Harvard Forest

Summer Research Program in Ecology

30th Annual Student Symposium

August 3, 2023

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cover photo: Abigayl Novak

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 2023 Summer Research Program

The Harvard Forest Summer Research Program in Ecology brings a diverse group of students to receive training in scientific investigation and experience in long-term ecological research. Audrey Barker Plotkin directed the 2023 program with the help of program coordinator Ben Goulet-Scott and program assistant (proctor) Abigayl Novak. 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 culminates in the Annual Student Symposium held on August 3, 2023, where students present their research findings to an audience of scientists, peers, and family.

Funding for the 2023 Summer Research Program

In 2023, the Harvard Forest Summer Research Program in Ecology was supported by the following organizations:

National Science Foundation
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

2023 Summer Research Program Students and Mentors

2023 Summer Research Program Students, Proctor, and Coordinator

2023 Summer Research Program Seminars

June 1	Rinku Roy Chowdhury, *Clark University*
June 15	Adrian Carper, *University of Colorado Boulder*
June 22	Lucy Hutyra, *Boston University & Harvard*
June 29	Kristin Godfrey, *National Ecological Observatory Network (NEON)*
July 13	Dan Johnson, *University of Florida*
July 27	Laura Figueroa, *University of Massachusetts Amherst*

2023 Summer Research Program Workshops & Activities

May 22	Opening DEIB Conversation. *Neenah Estrella-Luna, StarLuna Consulting*
May 23	Gender Equity & Diversity in Community. *Rachel DiBella, Harvard University*
May 25 & June 13	Working with Data and R. *Jackie Matthes, Harvard Forest*
May 30	Field Navigation. *Audrey Barker-Plotkin & Danelle Laflower, Harvard Forest*
June 6	Writing and Reviewing Research Proposals. *Ben Goulet-Scott, Harvard Forest*
June 8	Introduction to Environmental Graduate Programs at Harvard
June 8	Responsible Conduct in Research. *Logan McCarty, Harvard University*
June 17	Visit from Harvard Environmental Summer Programs
June 20	Science Communication. *Clarisse Hart, Harvard Forest*
June 27	Data Archiving. *Audrey Barker-Plotkin* & *Emery Boose, Harvard Forest*
July 6	Introducing the LTER Network. *LTER sites*
July 8	Arnold Arboretum with Harvard Environmental Summer Programs
July 11	Panel Discussion on Work/Life Balance. *Lucy Lee, Ann Lewis, & Neil Pederson, Harvard Forest*
July 18	Presenting Your Research. *Savanna Brown, University of Connecticut*
July 20	Service Day at Nipmuc Land Project
July 25	Career Panel. *Mushtaaq Ali, American Forests; Aja DeCoteau, Columbia River Inter-Tribal Fish Commission; Kate Parson, USDA Natural Resources Conservation Service; Aaron Weiskittel, University of Maine*

30th Annual Harvard Forest Student Symposium Schedule
August 3, 2023

9:00am **Opening Remarks**

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

Fernando Miguelena Blackaller *University of Florida*	Validation of SIPNET Model's Soil Respiration Forecasts using observations from Harvard Forest	21
Alassane Sow *Michigan State University*	Testing whether long-term soil collars are representative of stand-level soil respiration	24
Hannah Burrows *Harvard University*	Investigating Drivers of Tree-Stem Methane Emissions in Wetland and Upland Environments	12
Aerial Kruger *Portland State University*	The Flowing Frontier: Gaining Insight into the Dynamic Nature of Streams at Harvard Forest	18
Maegan Beckage *University of Vermont*	Modeling the impacts of climate change, altered disturbance regimes, and forest management on the forest carbon stocks of Northern New England forests	9

BREAK

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

Ainhoa Bezerra-Gastesi *Pomona College*	The Role of *Odocoileus virginianus* and *Alces alces* Browsing on Undisturbed Temperate Forests	10
Katherine Almquist *Skidmore College*	Impact of mycorrhizal crowding patterns on soil nutrient acquisition	7
Gena Blumencwejg *Colorado College*	Effects of a Warming Temperature on Microbial Evolution	11
*Anisa Robinson *University of Pennsylvania*	Going Underground: Root Exudation in Response to Soil Warming, Nitrogen Addition, and Tree-Fungal Association	22
*Isa Gooijer *Harvard University*	Going Underground: Effects of Soil Warming and Nitrogen Addition on Root Exudation Rates of Arbuscular and Ectomycorrhizal Associating Trees in Harvard Forest	14

12:00pm **LUNCH**

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

Isabella Stone *Willamette University*	Seedling persistence and passage in a hemlock-hardwood forest: filling in the gaps	25

Student Talks - Session III (cont.)

Arianne Lopez del Rincon *University of Florida*	Wood density differences across red oak and maple branches at Harvard Forest	19
Helen Tarrau *Miami Dade College*	Comparing survival of New England tree species based on life stage	26
*Anagali (Shace) Duncan *Stanford University*	Investigating the impacts of Japanese Knotweed on Black Elderberry	13
*Charitie Ropati *Columbia University*	Restoration of *Sambucus nigra* in Relation to Introduced Species on the Nipmuc Reservation & the Value of Traditional Ecological Knowledge	23

BREAK

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

Ben Baraga *Pomona College*	Projecting Long-Term Carbon Storage in Forests Across Distinct Modeling Tools: How LANDIS-II Can Assist in Carbon Offset Policy	8
Isa Kazen *University of Texas at Austin*	Characterizing Uncertainty in Ecological Forecasts between Plant Functional Types	16
Cheyanne Macagno *California Polytechnic State University, San Luis Obispo*	Investigating survival and mortality rates of first year, woody stem seedlings	20
Carlos Zuñiga *California State University, Dominguez Hills*	The Aboveground Response in a New Forest Edge	27
Katie Knight *Wellesley College*	Land Use History Exerts Long Term Effects on Tree Community Composition	17
Sam Jurado *Cornell University*	Analysis of Temperate Forest Methane Dynamics under Soil Moisture Limited Evapotranspiration Regimes	15

4:00pm **Closing Remarks**

5:30pm **Community BBQ**

*co-presenting

Katherine Almquist
Skidmore College

Mentors: Carina Berlingeri and Benton Taylor

Impact of mycorrhizal crowding patterns on soil nutrient acquisition

Mycorrhizal fungi are the extension cords of the underground soil ecosystem. As an extension cord lengthens the flow of power, allowing one to be stationary, mycorrhizal fungi act as an elongation of the roots of plants by forming a symbiotic relationship with them. The two primary types of mycorrhizal fungi: arbuscular (AM) and ectomycorrhizae (EM), both have an extracellular hyphal network used for nutrient foraging, but there are still vast differences among them. While AM and EM generally forage for their preferred form of nutrients, competition is still present and a driving factor impacting underground ecosystem dynamics. We hypothesize that trees surrounded by a different mycorrhizal type, hetero-mycorrhizal crowding (AM-EM), will increase competition, and competition between trees surrounded by the same mycorrhizal type, con-mycorrhizal crowding (AM-AM) and (EM-EM), will decrease competition. We also expect colonization rates of AM and EM fungi to decrease as competition for primary soil nutrients (nitrogen and phosphorus) decreases. We propose an observational field experiment to explore these hypotheses, collecting data on 40 trees from 20-20-meter plots chosen from the 35-hectare ForestGeo plot at Harvard Forest in Petersham, MA. Each tree was selected for root and soil collection based on tree type, *Acer rubrum* or *Quercus rubra*, and type of mycorrhizal colonization, arbuscular (AM) or ectomycorrhizae (EM). Mycorrhizal presence is expected to impact soil pH, carbon-to-nitrogen ratio, and provide insight into the impact of mycorrhizal interactions on soil nutrient acquisition strategies. Studying the crowding index and belowground nutrient acquisition strategies is fundamental in explaining the importance of mycorrhizal fungi and their impact on changing global ecosystems.

Ben Baraga

Pomona College

Mentors: S. Joseph Tumber-Dávila, Danelle Laflower, and Jonathan Thompson

Projecting Long-Term Carbon Storage in Forests Across Distinct Modeling Tools: How LANDIS-II Can Assist in Carbon Offset Policy

Forest carbon offset programs, both voluntary and regulatory, are being used as a widely adopted natural climate solution. Regulatory carbon offset programs like the one from the California Air Resource Board (CARB) would benefit from additional tools to vet carbon storage estimates before approving prospective applicants. We compared estimates of forest carbon dynamics from the default tool from the US Forest Service, Forest Vegetation Service (FVS), to those from the LANDIS-II forest landscape model, specifically to find out whether, given a specific cohort of tree stands with various management prescriptions, LANDIS-II and FVS yield similar estimates of long-term standing forest carbon. We ran nine distinct land management prescriptions across forest inventory plots in northern New England using FVS, then converted FVS output into LANDIS-ready inputs. Our findings indicate that FIA data is not inherently translatable between FVS and LANDIS, but our research has opened multiple paths forward. The main reason for the incompatibility was due to the difficulty of replicating FVS initial communities; the complex and often obscure ways FIA data was manipulated "under the hood" of FVS made a full translation impossible in such a short timeframe. This does not take away from our achievements this summer, as we nevertheless made great progress toward our goal by devising a replicable step-by-step translation process, and creating numerous 1:1 comparisons of management prescriptions and carbon storage graphs across the models. Next steps will involve creating simpler tree stands from scratch to calibrate the two models, then slowly ramping up complexity from there. This project has added valuable literature on a novel solution to the well-documented issue that is CARB's over-crediting of offset projects.

Maegan Elise Beckage

University of Vermont

Mentors: S. Joseph Tumber-Dávila, Danelle Laflower, and Jonathan Thompson

Modeling the impacts of climate change, altered disturbance regimes, and forest management on the forest carbon stocks of Northern New England forests

Forests play a critical role in climate change mitigation because they sequester and store carbon. Forest management can impact the amount of carbon stored in wood either as live forest biomass or in harvested wood products. In this project I sought to understand the impacts of forest management (with and without climate change) on forest carbon, how climate change and increased disturbances affect the amount of carbon stored in forests, and what land management practices increase resilience to climate change and forest carbon storage. I did this by utilizing the LANDIS-II landscape model. LANDIS simulates change in forests as a function of growth and succession. It models how these drivers are influenced by multiple environmental factors such as wind, fire, insects, land management, etc. All simulations were conducted on a 36 ha landscape that represents the northern hardwood forests of Essex, Vermont. This location was chosen because of its range in tree species with different climate resistant abilities. I tested different scenarios of climate change and increased ecological disturbances (with the expectation that climate change will alter and exacerbate disturbance regimes). Climate change is implemented in the model as elevated temperature and CO_2 level at a rate that reflects observational data. I used four different management prescriptions (uneven harvest, shelterwood harvest, climate adaptability harvest, and grow only) in this experiment. I compared the dynamics of tree species' biomass in each of the forest plots under each of the management prescriptions as well as the carbon levels. I found that the climate change scenario proved to increase the biomass of the forest, however the composition of the species in the forest had changed. Climate change combined with increased disturbances led to a slightly lower level of biomass in comparison to a static environment. The climate adaptability management prescription had the smallest harvest, thus retaining the most biomass and carbon storage on the landscape.

Ainhoa Bezerra-Gastesi
Pomona College

Mentors: Audrey Barker Plotkin and Greta VanScoy

The Role of *Odocoileus virginianus* and *Alces alces* Browsing on Undisturbed Temperate Forests

Tree seedlings are key in understanding the health of a forest. It is important to understand forest composition through seedlings to be able to make informed decisions on conservation efforts based on different natural pressures. One natural pressure that seedlings face are white-tailed deer (*Odocoileus virginianus*) and eastern moose (*Alces alces*) browsing. Deer and moose browsing can completely change seedling abundance and species composition, in turn changing future forest composition. I investigated the impacts of deer and moose browsing, collectively and individually, on forest structure and composition in an experiment at the Harvard Forest. In 2011, four 20x20m fenced sites were established in unharvested regions of the Harvard Forest, two in oak-dominated regions, and two in hemlock-dominated regions. At each site, there are three treatments: one fenced treatment where neither moose nor deer can enter (full exclosure), one fenced treatment that only allows for deer to enter (partial exclosure), and one unfenced control exclosure. I tested for differences in the treatments in seedling height, density, and species and found that there was significantly less browsing occurring on the seedlings in the full exclosure than the partial or control exclosures. I also found that there were significantly more trees over 2.5cm in diameter between 2011 and 2023 in the full exclosure plots. These results suggest that when both deer and moose have access to tree browsing they can have many different impacts on regeneration by altering tree density and seedling browsing. These data further our understanding of the effects deer and moose browsing can have on the future of temperate forests since browsing can reduce recruitment of small trees into the forest and can allow for more unpreferred browsing species to grow in the forest. Further studies can be done to see how creating exclosures around browsers' preferred species impacts their browsing habits.

Gena Blumencwejg

Colorado College

Mentor: Kristen DeAngelis

Effects of a Warming Temperature on Microbial Evolution

Climate change presents a significant environmental challenge, impacting global ecosystems and influencing evolution. Microbes play a vital role in ecosystem function and carbon cycling, making them important for predicting climate change impacts. To comprehend the effect of long-term warming on microbial evolution, understanding microbial communities' response is crucial. However, the effects of long-term warming on microbial communities remains unclear. We hypothesize that taxa in heated plots will grow more slowly when incubated at 15°C and 25°C due to limited microbial substrate availability, and that the temperature sensitivity of growth(Q_{10}) rate will show evidence of adaptation to long-term warming. Data from a 2020 quantitative stable isotope probing (qSIP) experiment(in which isotopes are incorporated into bacterial samples) using soils from Harvard Forest long-term warming plots are utilized to investigate these hypotheses. The experiment includes long-term warming, soil type, and 4 field replicates (incubated at 15°C or 25°C with ^{16}O or ^{18}O water), resulting in 64 samples with 8 density fractions each for a total of 512 samples. QIIME 2 is used to detect OTUs (operational taxonomic units, assigned at 99% sequence identity) in heated and control samples and to construct a phylogenetic tree. OTUs are then used to calculate the excess atom fraction (EAF)(which is how the incorporation of the isotope tracer is expressed) of each taxon and the EAF of plots on average (EAF_{25}/EAF_{15}). EAF is then mapped at the corresponding branch tips to account for phylogeny. Blomberg's K and Pagel's λ tests are used to assess phylogenetic signals of EAF and the change in EAF. To investigate the second hypothesis, the temperature sensitivity of growth (Q_{10}), is calculated for individual taxa through separate and combined OTU analyses. We expect to find that in warmed plots, the overall growth rates will be slower than control plots. We also expect that Q_{10} is phylogenetically conserved, and that Q_{10} will be greater in heated than control plots. These results will help in predicting and mitigating climate change effects.

Hannah Burrows
Harvard University

Mentors: Jonathan Gewirtzman and Jackie Matthes

Investigating Drivers of Tree-Stem Methane Emissions in Wetland and Upland Environments

Despite being relatively less abundant in the atmosphere, methane (CH_4) is a potent greenhouse gas, trapping significantly more heat than carbon dioxide (CO_2). Alongside industrial emissions, natural landscapes, namely wetland environments, account for roughly half of methane emissions to the atmosphere. The anoxic soil in wetland environments fosters methane generating microbes–methanogens–while upland soils foster methane consuming microbes–methanotrophs. However, in both wetland and upland environments, trees have been found to emit varying amounts of methane from their stems with the drivers behind these processes largely unknown. By studying the patterns behind this phenomenon, we are able to better understand methane's role in our forest's ability to sequester carbon. Thus, we sought to investigate tree-stem methane emissions across four species (*Nyssa sylvatica, Acer Rubrum, Tsuga canadensis,* and *Quercus rubra*), at two sites, and over the course of a month. We monitored 60 different trees at several points over the course of a month as the soil moisture and weather changed. In alignment with prior research, wetland trees acted like a conduit for methane generated in their soils, the 30 wetland trees emitted a median methane flux 4 times greater than the 30 upland trees. We found that black gum trees (*Nyssa sylvatica*) had a mean methane flux nearly 30 times higher than all the other trees. This supports the idea of species-specific traits, such as susceptibility to rot and photosynthetic rate, also leading to higher methane flux rates. However, each site and species contained a wide range of methane emission rates–including near zero flux. These results illustrate the variability among tree-stem methane emissions and the necessity for future study.

Anagali (Shace) Duncan

Stanford University

Mentors: Clarisse Hart, Nia Holley, Meg Graham MacLean, and Danielle Ignace

Investigating the impacts of Japanese Knotweed on Black Elderberry

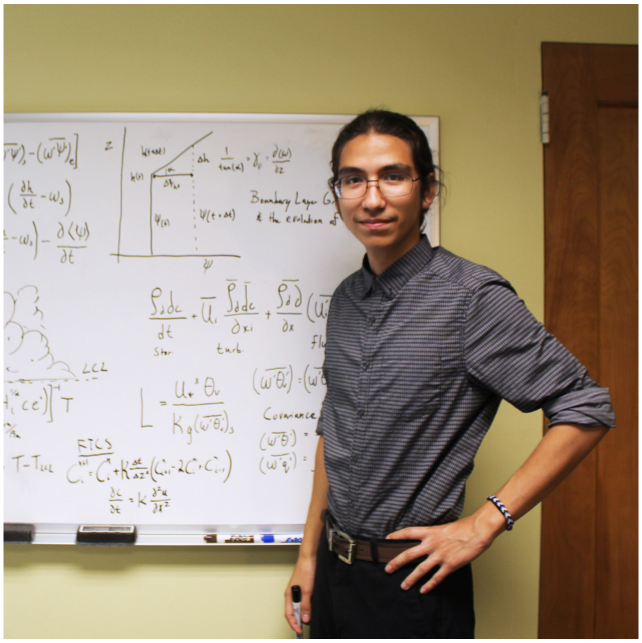
The colonization of the United States has profoundly affected its plants and ecosystems, leading to significant impacts on native plant species. With the arrival of European settlers, vast areas of land were transformed through deforestation, habitat alteration, and the introduction of non-native species. Our work with the Nipmuc people, the Indigenous tribe whose territory stretches throughout western and central Massachusetts, and south to Connecticut, has made it clear that two introduced species are among most pervasive and detrimental on the land they steward. One of these species is *Fallopia japonica* (Japanese knotweed). In our research project, we aim to investigate the impacts of planting a culturally important native plant species, Black Elderberry (*Sambucus nigra*), in an area of tribal land where introduced species have recently been manually removed. We set up 5 pairs of meter-square plots, half with an Elderberry sapling planted in the middle of the plot and half acting as a control with no Elderberry sapling. We then analyzed how knotweed and other plants returned in these plots. We discovered that the growing patterns of the introduced species were different based on both Elderberry presence and potentially the position of the plots relative to other environmental factors (e.g., a stream and tree). Additionally, Japanese knotweed tended to grow more frequently and taller in the Elderberry plots, contrary to our initial hypotheses. We believe that the relationship between the Japanese knotweed and the Black Elderberry are deeply dependent on one another, with the Japanese knotweed using its resources to try and choke out the Elderberry with increased foliage. By qualitatively comparing this study area to a plot with previously established three year old Elderberry plants nearby, we see that less knotweed was sprouting and we hypothesize that is because the competition for sunlight is eventually won by the larger elderberry.

Isa Gooijer
Harvard University

Mentors: Nikhil Chari, Thomas Muratore, and Benton Taylor

Going Underground: Effects of Soil Warming and Nitrogen Addition on Root Exudation Rates of Arbuscular and Ectomycorrhizal Associating Trees in Harvard Forest

Harvard Forest is a carbon sink. However, the question remains if it will continue to be a carbon sink as the climate changes and temperature rises. Through root exudation trees 'leak' carbon into the soil which impacts the carbon cycling of the forest. Root exudation is a mechanism that trees use to enhance their nutrient uptake (e.g., nitrogen). Trees provide carbon to soil microbes to promote mineralization which increases inorganic nitrogen availability. The tree takes up and uses this inorganic nitrogen for growth and survival. Previous research at Harvard Forest found that trees decrease their root exudation rates in response to soil warming. The strength of the response was dependent on the mycorrhizal fungi type they associate with. In Harvard Forest trees predominantly associate with either of two types of mycorrhizal fungi: ectomycorrhizal (EM) or arbuscular mycorrhizal (AM) fungi, which specialize in organic and inorganic nutrient economies, respectively. Currently, the soil is rich in organic nitrogen, but soil warming might increase the inorganic nitrogen availability. So, whereas EM associating trees thrive in the current organic nitrogen rich environment, AM associating trees might gain an advantage as inorganic nitrogen becomes more available in warmed soil. Therefore, this summer we hypothesized that the observed response is the result of a shift in nutrient economies from organic to inorganic. We collected root exudates from EM and AM associating trees from heated plots, nitrogen fertilized plots and heated+nitrogen fertilized plots to test if the effect was the result of soil warming, increased inorganic nitrogen availability or a combination of both. I anticipated the exudation rate for heated and nitrogen plots to decrease at similar rates for both types of trees (AM and EM). Our research contributes to understanding how root exudation rates of AM and EM trees are affected by climate change and how that impacts the carbon cycle.



Sam Jurado

Cornell University

Mentors: Sparkle Malone and Jackie Matthes

Analysis of Temperate Forest Methane Dynamics under Soil Moisture Limited Evapotranspiration Regimes

Methane is an important greenhouse gas that accounts for 42% of atmospheric warming since the pre-industrial period. While biogenic methane (CH_4) emissions are thought to be of a similar magnitude to anthropogenic emissions, they remain the largest source of uncertainty in the global CH_4 budget which impedes our ability to predict climate change. The methane dynamics of some environments, such as the temperate forests of the Northeastern United States (NEUS), are highly dependent on soil moisture availability. We predict that as a result of more extreme precipitation patterns, NEUS land-atmosphere interactions will increasingly fall within a soil moisture limited transitional evapotranspiration regime (SL-T) and promote positive soil moisture-precipitation feedbacks. These positive feedback loops may make NEUS soils more dependent on synoptic scale storms to provide moisture to the system. Since dry soils do not sequester methane as efficiently as moist soils, we anticipate that longer dry periods and more intense bursts of rain will limit the diffusion of methane into the soil. We employed the mixed Bowen ratio method - in which vertical concentration gradients of a target gas are multiplied by the known eddy diffusivity of a tracer gas - to calculate methane gradient fluxes for the growing season (JJAS) of the years 2022 - 2023. Evolving correlations between evaporative fraction (EF) and soil moisture were sorted into three evapotranspiration regimes: a sensible heat dominated dry regime, a transpiration dominated buffer regime, and a transitional regime leading to energy limited surface interactions. Results indicate that forest transpiration may have a major impact on land-atmosphere coupling strength that undermines the development of increasingly arid positive soil moisture-precipitation feedback loops and promotes the sequestration of methane within the buffer regime.

Isa Kazen

University of Texas at Austin

Mentors: Mike Dietze and Jackie Matthes

Characterizing Uncertainty in Ecological Forecasts between Plant Functional Types

In recent decades, the global community has widely acknowledged the ecological consequences tied to decision-making in human spheres such as industry, agriculture, and geopolitics. With this has come an increased interest in quantifying the efficiency of forests as carbon sinks. Ecological forecasting is a growing research area that has made it possible to predictively trace the terrestrial carbon cycle. Its success, however—in both creating reliable predictions and supporting improved decisional outcomes—depends on a robust understanding of uncertainty as it propagates from input to output. One source of such uncertainty for the SIPNET forecasting model arises from variability within parameters (distributions of size n=25), which differ between Plant Functional Types (PFTs). Here, we assess how the uncertainty associated with tree growth and soil respiration forecasts differs between temperate deciduous and conifer PFTs. To do this, we validated these forecasts against field measurements taken with dendrometer bands for tree growth, and a Picarro Mobile Gas Analyzer for soil respiration. Uncertainty was calculated using root mean squared error (RMSE) and mean absolute error (MAE). We then performed a sensitivity analysis of the tree growth and soil respiration forecasts to deciduous and conifer parameters. Using this information to identify the most influential parameters for each forecast and PFT, we calculated the coefficient of variation for each parameter distribution to determine its variability. Preliminary results indicate greater variability in SIPNET's conifer parameters, and we anticipate that overall uncertainty will be higher in forecasts made for coniferous PFTs, compared to forecasts made for deciduous PFTs.

Katie Knight

Wellesley College

Mentors: Audrey Barker Plotkin and Greta VanScoy

Land Use History Exerts Long Term Effects on Tree Community Composition

Harvard Forest may seem wild, but it has undergone significant transformations at the hands of humans. In the 1700s, European settlers cleared much of the original forest to make room for pasture and cultivated land, while the remaining tree patches were maintained as woodlots. Although these sites were abandoned in the late 1800s and a new generation of trees replaced the ones that were lost, the extent to which forest composition remained affected by past human activity was unclear. In order to assess whether land-use legacies fade or persist over time, I analyzed tree community composition in 42 permanent plots at Harvard Forest. The plots were established in 1937 and then re-measured in 1992, 2013, and 2023. Using multivariate analysis, I discovered that for each measurement period tree composition in plots with cultivated and pasture land use history was distinct from those with woodlot history. Furthermore it appears that pasture and cultivated tree composition is converging, albeit slowly, with woodlot composition over time. Despite this slight convergence, my findings demonstrate that Harvard Forest tree composition continues to reflect land use histories that are more than a century old.

Aerial Kruger
Portland State University

Mentor: Jackie Matthes

The Flowing Frontier: Gaining Insight into the Dynamic Nature of Streams at Harvard Forest

Harvard Forest's ecosystem is being drastically changed due to the Hemlock Woolly-Adelgid. Canopy cover becomes drastically diminished as trees are being decimated. This phenomenon also affects soil respiration, nutrient runoff, and the elevation of stream temperatures. My research involves the study of Harvard Forests streams and the disparate and interconnected relationship between the two stream systems found here: Arthur (Bigelow) brook and Nelson brook. What's fascinating is the color of Nelson brook. When observed, Nelson creek has a consistent, dark hue that resembles a cup of tea that has steeped for too long. Leaf litter and forest debris can be found along Nelson brook, but that isn't the direct source of the discoloration. The Black Gum Swamp flows into Nelson, and brings with it mucky, organic soils that have broken down and remained in the dried beds when flow rates are low. As rain falls, it washes this muck down into Nelson, giving it the color we see today. This causes Nelson creek to be fairly acidic (3.71-4.38) with high turbidity. Arthur brook is the direct opposite. With numbers falling closer to basic (4.53-5.73), this tells us that within seemingly the same ecosystem, these two streams are experiencing opposite environmental qualities. With my project, I delve into the significance of comprehending stream health and explore how water plays a pivotal role in understanding the ecology of forests and connecting ecosystems. My research aims to construct techniques aligned with Harvard Forest's broader outlook on developing forest conditions and integrity, providing lasting information for future comprehensive studies.

Arianne Lopez del Rincon

University of Florida

Mentor: Sophie Everbach

Wood density differences across red oak and maple branches at Harvard Forest

Trees direct their branches towards light openings in the forest to meet their photic needs. This cannot be done without the strategic allocation of growth resources, which can be measured as the amount of carbon used to form cell wall structures. To understand where this occurs, we measured wood density across increment and angle change sections of 10 red maple and 10 red oak branches. We chose these sections to consider the role of asymmetrical growth along one side of the pith (eccentricity) and/or the presence of tension wood (a reaction wood that forms along the upper side of angiosperm branches) in branch reorientation. Wood density estimates how much a plant invests in its wood, which may point to the parts of a branch at which growth resources like carbon are being placed. Wood density was calculated by the quotient of branch fresh volume and dry mass. A regression was run to determine whether areas of angle change show a pattern of lower or higher density. This may indicate angle change areas as centers for carbon material. We also conducted ANOVA tests to determine whether density differences can be attributed to eccentricity or tension wood. We expect to see wood density differences between above and below halves of a branch section and at areas of angle change. We also anticipate a wood density/tension wood percentage correlation by linear regression, rooted in the fact that tension wood is composed of different proportions of vessels and fibers in comparison to normal wood. If found, this can answer questions surrounding the anatomical components unique to tension wood and how they may affect wood density.

Cheyanne Macagno
California Polytechnic State University, San Luis Obispo

Mentor: Marcos Rodriguez

Investigating survival and mortality rates of first year, woody stem seedlings

Forests are large contributors to the oxygen produced on earth, the water available and important habitats for various plant and animal species, thus supporting biodiversity. In order to gain a better insight into how our forests may change in upcoming decades, we must look closer at our current seedlings to understand species composition and development over the years. The Harvard ForestGEO plot, located in Worcester County, Massachusetts (on ancestral Nipmuc land), is an ideal system to study as it is a closed canopy forest with varied habitats. For this study, we analyzed the survival rates of the most common tree species in New England forests, red maple (*Acer rubrum*), eastern hemlock (*Tsuga canadensis*), birch (*Betula* spp.), white pine (*Pinus strobus*), and oak (*Quercus* spp.). Correspondingly, we are focusing on first-year seedlings of each species. Each year the census is completed at 134 plots where we identify and tag individual seedlings to keep track of them over time. The data that was collected regarding survival and mortality helped us determine future species composition and is an important factor in how forests respond to climate change. After pooling the data from the five main species mentioned, we determined that 33% of seedlings survive their first year of sprouting, the lowest being eastern hemlock with 8% ± 0.01 survival and the highest being red maple with 46% ± 0.01 survival. We found that survivability varies between species and between years.

Fernando Miguelena Blackaller

University of Florida

Mentors: Mike Dietze and Jackie Matthes

Validation of SIPNET Model's Soil Respiration Forecasts using observations from Harvard Forest

Decades of research indicate that ongoing global climate change has been largely caused by anthropogenic effects, which can be attributed to methane and carbon dioxide emissions. Temperate forests such as the Harvard Forest, sequester immense amounts of carbon within the woody biomass and the soil. Thus, understanding the terrestrial carbon cycle is becoming increasingly important, as the components are responsible for the sequestration and flux (net movement over a specific area) of carbon. The implementation of short-term iterative forecasts allows for projections of the carbon fluxes across an ecosystem through a 35-day lead time. Compared to a centennial scale forecasts that are often used to predict long-term anthropogenic climate change, short-term forecasts can be readily validated and adjusted with concurrent data. In this study, we focused on validating the SIPNET model of soil respiration forecasts across Harvard Forest using soil collar data collected by the Picarro Mobile Gas Concentration Analyzer (Picarro G4301; Santa Clara, CA). Uncertainty was calculated using root mean square error (RMSE), mean absolute error (MAE), and bias. Preliminary results indicate that the SIPNET model's instantaneous forecasts underpredict soil respiration by several magnitudes. With given preliminary results, we conclude that the SIPNET forecast can be improved through increased soil respiration observations to improve daily forecasts.

Anisa Robinson

University of Pennsylvania

Mentors: Nikhil Chari, Thomas Muratore, and Benton Taylor

Going Underground: Root Exudation in Response to Soil Warming, Nitrogen Addition, and Tree-Fungal Association

Forest soils are among the world's largest organic carbon stocks. However, the effect of global change on belowground carbon cycling remains unclear. New England woodlands in the US serve as critical carbon sinks, and throughout these temperate regions, trees govern soil carbon dynamics via root exudation (release of organic carbon into soil) with the help of their mycorrhizae. Trees commonly interact with two types of mycorrhizal fungi to facilitate nutrient acquisition: ectomycorrhizal (EM) and arbuscular mycorrhizal (AM). AM and EM trees may respond differently to soil warming and nitrogen deposition because they are adapted to different nutrient economies. AM trees are typically situated in areas where inorganic nitrogen is more mobile in soils, making them suitable to inorganic nutrient economies. On the other hand, EM fungi produce enzymes which can acquire nitrogen from organic sources, making EM trees more suited to organic nutrient economies. So far, ongoing research has considered separate effects of soil warming, nitrogen availability, and tree-fungal associations on root exudation and soil carbon storage, but few studies have demonstrated their combined impacts. Here, we investigate how long-term soil warming and nitrogen fertilization alter root exudation rates and whether roots associated with different mycorrhizal types exude carbon differently in response to increased temperature and nitrogen availability. Roots and their exudates were sampled from a long-term interactive soil warming and nitrogen addition experiment at the Harvard Forest. We measured root exudation rates and expected for EM trees to respond more negatively to soil warming by nitrogen addition than AM trees, potentially reducing soil carbon inputs to EM dominated northern forests.

Charitie Ropati
Columbia University

Mentors: Clarisse Hart, Nia Holley, Meg Graham MacLean, and Danielle Ignace

Restoration of *Sambucus nigra* in Relation to Introduced Species on the Nipmuc Reservation & the Value of Traditional Ecological Knowledge

The Northeast region of the United States is heavily impacted by introduced species. Introduced plant species can have significant ecological and economic effects on the region's ecosystems and native plant communities, yet little is known about how the reintroduction of native plants affects the return of introduced plants. The Northeast region of the U.S. is home to a wide range of introduced plant species; some notable examples include *Fallopia japonica* (Japanese Knotweed) and *Rosa multiflora* (Multiflora rose), which are of particular concern on the tribal land of the Nipmuc people, our partners in this work. Introduced species can outcompete and even displace native plant species and can lead to a loss of biodiversity and alter ecosystem dynamics. As we work in service of the Nipmuc community, relational accountability is an important aspect of our methodology and is at the root of our study. This relationship guided our choice of site and focal plants for this experiment: Black Elderberry (*Sambucus nigra*) is a culturally important native plant whose growth tribal leaders wanted to understand in relationship to a Multiflora rose, a common invasive plant on their reservation land. We first manually removed Multiflora rose and Japanese knotweed. We then established five 1-meter-square plots and planted an Elderberry sapling in the center of each. For 4 weeks, each week we measured the photosynthetic rates of each elderberry plant using a closed path infra-red gas analyzer system and also tracked the regeneration of introduced species. We found that knotweed grew in the established elderberry that were closer to a smaller stream, whereas the patches where there was no elderberry there were less knotweed. This is significant in thinking about and developing restoration practices for native species, like black elderberry. The most important and meaningful role in this research was the establishment of our relationship between our team and tribal members; And ensuring we are accountable to our relations. Creating and maintaining respectful and mutually beneficial relationships between researchers and Indigenous communities is of utmost importance, in part because Indigenous peoples have historically been mistreated by academic researchers and institutions Indigenous research methodologies functions to recognize, maintain, and expand Indigenous sovereignty.

Alassane Sow

Michigan State University

Mentors: Ashley Keiser, Jackie Matthes, and Corey Palmer

Testing whether long-term soil collars are representative of stand-level soil respiration

Measuring soil respiration over time is common across the Long Term Ecological Research network, and this long term record can be used to help investigate changing carbon sinks, or the impact of increased atmospheric CO_2 and temperature on overall ecosystem function. Within two eastern hemlock stands (*Tsuga canadensis* L.) at Harvard Forest, soil respiration is continuously measured when the soil is not frozen. The paired hemlock stands are differentially infested by the Hemlock Wooly Adelgid, an invasive insect that sucks sap from hemlocks resulting in the loss of leaves and branches, and eventual death. Recording soil respiration in these plots can help predict how forest health correlates with its ability to be a carbon sink, and how soil respiration responds to forest succession. Since measurements began in 2015, mean daily soil respiration was consistently higher in the healthier stand. However, respiration is highly variable between chambers. The goal of this study is to investigate if variation within a stand confounds the results from comparison analyses between stands. In this study, 60 PVC collars (30 at each stand) were installed to measure finer-scale soil respiration around the permanent soil collars. The data was used in kriging interpolations to map respiration across the 16m^2 plots surrounding the permanent soil respiration collars. Within each plot, we also conducted plant surveys to identify species presence and abundance. We found that placement of collars adjacent to live trees increased respiration rates. Microscale variations did not confound the results of comparison analysis but interpolation could be a powerful tool to choose best sampling locations. Our results emphasize that landscape variation can modify soil respiration rates and our ability to reliably scale plot-level data.

Isabella Stone

Willamette University

Mentors: Daniel Johnson and Lukas Magee

Seedling persistence and passage in a hemlock-hardwood forest: filling in the gaps

Natural disturbance events often create canopy gaps, driving changes in forest structure and composition. Understory individuals compete for resources made available by canopy tree death. We investigated how gap-phase dynamics impact seedling regeneration to understand how long it takes for a seedling to reach the sapling layer and how many seedlings it takes to make a sapling for five temperate forest tree species. We related seedling height and age while controlling for gaps. We collected data in 402 plots (1 m^2), located in the Harvard ForestGEO plot, arrayed around recently dead canopy trees (n = 53) and 16 live control trees. All woody seedlings with a DBH < 1 cm were identified, mapped (within the 1 m^2 plot), and measured for height in 2021, 2022 and 2023. Canopy cover was rated 1-5 from complete shade to complete sun per plot. We projected the number of seedlings required to make one 1.5 m sapling and passage time to that height. We found that the passage time for seedlings varied across species with a maximum of 48 years for eastern hemlock under closed canopies, and minimum of 13 years for birch in full canopy gaps. We simulated that it would require at least 20 seedlings for birch in canopy gaps and at the other extreme hemlocks needed an average of 115 seedlings under closed canopies to make one sapling. We harvested seedlings under different light levels to compare to our predicted age-to-height correlations. We found that our estimated age for a given height was significantly less than the observed age for the same height suggesting our projects of passage time were conservative. Our results highlight the longevity of seedlings in the understory and the importance of canopy gaps for sapling recruitment.

Helen Tarrau

Miami Dade College

Mentor: Marcos Rodriguez

Comparing survival of New England tree species based on life stage

Forests play a huge role in mitigating climate change, as they serve as carbon sinks. Prioritizing the regeneration and conservation of old growth forests is vital due to their role in carbon sequestration. Survival of trees can vary among different life stages and species, for a wide range of reasons, light dependency, and size. To have a better understanding about how survival varies amongst life stages and species, we focused on the survival of red maple (*Acer rubrum*), red oak (*Quercus rubra*), Eastern hemlock (*Tsuga canadensis*), White pine (*Pinus strobus*), and Birch species (*Betula* spp). as seedlings, saplings, and adults. We defined life stages as seedlings (10 cm DBH); this was done in the 35 ha ForestGEO plot at Harvard Forest. Seedling data was taken from the 134 plots within the ForestGEO plot, while sapling and adult data was taken directly from previous research done in the plot. We used R to analyze our results using a logistic regression test to model survival, treating species and life stages as fixed effects. We found that survivability varies based on species and life stage, showing that there is an interaction between them. We saw an overall low percentage of seedlings survival with red oak having the highest survival with a p-value of 0.14 in comparison to birch spp. which had p-value of 0.02. When it came to adult survival, the p-value varied from 0.54 at the lowest and 0.89 at the highest in a five year period. As disturbances and diseases persist in the forest, comparing species and life stages can lead us to understand how individuals are reacting to these changes. This information can be used to get a better understanding of future forest regeneration and highlights the importance of long term monitoring like that done at Harvard Forest.

Carlos Zuñiga

California State University, Dominguez Hills

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

The Aboveground Response in a New Forest Edge

As human development continues to encroach upon our forested landscapes, it will lead to further fragmentation. Among the most affected are the forests of the northeastern United States, which has experienced significant agricultural and urban expansion, resulting in mosaics of fragmented forest and non-forest shaped by human activity. An increasing number of forest edges are being formed, which impose unique microenvironmental gradients on the forest than those found within the interior. Currently, we do not know how quickly these gradients alter the growth rates of trees found along the edge. The impact of forest edge proliferation could be profound as the temperate forest plays a role as one of the world's largest terrestrial carbon sinks. Still, it is also the most heavily fragmented forest biome on the planet, with about 23% of it within 30 meters of a non-forested edge. To measure the immediate impacts of edge creation on tree growth, we cut down a 180-by-45-meter section of Harvard Forest. Using the south-facing edge we created a set of 6 plots that are each 15 by 30 meters in size, with tree species like red oak (*Quercus rubra*), red maple (*Acer rubrum*), eastern white pine (*Pinus strobus*), and black birch (*Betula lenta*). In each plot, we deployed dendrometer bands to monitor tree growth. We measured tree growth in terms of diameter at breast height for all 104 trees over eight weeks along with collecting tree growth data from red maples and red oaks with point dendrometers installed. The manipulated forest edge demonstrates strong edge-to-interior gradients for microenvironment variables similar to older forest edges: however, the growth response of trees along the edge to interior gradients shows varied responses to these gradients.

2023 Harvard Forest Personnel

Barker-Plotkin, Audrey - Site Manager, Senior Researcher & Director of Summer Program

Bhatnagar, Jennifer - Bullard Fellow

Boose, Emery - Information Manager & Senior Scientist

Bowlen, Jeannette - Sponsored Research Administrator

Chiasson, Laurie - Department Coordinator

Colburn, Elizabeth - Aquatic Ecologist

Dietze, Michael - Bullard Fellow

Duveneck, Matthew - Research Associate

Dyer, Jillian - Research Assistant

Fuchs, Meg - Director of Administration & Facilities

Goulet-Scott, Benjamin - Higher Education & Laboratory Coordinator

Griffith, Lucas - Woods Crew

Grossman, Daniel - Bullard Fellow

Hall, Brian - GIS Specialist

Hall, Julie - Assistant Information Manager

Hart, Clarisse - Director of Outreach & Education

Hinkle, Katharine - Schoolyard Ecology Program Coordinator

Holbrook, Noel Michele - Director of Harvard Forest

Johnson, Emily - Stakeholder Engagement Coordinator

Kalinin, Alexey - Post-Doctoral Fellow

Lacwasan, Oscar - Woods Crew

Laflower, Danelle - Research Assistant

Laford, Diona - Administrative Assistant

Lee, Lucy - Research Assistant

Lewis, Ann - Schoolyard Ecology Data Mentor

Mapes, Lynda - Bullard Fellow

Matthes, Jackie - Senior Scientist

Maynard, Nick - Woods Crew

Meunier, Roland - Woods Crew

Morin, Alisha - Accounting Assistant

Novak, Abigayl - Summer Program Proctor

O'Keefe, John - Museum Director (Emeritus)

Orwig, David - Forest Ecologist

Pasquarella, Valerie - Researcher

Pederson, Neil - Forest Ecologist

Plisinski, Joshua - Research Assistant

Quigley, Kaden - Woods Crew

Richardson, Lisa - Financial Administrator

Roy Chowdhury, Rinku - Bullard Fellow

Sharp, Jordan - Research Assistant

Smith, Laura - Research Assistant

Stambaugh, Michael - Bullard Fellow

Thompson, Jonathan - Research Director & Senior Ecologist

Tumber-Dávila, S. Joseph - Post-Doctoral Fellow

VanScoy, Greta - Education Coordinator & Field Technician

VanScoy, Mark - Research Assistant

Wisnewski, John - Woods Crew

Wood, Elaine - Laboratory Assistant

Yesmentes, Peter - Summer Program Assistant Chef

Zima, Tim - Summer Program Chef

Notes

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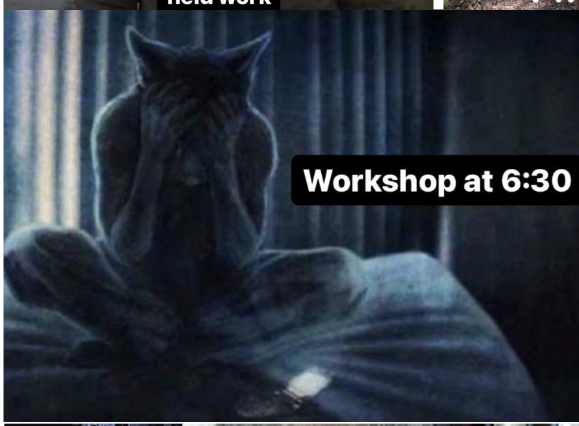
Bernie
I am once again asking
someone please help me with
field work


First day of school !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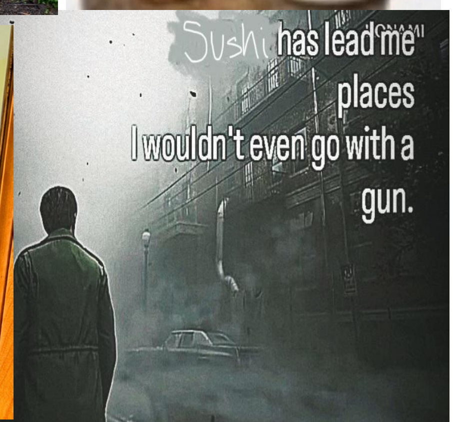
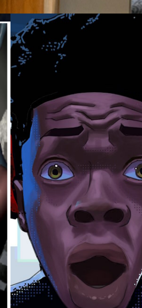
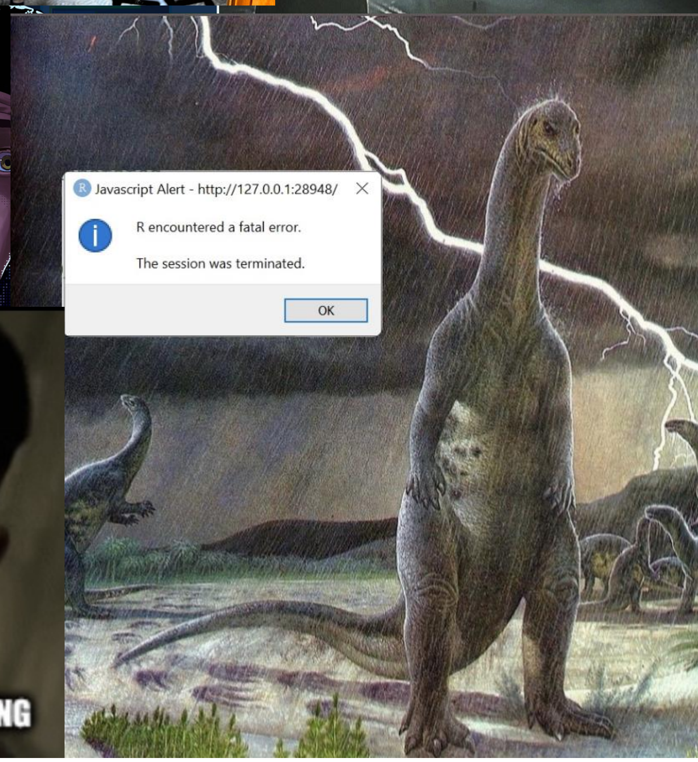
HARD WORK
IN PROGRESS


"Sushi has lead me"
places
I wouldn't even go with a
gun.


FISHER HOUSE GETS A LITTLE...
QUIRKY AT NIGHT

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WHEN YOU GET TO YOUR PLOTS BUT FORGOT SOMETHING
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The End

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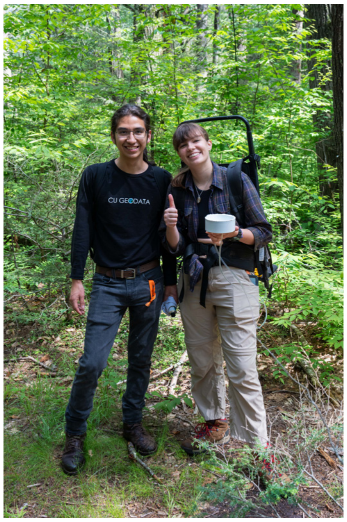
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