, transport, and emission pathways of methane through trees. These findings will contribute to resolving major uncertainties in inventories and models of forest methane budgets, which are necessary to inform climate models, predictions, and mitigation efforts.

Danielle Mazur (left)
The Bement School

Karen Murphy (right)
Summit Academy

Mentors: Clarisse Hart, Katharine Hinkle, and Neil Pederson

Storm Stories: Tree's Tales of Growth Following Wind Storms

Many factors stress trees in the Northeast. Weather related events, such as drought, unseasonable frost, extreme heat, and storms can negatively impact forests. To assess evidence of tornadic activity in tree rings, a forest site, Slab City, affected by the tornado of 1953 was identified. Physical examination yielded eight trees of six different species with physical markers of suspected wind damage. Five control trees with no physical signs were included. Trees were cored using an increment borer. Sample cores were processed and inspected microscopically. Tree rings were analyzed and dated using cross dating techniques. Once located, the 1953 ring as well as the rings preceding and following 1953 were analyzed. Eight of the trees sampled show evidence of growth change in the rings 1952, 1953, and 1954. The 1953 ring of seven trees shows mid-growing season stress; five samples showed growth release in their 1954 ring. Results show that windstorm events are cataloged in tree rings. The rings show that tornados may be traumatic for one individual, but create growth opportunities for another. Using the 1953 ring in Slab City trees may help crossdate and predict growth and recovery rates considering that events such as the 1953 tornado may increase.

2024 Harvard Forest Personnel

Alexander, Teressa - Summer Program Assistant Coordinator
Barker-Plotkin, Audrey - Site Manager, Senior Scientist & Director of Summer Program
Bennett, Katherine - Schoolyard Ecology Field Mentor
Blumstein, Meghan - Bullard Fellow
Boisvert, Chrystal - Accounting Assistant
Boose, Emery - Information Manager & Senior Scientist
Bowlen, Jeannette - Sponsored Research Administrator
Colburn, Elizabeth - Aquatic Ecologist
Danielson, Erik - Lab Technician
Davis, Tiffany - Schoolyard Ecology Peer Mentor
De Freece Lawrence, Keshia - Education Specialist
Duveneck, Matthew - Research Associate
Dyer, Jillian - Research Assistant
Eid, Elodie - Education Coordinator
Ewan, Peyton - Field Technician
Fuchs, Meg - Director of Administration & Facilities
Gabrenas, Morgan - Woods Crew
Gao, Xiaojie - Postdoctoral Fellow
Gluskin, Matt - Field Technician
Goulet-Scott, Benjamin - Higher Education & Laboratory Coordinator
Griffith, Lucas - Land & Facilities Manager
Hall, Brian - GIS Specialist
Hall, Julie - Assistant Information Manager
Hart, Clarisse - Director of Outreach & Education
Hart, Zachary - Lab Technician
Hegwood, Naomi - Research Technician
Hill, Elijah - Woods Crew
Hinkle, Katharine - Schoolyard Ecology Program Coordinator
Holbrook, Noel Michele - Director of Harvard Forest
Holley, Cheryll - Bullard Fellow
Hunt, Shirley - Department Coordinator
Irvine, Maya - Field Technician
Johnson, Emily - Stakeholder Engagement Coordinator
Johnson, Josh - Woods Crew
Jurado, Sam - Field Technician
Lacwasan, Oscar - Woods Crew
Laflower, Danelle - Research Assistant
Lee, Lucy - Research Assistant
Lewis, Ann - Schoolyard Ecology Data Mentor
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McDonald, Noah - Bullard Fellow
Meunier, Roland - Woods Crew
Morin, Alisha - Accounting Assistant
Noguiera Gomes, Larissa - Field Technician
O'Keefe, John - Museum Director (Emeritus)
Orwig, David - Forest Ecologist
Pallant, Julie - Website Support (remote)
Pederson, Neil - Forest Ecologist
Plisinski, Joshua - Research Assistant
Potter, Sam - Field Technician
Richardson, Lisa - Financial Administrator
Ross, Sadie - Field Technician
Siddig, Ahmed - Bullard Fellow
Smith, Laura - Research Assistant (remote)
Snow, Pam - Education Assistant
Talib, Ammara - Postdoctoral Fellow
Thompson, Jonathan - Research Director & Senior Ecologist
VanScoy, Greta - Education Coordinator & Field Technician
VanScoy, Mark - Research Assistant
Wood, Elaine - Laboratory Assistant
Woodworth, Elena - Field Technician
Yesmentes, Peter - Summer Program Assistant Chef
Zima, Christopher - Summer Program Assistant Chef
Zima, Tim - Summer Program Chef
Zwieniecki, Maciej - Bullard Fellow

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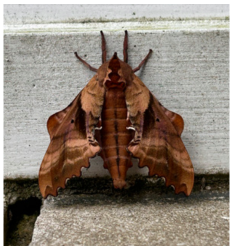
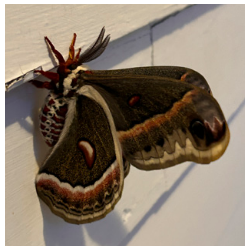
HARVARD FOREST SUMMER RESEARCH PROGRAM IN ECOLOGY 2024





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