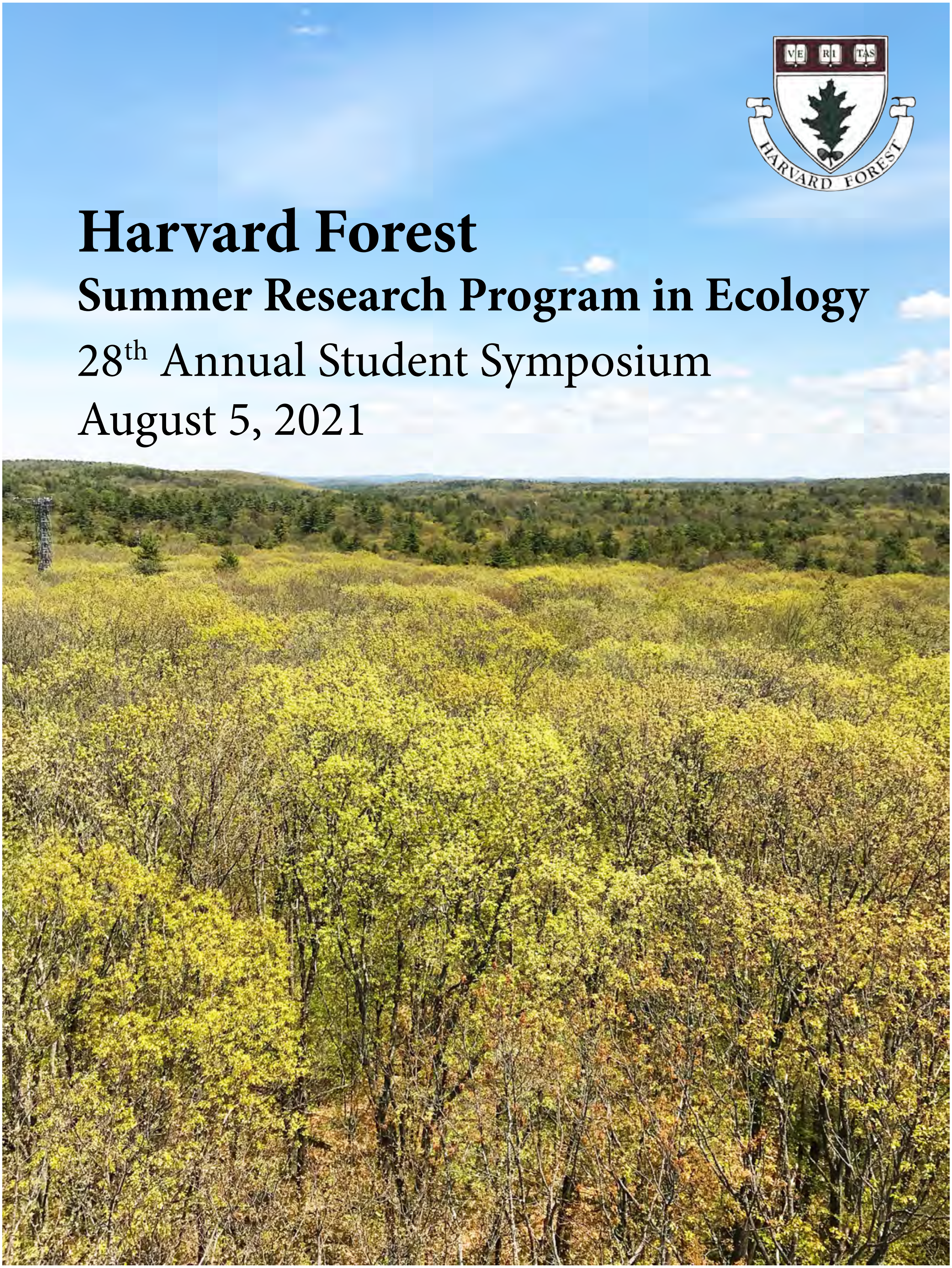
Harvard Forest

Summer Research Program in Ecology

28th Annual Student Symposium

August 5, 2021



28th Annual Harvard Forest Student Symposium

August 5, 2021

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 that includes Shaler Hall, the Fisher Museum, and the John G. Torrey Laboratory 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 2021 Summer Research Program

Due to the ongoing global pandemic, the 2021 Harvard Forest Summer Research Program in Ecology took place virtually. A diverse group of 18 students from across the United States including Puerto Rico met with research mentors and each other using the platforms Zoom and Gather. In spite of physical distance, the students engaged with a full schedule of programming in addition to their research projects which focused on applying computational methods to existing large datasets. The program included weekly seminars, workshops, visits from scientists and practitioners, and virtual community building. The 2021 program was co-directed by Audrey Barker-Plotkin and Sydne Record and supported by the assistant program coordinator Ben Goulet-Scott and the Harvard Forest administrative team. The Harvard Forest Summer Research Program in Ecology culminates in the Annual Student Symposium held on August 5, 2021, where students present their research findings to an audience of scientists, peers, and family.

2021 Summer Research Program Students and Assistant Program Coordinator

Funding for the 2021 Summer Research Program

In 2021, 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)
REU Site: A Forest full of Big Data: the Harvard Forest Summer Research Program in Ecology 2015-2019 (DBI-1459519)
LTER: From Microbes to Macrosystems: Understanding the response of ecological systems to global change drivers and their interactions (DEB-1832210)
CAREER: Soil Microbial Ecology and Evolution in a Warming World (DEB-1749206)

Harvard University

Faculty of Arts and Sciences
G. Peabody "Peabo" Gardner Memorial Fund
Living Diorama Scholarship Fund
Reuben Tom Patton Scholarship Fund

2021 Summer Research Program Seminars

June 3	Understanding carbohydrate storage in plants: A story about science and finding your 'sweet spot' in it. *Morgan Furze, Yale University*
July 1	Birds and science: the view from two wheels. *Scott Edwards, Harvard University*
July 8	Understanding phloem functioning in the context of water stress. *Jess Gersony, University of New Hampshire*
July 13	Remotely sensible: using Earth observing satellites to monitor ecosystem pattern and process. *Valerie Pasquarella, Boston University*
July 22	Plant-Soil feedbacks in forest communities. *Jackie Hatala-Matthes, Wellesley College*
July 27	Understanding Tree-Soil-Geology-Human interactions though (my personal lens of) metals. *Justin Richardson, University of Massachusetts Amherst*

2021 Summer Research Program Workshops

May 24	Harvard Forest Orientation. *Audrey Barker-Plotkin*; Sydne Record, Bryn Mawr College; Missy Holbrook*; Laurie Chiasson*; Diona Laford*; Alisha Morin*; Lisa Richardson*; Meg Hastings*; Jeannette Bowlen* (*Harvard Forest)*
May 24	Harvard Forest Virtual Tour 1. *Audrey Barker-Plotkin, Harvard Forest; Ben Goulet-Scott, Harvard University*
May 25	Title IX Training. *Rachel DiBella, Harvard University*
May 26 & June 1	Reading Scientific Articles. *Ben Goulet-Scott, Harvard University*
May 26, 28, June 2, 4	Reproducible Research with R. *Sydne Record, Bryn Mawr College*
May 27 & June 2	Writing Research Proposals. *Ben Goulet-Scott, Harvard University*
May 27 & June 1	Introduction to Research Networks. *Kristin Godfrey, NEON; Audrey Barker-Plotkin, Harvard Forest; Tim Whitby, Ameriflux*

2021 Summer Research Program Workshops *(cont.)*

May 27	Harvard Forest Virtual Tour 2. *Greta VanScoy, Harvard Forest*
May 28 & June 4	Data Archiving. *Emery Boose, Harvard Forest; Audrey Barker-Plotkin, Harvard Forest*
June 3	Telling Global Change Stories. *Clarisse Hart, Harvard Forest*
June 10	Best Practices for Peer Review. *Ben Goulet-Scott, Harvard University*
June 15, 23	Introduction to GitHub. *Sydne Record, Bryn Mawr; Mike Dietze, Boston University*
July 16	Responsible Conduct of Researchers. *Logan McCarthy, Harvard University*
July 20	Presenting Your Research. *Ben Goulet-Scott, Harvard University*

Chat with Scientists Guest List

May 26	Jonathan Thompson, *Harvard Forest* & Audrey Barker-Plotkin, *Harvard Forest*
June 1	Serita Frey, *University of New Hampshire* & Missy Holbrook, *Harvard University*
June 8	Meghan Blumstein, *Massachusetts Institute of Technology* & Emma Conrad-Rooney, *Boston University*
June 11	Nikhil Chari, *Harvard University* & Benton Taylor, *Harvard University*
June 15	Pam Templer, *Boston University* & Kristen DeAngelis, *University of Massachusetts Amherst*
June 18	Paige Kouba, *University of California Davis* & Alexis Helgeson, *Boston University*
June 22	Neil Pederson, *Harvard Forest* & Mike Dietze, *Boston University*
June 25	Danielle Ignace, *Harvard Forest/University of British Columbia*
June 29	Joshua Plisinski, *Harvard Forest* & Lucy Lee, *Harvard Forest*
July 6	Adriana Romero-Olivares, *New Mexico State University* & Mallory Choudoir, *University of Massachusetts Amherst*
July 9	Lynn Adler, *University of Massachusetts Amherst* & Seanne Clemente, *University of Massachusetts Amherst* & Laura Figueroa, *Cornell University*
July 13	Jessica Wilkinson, *The Nature Conservancy* & Candace Fujikane, *University of Hawaii*
July 20	Lesley-Ann Dupigny-Giroux, *University of Vermont*
July 23	Toni-Lyn Morelli, *U.S. Geological Survey*
July 27	Kirisitina Sailiata, *Macalester College*

28th Annual Harvard Forest Student Symposium Schedule
August 5, 2021

1:00pm Opening Remarks from Audrey Barker-Plotkin (Program Co-Director)

1:05pm Group 1 Elevator Pitches (on Zoom)

Benjamin Glass *Middlebury College*	Impact of spatial ecology on co-located Eddy Covariance Flux Towers
Christina Francis *Johns Hopkins University*	Using Site-Specific Soil Moisture Data to Better Forecast Ecosystem Water Fluxes
Tanai Dawson *Western Michigan University*	The Effects of Tree Mortality on Carbon Flux Variability in Harvard Forest
Rafael Viana Furer *Macalester College*	Beyond Western Frameworks: Caring for Future Generations
Faith Blalock *Brown University*	Beyond Western Frameworks: Cultivating Reciprocity, Respect, Reverence, and Responsibility
Samantha Olivares-Mejia *Haverford College*	Uncovering Land Use Histories: How Disturbance Impacts Forested Sites in the National Ecological Observatory Network
Sarah Sosa *Rowan University*	Near-term Forecasting of Carbon and Water Fluxes
Joseph Toman *University of California Berkeley*	Agricultural and rangeland land use history in NEON sites
Xaun Wilson *Howard University*	A Model and Its Inputs: Understanding sources of uncertainty for a model of carbon flux dynamics within Harvard Forest

1:20-2:30pm Group 1 Poster Session (on Gather)

2:30-3:00pm Break

28th Annual Harvard Forest Student Symposium Schedule (*cont.*)

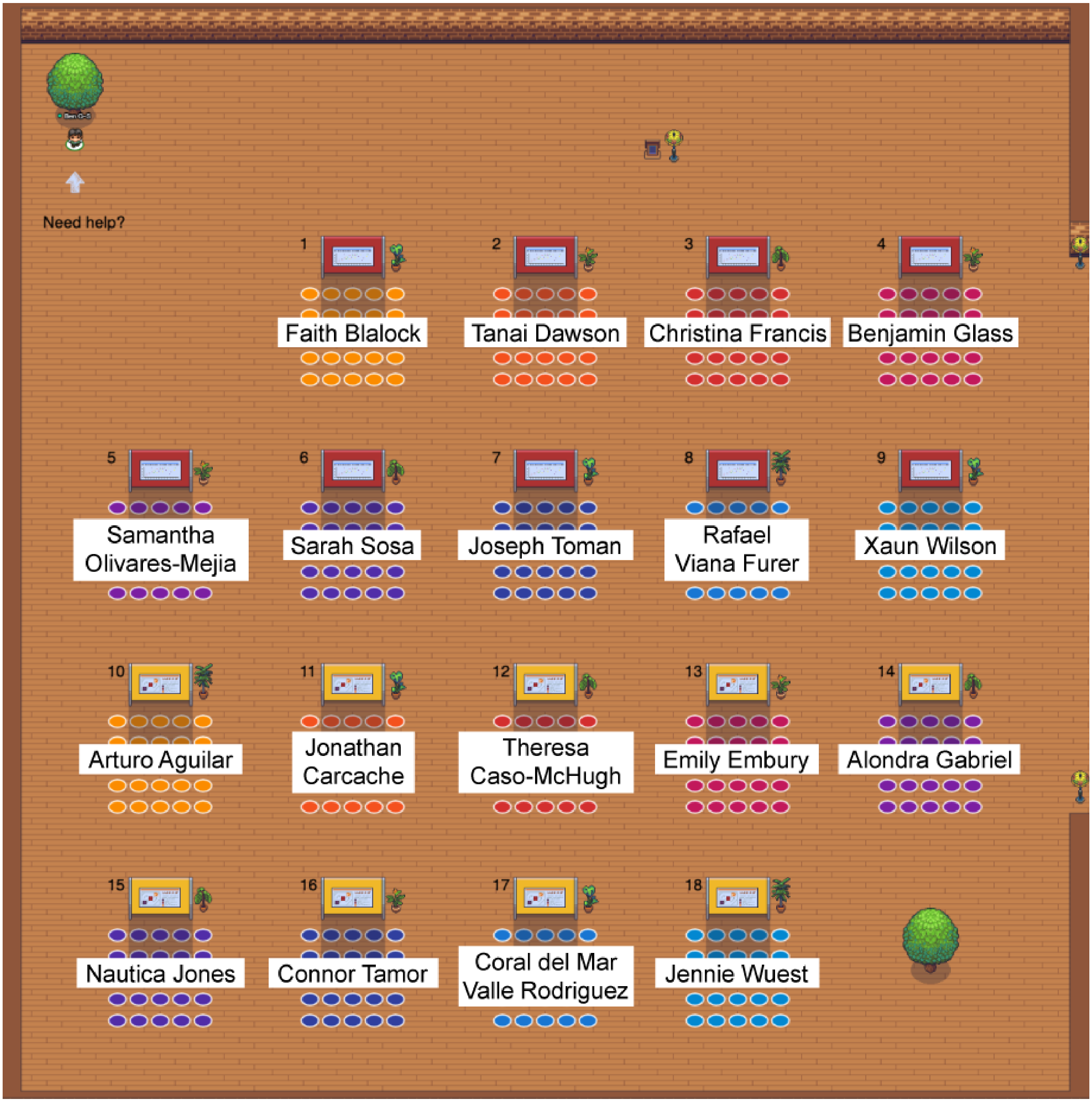
3:00pm Group 2 Elevator Pitches (on Zoom)

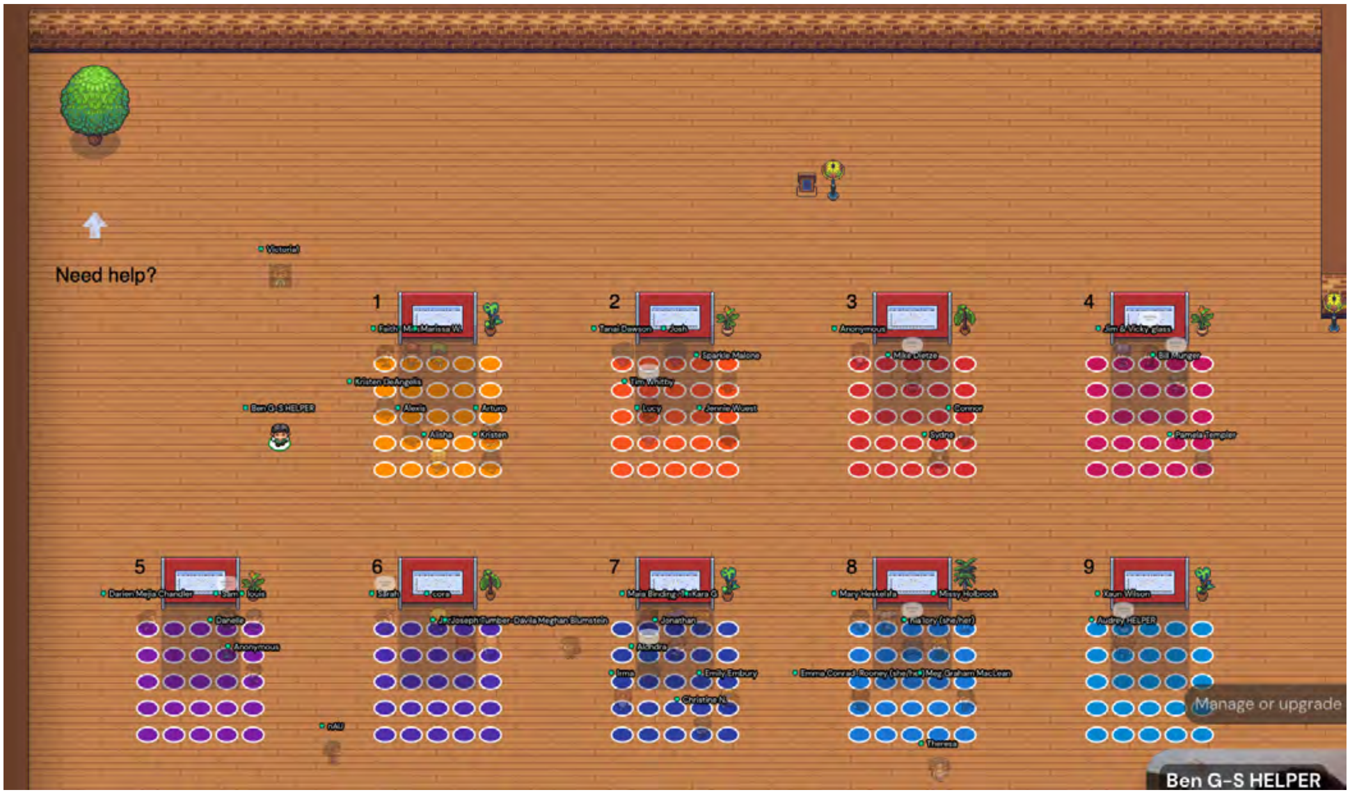
Arturo Aguilar *Harvard University*	Exudate in, Carbon out: the effect of specific root exudates on soil carbon dynamics
Jonathan Carcache *Florida International University*	Fungi of the Future: Investigating Dominant Fungal Taxa Throughout Global Change Treatments
Theresa Caso-McHugh *Massachusetts Institute of Technology*	Utilizing Traits-based Clustering Analysis to Find Genomic Evidence of Substrate Utilization Adaptation in LTER Warming Plot Isolates
Emily Embury *Wheaton College*	Soil fungal diversity in response to multiple global change stressors
Alondra Gabriel *University of Puerto Rico Arecibo*	Comparative genomics analysis to characterize adaptations in actinobacterial genetic patterns of Carbohydrate-Active Enzymes under long-term warming conditions
Nautica Jones *University of Louisiana at Monroe*	Assessing need and potential for assisted allele migration in the Northeast
Connor Tamor *Cornell University*	Effects of Atmospheric Deposition on Carbon Sequestration in Temperate Forest Ecosystems
Coral del Mar Valle Rodríguez *CUNY Hunter College*	Estimating the Risk of Forest Carbon due to Invasive Forest Insects
Jennie Wuest *Fordham University*	Characterizing the Response Levels of Fungal Taxa to Drivers Global Change

3:20-4:30pm Group 2 Poster Session (on Gather)

4:30-5:00pm Social Time (on Gather)

The 2021 Harvard Forest Summer Program virtual poster session on Gather




Need help?
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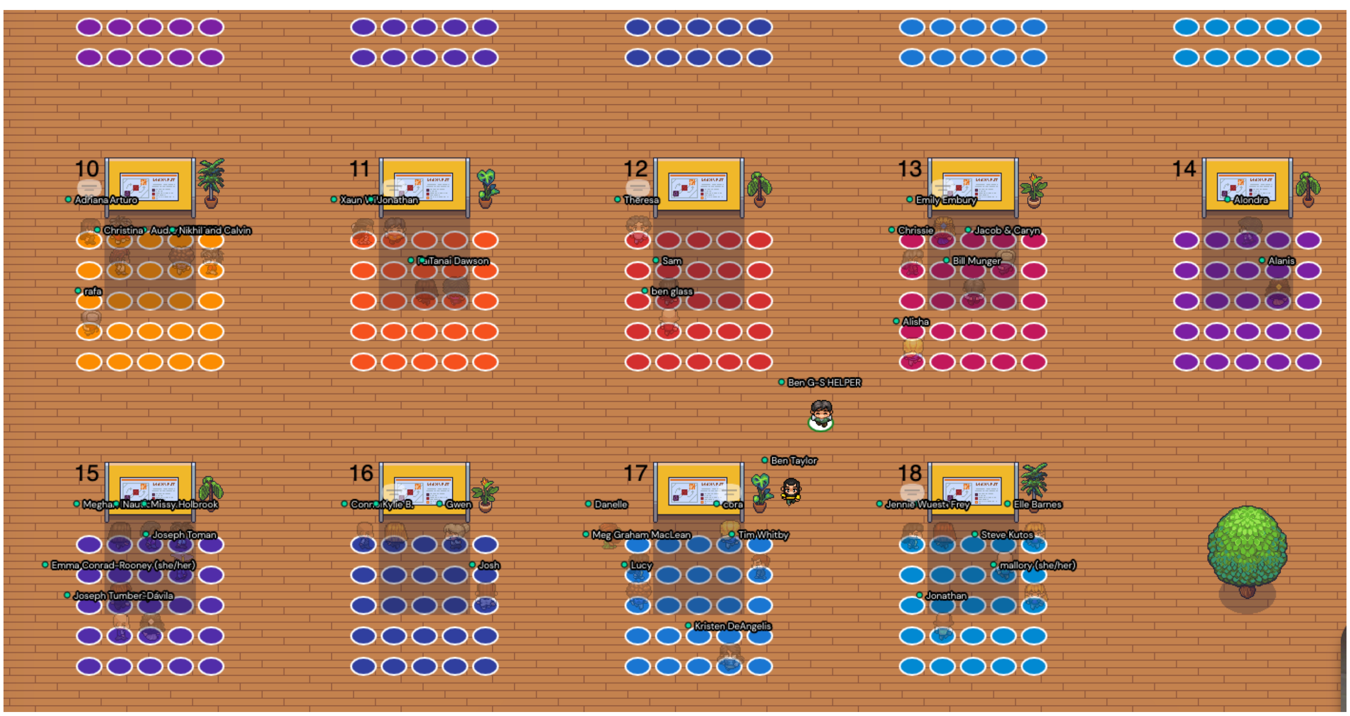
Manage or upgrade
Ben G-S HELPER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Benjamin Glass
Middlebury College

Mentors: Tim Whitby and Bill Munger

Impact of spatial ecology on co-located Eddy Covariance Flux Towers

In New England, temperate forests act as important regional carbon sinks. However, the rate of carbon dioxide uptake within these forests varies over space. This research aimed to improve Harvard Forest's carbon flux models by accounting for variations in spatial ecology around two separate, but closely-located, Eddy Flux Towers in Harvard Forest. This research explored (a) how spatial variation affected each carbon flux tower individually, and (b) whether the two tower measurements similarly covaried due to spatial variation. Using an established Flux Footprint Prediction (FFP) model, I derived spatial footprints for hourly carbon flux measurements at EMS and NEON towers from the last 4 years (2017-2020). I then extracted summary statistics on spatial ecological characteristics (species percentages, canopy height, and spectral indices) of each hourly footprint and calculated percentage overlap of tower footprints. I found that the absolute difference in flux measurement between towers decreases as the spatial overlap of tower footprints increase. I also found that carbon dioxide flux is negatively correlated to tasseled cap greenness during the growing season (May-September) in times of high temperature and light-availability. Carbon dioxide flux shows little relationship with canopy height and species distribution data. This is likely because the value ranges of these spatial data within EMS and NEON footprints are small. Measuring a more heterogeneous landscape would likely yield a more defined relationship. In general, accounting for spatial variability in Harvard Forest's carbon flux models will allow researchers to model and forecast flux measurements more accurately. An accurate assessment of forest carbon uptake and emission is essential to understand the extent to which temperate forests can be utilized as a natural climate solution.

Christina Francis

Johns Hopkins University

Mentors: Alexis Helgeson, Sparkle Malone, and Mike Dietze

Using Site-Specific Soil Moisture Data to Better Forecast Ecosystem Water Fluxes

Soil moisture plays an important role in the ecological water cycle, which is relevant in the conversation of climate change, as global concentrations of atmospheric water vapor are projected to increase, and different areas of the globe are expected to experience drought conditions while others will face heavy precipitation events and flooding. The Predictive Ecosystem Analyzer (PEcAn) is an open-source ecological workflow management software that can be used to run reproducible forecasts of the movement of water within an ecosystem. Through this research project, we investigated how the incorporation of site-specific soil moisture data into the PEcAn workflow influenced the water flux outputs of ecological forecasts. Four study sites, that are a part of of the national ecological observatory network (NEON), represented varying ecosystems across the United States: a woody wetland and evergreen forest located in northern Florida (Ordway-Swisher), a sonoran desert in southern Arizona (Santa Rita), a dynamic forest with deciduous to boreal transitions in New Hampshire (Bartlett), and a native tall grass prairie in Kansas (Konza). We ran two simplified photosynthesis and evapotranspiration (SIPNET) models for each site during the month of April 2021, using site-specific ecological data with and without soil moisture information. Observed water flux outputs were analyzed using two-sample t-tests to evaluate the impact of soil moisture data on the predicted movement of water throughout each ecosystem. As this project necessitated modifications to the PEcAn workflow to improve the accuracy of its forecasts, the fruits of this study should contribute to advancements in the field of ecological forecasting.

Tanai Dawson

Western Michigan University

Mentors: Tim Whitby and Bill Munger

The Effects of Tree Mortality on Carbon Flux Variability in Harvard Forest

Tree mortality, while having a range of potential effects on the carbon flux measurement variations of an ecosystem, is not as often studied as other effects on carbon flux variations. In this regard, more work is needed and encouraged to understand more on how environmental fluxes are affected by tree mortality. Inside of Harvard Forest, I would like to work on a project that obtains a measure of responses to tree mortality events that can be obtained through flux measurements and available remote sensing data. With detecting a measurable response in the fluxes that pertain to tree mortality, do these responses affect carbon flux variations from year-to-year? Footprint models are used to analyze and gather implications on flux tower measurements to produce position and size of surface areas as accurately as possible. With extracted footprints models from tower flux measurements and aerial data from remote sensing. Over the course of this summer, I have worked adapting the flux tower measurements of both the NEON and Hemlock towers to the footprint analysis used for the EMS flux tower measurements. This served as a basis for gathering footprint analysis comparisons between the towers and gathering the necessary data to pair with remote sensing. Relevant images are then obtained, and we can see the amount greenness of observed tower areas in the forest and how they differ from year-to-year. A measurable amount of yearly loss of greenness in these images can be used to determine events of tree mortality. This project can show how significant tree mortality is when considering the large carbon flux variations.

Rafael Viana Furer

Macalester College

Mentors: Marissa Weiss, Danielle Ignace, and Meghan Graham MacLean

Beyond Western Frameworks: Caring for Future Generations

Western science is one way of understanding the natural world. Many foundational scientific practices emerged as justifications for the enslavement and attempted genocide of Black and Indigenous people, identities I share. Deconstructing scientific methodologies is one essential way that current and future research housed under Western institutions can begin to repair relationships with Black, Indigenous, and other marginalized communities. Institutions, such as Harvard University, have a responsibility to correct practices that perpetuate extractive and harmful relationships to the environment and people. White supremacy and imperialism impact large portions of the world in different yet interconnected ways. Forming relationships independent of imperialist systems provide Indigenous and other marginalized communities with new frameworks for self-determination. Western institutions can develop frameworks and projects with, by, and for local communities. In order to build a Harvard Forest-specific framework we interviewed Indigenous scientists on how their work differs from Western science, analyzed papers that center Indigenous ethics in research, and hosted conversations with Nipmuc stakeholders. Our conversations illuminated the fundamentality of intentional reciprocity when caring for our environment. This initial summer project is a small piece of a much larger commitment made by my research group to knowledge sharing and co-creation with the Nipmuc. My desire to heal my relationship to land and be a good guest shapes my work as a student and beyond. Through conversations, accountability, and trust I hope to engage in harm-reducing work that leads to the rematriation of Nipmuc lands. Our efforts to build authentic reciprocal relationships that persist beyond the scope of any particular project is the first step in our “deconstructing Western scientific methodologies” framework. I invite other scientists to engage with our work as well as the work of those who came before us to increase awareness of harmful scientific practices and correct those methods.

Faith Blalock
Brown University

Mentors: Meghan Graham MacLean, Danielle Ignace, and Marissa Weiss

Beyond Western Frameworks: Cultivating Reciprocity, Respect, Reverence, and Responsibility

In a culture that prioritizes western ways of knowing over others, scientific practices become inaccurate and oppressive. In the context of ecology, an exclusively western framework results in scholarship that operates on and perpetuates the exploitation, genocide, and erasure of Indigenous land, people, and knowledge. The Nipmuc are the traditional stewards and inhabitants on the land currently called Harvard Forest. The Nipmuc were violently dispossessed of this land from settlers in 1722 and, until recently, Harvard has failed to acknowledge that violent history and the role they play in perpetuating displacement. This summer I looked at how Harvard Forest can conduct their work with, by, and for the Nipmuc instead of continuing to exclude and marginalize Indigenous people and knowledge. This project aimed to establish a collaborative relationship with the Nipmuc through building trust and collective futures. To frame our conversations with Nipmuc representatives, my research team reviewed various literature on authentic inclusion of Indigenous knowledge and community based participatory research. My research partner and I also conducted interviews with Indigenous people whose work engages with western science. The motivation for these interviews came out of my desire to map spaces and careers with practices and values that extend beyond settler frameworks. These interviews have been helpful in seeing how incorporating Indigenous knowledge forces us to form more holistic approaches to ecology and conservation. Hopefully, the knowledge we engaged with in relationship building, interviews, and literature shows all of us how to cultivate holistic practices rooted in reciprocity, respect, reverence, and responsibility instead of exclusively western frameworks.

Samantha Olivares-Mejia

Haverford College

Mentor: Sydne Record

Uncovering Land Use Histories: How Disturbance Impacts Forested Sites in the National Ecological Observatory Network

Forests are widely studied to help understand and combat climate change as they are an integral part of the global ecosystem aiding in climate regulation, water supply, and biomass production. Information on historic land disturbance is needed to understand modern biodiversity and productivity trends in forests as well as make informed decisions regarding future land use, however spatial information on historic land use is limited. This project investigates the historical land use of forested sites within the National Ecological Observatory Network (NEON) which provides data for research projects across the United States. Land use histories were collated from site archives, public databases and primary investigators for forested NEON sites. The data was then standardized and merged into pre-existing spatial files using R. For sites that did not have previous spatial files, historical aerial photographs and maps were digitized using QGIS. Fifteen data products were created which contain detailed information on local disturbances over time for the Bartlett Experimental Forest(BART) and the Smithsonian Environmental Research Center(SERC) with historic land use dating back into the late 19th century. Collated land use histories will help close a knowledge gap for future research projects at forested NEON sites. The incorporation of historic spatial information will also increase the predictive ability of forecasting models and effectiveness of forest management strategies.

Sarah Sosa

Rowan University

Mentors: Alexis Helgeson, Sparkle Malone, and Mike Dietze

Near-term Forecasting of Carbon and Water Fluxes

Increasingly advancing ecology requires a fundamental shift, in thinking from measuring and monitoring, to using data to anticipate change, make predictions, and inform management actions. Near-term forecasts provide the opportunity to access the repetition of a computational procedure, iteratively, to perform analyses and predictions in light of new evidence. Eddy covariance is the methodology for measuring carbon dioxide exchange from the atmosphere, net ecosystem exchange; NEE. The SIPNET (Simplified Photosynthesis and Evapotranspiration model) measures terrestrial ecosystem carbon and water flux exchange. The primary objective of my project is to parameterize the SIPNET model for Harvard Forest. HF (HARV) is a terrestrial NEON field site located approximately 65 miles west of Boston, Massachusetts in the county of Worcester, represented as a typical northeastern rural/wildland. Whereas I studied five different NEON sites that were forecasted to depict each mathematical analysis trend of NEE. I found that from the beginning of July 5th to August 2nd, each site serving different biomes completed the similar trend, as the forecast period progressed, NEE in units of kgC/m2 would exponentially decay. Revealing that CO2 uptake is actually concentrated in the growing season of June. The ability to forecast this month-long period is due to eddy's hourly resolution and 16-35 day duration, and thus for any point in time we compare observations to predictions made 1 to 16 or more days in advance. These results suggest that the dynamics between NEE and transition season have a declining factor than forecast would during midseason.

Joseph Toman
University of California Berkeley

Mentor: Sydne Record

Agricultural and rangeland land use history in NEON sites

The effort to understand and assess the changes our landscapes and climate have and continue to undergo has grown. Especially within the past decade, instrumentation, national and global data networks, and the accessibility to the big environmental data these resources produce have far outpaced the rate in which data is being analyzed and understood. To be able to accurately forecast these ecosystem processes, the extent of anthropogenic alteration must be understood as well. This study attempted to contextualize current landscape dynamics through an examination of agricultural and rangeland land use in select NEON sites and analyze their impact on site vegetation biomass and diversity. To do this, this study looked at grazing intensity in different pastures and the change in the percent cover of mesquite and native perennial grasses. The trend was seen that the greater and more recent the grazing, the more drastic the shift of percent cover from native perennial grasses to mesquite. This study is crucial to understand our environment and bridge the land use knowledge gap in large environmental data networks, such as NEON, which tend to revolve around relatively recent inputs and require further intersectional analysis. Furthermore, this study compares the consistency of large observatory networks like NEON with long term data that has been collected from the local sites.

Xaun Wilson
Howard University

Mentors: Alexis Helgeson, Mike Dietze, and Sparkle Malone

A Model and Its Inputs: Understanding sources of uncertainty for a model of carbon flux dynamics within Harvard Forest

Forests are important for greenhouse gas mitigation. To understand the strength of their impact, I am studying Net Ecosystem Exchange (NEE) rates in a broadleaf deciduous forest in the North Eastern U.S using the SIPNET model. The SIPNET model is a simplified ecosystem model which uses carbon pools to forecast NEE rates one to 35 days into the future. The primary objective of my project is to understand the impact of ecosystem model inputs on overall model uncertainty. I ran the SIPNET model from June 1st, 2021 through June 30th, 2021 to compare outputs of the forecast when one input is allowed to vary while all others are held constant. Understanding data contributions to forecast uncertainty advances our ability to optimize data collection for improved model outcomes.

Arturo Aguilar

Harvard University

Mentors: Nikhil Chari and Benton Taylor

Exudate in, Carbon out: the effect of specific root exudates on soil carbon dynamics

Soil organic matter (SOM) dynamics hold considerable influence over soil carbon cycling and sequestration of carbon from the atmosphere. Specifically, a portion of SOM chemically binds with minerals to form mineral-associated organic matter (MAOM), resulting in the immobilization of carbon for decades to centuries. Plant root exudates, low-molecular-weight organic carbon compounds such as carbohydrates, organic acids, and amino acids, are thought to influence the formation and loss of SOM. The effect of root exudates on SOM pools is known to vary between specific exudate types. To quantify this varying effect, we analyzed data from an artificial root experiment that isotopically traced exudate carbon in SOM pools. We then integrated the data from this experiment into a quantitative review of studies on the effect of specific root exudates on soil carbon dynamics. The experimental results show that exudate type had no significant effect on the change in MAOM carbon of soil samples. However, the allocation of labeled carbon was significantly higher in the carbohydrate treatment. Data from the quantitative review found that carbohydrate exudate causes a small net increase in SOM carbon while amino acid and organic acid exudates exert a net negative effect on SOM pools. These results suggest that exudate inputs cause an overall increase in the amount of carbon lost from soil. The findings of this study contribute to a better understanding of root exudation's role in the global carbon cycle and may improve future carbon cycle modeling.

Jonathan Carcache

Florida International University

Mentors: Adriana Romero-Olivares and Serita Frey

Fungi of the Future: Investigating Dominant Fungal Taxa Throughout Global Change Treatments

Fungi play an integral role in forest ecosystems. Despite their importance, fungi, and the communities they form are highly influenced by global change factors such as global warming and nitrogen pollution. Studies investigating the impacts of these global change factors are prevalent, however the composition of fungal communities altered across global change factors is understudied. The aim of this study is to utilize previously collected soil fungal sequence datasets to gain a deeper understanding of how fungal communities change with long-term soil warming and simulated nitrogen deposition. My specific objective of this collaborative study is to conduct a meta-analysis that investigates how dominant fungal taxa vary across the global change treatments. Statistical analysis and figures were all produced on R-Studio using the packages “ggplot2” and “phyloseq”. I found that overall fungal community composition at the order level shifts between both studies and treatments but more so between studies. In study 2 (soil warming) there was a noticeable difference in composition, where the abundance of members of the Russulales order increased. Similarly, in study 5 (nitrogen deposition), the abundance of members of the Hypocreales order increased. Understanding the composition of fungal communities across treatments will aid in the prediction of what future microbiomes could look like. Predicting microbiomes can give land managers and conservationists an edge when it comes to battling global change factors.

Theresa Caso-McHugh
Massachusetts Institute of Technology

Mentors: Kristen DeAngelis and Mallory Choudoir

Utilizing Traits-based Clustering Analysis to Find Genomic Evidence of Substrate Utilization Adaptation in LTER Warming Plot Isolates

Anthropogenic climate change significantly influences many facets of life on Earth. A noteworthy example is the soil microbiome, which may be substantially affected by the warming expected to occur due to rising global temperatures. Microbes are key forces in the carbon cycle and produce extracellular enzymes that process and create soil organic matter (SOM). In studies conducted at the Harvard Forest Long-Term Ecological Research (LTER) site warming experiment, long-term warming of soils affects the community structure and genetic profile of microbial soil communities. Long-term warming has also been found to lower the quantity of SOM, alter the relative abundance of SOM's various types in the soil, and increase the ability of soil microbes to degrade SOM, particularly more complex types. The aim of this project was to analyze the genomes from 42 different isolates that have been collected from both the control and warmed LTER plots for adaptive traits. A computational method detailed in Finn et al., 2021 clusters predicted genes from genome collections based on pairwise similarity. Each of the clusters is annotated with the protein group's function, and a matrix of genomes with their associated trait data is produced. These methods are of particular relevance to the substrate utilization results seen in the LTER, because they have allowed me to determine genomic traits associated with the observed growth phenotypes seen in the substrate utilization data. Using the 42 genomes of various taxa sequenced from LTER warming plot isolates, I have utilized the clustering method detailed above to find traits-based evidence of adaptation in the LTER warming plot isolates, as well as analyzed the extent to which this evidence corroborates the substrate utilization changes observed previously. I expect that evidence of adaptation will be seen in the form of a statistically significant difference in the enrichment of traits related to substrate utilization between the warm plot isolates and the control plot isolates.

Emily Embury

Wheaton College

Mentors: Adriana Romero-Olivares and Serita Frey

Soil fungal diversity in response to multiple global change stressors

Soil warming, nitrogen enrichment, and non-native plant invasions can alter soil fungal communities, and such communities play an important role in soil nutrient decomposition and carbon cycling. Understanding how fungal communities shift due to these global change drivers can inform how the composition of soil organic matter and the soil's carbon storage capabilities may shift with climate change and anthropogenic-driven ecosystem alterations. A collaborative research project was conducted to utilize previously collected soil fungal sequence datasets to gain a deeper understanding of how fungal communities change with long-term soil warming, simulated nitrogen deposition, and non-native plant species invasions. My goal within this larger project was to analyze how the alpha and beta diversity of soil fungi have changed in response to the three global change treatments. To answer this question, the alpha and beta diversity of four datasets were analyzed, and ANOVA tests were utilized to look for significant variation of diversity across the global change drivers. It was found that there is significant variation of beta diversity, but no significant variation of alpha diversity between control plots and all three global change drivers. These results suggest that species richness (alpha diversity) is not strongly impacted by warming, nitrogen enrichment, or non-native species invasion, but community composition (beta diversity) is affected by all three global change drivers. This suggests that fungal communities will likely experience changes in community composition from future climate change and other anthropogenic disturbances.

Alondra Gabriel

University of Puerto Rico Arecibo

Mentors: Mallory Choudoir and Kristen DeAngelis

Comparative genomics analysis to characterize adaptations in actinobacterial genetic patterns of Carbohydrate-Active Enzymes under long-term warming conditions

Long-term soil warming is predicted to induce adaptations in soil bacteria generating alterations in the carbon cycle. Soil bacterial adaptations under warming conditions may involve modifications of Carbohydrate-Active Enzymes (CAZymes). Harvard Forest long-term soil warming experiments provided data to look over how more than 20 years of soil warming prior to present can drive shifts in the forest soil carbon cycle. It has been performed by designing heated plots which have cables to induce warming effect and control plots which have been left undisturbed. Genomes from 12 actinobacteria strains isolated from the Harvard Forest long-term soil warming experiments were analyzed using the dbCAN2 meta server to predict genes and classes of CAZymes. Using the ggplot2 package from Rstudio CAZymes data were plotted to show qualitative differences in CAZymes classes among types of plots. As a result, 771 CAZymes genes were found corresponding to the 6 classes: Glycoside Hydrolases (GH), Glycosyl Transferases (GT), Carbohydrate Esterases (CE), Polysaccharide Lyases (PL), Auxiliary Activities (AA) and Carbohydrate-Binding Modules (CBM). Changes in CE relative abundance, which contribute to the decomposition of protected carbohydrate substrates, were observed between heated and control plots. Reduction of a 4.0% of this CAZyme class in warm plots suggests that warming can play a similar role in decaying protected carbon substrates promoting less participation of CE. Understanding genetic patterns of Carbohydrate-Active Enzymes would increase our comprehension of adaptive traits related to global warming and predict disturbances in the global carbon cycle.

Nautica Jones

University of Louisiana at Monroe

Mentor: Meghan Blumstein

Assessing need and potential for assisted allele migration in the Northeast

Shifts in climate have been implicated as a cause for increases in disease spread, drought and flooding events, strength and frequency of storms, and offsets in seasonal progressions (Korner & Basler, 2010). Seasonal progressions stimulate the phenological responses of plants and thus are vital to the timing of their life cycle (Korner & Basler, 2010). Understanding phenological responses to climate change is fundamental to conservation and climate change prediction and mitigation (Fahey et al., 2010).These responses are dictated by both genetic and environmental factors and a forest's ability to adapt varies according to species composition, gene flow, and genetic variation, among others (Aitken et al., 2008). Given that trees are highly locally adapted and phenology is an adaptive trait, we would expect phenological timing to vary significantly among allopatric populations (Aitken et al., 2008). To investigate this I will analyze phenocamera images from several temperate forest sites across northeastern North America in RStudio using package Phenopix and extract the phenological data of the northern red oak (*Quercus rubra*) trees pictured. My report on the phenological data will use the amount of standard deviation between start of season dates as a proxy measure of standing genetic variation; allowing me to ascertain populations' potential to adapt to a warmer climate.

Connor Tamor

Cornell University

Mentors: Emma Conrad-Rooney and Pamela Templer

Effects of Atmospheric Deposition on Carbon Sequestration in Temperate Forest Ecosystems

Since the industrial revolution, humans have increased atmospheric concentrations of greenhouse gases (GHGs), including carbon dioxide (CO2), methane, and nitrous oxide, which together lead to climate change. Forests currently store approximately 30% of CO2 emitted by human activities, so understanding the biogeochemical processes that cycle carbon (C) through forest ecosystems is crucial to combat increasing GHGs and climate change. While atmospheric N deposition and its effects on forest ecosystems have been well-studied, patterns and trends of atmospheric deposition of non-N compounds are less well known. Furthermore, few have studied the impact of these forms of atmospheric deposition on C sequestration in forest ecosystems. The two main questions we addressed include: (1) what patterns and trends exist in non-nitrogen atmospheric deposition over time and (2) how does atmospheric deposition affect C sequestration in Northeastern U.S. temperate forest ecosystems? Using publicly available atmospheric deposition data from the National Atmospheric Deposition Program (NADP), C flux data from Harvard Forest, and C flux and biomass data from Hubbard Brook, we ran several regression analyses to examine potential trends between atmospheric deposition and C sequestration over time. We found that, in general, non-nitrogen forms of atmospheric deposition have decreased over time. Rates of C sequestration at Harvard Forest have increased, while C sequestration at Hubbard Brook has remained stagnant over time. We also found that only calcium (Ca) atmospheric deposition may influence C sequestration, with positive relationships at Harvard Forest and inverse relationships at Hubbard Brook. These contrasting results suggest that Ca deposition is an important control on C sequestration in temperate forests, but not always in the same ways across different forest types. Further exploration of how Ca controls C sequestration will help us better predict how forests may or may not mitigate the adverse effects of climate change in the future.

Coral del Mar Valle Rodríguez

CUNY Hunter College

Mentors: Mayra Rodríguez González, Danelle Laflower, Joshua Plisinski, and Jonathan Thompson

Estimating the Risk of Forest Carbon due to Invasive Forest Insects

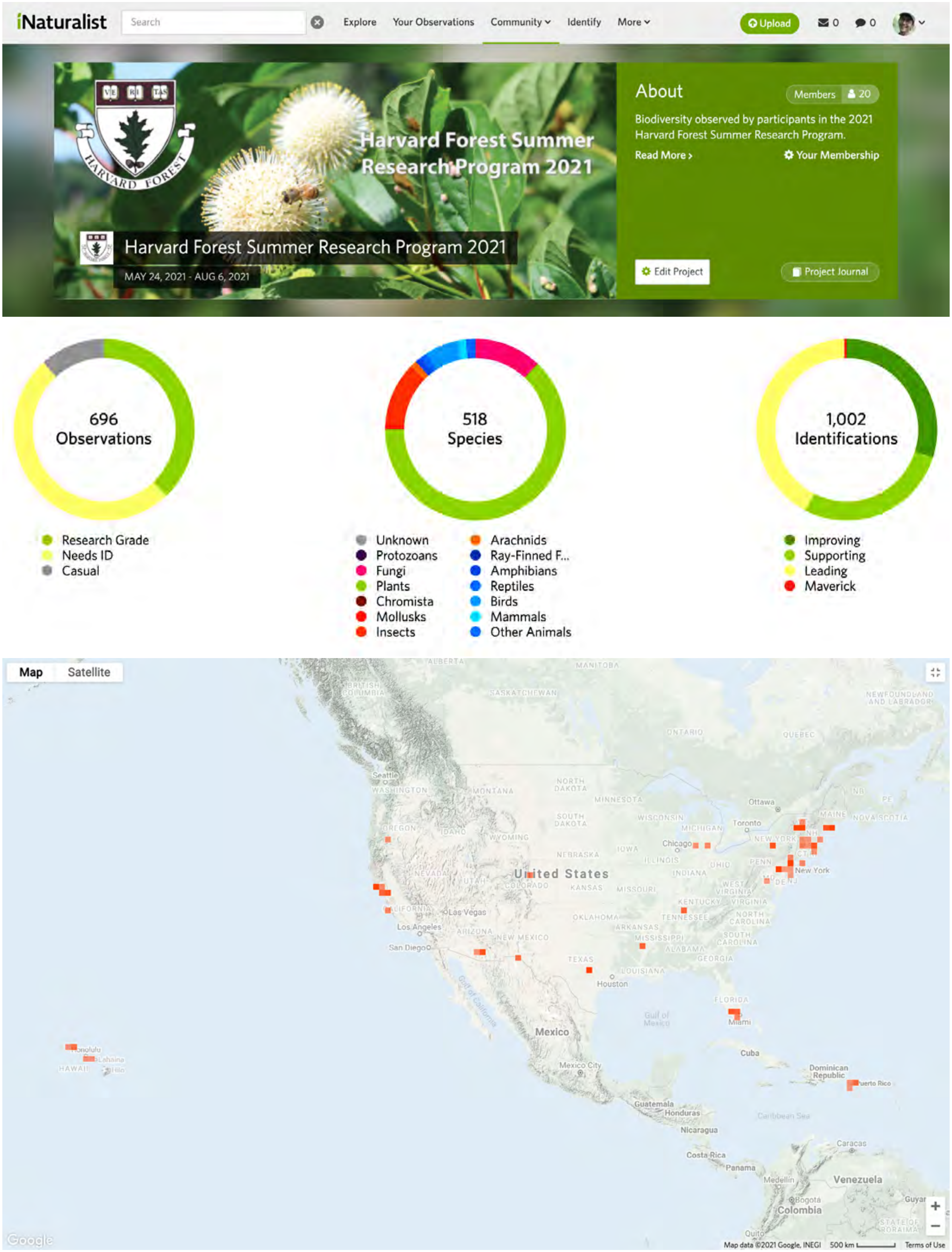
Northeastern forests are important carbon sinks that are threatened by invasive insects. The state of Massachusetts aims to reach net-zero carbon emissions by 2050, in part by relying on forest carbon sequestration. It is unknown how insects may affect this goal. Three insect species impacting forest carbon in the region are the Asian long-horned beetle (*Anoplophora glabripennis*; ALB), hemlock woolly adelgid (*Adelges tsugae*; HWA), and emerald ash borer (*Agrilus planipennis*; EAB). This study uses the LANDIS-II forest landscape model to estimate these insects' impact on aboveground forest carbon in Massachusetts for 2015 (initial infestation), 2050, and 2105. I focused on nine 3,600-hectare sample landscapes with three initial host tree species abundances (low, medium, high), applying three simulation scenarios: no insects (control), infestation, and salvage logging after infestation. I estimate impacts on forest carbon based on the difference between control and treatment scenarios. For all insect species on all landscapes, carbon stocks decreased during the initial infestation. Specifically, carbon stores decreased 0.9-1.2 Mg/ha, 5.7-15.9 Mg/ha, and 0.2-1.04 Mg/ha for ALB, HWA, and EAB, respectively. A reduction in 2050 carbon stores was observed for ALB and HWA. However, for the EAB landscapes, carbon stores increased by 2050 where host tree abundance was lowest. For ALB and EAB, carbon stores increased by 2105 for all landscapes, compared to the control (4.18-5.7 Mg/ha, and 1.6-4.9 Mg/ha, respectively). In contrast, HWA decreased carbon stores (2.9-11.3 Mg/ha) by 2105. Compared to carbon stores in infestation-only scenarios, salvage logging helped mitigate invasive insect species impacts by 2105 by allowing more space for forest regeneration and growth. However, for near-term policy goals (e.g., 2050) insect and logging may hinder the ability of Massachusetts to achieve its carbon goal.

Jennie Wuest
Fordham University

Mentors: Serita Frey and Adriana Romero-Olivares

Characterizing the Response Levels of Fungal Taxa to Global Change Drivers

Human activity in the last several centuries has resulted in a number of global change stressors which have had effects on global ecosystem compositions and activities. Anthropogenic activity has resulted in the increase of atmospheric nitrogen (N) deposition, rising global atmospheric temperature, and non-native species invasion. Previous studies at Harvard Forest have examined the alteration of fungal community composition in response to non-native species invasion on its own, as well as alongside abiotic factors occurring as a result of anthropogenic activity such as simulated N deposition and soil warming; however, an effort to look across datasets has not yet been completed. The aim of this study was to investigate and characterize the response levels of individual fungal taxa to environmental change drivers across the last decade of studies on soil warming, soil N enrichment, and garlic mustard and hemlock woolly adelgid invasion at Harvard Forest. Using datasets containing fungal operational taxonomic units (OTUs) identified from soil samples from sites receiving individual and combined treatments of N fertilization, soil warming, and non-native species invasion, Indicator Species Analysis was performed to test for OTUs that had statistically significant elevated frequencies in one or more of the treatments. Cohen's d was calculated as a measure of effect size, i.e., the change in OTU relative abundance from control and experimental treatments. We found that indicator species with strong positive effect sizes varied by treatment type; for example, the treatment with the highest level of nitrogen fertilization had the largest number of indicator species. In terms of the study focusing on hemlock woolly adelgid invasion, we found fifteen taxa that showed strong positive responses to both moderate and severe invasion. In addition, twenty taxa were found to be statistically significant indicator species for multiple treatments. These results are significant because fungi serve as important ecosystem regulators, and understanding their responses to future climatic conditions can help us prepare a response to that change.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Biodiversity observed by participants in the 2021 Harvard Forest Summer Research Program.
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696 Observations
Research Grade
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Casual
518 Species
Unknown
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Mollusks
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Reptiles
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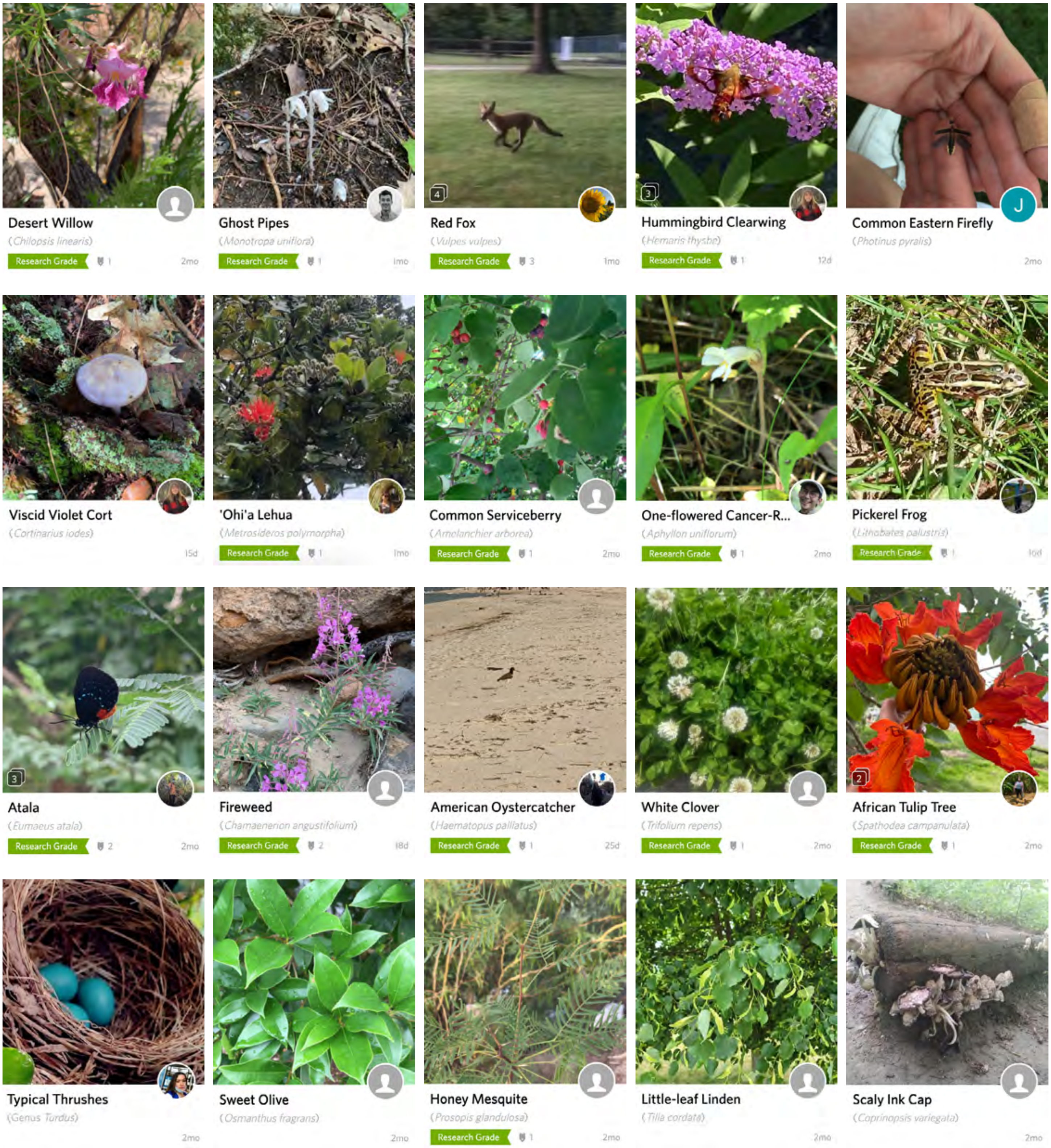
Desert Willow
(Chilopsis linearis)
Research Grade 1 2mo
Ghost Pipes
(Monotropa uniflora)
Research Grade 1 1mo
4
Red Fox
(Vulpes vulpes)
Research Grade 3 1mo
3
Hummingbird Clearwing
(Hemaris thysbe)
Research Grade 1 12d
J
Common Eastern Firefly
(Photinus pyralis)
2mo
Viscid Violet Cort
(Cortinarius iodes)
15d
'Ohi'a Lehua
(Metrosideros polymorpha)
Research Grade 1 1mo
Common Serviceberry
(Amelanchier arborea)
Research Grade 1 2mo
One-flowered Cancer-R...
(Aphyllon uniflorum)
Research Grade 1 2mo
Pickerel Frog
(Lithobates palustris)
Research Grade 1 10d
3
Atala
(Eumaeus atala)
Research Grade 2 2mo
Fireweed
(Chamaenerion angustifolium)
Research Grade 2 18d
American Oystercatcher
(Haematopus palliatus)
Research Grade 1 25d
White Clover
(Trifolium repens)
Research Grade 1 2mo
2
African Tulip Tree
(Spathodea campanulata)
Research Grade 1 2mo
Typical Thrushes
(Genus Turdus)
2mo
Sweet Olive
(Osmanthus fragrans)
2mo
Honey Mesquite
(Prosopis glandulosa)
Research Grade 1 2mo
Little-leaf Linden
(Tilia cordata)
2mo
Scaly Ink Cap
(Coprinopsis variegata)
2mo