Harvard Forest

Summer Research Program in Ecology

33rd Annual Student Symposium

August 6, 2026




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HARVARD FOREST

cover photo: Gretchen Bahmueller

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.

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. We acknowledge that this land is the ancestral home territory of the Nipmuc people, and are committed to continuing to build a relationship with the tribe to ensure that the land and its benefits are mutually accessible and sustaining. 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 2026 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 2026 program with the help of program coordinator Ben Goulet-Scott and program assistant (proctor) Gretchen Bahmueller. 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 6, 2026, where students presented their research findings to an audience of scientists, peers, and family.

Funding for the 2026 Summer Research Program

In 2026, 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)
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The Living Diorama Scholarship Fund
Martin H. Zimmermann Memorial Fund
John B and Edith M. Downs Memorial Trust

Washington & Lee University
University of Connecticut
University of Massachusetts Lowell

Quercus Fund Inc.

2026 Summer Research Program Students and Mentors

2026 Summer Research Program Students, Proctor, and Coordinator

2026 Summer Research Program Seminar Speakers

June 4	Jess Gersony, *Smith College*
June 25	Ahmed Siddig, *Harvard Forest*
July 2	Scott Edwards, *Harvard University*
July 9	Lucy Hutyra, *Boston University*
July 16	Max Piana, *Harvard University Graduate School of Design*
July 23	JoLeisa Cramer, Caroll Goranson, and Matthew Wenzel, *NEON*
July 30	Banu Subramaniam, *Wellesley College*

2026 Summer Research Program Workshops & Activities

May 26	Field Tour: Long-term Research Sites at Harvard Forest. *Greta VanScoy & Emery Boose, Harvard Forest*
May 26	General Lab Safety Training. *Mary Lindstrom, Harvard University*
May 27	Gender Equity & Diversity in Community. *Rachel DiBella, Harvard University*
June 1	Writing and Reviewing Research Proposals. *Ben Goulet-Scott, Harvard Forest*
June 8	Communicating About Global Change. *Clarisse Hart, Harvard Forest*
June 11	Arnold Arboretum & Cambridge visit with Harvard Environmental Summer Programs & Responsible Conduct of Research. *Logan McCarty, Harvard University*
June 15	Using R in Ecology. *Xiaojie Gao & Danelle Laflower, Harvard Forest*
June 22	Quantitative Fundamentals of Time-Series Analyses. *Benton Taylor, Harvard University*
June 25	Day of Service at Pequoig Farm. *Keely Curliss, Willow Daly & Anoki Mann*
June 29	The Forest in the Trees Screening. *John O'Keefe, Greta VanScoy & Ben Goulet-Scott, Harvard Forest*
July 6	Best Practices with Data. *Audrey Barker Plotkin & Emery Boose, Harvard Forest*
July 13	Graduate School Discussion. *Junior Burks, Eve Farrell, John Paul Hellenbrand & Halina Saydam*
July 20	Presenting Your Research. *Ben Goulet-Scott, Harvard Forest*
July 27	Career Panel. *Shyloh Favreau, UNH Cooperative Extension; Todd Mistor, Boston Parks & Recreation; Linda Ordiway, US Forest Service*

33rd Annual Harvard Forest Student Symposium Schedule
August 6, 2026

9:00am **Opening Remarks**

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

Calla Andrews *Washington & Lee University*	Does this Heat Make Me Look Skinny? An Analysis of the Effects of Soil Warming on Body Condition in a Widespread Woodland Salamander	7
Adrián González Rivera *University of Puerto Rico at Cayey*	Woodland Salamanders in Dryer Times and Fragmented Landscapes	12
Sarah Rose Eagen *Cornell University*	Understanding the Ecological Role of Coyotes at Harvard Forest Through Bioacoustics, Dispersal, and Individual Identification	11
Kyla Ritchie *University of North Carolina at Chapel Hill*	Understanding influences of mycorrhizal type vs. leaf litter quality on nitrogen cycling in temperate forests	22
Caleb Jaffe *Harvard University*	Connecting Soil Proteolytic Activity to Species Composition and Primary Productivity in Temperate Forests	14

BREAK

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

Gabriella Powell *University of Massachusetts Lowell*	An Intersensory Comparison Study: differential wounding response & sensor performance of different sap flow sensor designs	21
Isabella Ciarlet *Brandeis University*	Forest Stressors: Effects of Fragmentation and Drought on Forest Regeneration	9
Eve Speredelozzi *University of Massachusetts Amherst*	Hyphal Response to Hurricane Disturbance Microtopography in a Temperate Forest	23
Elinor Hershkowitz *Bowdoin College*	Assessing the Relationship between Soil Moisture and Redox Potential in Hurricane-Impacted Soils	13
Hollis Cole *University of Massachusetts Boston*	Living Life on the Edge: How Forest Edges Impact Leaf Litter Decomposition and Arthropod Interactions	10

12:00pm **LUNCH**

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

Audra Jenike *Denison University*	Observing Nitrous Oxide Dynamics in a Temperate, Forested Stream	15
Garrik Wilkins *Mount Wachusett Community College*	Root biomass and morphology changes across a forest edge gradient with precipitation manipulation	26
Gianna Mantegna *Maryville College*	A Look Back at Looking Forward: A Reflection on the New England Lanscape Futures Models	17
Luna Yin *Harvard University*	Rough Around The Edges: Investigating Increased Biomass at Temperate Forest Edges	27
Mia Breznau *Western Michigan University*	Effect of edge formation on temperate deciduous forest species growth and composition along the edge-to-interior gradient	8

BREAK

2:30pm **Student Talks - Session IV**

Sophia Rasic Stagnar *State University of New York at New Paltz*	Leaf litter quantity and microclimate conditions in temperate forests drive rates of soil respiration across an edge to interior gradient	24
Ethan Liao *Harvard University*	Quantifying Differential Impacts of Forest Edge Influence on Autotrophic and Heterotrophic Respiration	16
Sobhan Nickzad *Willaim Patterson University*	Non-Structural Carbohydrate Dynamics Under Forest Fragmentation and Altered Water Availability	20
Evelyn Munoz *University of Arizona*	Assessing the Influence of Precipitation Manipulation on Canopy Phenology in a Forest Edge Manipulation Experiment	18
Elyse Nevins *North Carolina State University*	Comparative analysis of *Nyssa sylvatica* root traits and morphology on a depth gradient within the Black Gum Swamp	19
Tom Weber *Colorado State University*	Intracanopy Plasticity in Leaf Morphological Traits Across Species of Eastern Deciduous Trees	25

4:00pm **Closing Remarks**

5:30pm **Community BBQ**

Calla Andrews

Washington & Lee University

Mentors: David Marsh and Ahmed Siddig

Does this Heat Make Me Look Skinny? An Analysis of the Effects of Soil Warming on Body Condition in a Widespread Woodland Salamander

Temperatures have been steadily increasing over the past century, reaching record highs across the globe, leading to worry about potential harm to ectotherms that rely on cool, moist environments, including amphibians. Higher temperatures have the potential to harm the Eastern redback salamander, *Plethedon cinereus*, a widespread species of lungless terrestrial salamander that makes up a large portion of biomass in eastern deciduous forests. However, there is limited knowledge on how higher temperatures impact body condition and survival rates in *P. cinereus*. Our study looked at the difference in body condition and survival rates in individuals of *P. cinereus* in control, disturbance control, and heated plots. Surveys of surface-active salamanders took place at night and were supplemented by weekly daytime surveys of cover boards. We used the mark-capture-recapture method as a proxy for survival rates, and a regression of log(mass) on log(SVL) and log(TVL) to calculate body condition. We also gathered information on movement patterns of recaptured salamanders. We expect individuals found in heated plots to have lower body conditions and survival rates than those in control plots, which would indicate that higher temperatures play a negative role in survival and maintaining body condition. Data on survival rates, growth rates, and movement patterns could be used to inform models forecasting the effects of climate change on woodland salamander populations. Additionally, the information from this study will help researchers evaluate the potential impacts of higher temperatures on forest food webs.

Mia Breznau

Western Michigan University

Mentors: John Paul Hellenbrand and Andrew Reinmann

Effect of edge formation on temperate deciduous forest species growth and composition along the edge-to-interior gradient

Due to centuries of deforestation and habitat fragmentation, the temperate forest is the most fragmented biome on earth, with a quarter of forest cover existing with 30 meters of non-forest land cover. Proximity to an edge is known to drastically change forest microclimate conditions, with increased light intensity, humidity, and temperature fluctuations at edges compared to the interior. Though it is well established that these altered microclimate conditions change the growth responses of trees, there has been limited work tracking the progression of growth and composition changes in the tree community following edge formation. However, a changing forest community has wide-reaching implications on ecosystem function. For example, declines in oak abundance across the northeastern US are associated with declines in biodiversity as well as altered forest hydrology and carbon cycling. To understand how trees at the edge are responding to this new environment, I measured the weekly growth of 160 canopy trees, in addition to completing an inventory of seedling composition and distribution at the CLIFF site of Harvard Forest. I hypothesize that although limited compositional changes will be seen in the years immediately following edge creation, growth trends will show immediate advantage towards drought-tolerant canopy species like red oak (*Quercus rubra*) as opposed to more drought-sensitive species like red maple (*Acer rubrum*). However, the seedling layer is expected to show an inverse trend, with the ratio of maples being higher across the edge environment than oaks. Additionally, results from statistical analysis of field measurements are expected to show a general increased basal area increment (BAI) across species in edge trees. Though it is difficult to expand a snapshot of growing trends and understory composition to predict changes across an entire forest, these results will provide insight into how deciduous trees are responding to edge environments and which species are more edge-philic than others.

Isabella Ciarlet

Brandeis University

Mentors: Joy Winbourne and Evonne Aguirre

Forest Stressors: Effects of Fragmentation and Drought on Forest Regeneration

Increased forest clearing for agriculture and development has intensified forest fragmentation worldwide, resulting in edge-effects, which expose forest boundaries to greater sunlight, wind, and fluctuations in temperature. At the same time, climate change is increasing the frequency and severity of drought. Consequently, these combined disturbances give rise to novel environmental conditions and may influence forest regeneration, yet their combined effects on the physiology of young trees remain poorly understood. This study aimed to investigate how temperate forests' edge conditions and experimental drought influence the photosynthetic performance and post-drought recovery of understory tree seedlings and saplings. To do this, a total of 593 seedlings and saplings representing seven tree species were surveyed within ambient and drought treatment plots at the forest edge (0m) and interior (30m) at Harvard Forest's Climate Interactions with Forest Fragmentation (CLIFF) experiment. From these, I selected 60 representative seedlings and saplings for repeated measurements of photochemical efficiency (Fv/Fm) and the photosynthetic performance index (PI_{abs}) using a portable chlorophyll fluorometer following the experimental drought period. I hypothesized that seedlings and saplings would have enhanced photosynthetic productivity at the forest edge, under ambient conditions, but that drought would diminish these advantages and delay post-drought recovery compared with interior forests. By examining how drought and fragmentation influence seedling and sapling photosynthetic performance and recovery, this study provides insight into the mechanisms that may drive future changes in forest composition, recruitment, and carbon storage.

Hollis Cole

University of Massachusetts Boston

Mentors: Laura Figueroa and María Fernanda Rojas-Campos

Living Life on the Edge: How Forest Edges Impact Leaf Litter Decomposition and Arthropod Interactions

Temperate broadleaf forests are one of the biggest contributors to terrestrial carbon sinks, however they are also the most fragmented forest biome. Fragmentation changes the structure and function at the forest edge. We aim to understand how the edge effect and its interaction with flood and drought conditions impact leaf litter decomposition rates, the soil macroinvertebrate community, and the trophic cascade of spiders, understudied yet vital predators, to the soil macroinvertebrate community. We hypothesize that there will be higher decomposition rates and greater invertebrate richness and abundance in the irrigated plots. There will be a negative spider trophic cascade under drought conditions and a higher trophic cascade and indirect effect on leaf litter decomposition with more active hunting spiders in ambient conditions. The experiment took place at the Climate Interaction with Forest Fragmentation (CLIFF) site in Harvard Forest. From 2024 to 2026 we sampled 18 total plots each year across three forest contexts: interior, edge and clearing, with different water treatments: drought, ambient, and irrigated conditions. I measured the change in weight of leaf litter bags put out from 2024-2026 to calculate the decomposition rate. I sampled soil macroinvertebrates by collecting leaf litter and putting it into berlese funnels to extract and identify them. To assess trophic interactions, I pioneered nonlethal rapid biodiversity surveys of spiders through active searching during the day and at night to progress arthropod welfare in research. Soil macroinvertebrates are a crucial part of decomposition, which is essential for life on Earth. Increasingly extreme and frequent conditions like droughts and floods as well as heavy fragmentation of temperate broadleaf forests jeopardize the ecosystem services these forests provide that maintain our quality of life.

Sarah Rose Eagen
Cornell University

Mentors: Lisa Brooks and Ahmed Siddig

Understanding the Ecological Role of Coyotes at Harvard Forest Through Bioacoustics, Dispersal, and Individual Identification

Eastern coyotes (*Canis latrans*) have rapidly expanded their range throughout New England, establishing populations in suburban and urban environments despite ongoing human-caused mortality. This makes them an excellent model for understanding how large predators adapt to human-altered landscapes. This study examines the coyote family resident at Harvard Forest, focusing on how their spatial use shifts across the summer pup-rearing season and how their territory, which spans major roadways including Route 32, shapes their movement. Twelve motion-sensor cameras were deployed alongside four other Amherst College cameras throughout Harvard Forest property in Petersham. We identified these sites based on field-tracking methods (scat, scent marking, tracks, and travel corridors), which were highly correlated with beaver activity and prior tracking data by Lisa Brooks. These cameras were focused on capturing coyote and beaver activity but also captured incidental detections of two other main large mammals in the area: bobcats and black bears, as well as many other fauna. Alongside camera traps, three passive acoustic monitoring devices were deployed in areas of high coyote activity. We also incorporated a broader dataset of coyote activity collected throughout Harvard Forest between October 2025 and July 2026. Bioacoustic monitoring was successfully established, yielding an array of coyote howls and supplementary beaver sounds, including baby yips, tail slaps, and swimming sounds. These bioacoustic recordings are the first of their kind in this area and will be able to be used in the future for supplementary behavioral analysis. Camera data have also documented coyotes crossing Route 32 with pups. Analysis of the timing, frequency, and family member identification associated with these crossings is ongoing and will be integrated with occupancy modeling across camera locations to characterize seasonal shifts in spatial use. These findings will contribute to Lisa Brooks' book on Eastern Coyotes, as well as MassCoyote, a new regional citizen science initiative, supporting broader public understanding of these often misunderstood predators.

Adrián González Rivera

University of Puerto Rico at Cayey

Mentors: Ahmed Siddig and David Marsh

Woodland Salamanders in Dryer Times and Fragmented Landscapes

Forest fragmentation creates edge environments that alter light, temperature, and moisture conditions, potentially affecting terrestrial salamanders that depend on cool and moist microhabitats. Additionally, climate change related decline in precipitation patterns is expected to further complicates forest fragmentation impacts. The Eastern Red-backed Salamander (*Plethodon cinereus*) is widely recognized as a bioindicator of forest ecosystem integrity because of its sensitivity to changes in their surrounding habitats. This study evaluated how forest edge distance and experimental moisture treatments influence the abundance, frequency of occurrence, and body condition of *P. cinereus* within the Climate Change Interaction With Forest Fragmentation (CLIFF) experiment at Harvard Forest. Weekly surveys were conducted between June and July 2026 across six experimental plots representing drying, control, and moist treatments. Each plot contained two transects (40m each) extending from the forest edge to the interior, with six cover boards per transect. During each survey, salamander presence, abundance, occurrence, life stage, snout–vent length (SVL), total length (TL), and body mass were recorded. Data were organized and analyzed in R using generalized linear mixed models (GLMMs) to evaluate the effects of edge distance, moisture treatment, and their interaction, while body condition was assessed from the relationship between body mass and SVL. A total of 36 salamanders were detected during 648 cover board surveys, with adults representing the most frequently observed life stage. Preliminary analyses revealed a strong positive relationship between body size and body mass and suggested variation in salamander detections among moisture treatments and along the edge-to-interior gradient. These preliminary findings support the hypothesis that forest edge effect and moisture availability jointly influence *P. cinereus* populations and provide a foundation for understanding how forest fragmentation and climate change interact to shape salamander populations in northeastern temperate forests.

Elinor Hershkowitz
Bowdoin College

Mentors: Marissa Hanley, Halina Saydam, and Hannah Naughton

Assessing the Relationship between Soil Moisture and Redox Potential in Hurricane-Impacted Soils

Soil organic carbon and soil moisture drive anaerobic microbial functions by fueling oxygen demand and constraining oxygen availability respectively. By impacting metabolic rates and water accumulation, temperature and precipitation affect microbial carbon turnover, decomposition, and soil moisture, ultimately influencing anoxic microsite development. Though dominant microbial processes and gases exchanged depend on soil aeration, it remains unknown whether altered litter inputs and microtopography resulting from hurricane disturbance affect the extent to which soil moisture impacts soil redox potential. We hypothesized that both *Quercus rubra* (red oak) and *Acer rubrum* (red maple) tree throw depressions would retain more moisture than flat transects, prompting lower redox potential. Further, we hypothesized that *Q. rubra* depressions would yield higher ferrous iron concentrations and lower redox potential than *A. rubrum* depressions resulting from higher water accumulation associated with greater pit depths. To assess microtopographic influences on soil moisture, volumetric moisture content (VMC) was measured at *Q. rubra* pits, *A. rubrum* pits, and flat transects within the hurricane experimental plot. Gravimetric moisture content (GMC) was also calculated via the drying of the top 15 cm of soil at each site. To evaluate microtopographic redox dynamics, redox potential was measured at each site and hydrochloric acid (HCl) extractions were performed on subsamples of field-moist topsoil to assess reduced iron concentrations relative to total iron content. To assess the metabolic substrates available for microbes to mineralize, we recorded soil organic matter (SOM) depth and leaf litter depth, and quantified SOM via loss on ignition. Contrary to our hypotheses, *Q. rubra* depressions were found to be more aerated, with *A. rubrum* depressions exhibiting both lower soil moisture and redox potential. Additionally, SOM was highest at *Q. rubra* depressions, and redox potential was found to increase with soil moisture, indicating that organic matter and litter quality, as opposed to soil moisture, may be the dominant drivers of redox potential. Enhancing our predictions of anoxic microsite development across microtopography will aid in our understanding of greenhouse gas fluxes and carbon storage via soil organic carbon (SOC), crucial steps in facilitating climate adaptation and predicting ecosystem resilience.

Caleb Jaffe

Harvard University

Mentors: Eve Farrell and Benton Taylor

Connecting Soil Proteolytic Activity to Species Composition and Primary Productivity in Temperate Forests

Nitrogen (N) is an essential element required for all life on earth, composing proteins, DNA, and metabolic cofactors. As such, N cycling within the biosphere is a critical regulator of primary productivity, as N frequently acts as a limiting nutrient of tree growth in temperate forests. Proteases — a class of enzymes that depolymerize proteins into free amino acids and peptides — are the biotic workhorses of N cycling in forest soils, catalyzing the rate-limiting step of N mineralization. While the role that proteases play in N cycling is well established, drivers of spatial differences in protease activity across forest soils and how these spatial differences correlate with primary productivity remain largely unexplored. To better understand these relationships, protease activity was measured in soil samples collected from the Harvard Forest ForestGEO Plot, a 35 hectare forest plot that has been censused on a 5-year basis since 2014. Samples were collected at the center of 20 x 20 meter quadrats, and quadrats dominated by ectomycorrhizae (EcM) associated tree species, arbuscular mycorrhizae (AM) associated species, and a mix of EcM and AM species were selected for proteolytic analysis. We hypothesized that protease activity would be higher in EcM dominated tree stands than in AM dominated tree stands, as EcM fungi secrete proteases directly into the rhizosphere, while AM fungi rely on proteases secreted by saprotrophic fungi to degrade proteins. However, we found that protease activity was higher in AM dominated and mixed stands than in EcM dominated stands. In addition, we found that tree growth rate is positively correlated with protease activity. Together, these results suggest that enzymes secreted by saprotrophic fungi rather than EcM fungi are primarily responsible for protein degradation in soils, and that the proteases secreted by these fungi may play a critical role in promoting aboveground primary productivity.

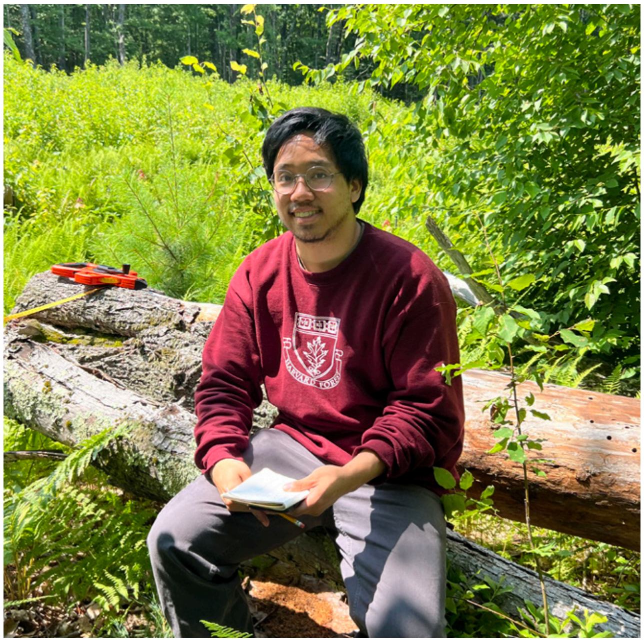
Audra Jenike

Denison University

Mentors: Abby Beilman and Kelly Aho

Observing Nitrous Oxide Dynamics in a Temperate, Forested Stream

Inland freshwater ecosystems are globally significant settings for greenhouse gas (GHG) production and emissions, yet their roles in GHG cycling are often diminished in comparison to terrestrial and anthropogenic sources. While regional GHG budgets have often excluded inputs from freshwater, rivers and streams actively transform the carbon and nitrogen cycles, producing and emitting GHGs at a disproportionately large scale relative to the area they occupy. Thus, it is critical to understand freshwater GHG dynamics and incorporate this understanding into modern GHG budgets. Nitrous oxide (N_2O), an ozone-depleting GHG that is 273 times stronger than carbon dioxide (CO_2), may have a globally significant flux from inland waters, yet its sources and behavior are poorly constrained. Therefore, this study observed N_2O dynamics in Harvard Forest's Arthur Brook (an upland, forested stream) to investigate temporal and hydrological patterns in N_2O variation and further our understanding of which biogeochemical processes drive N_2O production. We deployed equipment which continuously measured N_2O, CO_2, dissolved oxygen (DO), temperature, pH, conductivity, and discharge at Arthur Brook throughout June and July 2026. We aimed to further our understanding of N_2O dynamics by constructing a time series of each parameter, then visually and quantitatively analyzing correlations between them. Preliminary findings show that N_2O varies diurnally with DO dominantly influencing N_2O production. These patterns help us hypothesize which in-stream microbial or abiotic pathways (i.e. incomplete denitrification, nitrification) are responsible for N_2O production in temperate, forested streams. Understanding which processes produce N_2O and under which conditions these processes are favored is crucial for developing accurate GHG budgets, which guide regional GHG emission targets and environmental policy.



Ethan Liao

Harvard University

Mentors: John Paul Hellenbrand and Andrew Reinmann

Quantifying Differential Impacts of Forest Edge Influence on Autotrophic and Heterotrophic Respiration

Forest fragmentation is a prevalent issue both globally and in temperate forests of the Northeast US, forming edges with warmer, drier, and windier microclimates that alter carbon storage potential. In particular, soil respiration, the largest terrestrial to atmospheric carbon flux, varies along edge-to-interior gradients. However, current literature on forest edge soil respiration often overlooks the distinct responses of autotrophic and heterotrophic respiration. While autotrophic respiration by plant roots releases recently sequestered carbon, heterotrophic respiration by microbes releases carbon from soil organic matter, potentially reducing long-term carbon storage. Using Harvard Forest's CLimate Interactions with Forest Fragmentation (CLIFF) experiment, I explored both components of soil respiration in a temperate forest edge-to-interior gradient under drought, ambient, and irrigated conditions. I measured soil respiration across six plots using a LI-COR 8100/7810 alongside soil moisture and soil temperature taken by handheld probes. At 0m and 30m from the edge, I measured untrenched collars for total soil respiration and trenched collars for heterotrophic soil respiration. I hypothesized that (1) changes in soil respiration along the edge-to-interior gradient would be driven by changes in heterotrophic respiration and (2) the ambient plot would have the greatest percent heterotrophic respiration. Across all treatments, total and heterotrophic soil respiration both declined from the forest interior to the edge, with the strongest responses in the irrigated plots and weakest responses in the drought plots. I also modeled Q_{10} values, a measure of temperature sensitivity, finding that 0m collars had lower Q_{10}s than 30m collars and trenched collars had slightly lower Q_{10}s than their untrenched counterparts. These findings on heterotrophic and autotrophic soil respiration at forest edges can help make carbon storage models more precise and dynamic as they continually include data on how each kind of respiration responds to different conditions such as those tested at CLIFF.

Gianna Mantegna

Maryville College

Mentors: Lucy Lee and Josh Plisinski

A Look Back at Looking Forward: A Reflection on the New England Lanscape Futures Models

Quantifying rates of land use and land cover change matters because of its far-reaching effects on biodiversity loss and climate change. The New England Landscape Futures Project (NELF) brought together researchers as well as land use and conservation practitioners to co-develop scenarios of potential futures in New England based on different visions of how land use might change from 2010 to 2060. Since we now have land-use data from 2020, this study reviews the differences between the 2020 NELF simulations and the 2020 observed data. I investigated the extent to which observed changes in specifically development and conservation from 2010 to 2020 align with the NELF scenarios by using total disagreement, a local Moran's I test, and the absolute difference between the simulated maps and observed data. I found that the "Go It Alone" scenario matched closest for rates and placement of conservation, whereas the "Connected Communities" scenario was closer in matching placement of development. It was difficult comparing new development because of differences in classification in the land use database for NELF compared to the classification system I used. Additionally, the NELF scenarios overestimated the correct amount of conservation due to large sections of Maine receiving conservation in the reference period of 1990-2010, but much less between 2010-2020. This study shows that development has become more clustered and that there is less conservation compared to recent trends.

Evelyn Munoz

University of Arizona

Mentors: Sidnee Everhart and Bob Fahey

Assessing the Influence of Precipitation Manipulation on Canopy Phenology in a Forest Edge Manipulation Experiment

Temperate forest edges are underrepresented in studies of ecosystem response to global stressors despite their growing ecological prominence driven by increasing fragmentation and land use change. Tree phenology is an important aspect of ecosystem dynamics that can track responses to global change drivers like increased drought severity. The effects of fragmentation, edge creation, and flash events, like drought, are currently being studied at the Harvard Forest Climate Interactions with Forest Fragmentation (CLIFF) experiment. CLIFF was formed as a new edge from an intact forest patch in 2023, and it encompasses three treatments, precipitation removal, reference, and precipitation addition. We investigated the interactive effects of edge development and precipitation manipulation by asking: How does precipitation manipulation at a forest edge affect crown density and vitality, measured in terms of leaf density and greenness? We approached this question by analyzing repeat digital photograph series of northern red oak (*Quercus rubra*), red maple (*Acer rubrum*), and black birch (*Betula lenta*) using the *phenopix* image analysis R package. Greenness was calculated through the Green Chromatic Coordinate (GCC), a vegetation index extracted from an area of interest (AOI) based on green light reflected relative to total red, green, blue brightness. We hypothesized that crown density and greenness would decrease more prominently from early season peak in the precipitation removal plots relative to the reference and precipitation addition plots. Our findings suggest some effect of the experimental precipitation manipulation on tree phenological patterns, but also substantial variation across species and among individuals within a species. This study contributes to understanding forest functioning and tree response to stress in temperate edge forests compared to interior forests. Tracking tree and forest responses in edge forest environments is crucial as both extreme weather events and fragmentation increase at an unprecedented rate.

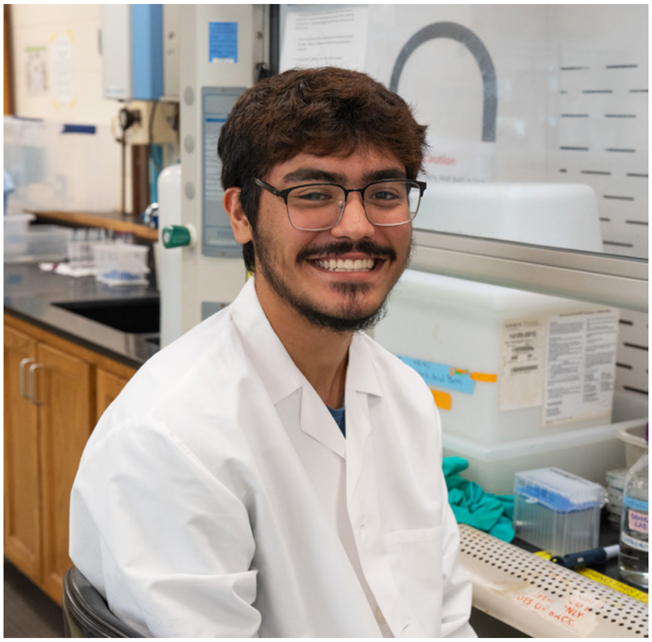
Elyse Nevins

North Carolina State University

Mentors: Junior Burks, Katherine Harpenau, and S. Joseph Tumber-Dávila

Comparative analysis of *Nyssa sylvatica* root traits and morphology on a depth gradient within the Black Gum Swamp

Fine roots are critical to essential wetland processes, including nutrient cycling and soil aeration[e1] , and may provide important context to above-ground functioning. Yet, our understanding of root trait adaptation in wetland specialists, like that of *Nyssa sylvatica*, is limited. This study investigated fine root trait variance across three primary tree species found within the Harvard Forest Black Gum Swamp along a soil depth gradient. I hypothesized that *N. sylvatica* roots would display more wetland-adapted traits, specifically those of wider root diameter, shorter specific root lengths, higher levels of carbon-to-nitrogen, and the presence of aerenchyma, than that of the generalist species *Acer rubrum* and *Tsuga canadensis* across the soil depth profile. Given the swamp's dominant tree species are *N. sylvatica*, *A. rubrum*, and *T. canadensis*, I took ten soil cores using a hemispheric peat corer by each target tree species, totaling 30 cores up to a maximum depth of 1 meter. I extracted fine roots in 10 cm increments with depth and identified them to the species level. I then measured fine root traits using RhizoVision and statistically analyzed the resulting data in RStudio. The specialist species, *N. sylvatica*, maintained distinctly different root system dynamics compared to generalist species, likely associated with its success in the saturated ecosystem of the Black Gum Swamp. *N. sylvatica* also displayed the presence of aerenchyma, a key feature pertaining to improved function in anaerobic soils, as well as wider diameters and rooting depths. These findings ultimately improve knowledge of wetland adapted plant species and their root systems and provide additional insight into their role in ecosystem function.



Sobhan Nickzad

Willaim Patterson University

Mentor: Audrey Barker Plotkin

Non-Structural Carbohydrate Dynamics Under Forest Fragmentation and Altered Water Availability

Forests act as critical global carbon sinks, yet accelerating fragmentation and climate-induced drought threaten forest carbon sequestration. Non-structural carbohydrates (NSCs), primarily soluble sugars and starches, serve as vital physiological buffers for trees when stress limits carbon fixation. This project investigates how carbon storage changes under the single and interactive effects of forest fragmentation and reduced or increased water availability. Further, we are interested in whether carbon allocation shifts between storage or growth under these stressors. We hypothesize that NSC levels will be highest in trees closer to the edge and with more water, as light and water drive photosynthesis. We leveraged the Climate Interactions and Forest Fragmentation (CLIFF) experiment, which combines a forest edge treatment with a natural soil moisture gradient that is amplified through seasonal drought and irrigation treatments. We investigated stem wood cores from 32 red oak (*Quercus rubra*) trees across the initial 3 years of the CLIFF experiment. We ground these samples to a fine powder, then extracted the sugars with hot ethanol, and digested a starch hydrolysate via a two-step enzymatic digestion. We colorimetrically quantified soluble sugar and starch hydrolysate fractions using spectrophotometry and analyzed via linear regression modeling in R. Preliminary results suggest that there is a trend of increasing starch with increasing soil moisture along the natural soil moisture gradient. By quantifying how NSC storage responds to exposed edge microclimates and severe drought, this research provides information needed to accurately project whether fragmented forests will persist as global carbon sinks.

Gabriella Powell

University of Massachuestts Lowell

Mentors: Evonne Aguirre and Joy Winbourne

An Intersensory Comparison Study: differential wounding response & sensor performance of different sap flow sensor designs

Sap flow sensors are widely used to quantify whole plant water use, responses to environmental conditions and modeling transpiration rates. Sap flow sensors are instruments that measure the movement of water through a tree's xylem, however the installation of sap flow sensors requires a probe insertion that triggers physiological responses that can affect sap flow measurements. This wounding response must be accounted for when generating whole plant rates of transpiration. The time it takes for wounding tissue to develop and stabilize may differ among sap flow sensors, I will compare three sensors, the ICT, JS5 and the RSF. I ask the question 1) How does commercially available sensor (ICT) compare to the DIY version of the sensor (JS5)? 2) How do different sap flow sensor systems vary in the wound response they induce? I hypothesized that H1: The JS5 and ICT sensors provide comparable values despite small differences in probe design and datalogger configuration. H2: The ICT and JS5 will have a similar wound response (both in timing and magnitude of impact on heat pulse velocity), compared to the RSF probe. I will install all three sap flow sensors into one red oak and one red maple tree, and during that time I will collect data from each sensor, assess internal wounding by injecting dye below each probe site and then taking a core sample above the wound. The core will be examined to see how the dye moved through the xylem and that will allow me to detect whether any vascular connections were disrupted. I will compare sensor data, and dye movement between the oak and maple to evaluate how sensor design and species influence wounding. By comparing the performance of two low cost, DIY sensors (the JS5 and RSF) with a more established commercial system (ICT), this project evaluates whether inexpensive alternatives can provide reliable sap flow measurements.

Kyla Ritchie

University of North Carolina at Chapel Hill

Mentors: Alaina Bisson and Benton Taylor

Understanding influences of mycorrhizal type vs. leaf litter quality on nitrogen cycling in temperate forests

Trees in temperate forests play a significant role in global nutrient cycling through the deposition of nitrogen (N) from fallen leaves, which are broken down, mineralized, and nitrified by soil microbes and taken back up through tree roots, often with the help of mycorrhizal symbionts. Ectomycorrhizal (EcM) and arbuscular mycorrhizal (AM) fungi are the two most prolific types of mycorrhizal fungi in temperate forests, with most tree species associating with one or the other. Differing nutrient acquisition strategies between EcM and AM fungi, as well as differing leaf litter quality of trees associating with EcM or AM, are thought to affect patterns where EcM dominated forest stands accumulate more organic N, while AM stands accumulate more inorganic N. However, it is not known whether the quality of the leaf litter or the type of mycorrhizal symbiont is what is causing these differing nutrient economies. In this study I am asking, how do leaf litter and mycorrhizal type influence N mineralization and nitrification in temperate forest systems? Groups of plots were set up in AM and EcM dominated stands and leaf litter layers in those plots were taken up and replaced to create match and mismatch leaf litter treatments, a disturbance control, and a control plot where leaf litter was left as is. Ammonium and nitrate levels in the soil were measured at two timepoints, the second being after a 30 day incubation period, to calculate rates of mineralization and nitrification in different treatments. Variance among treatments was assessed. I hypothesized that mycorrhizal type and leaf litter type would have an interactive effect where rates of N cycling would be altered by both treatments. Results from this study could help provide nuance to forest elemental cycling frameworks, especially when trying to predict how species shifts with climate change will affect elemental cycling and overall forest response to global change.

Eve Speredelozzi

University of Massachusetts Amherst

Mentors: Marissa Hanley, Halina Saydam, and Hannah Naughton

Hyphal Response to Hurricane Disturbance Microtopography in a Temperate Forest

Temperate forests have a large impact on greenhouse gas cycling, making up 16% of land area on Earth and 34% of global carbon sinks. As climate change increases the frequency and intensity of extreme weather events, natural disasters such as hurricanes may become more commonplace in temperate forests, disrupting ecosystems and changing landscapes. Hurricane disturbances create new microtopography on the forest floor consisting of pits and mounds formed by the upturned root system. These variations in microtopography may have large effects on the soil ecosystem and its nutrient cycling processes. My project looks specifically at mycorrhizal fungi populations, which influence nutrient cycling by: promoting tree growth which stores carbon in woody biomass, breaking down decaying plant litter to be stored in the soil long-term as soil organic matter, and transforming nutrients into microbially accessible forms. To explore this dynamic between fungal hyphae and hurricane associated microtopography, soil sampling was conducted at the Harvard Forest at the Hurricane Manipulation Experiment plot where in 1990, ~65% of standing tree biomass was felled. Mycelium was extracted from soil samples inside of pit formations as well as a flat transect, and hyphal length was measured as a proxy for fungal biomass in both organic and mineral soil horizons. I hypothesize that greater hyphal length occurs in pits compared to flat transect due to pits providing a favorable habitat for mycorrhizal hyphae, with higher soil moisture and greater accumulation of plant material available for decomposition. Preliminary findings suggest that hurricane disturbances and related microtopography are not likely to drive differences in mycorrhizal biomass. Future studies may look into differences in fungal species or traits and how they impact carbon storage in pits versus flat flat transects.

Sophia Rasic Stagnar

State University of New York at New Paltz

Mentors: John Paul Hellenbrand and Andrew Reinmann

Leaf litter quantity and microclimate conditions in temperate forests drive rates of soil respiration across an edge to interior gradient

Temperate forests are the most fragmented biome, where 23% are within 30m of an anthropogenic edge. They are also the largest terrestrial carbon sink, accounting for one third of all C sequestration. Recent research has shown that forests in proximity to non-forest landcover have altered carbon cycles, suggesting that fragmentation via edge effects could jeopardize the stability and magnitude of this vital C sink. Soil respiration fluxes are the largest C flux to the atmosphere within terrestrial ecosystems and therefore are a useful measure to study changes in C cycling. However, our understanding of edge impacts on soil respiration are derived from structurally mature forest edges, which omit a crucial window of immature forest development following edge formation. We aim to determine the mechanisms driving soil C fluxes across edge-influenced forests by quantifying the impacts of a leaf litter manipulation experiment at structurally immature and mature forest edges. We placed a total of 48 soil collars across four 15m x 30m plots at two ‘young’ edges located at the Climate Interactions with Forest Fragmentation (CLIFF) site, and two ‘old’ edges located at a site fragmented more than 60 years ago in the Harvard Forest. Within each site, six collars were installed at 0m and at 30m from the forest edge. Collars ranged across three leaf litter treatments: ambient, addition, and removal. Respiration measurements were collected on a biweekly basis from June to July. Through this leaf litter manipulation experiment, we aim to identify the mechanisms that drive soil respiration within edge-influenced forests across time.

Tom Weber

Colorado State University

Mentor: Laura Ostrowsky

Intracanopy Plasticity in Leaf Morphological Traits Across Species of Eastern Deciduous Trees

While the plant kingdom exhibits some of the highest phenotypic plasticity in nature, their ability to acclimate to the rising temperatures and changing precipitation patterns of the Anthropocene is not fully understood. For deciduous tree species, an area of interest has been intracanopy leaf plasticity, or the multiple phenotypes of leaf form and function a single genotype can express in response to the environment. Intracanopy plasticity significantly contributes to overall individual performance by influencing light penetration, water use efficiency, and the carbon balance of leaves, yet it remains only partially documented across eastern species in situ. Moreover, there is little knowledge on the maladaptive potential and the role of intracanopy leaf plasticity in forest succession to inform predictions of species composition. To characterize the magnitude and direction of intracanopy leaf plasticity, we used a canopy air lift to sample leaves at normalized height intervals for 20 trees across 5 species (*Quercus rubra, Acer saccharum, Acer rubrum, Prunus serotina, Betula lenta*). To account for the environment, microclimate sensors were placed in the top, middle, and bottom portions of each individual's crown and solar irradiance was measured directly above the sites of leaf collection. I hypothesized that intracanopy plasticity would be higher in shade tolerant species, since the developmental pathways that allow for shade tolerant leaves during juvenile stages remain available in mature crowns. Preliminary results from the measurements of leaf scans show strong increases in leaf thickness and leaf mass per area (g/m^2) as crown height increases. Additionally, there is a strong qualitative increase in minor vein density and thickness for *Acer saccharum*, and a stark difference in minor vein architecture between *Acer* sp. and *Prunus serotina*. Further exploration in estimating the full range of intracanopy leaf plasticity could help our understanding of species ranges and life history strategies of eastern deciduous trees.

Garrik Wilkins

Mount Wachusett Community College

Mentors: Junior Burks, Katherine Harpenau, and S. Joseph Tumber-Dávila

Root biomass and morphology changes across a forest edge gradient with precipitation manipulation

Increased forest fragmentation and intensified precipitation are amplifying ecosystem stress in northeastern United States temperate forests. However, we currently have a limited understanding of the belowground impacts of land-use change and climate stressors on belowground tree dynamics. To address this, I explored how root biomass and morphology of *Acer rubrum*, *Quercus rubra*, and *Pinus strobus* change with time across a land cover gradient (forest clearing to interior) as well as with a precipitation manipulation treatment (drought and water addition). I hypothesized: 1) Root biomass *Quercus rubra* as the dominant species present at the forest edge and concentrated at deeper depths to support enhanced groundwater acquisition; 2) Root traits will vary across species according to the general differences in their rooting strategies, with increased variability reflecting plasticity or adaptation to water stress and edge effects over time. The Climate Interactions with Forest Fragmentation (CLIFF) experiment at Harvard Forest provides insight into the potential implications of present changes in land use and environmental stressors on northeastern United States forests. At the CLIFF site, I collected soil cores to extract roots from and measured the ratio of the species' biomass and morphological root traits (branching intensity, specific root length, root density, root tip number, etc.). These root data show the observable belowground dynamics at each depth increment, across the land cover gradient, amidst the water manipulation treatments (drought, control, and addition), at varying depth increments, and analyzed across multiple time points (June/July 2024; June 2025; October 2025). These findings provide key information on the changes temperate forest systems experience through time and elucidate the changes in forest productivity with ecological stress.

Luna Yin

Harvard University

Mentors: Nik Bates-Haus and Danelle Laflower

Rough Around The Edges: Investigating Increased Biomass at Temperate Forest Edges

Around the globe, large contiguous forests are being broken up into smaller patches by newly constructed roads and fields flattened for agriculture. Today, 20% of all forests are located within 100 meters of a non-forest edge. Compared to forest interiors, trees near edges receive more wind and sunlight exposure as well as altered nutrient deposition. However, common biomass models based on forest interior data do not account for these conditions. In 2015, studies found that carbon stock models overestimated the biomass of global tropical forests by 10% because they did not account for biomass reductions near forest edges. While research on tropical forests has generally found lower biomass near edges, the impact of edges on temperate broadleaf forests is still being debated. Studies using satellite data to estimate biomass have pointed to a decrease in biomass near temperate forest edges, while field studies indicated the opposite trend. The goal of my study is to clarify the impact of edge conditions on temperate forest biomass and investigate how biomass estimates based on remote sensing can fail to account for edge effects. I measured trees at 63 forest edge plots located across central Massachusetts and found that, on average, biomass density at edges was significantly higher than forest interiors. I also developed a machine learning model that estimates forest biomass based on airborne LiDAR measurements of canopy height and trained it on forest interior data. When tested on plots at forest edges, the model underestimated biomass by around 10%. These findings reveal a biomass enhancement at forest edges that can be missed by models reliant on remote sensing and calibrated with forest interior data. As such, this study plays a key role in informing future research on temperate forest edge effects and developments towards improved, edge-aware forest models for carbon capacity calculations.

2026 Harvard Forest Personnel

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Zima, Tim - Summer Program Chef

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