Northeastern States Research Cooperative (NSRC) FY2021
USDA FS Award #: 21-DG-11242307-040

Interim Progress Report
Period ending December 31, 2024

Administration and Information Transfer

The Northeastern States Research Cooperative (NSRC; https://nsrcforest.org/) is a research-granting program administered collaboratively by the USDA Forest Service Northern Research Station, the Rubenstein School of Environment and Natural Resources at the University of Vermont, the Department of Natural Resources and the Environment at the University of New Hampshire, the Center for Research on Sustainable Forests at the University of Maine, the State University of New York College of Environmental Science and Forestry, and the Hubbard Brook Research Foundation. NSRC's goal is to foster research that is relevant and beneficial to the people who live within the Northern Forest boundaries, work with its resources, use its products, visit it, and care about it.

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1. Develop a multi-stakeholder platform for the Northern Forest to inform research priorities and recruit a strategic roster of funded research projects.
2. Support high priority scientific research through efficient research administration, data archiving and sharing, and annual financial and technical monitoring and reporting.
3. Share and foster dialogue regarding research findings and synthesis to stakeholders through multiple communication channels.

Between January 1 and December 31, 2024, NSRC:

- Conducted outreach and communications activities to increase the visibility of the NSRC with people who live within the Northern Forest boundaries, work with its resources, use its products, visit it, and care about it.
- Monitored and tracked all research and Indigenous Forest Knowledge Fund (IFKF) projects.
- Organized a special session at the 2024 Forest Ecosystem Monitoring Cooperative conference in Burlington, Vermont, highlighting research from 2020 and 2021 projects to over 50 people.
- Rebranded NSRC with activities including updated colors, a new logo, and a redesigned NSRC website. The new website is set to launch in the Spring/Summer of 2025.
- Initiated collaboration with the Northern Research Center communications team.
- Modified reporting workflows to include more robust review of research progress based on information contained in annual reports.

Summary of progress in 2024

Objectives and tasks described in the NSRC 2021 proposal narrative are on schedule and described below.

1. **Develop a multi-stakeholder platform for the Northern Forest to inform research priorities and recruit a strategic roster of funded research projects.**

    - External Advisory Council (EAC) formed—Complete.
    - EAC meets and recommends priorities for research—Complete.
    - Successful Request for Proposals (RFP) process—Complete. 2 RFPs were released for this award.
        - **The general fund** received 33 research project proposals requesting $5.2 million in funding; 11 grants were awarded totaling nearly $2 million of federal funding and close to $1.1 million of matching funding.

    - **The IFKF** received 10 proposals requesting $3.2 million in funding; 3 grants awarded totaling nearly $2 million in funding.
- Research project awarded—Complete, view all of the projects on our website and in table 1 below.
- IFKF projects awarded—Complete, view all of the projects on our website

2. **Support high priority scientific research through efficient research administration, data sharing, and annual financial and technical monitoring and reporting.**
    - Annual technical and financial reporting—Ongoing. In 2024, the NSRC management team modified reporting workflows to include more robust review of research progress based on information contained in annual reports.
    - Research outputs, to include scholarly and public-facing publications and activities—Ongoing. This award supported the development of 9 scholarly articles, 25 presentations, and 15 other communications materials during this reporting period (see appendix A). Additionally, these research projects supported 18 graduate students and 15 undergraduates.
    - Project data archived with the Forest Ecosystem Monitoring Cooperative (FEMC)—Ongoing. An NSRC collection with available data is accessible on the FEMC website.

3. **Share and foster dialog regarding research findings and synthesis to stakeholders through multiple communication channels.**
    - Communications outputs—New NSRC logo, FEMC conference special session, print publications, press releases, and project specific communications materials.
    - NSRC website with current list of projects, research outputs—Communications team is in the process of updating the website. The current website is used by PIs and partners to find projects, RFP information, and publications.
    - Engagement with partners and the public—Ongoing, key partners include the USFS, the universities in the Northern Forest, and members of the EAC.

Table 1: Regional Research and Indigenous Forest Knowledge Fund projects funded through NSRC 2021 (*21-DG-11242307-040*)

NSRC 2021 Research Projects	*PI*	*Lead Institution*
Eastern White Pine Health Monitoring through Remote Sensing Assessment of Foliar Traits	Parinaz Rahimzadeh	University of Maine
***Effects of Timber Harvesting on the Wetland Ecology of Northeastern Lowland Forests**	Christina Murphy	USGS Maine Coop Fish & Wildlife Research Unit, U. of Maine
Impacts of Extreme Climate Events on Tree Regeneration in the Northern Forest	Jay Wason	University of Maine
***Implementing Forest Adaptation Options for Northern Forest Ecosystems**	Anthony D'Amato	University of Vermont
Invasive Pest Effects on Tree Demographics Across the Northeastern US	Jeff Garnas	University of New Hampshire
Investigating the Role of Mycorrhizal Fungi in New England Forest Management	Caitlin Hicks Pries	Dartmouth College
Jumping Worm Invasion and Impact in the Northern Forest	Tim McCay	Colgate University
Oak at the Edge: Investigating the Importance of Fire as a Tool in Oak Range Expansion	Matthew Vadeboncoeur	University of New Hampshire

***Quantifying Changes in Forest Condition, Connectivity and Resilience in the Northeast Using Geospatial and Remotely Sensed Data**	Melissa Clark	The Nature Conservancy
***Trail Forks and Merges: Exploring Social Impacts from Recreational Mountain Biking in Northern Forest Communities**	Kimberly Coleman	SUNY Plattsburgh
Wildlife in the WUI: Investigating Forest Characteristics and Impacts on Mammalian Diversity in the Wildland-Urban Interface	Daniel Bogan	Siena College
NSRC 2021 Indigenous Forest Knowledge Fund (IFKF) Projects	**PI**	***Lead Institution***
Building Stewardship Capacity: Protecting the Brown Ash of the Northern Forest	John Daigle	University of Maine
Monitoring Moose and Other Culturally Important Wildlife on Penobscot Indian Nation Lands Using Remote Cameras	Benjamin Simpson	The Penobscot Nation
Supporting Abenaki Stewardship of the Ecologically Rare and Culturally Important Atlantic White Cedar Swamp Ecosystem	Heidi Asbjornsen	University of New Hampshire

* indicates the project is finished. The final report for each research project will be attached to the final award report and is available in Appendix B.

Collaboration with Forest Service

Daniel Dey serves as the Forest Service liaison with NSRC. He contributes expertise to all aspects of NSRC activities, including the development and implementation of research projects and IFKF research competitions, participation in the EAC as an observer, and coordination and management activities.

Next reporting period

During the next reporting period, NSRC will work on activities related to objectives 2 and 3 and ensure the successful completion of research project.

The main portion of this annual report is composed of summaries of progress for the administration project, ongoing research projects, and IFKF projects.

Ongoing Research Projects

Eastern White Pine Health Monitoring through Remote Sensing Assessment of Foliar Traits

Principal Investigator: Parinaz Rahimzadeh, Ph.D. Associate Professor, School of Forest Resources, University of Maine, Orono, Maine

Summary of progress in 2024

The team developed two research projects under leaf level analysis in 2022 and 2023 based on the field data collected in 2022 from an Eastern White Pine (Pinus strobus L.; EWP)-dominated site in Bethel, Maine to 1) detect white pine needle damage (WPND) using a combination of field-measured foliar traits and several remote sensing-derived spectral vegetation indices (SVIs), and 2) model foliar traits such as nitrogen (N), chlorophyll (Chl), and equivalent water thickness (EWT) using remote sensing data. In 2024, these two research projects were completed.

Additional field data were collected for a landscape-level study in four EWP-dominated stands in Maine (Auburn, Bethel, Demeritt, and Davis) in the summer of 2023 to model 1) leaf area index (LAI) and live crown ratio (LCR), and 2) to develop a standard EWP health index using remote sensing data following the existing literature and USFS EWP stand management (silviculture) protocols.

Plans for 2025

To assess how environmental factors, such as sky condition and illumination and segmentation techniques, influence the accuracy and consistency of LAI measurements in the field collected using Digital Hemispherical Photography (DHP) method, the LAI will be measured through three approaches: (i) CANEYE software, (ii) python-derived LAI with K-means segmentation and (iii) python-derived LAI with convolutional neural networks (CNN) segmentation. The LAI values will be compared with LiCOR 2200TC-derived LAI estimates to check the consistency among various methods. Moreover, to systematically assess the effect of sky conditions and illumination on DHP segmentation, the collected DHP data will be categorized into four distinct conditions: (i) clear sky with bright illumination, (ii) cloudy sky with bright illumination, (iii) cloudy sky with dull illumination, and (iv) rainy sky with dull illumination and their accuracies will be compared.

Description of alignment with or collaboration with USFS and other partners

This project has closely collaborated with USFS and Maine Forest Service in the past three years and the products are designed to be directly used for EWP health monitoring by USFS and Maine Forest Service (MFS). Forest pathologists Dr. Isable Munck, Dr. Cameron McIntire (USFS, New Hampshire), and Aaron Bergdahl from the MFS, Augusta are involved in the project. Aaron Bergdahl helped with identifying appropriate sampling locations, acting as a mediator between the forest landowners in both summer 2022

and 2023. He helped with data collection and reviewed the techniques that were used. He also provided feedback on study results. Similarly, Drs. Isabel Munck and Cameron McIntire have been supporting the project by providing feedback on preliminary results. Dr. José Eduardo (Dudu) Meireles, Assistant Professor at the University of Maine (UMaine), helped with spectral data collection and data processing. Collaborators periodically join the research discussions and review the data processing methodology. Dr. William Livingston also from SFR, UMaine has been supporting this project through regular discussion and supervision of the methods that have been applied.

Products

- Das, P., Rahimzadeh-Bajgiran, P., Livingston, W., McIntire, C. D., & Bergdahl, A. (2024). Modeling forest canopy structure and developing a stand health index using satellite remote sensing. Ecological Informatics, 84, 102864. https://doi.org/10.1016/j.ecoinf.2024.102864
- Timalsina, S., Rahimzadeh-Bajgiran, P., Das, P., Meireles, J. E., & Bhattarai, R. (2024). Monitoring eastern white pine health by using field-measured foliar traits and hyperspectral data. Sensors, 24(18), 6129. https://doi.org/10.3390/s24186129

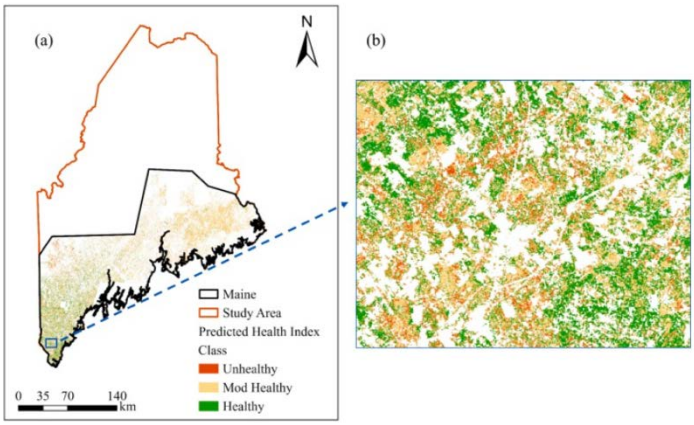
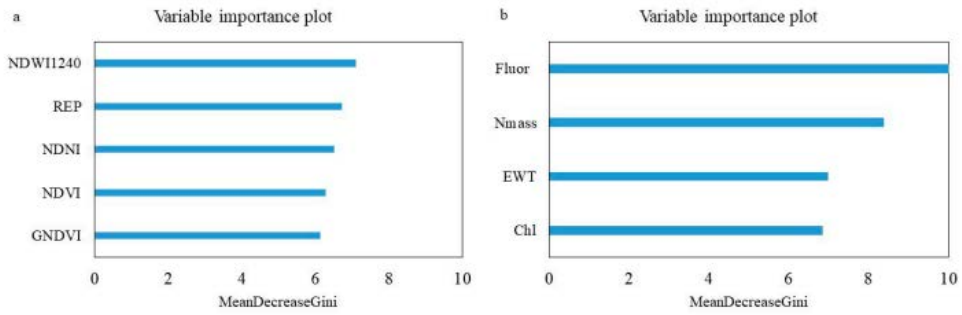


Figure 1: Eastern white pine (EWP) stand health index map for (a) southern Maine, USA, and (b) highlighted over an area (Landscape-level project) (Das et al., 2024)

- Das, P. and Rahimzadeh-Bajgiran P., Remotely Sensed Estimation of Live Crown Ratio (LCR) for Eastern White Pine (EWP) Health Assessment", ASPRS 2024 Geo Week, February 11-13, 2024, Denver, CO, USA.
- Timalsina, S. and Rahimzadeh-Bajgiran P., Assessing White Pine Needle Damage (WPND) Impact on Eastern White Pine (EWP) Health through Modeling Foliar Traits using Remote Sensing Data, ASPRS 2024 Geo Week, February 11-13, 2024, Denver, CO, USA.
- Timalsina, Sudan, "Monitoring Eastern White Pine Health by Using Remote Sensing Assessement of Foliar Traits" (2024). Electronic Theses and Dissertations. 3982. https://digitalcommons.library.umaine.edu/etd/3982
- IEEE Maine January 2025 Newsletter (https://r1.ieee.org/maine/wp-content/uploads/sites/29/Beacon_January25.pdf)

Figure 2: The Variable Importance Plot (VIP) for (a) the best-performing random forest (RF) model using remotely sensed SVIs and (b) the best RF model using field-measured trait for white pine needle damage detection (leaf-level project).



Impacts of extreme climate events on tree regeneration in the Northern Forest

Principal Investigator: Jay Wason, University of Maine

Summary of progress in 2024

Figure 1: University of Maine undergraduate students assessing phenological stages of trees in our winter warming experiment. Photo credit: Jay Wason

The project has made significant progress on all research and outreach goals in 2024. In 2024, the graduate student working on this project led the successful execution of both the winter warming study and heat and drought study. For the winter warming study, the project integrated this into a laboratory that the PI teaches for first-year forestry students. An undergraduate student completed their capstone project using some of the data. Collaboration with the USFS helped get critical measurements of cold tolerance for these trees. This work was presented at the Forest Ecosystem Monitoring Cooperative's Annual Meeting in December. For the heat and drought study, the team hired a different undergraduate student to work as a field technician for the summer. She successfully applied for additional university funding for her work and is now conducting an independent study related to this project that will become part of her honors thesis. All major data collection has been completed and manuscripts for both studies are being drafted. A highlight of this summer was the production of a public video related to the work that was shared widely.

Plans for 2025

The focus of 2025 is on manuscript writing, completing an undergraduate honors thesis, and a graduate student master's thesis. In addition, the team will hold the final annual cooperators meeting and conduct the workshop with practitioners.

Description of alignment with or collaboration with USFS, other partners, or the public

The team continues to work with partners at the 6 research installation locations (Schoodic Institute, Blue Hill Heritage Trust, Newell Tree Farm, UMaine, Piscataquis County Soil and Water Conservation District, and the Forest Society of Maine). Each of these partners is hosting a research site and helped with planting and monitoring the trees. These sites will be decommissioned in summer 2025. The team also collaborated with John Butnor (USFS) to measure cold tolerance of the trees throughout the midwinter warming study.

Invasive pest effects on tree demographics across the northeastern US

Principal Investigator: Dr. Jeff Garnas, University of New Hampshire

Summary of progress in 2024

In 2024, the project utilized the customized Forest Service Forest Inventory and Analysis database and SQLite queries made in 2022 and 2023 to address the impact that invasive pests may have had on host species demographics and carbon sequestration (Objective 1). The team found that changes in host demography in the face of invasive pests heavily depends on the biology of the host as well as the epidemiology of the pest. Researchers modeled rates of turnover by the estimated sapling abundance (ESA, recruitment) and baseline relative mortality (BRM, mortality). Both the ESA and BRM of *Fagus grandifolia,* the host of Beech Bark Disease, increase presumably due to prolific resprouting after bole death. Likewise with *Ulmus americana,* the host of Dutch Elm Disease, likely due to the relatively quick generation time of elm. Conversely, the ESA and BRM of *Tsuga spp.* due to Hemlock Wooly Adelgid (HWA), *Fraxinus spp.* due to Emerald Ash Borer (EAB), and *Quercus spp.* due to Spongey Moth (SM) change little or not at all (Objectives 1 and 3). To assess the impact on carbon sequestration, the team compared live carbon stocks between 2010 and 2020 as a function of pest duration by 2020 (Objective 2). Carbon sequestration rates of *F. grandifolia* recover after ~30 years of infestation. In other systems, carbon sequestration rates are either fundamentally altered or are unaffected.

Plans for 2025

The project will be further exploring the short and long-term impacts of forest structural change on tree biomass (maximum, empirical, and trajectory). Two manuscripts are currently being produced with the intention of submitting them for publication in peer-reviewed journals within the next 5 months. Additionally, this work will be presented in part at the 33rd USDA Interagency Research Forum on Invasive Species in Annapolis, MD. The project will be wrapping up by June 2025.

Description of alignment with or collaboration with USFS, other partners, or the public

The team is actively collaborating with Randall Morin (USFS, York, PA), Andrew Liebhold (USFS, Morgantown, WV), Prof. Songlin Fei (Purdue University, IN), and Prof. Carrie Fearer (Virginia Tech, VA) who provide feedback on the project's progress. Formal meetings in June and November of 2024 discussed the project's progress and trajectory. The supported postdoc on the project, Dr. Bascom, frequently met with Randall Morin virtually to discuss technical aspects of working with the data as well as discussing the project generally.

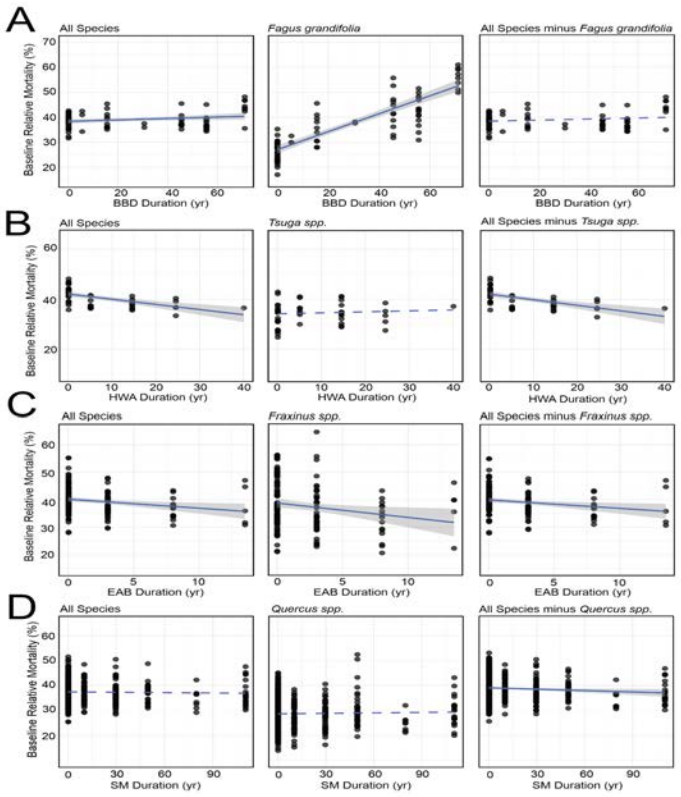


Figure 4. Demographic trends of mortality among host tree species vary by biology, epidemiology of pest. The BRM of all species (right), host species (center), and all species minus host species (left) as a function of the duration of a particular pest. Each dot represents a county grouping that share a common pest duration range and have a minimum number of host-positive FIA plots. A) The demographic structure of *F. grandifolia*, the host of BBD, increases as a function BBD duration. This is in stark contrast to *Tsuga spp.* in the context of Hemlock Wooly Adelgid (B), in which there is no demographic shift. *Fraxinus spp.* the host of Emerald Ash Borer (EAB), displays a decrease in BRM as a function of EAB duration. Because the trend of *Fraxinus* mirrors that of All Species and All Species minus *Fraxinus*, we consider this a pre-existing trend, and we may not yet be able to detect how *Fraxinus* populations respond to EAB until more time as passed. Spongy Moth (SM) has had little effect on the landscape scale mortality of *Quercus spp.* E) The BRM of *U. americana* has increased as a function fo Dutch Elm Disease (DED), counter to demographic trends of co-occurring species. Solid line indicates a linear regression model with a $p<0.05$, dashed $p>0.05$. Grey shading is the 95% confidence interval around the linear regression model.

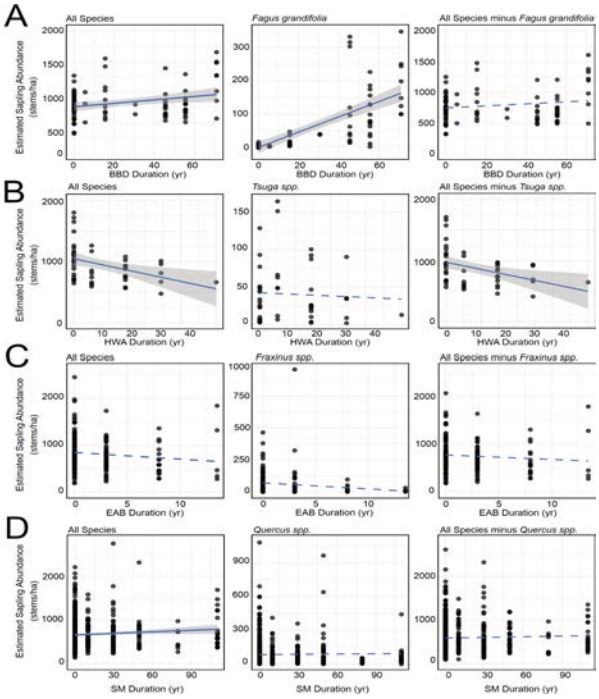


Figure 5. Only *F. grandifolia* and *U. americana* show shifts in recruitment in response to invasive species. The ESA of all species (right), host species (center), and all species minus host species (left) as a function of the duration of a particular pest. Each dot represents a county grouping that share a common pest duration range and have a minimum number of host-positive FIA plots. A) The modeled recruitement of *F. grandifolia*, increases as a function BBD duration. Neither *Tsuga spp.* (B), *Fraxinus spp.* (C), nor *Quercus spp.* (D) increase rates of recruitment in response to invasive pests. While not as responsive as *F. grandifolia,* we detected an increase in *U. american* (E) as a function of Dutch Elm Disease. Solid line indicates a linear regression model with a $p<0.05$, dashed $p>0.05$. Grey shading is the 95% confidence interval around the linear regression model.

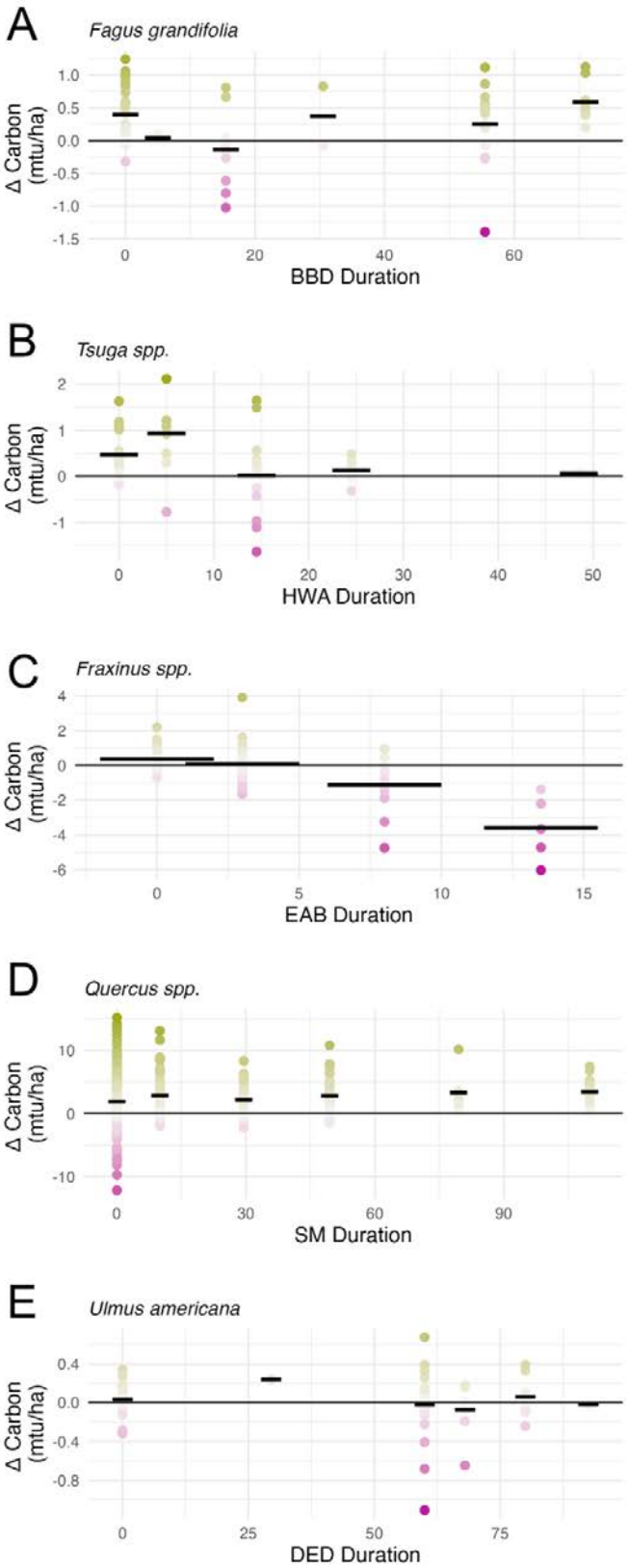


Figure 6 Changes in live aboveground carbon between 2010 and 2020 as a function of pest duration in 2020. Each dot represents a county grouping that share a common pest duration range and have a minimum number of host-positive FIA plots. Solid black lines at each duration point indicate the mean change in carbon. A) Carbon sequestration rates of live *F. grandifolia* stems declines at ~15 years of BBD infestation in line with the "killing front" observed in those forests. However, sequestration rates recover after ~30 years as stems regenerate. B) Along a similar time scale, carbon sequestered by live *Tsuga spp.* stems declines. In contrast to *F. grandifolia,* however, the rate of sequestration does not recover as *Tsuga spp.* is a poor regenerator. C) Carbon stored in live *Fraxinus spp.* stems declined dramatically between 2010 and 2020. Given the novelty of EAB, we will have to see whether sequestration rates recover like *F. grandifolia* or not like *Tsuga spp.* D) Spongy Moth, which is not known to cause wide-scale morality, has had little effect on *Quercus spp.* carbon sequestration rates. E) Likewise, there is little change to the carbon sequestration rates due to *U. americana*, potentially compounded by the relative rarity of *U. american* stems.

Investigating the role of mycorrhizal fungi in New England Forest management

Principal Investigator Caitlin Hicks Pries, Associate Professor, Dartmouth College

Summary of Progress

In the year 2024, two scientific papers were drafted and submitted detailing the results of the seedling studies. The first, which is currently in revision for the *Canadian Journal of Forest Research*, is "Negative effects of competition outweigh benefits of arbuscular mycorrhizal facilitation for seedling success in a managed temperate hardwood forest." This manuscript is being led by former undergraduate thesis student, Eva Legge. The second, which is currently in review in *Ecological Applications* is "Mycorrhizal legacy mediates seedling success following timber harvesting in Northeastern forests." This manuscript is being led by former PhD student, Amelia Fitch. The research described in these papers was funded by this grant. In 2024, final soil samples were collected from the control and harvested arbuscular (AM) and ectomycorrhizal (EcM) dominated plots in June to compare with the samples collected pre-treatment in 2019/2020. The team is comparing how carbon and nitrogen stocks and the amount of particulate and mineral-associated carbon and nitrogen have been affected by harvesting and whether responses differ in stands that were formerly dominated by arbuscular or ectomycorrhizal-associated trees. Undergraduate researchers have been processing and fractionating these soil samples. At this point, all soils have been processed and about 75% have been fractionated into mineral-associated and particulate matter pools. A portion of these soil samples was reserved for DNA extractions and PLFA/NLFA analyses to continue the work characterizing the effect of harvesting on mycorrhizal communities.

Plans for 2025

- Finish revisions of the manuscript for *Canadian Journal of Forest Research* and resubmit.
- Handle potential revisions of the manuscript currently in review at *Ecological Applications*.
- Finish fractionating soils from Corinth, prepare samples for CN analysis, and analyze data.
- A Dartmouth undergraduate will present the soil results at the Karen E. Wetterhahn Science Symposium (undergraduate research symposium) in June 2025.
- Send soil samples out to an external lab for PLFA/NLFA analyses
- Extract DNA from 2024 soils and send it out for ITS sequencing.
- Analyze DNA data for how microbial communities in the harvested sites have changed over time.

Description of alignment with or collaboration with USFS, other partners, or the public

In 2024, the team gave a webinar arranged by Ali Kosiba and the University of Vermont Extension Forestry on "Mycorrhizal fungi and forestry in Northeastern forests". The webinar can be watched here: https://www.youtube.com/watch?v=PLZutwy5kts

Figure 7: A porcupine visited one of our plots while we sampled soil in June 2024.

Figure 8: One of the soil samples collected in June 2024.

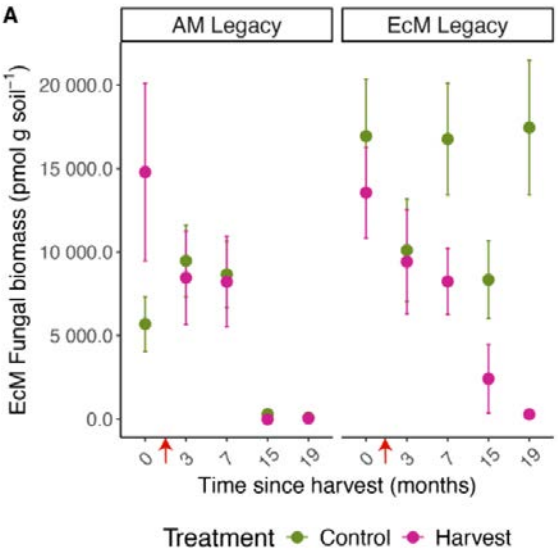


Figure 9: The biomass of ectomycorrhizal fungi continued to decrease over the two years following harvesting in forest stands previously dominated by EcM-associating trees (EcM legacy), but this did not affect growth or survival of EcM seedlings (Fitch et al.)

Oak at the edge: investigating the importance of fire as a tool in oak range expansion

Principal Investigators: Matthew Vadeboncoeur, Research Assistant Professor, University of New Hampshire. Natalie Cleavitt (Cornell), Khanh Ton (UNH MSc student), Heidi Asbjornsen (UNH), Andy Fast (UNH Cooperative Extension)

Figure 10: Left: Anthony Pera (Cornell undergraduate) takes a leaf area index measurement at seedling height in a regenerating prescribed burn at the Bartlett Experimental Forest; these seedlings were transplanted from the 2023 mesocosm experiment. Right: Chris

Summary of Progress in 2024:

Data collection and analysis

- Soil samples analyzed for pH, Ca, Mg, K, P, Pb (ppm), and organic matter.
- Roots from potted seedlings analyzed for mycorrhizal colonization.
- All plots were revisited to assess seedling growth and health variables including: height, diameter at root collar, extension growth, number of leaves, live and dead branches, herbivory and pathogen damage.
- Leaf area index at the seedling height was measured at each plot.
- Leaf samples were collected from tagged oak seedlings for nitrogen analysis.
- Oak seedling roots collected from outside of established transects for analysis of mycorrhizal colonization.
- Statistical analyses of above data.

Communications and outreach

- Ton. K. UNH NREN Seminar, February 2024.
- Ton, K. Prescribed fire improves red oak regeneration in northern New Hampshire. Poster presentation, New England SAF, Burlington VT, March 2024.
- Ton, K. Oral presentation, Annual Hubbard Brook Meeting, Plymouth NH, July 2024.
- Ton, K. Poster presentation, Ecological Society of America, Long Beach CA, August 2024.
- Ton, K. Oral presentation, International Oak Symposium, Knoxville TN, October 2024.
- Ton, K. Oral presentation, UNH ESRC Seminar, December 2024.
- Cassel, A. Fighting fire and fear. Hubbard Brook Ecosystem Study. https://hubbardbrook.org/fighting_fire/
- Gosling, N. Regenerating Northern Oak Forests Using Prescribed Fire. UNH Today. May 20, 2024. https://www.unh.edu/unhtoday/regenerating-northern-oak-forests-using-wildfire/
- Brooks, D. UNH researchers wonder if controlled burns really do help red oak. Concord Monitor, Granite Geek. May 21, 2024. https://granitegeek.concordmonitor.com/2024/05/21/unh-researchers-wonder-if-controlled-burns-really-do-help-red-oak/
- Regenerating Northern Oak Forests Using Wildfire. NH Weekly Market Bulletin. June 5, 2024.

Problems or Changes:

- Seedlings planted in one of the study stands at Bartlett Experimental Forest were eaten by deer during the winter or spring of 2024. The project will proceed with only an analysis of growth of seedlings within the burned stand (against the potting soil treatment and local leaf area index).
- Tree core collection was planned for the late summer or early fall of 2024, but was not completed due to a forearm sprain of the graduate student, followed by a broken toe and foot sprain of the PI. These collections are now planned for the early-mid summer of 2025.

Plans for 2025:

Complete lab analyses of samples taken for foliar nitrogen and carbon isotopes, soil available nitrogen, and root mycorrhizal colonization. Field collection of tree cores from three historically burned stands; dendrochronology analysis of oak population age structure.

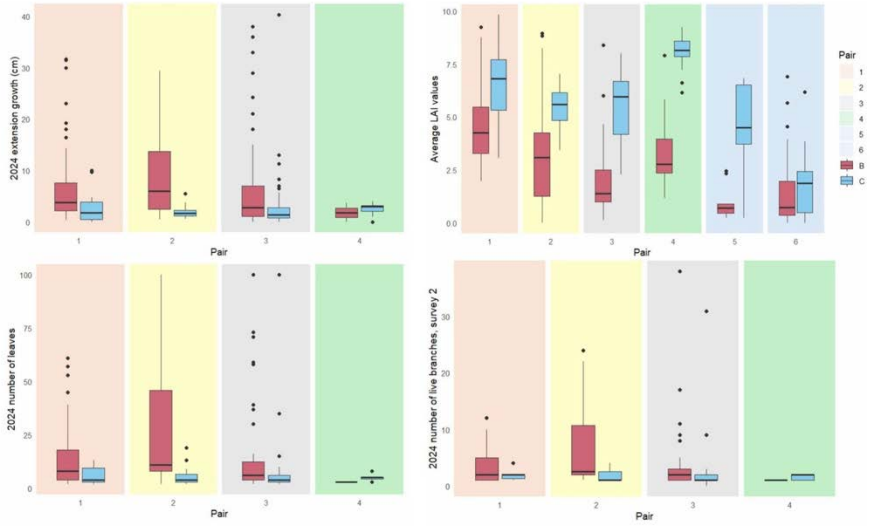


Figure 10: Summary statistics of oak seedlings surveyed in summer 2024 at four pairs of burn-unburn stands (Stevens Brook shelterwoods (1) – in orange, Hogsback seed tree harvests (2) in yellow and shelterwoods (3) in grey, and Crawford Notch wildfire (4)

Communications and outreach

- Presentation of results-to-date at multiple venues. Identified opportunities include:
    - North Atlantic Fire Science Exchange Student Webinar
    - UNH Grad Research Symposium (April)
    - MS thesis defense at UNH (April)
    - National SAF (October - Hartford CT)
    - Presentation of results at GSD SAF (by collaborators?)
    - Integration of the results into educational materials provided to UNH extension county foresters and the Northeast Silviculture Institute for Foresters
- Written products, including:
    - An article will be submitted to a special issue on oak ecology in Forest Ecology and Management
    - An article in a publication that targets forest landowners and forest managers throughout the region (e.g. *NESAF Quarterly* or *Northern Woodlands*)
    - A Cooperative Extension "factsheet," or technical guide, for land managers detailing management recommendations based on research outcomes.

Alignment and Collaboration with USFS and stakeholders

This project was motivated by conversations with John Neely about prescribed fires that had been implemented on the WMNF, and throughout the project the team has engaged with USFS scientists and managers to align the research direction with the needs of these stakeholders.

Wildlife in the WUI: Investigating Forest Characteristics and Impacts on Mammalian Diversity in the Wildland-Urban Interface

Principal Investigator: Daniel Bogan, Siena College

Summary of progress in 2024

Progress during 2024 was mixed. Collaborators continued analyzing forest change across the wildland-urban interface using FIA data. The release of the 2020 Wildland-Urban Interface expands the space-for-time analysis, allowing us to compare pre-1990's WUI with a longer new WUI change class. Previously, the new-WUI change class spanned two decades. The current definition includes three decades (new WUI 1990-2020).

The updated WUI framework enables us to use current classifications of the three WUI change classes, and the team expects this improvement to benefit future field analyses comparing between areas recently disturbed by housing development with old-WUI and non-WUI Wildlands. Using the newest data will require additional geospatial analyses and revised stratified-random selection of study sites.

Initial attempts to continue field investigations during 2024 fell short due to the inability to hire current undergraduate students. Time spent during spring 2024 screening students soon turned to courting potential candidates, and eventually failed to onboard summer research students. Students elected to go home for the summer, sought employment for higher pay outside of the profession, or sought internships as required for their degrees.

Project collaborators ("Co-PI's") organized a session to present current analyses of WUI and FIA data at the Forest Inventory and Analyses (FIA) Science Symposium: Toward Tomorrow's Forests Together 2024, November 19-21, 2024[1]. Riemann, Sonti, and Bogan each presented a talk as part of the online symposium.

Problems or changes

Previous field seasons faced two main challenges at alternating times: lack of field technicians and lack of private land access. Due to internal restrictions, which greatly limited the ability to hire and work with field researchers as staff (non-student research technicians), the work-around seems to be hiring contractors, on contract, to work as research technicians to assist the study. Unfortunately, this realization was determined far too late to implement for the 2024 field season. Significant time was lost seeking solutions for hiring research staff.

Specific Changes for 2025

- Hire consultants (research technicians) by contract (*to avoid difficulties and limitations when hiring staff directly employed by Siena College*).
- Conduct a Public Outreach Campaign to secure landowner permission for study sites.

Plans for 2025

The team plans to incorporate the changes (above) to achieve the research objectives. Working with

[1] Details of the organized session, and the talks (titles and abstracts) by project partners are presented at the end of this report.

Siena's grants administration, a no-cost extension will be requested to modify the original timeline to complete the project by summer 2026. Working with collaborators and project partners, the team will hire students and research technicians (*by contract*), implement a public outreach program to secure land access and conduct the intended field research protocols.

Winter/Spring 2025

- Hire contractors (2) for the 2025 field season
- Implement Public Outreach Campaign
- Hire multiple Siena undergraduates to assist the study throughout the year
- Seek funding to support additional summer research students through internal (Center for Undergraduate Research and Creative Activity; *here*) and external sources.

Spring/Summer/Fall 2025

- Conduct field studies following the original sampling protocol at stratified, randomly selected locations in all three WUI change classes: old-WUI (pre-1990), new-WUI (1990-2020) and non-WUI (forested) lands. This involves the original plans to conduct camera-trap wildlife (mammal) surveys, estimate small mammal abundance and diversity, measure site characteristics at each study location for quantitative analyses and comparison with USFS FIA data.
- Process data on a weekly basis (i.e., entering field data, summarizing progress, and *evaluating progress for success or need to adjusting protocols as necessary.*
- Present initial results at The Wildlife Society's 32nd Annual Conference, Edmonton, Alberta, Canada 2025.

Winter/Spring 2025/26

- Analyze data, prepare summary reports, manuscript drafts, and final reporting
- Continue public outreach to disseminate study findings
- Present results at a regional spring conference (Northeast Natural History Conference and/or Northeast Association of Fish & Wildlife Agencies)

Description of alignment with or collaboration with USFS, other partners, or the public

The Wildlife in the Wildland-Urban Interface research project continues to be a direct collaboration with USFS Northern Research Station staff. The team includes co-PI's Rachel Riemann, M. Phil., Dr. Nancy Sonti, Dr. Miranda Mockrin, and Dr. Jonathan Knott.

Conference Presentations 2024

Forest Inventory and Analyses (FIA) Science Symposium: Toward Tomorrow's Forests Together 2024, November 19-21, 2024

- https://research.fs.usda.gov/programs/fia/sciencesymposium#special-journal-issue

ORGANIZED SESSION: Assessing future forests--Measuring change in the forested wildland urban interface
ORGANIZERS: Rachel Riemann, Nancy Sonti, and Jon Knott

Presentations and abstracts are available upon request.

Building Stewardship Capacity Protecting the Brown Ash of the Northern Forest

Principal Investigator: John Daigle, University of Maine

Progress in 2024

Following the full length 2023 field season, each of the study site locations for this project were revisited following silvicultural treatment completion and the established inventory plots were resampled during this 2024 field season. In addition to this forest inventory data collection, emerald ash borer sampling, using trap tree (count = 4) and purple panel traps (count = 12), were also completed. Progress was also made in setting up and conducting the Tribal Nation "Brown Ash and Emerald Ash Borer" community meetings in 2024.

The primary field site locations for this project are Frenchville, ME; Garfield, ME; Readfield, ME; and Farmington, ME. At each of these sites the same rigorous field inventory of vegetation was conducted as was in 2023. In total across these four sites over 1800 trees were measured and assessed for key variables in describing these sites for reporting on changes and responses of the forest to the silvicultural treatments applied at each location.

Mr. Everett and his Wabanaki Youth in Science (WaYS) intern Sydney Cyr (Descendent of the Mi'kmaq Nation) assisted in the field inventory at all four of the study sites as was done in 2023. Inventory data is being analyzed to produce pre- and post-harvest comparisons of stand and stocking and other formal forest vegetation summaries. Mr. Everett and Ms. Cyr also again hung, tended, and recorded EAB monitoring results for 12 purple panel traps across the four primary study sites. None of the purple panel traps recorded an emerald ash borer detection aside from the Frenchville, ME location (32 adult EAB beetles collected), which was already a known EAB detection site. Trap trees (i.e. intentionally girdled ash trees that are used to monitor for EAB) were also installed at each study site again. In late fall these trees were harvested and peeled to check for the presence of EAB and once again only the Frenchville, ME site showed a positive detection of EAB (76 EAB larvae and larval feeding galleries identified). As was mentioned in the 2023 accomplishment summary; from this trap tree data, the team was able establish a baseline density measurement for EAB and early analysis of this data shows a significant increase in EAB density at the Frenchville site. This aligns with the recent expansion of generally infested areas of the Northern Maine emerald ash borer quarantine area established by the Maine Forest Service. In addition to field data collection seeds were also collected at study site locations. The small number of seeds collected, their low viability, and interest among Tribal partners pointed to the use of this seed for immediate propagation attempt as opposed to submission into long-term storage facilities for genetic research. Any propagated seedling will be donated to the Passamaquoddy Forestry, Tribal Ash Nursery.

Mr. Everett also secured IRB approval to hold four community meeting focus group sessions within each Tribal Nation partner community. In 2024 based on the alignment of schedules among Tribal Nation natural resource staff and community members two of these four Tribal Nation community meetings were held. One meeting was held with the Mi'kmaq Nation Tribal community on January 30th and the joint Passamaquoddy Tribal Nation community meeting was held on March 14th. The audio for these Tribal Nation community meetings is being transcribed and shared back to Tribal Nation community members that participated, for member checking procedure. Once approved, the analysis of this transcript will lead to the development of a report for those three Tribal Nation community partners.

An update of progress in the project was shared with project partners and beyond at a recent meeting hosted at the University of Maine in Orono, ME. The Ash Protection Collaboration Across Wabanakik (APCAW), Future of Brown Ash Meeting.

Problems or Changes

As indicated in the no-cost extension request for this project, logistical hurdles surrounding the harvest conditions at each of the four study sites in this project forced harvest operations to hold off until winter 2024 and into the drier periods of summer 2024. The team struggled to align natural resource staff and community member schedules to hold the last two Tribal Nation community meetings (i.e. Penobscot Nation, and Houlton Band of Maliseet Indians). On two separate occasions, these meetings were scheduled and due to unforeseen circumstances in the community they needed to be postponed and eventually canceled due to scheduling challenges. The project team is still interested in conducting the Tribal Nation community meetings and have left the option on the table for each of the two remaining Tribal Nations to find a date this year.

Plans for Final Months of Project Period

As previously mentioned, the remaining two Tribal Nation community meetings are still open for scheduling before the project end period. These might occur if scheduling can align between Tribal Nation natural resource staff and community members.

The Ash Protection Collaboration Across Wabanakik will travel to Tucson, AZ to present about the work this lab group conducts with Tribal Nation partners surrounding brown ash (*Frainus nigra*) at the National Native Seed Conference.

Resulting from the silvicultural treatments at each study site are piled trees that have been cut in execution of each silvicultural treatment. Many of these logs were harvested and reside on site at the study sites that are within the boundaries of the state quarantine regulation for emerald ash borer.

Description of Alignment with Key Partners and Collaborators

Meeting with project partners has been a critical aspect of this project. Keeping all Tribal Nation partners in the loop as to the status of the project has been accomplished with email check-ins and occasional Zoom calls as well as at reoccurring events put on virtually and in-person by the Ash Protection Collaboration Across Wabakik. You can see the series of events for 2024 by clicking here. This lineup of events has been reliant on the skills and knowledge gained by Mr. Everett in researching and conducting this current research project funded by the NSRC. The events held in 2024 are as follows:

- Scarborough Library Talk: Emerald Ash Borer in Maine and the Current State of Ash Trees
- APCAW Talk at the Museum of the White Mountains
- PhD Defense of Emily Francis
- Maine Land Trust Network Ash Forest Field Trip
- Monticello Ash Seed Collection Event
- Future of Brown Ash Meeting

Sharing the goals and priorities of the Tribal Nation partners, through this research project, has not only helped further define the path of this research project, but it has also strengthened the collaboration of this extensive network of collaborators focused on ash preservation and protection.

Monitoring Moose and Other Culturally Important Wildlife on Penobscot Nation Lands Using Remote Cameras

Principal Investigator: Benjamin Simpson, Penobscot Nation DNR
Benjamin.simpson@penobscotnation.org

Project Abstract

The purpose of this project is to develop a multi-species monitoring program using remote cameras to track populations trends of moose and other wildlife species found on Penobscot Nation (PN) lands. This project will help PN sustain healthy populations of wildlife to protect Native traditions and also serve as an educational tool to engage tribal members and preserve Penobscot culture. The project proposed setting 80 cameras on the PN lands using an established protocol for monitoring wildlife in the region. A photo tagging tool has been adapted to include the Penobscot names of animals so that tribal members can identify wildlife in pictures using their native language. The team will also use camera photos of moose to rate hair loss of moose in pictures to evaluate impacts from winter ticks. To evaluate annual changes in species occupancy (with a focus on moose), the data will be combined with other regional data using the same camera protocol and analyzed using dynamic occupancy models. Hair loss rankings and other existing data will be used to evaluate the impacts of ticks on changes in moose occupancy and solicit advice from tribal members on important variables for other species. The team will use the AMMonitor framework to evaluate annual occupancy outputs and integrate the decision-making approach of the PN to inform any changes in management for wildlife on Tribal lands.

Figure 11: This photo shows the basic camera set up with a snow-stake in the foreground used to measure snow depth. A turkey feather is also attached to the snow stake to act as attractant.

Progress in 2024

The 76 cameras that were deployed during the 2022-2023 season continue to be monitored. These 76 cameras were deployed with new SD cards following the first check. An additional 33 potential camera sites were identified with deployment for those scheduled in 2025. All the images from the first check and about 75% of images from the second check have been uploaded to AMMonitor. These images were annotated with species identification information by 24 undergraduate students and a team of 39 volunteers. Following species identification, the team has begun assessing hair loss for images where moose were detected using a quadrant scoring system. Over 75 thousand photos have been uploaded to AMMonitor and annotated by the team of students and volunteers. Over 30 different taxa have been observed, including roughly 70 thousand detections of moose, 10 thousand detections of white-tailed deer (*Odocoileus virginianus*), and 2 thousand detections of black bear (*Ursus americanus*). Furthermore, the project supports 2 undergraduate student research projects. One student's project will examine habitat use

of white-tailed deer, while another will focus on developing education and outreach materials for K-12 students of the Penobscot Nation.

Plans for 2025

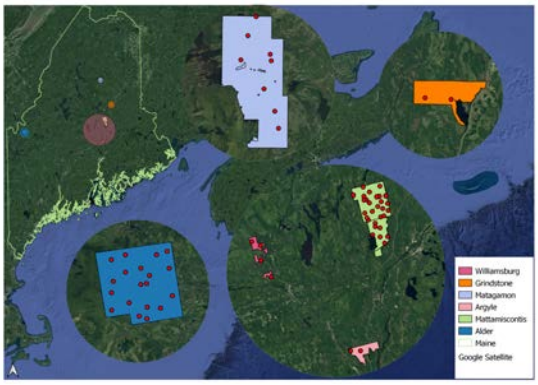


Figure 12: This figure shows all camera locations across Tribal Trust lands. Figure was created by Nina Kappel

As many of the 33 new cameras sites will be deployed in January of 2025 in order to capture the time of year that moose are showing signs of hair loss from winter tick. Using the moose detection and hair loss data, the team plans on developing a multi-state occupancy model to determine if tick infestation (and subsequent hair loss) impacts site occupancy. Additionally, the team will quantify patterns of hair loss on wild moose during the winter and early spring which have historically been limited to captive studies. Species identification and moose hair loss assessment for all the images collected from the primary and secondary camera checks is expected to be completed. In addition to developing occupancy models to examine the potential impacts of hair loss on occupancy and quantifying patterns of hair loss, the team will investigate the potential of using camera surveys to estimate moose population size.

Figure 13: Trail camera photo of a cow moose showing significant hair loss on the front shoulder and neck from winter tick infestation. The effects of winter tick infestations are most evident in early spring as moose are shedding their winter coats.

Collaboration

The team includes PI Benjamin Simpson from the Penobscot Nation DNR and co-PI's Dr. Alexej Siren from the University of New Hampshire, Dr. Sabrina Morano from the University of Maine and graduate student Nina Kappel also from the University of Maine. Co-PI's Dr. Theresa Donovan from the University of Vermont and Dr. Laurence Clarfeld from the University of Vermont are still attached to the project but in a much lighter capacity than originally planned. The project has also taken on two undergraduate students who will be using camera data for separate analysis that they will use for senior projects. Brendan McGowan and Courtney White, both from the University of Maine, are still researching ideas for their data analysis. There are also a number of volunteers from the University of Maine, the University of Massachusetts and the University of New Hampshire who are helping to tag camera photos.

Supporting Abenaki stewardship of the ecologically rare and culturally important Atlantic White Cedar Swamp Ecosystem

Principal Investigator: Heidi Asbjornsen, Professor of Ecosystem Ecology, University of New Hampshire

Summary of Progress in 2024:

Data collection and analysis

- Thirty-six 10m diameter circular plots were established throughout Bradford Bog, New Hampshire (NH). Twenty-four contained Atlantic White Cedar (AWC) seedlings and 12 contained no AWC seedlings.
- Environmental data were collected from each plot: light, temperature, canopy density, soil porewater redox potential and pH, vegetation community % cover, mature tree DBH within 5m radius of plot center, height and diameter of AWC seedlings within 1m radius of plot center, total AWC seedling count within entire plot.
- Soil samples were collected from each plot for surface and at-depth microbial community analysis.
- Preliminary data analysis and visualization were conducted using R software.
- Six semi-structured interviews with eight individuals (n=8) were conducted via Zoom and in-person with NH conservation staff of land trusts.
- Interview audio was transcribed with TranscribeMe.
- Responses were analyzed with Quirkos Software.
- Structural coding and synthesis were completed with Excel.

Communications and outreach

- Ciampitti, R. Investigating the Regeneration of Atlantic White Cedar in Bradford Bog, Oral Presentation, Forest Ecosystem Monitoring Conference, 12 December 2024, University of Vermont, Burlington, USA.
- University of New Hampshire Coastal Restoration and Resilience Web Site (Moore Lab): "What's Happening with Atlantic White Cedar?" https://sites.usnh.edu/moorelab/field-updates/field-notes-2024-v2-4/"
- Lish, G. Conservation easements and contested Indigenous groups: how are New Hampshire land trusts navigating land stewardship and access? Poster Presentation, Turtle Island Indigenous Science Conference, 21 - 23 May 2024, University of Regina, Saskatchewan, Canada.
- Lish, G. How are New Hampshire land trusts navigating stewardship with contested Indigenous groups? Oral Presentation, Forest Ecosystem Monitoring Conference, 12 December 2024, University of Vermont, Burlington, USA.

Problems or Changes:

- Due to the withdrawal of a previous graduate student, a new MSc student (Reece Ciampitti) and his major advisor (Dr. Gregg Moore) joined the project, focusing on assessing regeneration dynamics of Atlantic White Cedar in the Bradford Bog. Additional funding was secured to support Reece for a second year in order to complete his MSc degree and fulfill the original objectives of the project.

- Graduate student Gigi Lish's early research used document analysis and preliminary interviews to explore Abenaki relationships with the Bradford Bog. While broad relationships between Abenaki communities and the Bradford Bog area were evident, not enough specific information was available to support graduate level analysis of Abenaki relationships with the Bradford Bog, as intended. The research was thus broadened to consider Abenaki relationships with Atlantic White Cedar ecosystems in the region and then broadened again, refining the questions to align with those expressed as relevant by land trust staff: 1) how are land trusts incorporating native peoples' community relationships into land trust practices, and 2) when considering the incorporation of Native relationships into stewardship practices, to what extent are land trusts affected by a) an absence of tribal federal recognition, and b) the publicly contested nature of a tribe?

Plans for 2025:

Data collection and analysis

- Reece will conduct microbial community genomic extraction and analysis from soil samples.
- Reece and Moore's team will collect a second season of environmental data (same environmental data collected as in summer and fall of 2024).
- All resulting data will be summarized and processed. Statistical results will be provided.
- Graduate student Gigi Lish will complete qualitative analysis of interviews, prepare and submit a manuscript, and defend a M.S. thesis in spring 2025.

Communications and outreach

- Presentation of results-to-date at multiple venues.
- Building off the on-site meetings conducted in 2024 (see details below) and the recent professional presentations by Reece and Gigi (see details above), the team is currently in the process of planning a workshop event (February or early March 2025) with all project collaborators in Bradford to communicate project progress, align project goals with any new information or developments, and seek suggestions and feedback on future work.

Alignment and Collaboration with USFS and stakeholders:

From the beginning of the project, the team has engaged with project collaborators from the major stakeholder groups interested in the conservation, restoration, and management of the Bradford Bog, names and affiliations available upon request.

Specific activities focused on engaging project collaborators:
Project collaborators have been important at critical junctures during the reporting period. In early summer of 2024, the team joined several key project collaborators (Andrews, W Gould, McCandlish, and Eldrich) on-site to introduce Gregg Moore and his new graduate student (Reece Ciampitti) to the group, and to discuss collaborators' goals to find synergies for Reece's thesis research plans. In the informal discussions, the team found clear opportunities to co-generate research questions for Reece to address collaborators' goals and intellectual curiosities regarding AWC conservation and management within Bradford Bog. Several other meetings were held with collaborators on-site throughout the summer and early fall of 2024, which helped familiarize the team with the property boundaries and identify sites. The local knowledge of the collaborators was critical to optimizing Reece's experimental design and research plan, and to ground Reece's research within a local and purpose-driven context with a focus on co-generation of knowledge. Additionally, Lish attended the New Hampshire Land Trust Coalition Fall 2024 Workshop with Emma Tutein at UNH Extension.

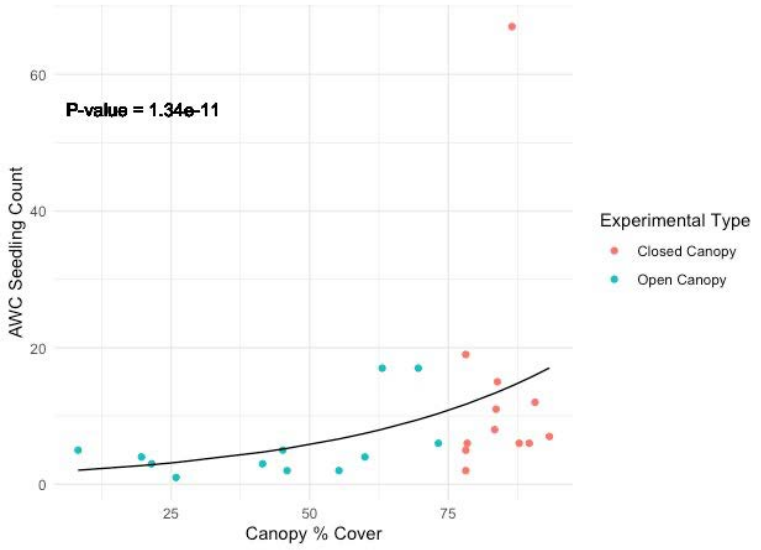


Figure 14: Scatter plot of canopy density across all plots with Atlantic white cedar seedlings present. Closed Canopy (colored as red) represents plots with canopy density >70% and Open Canopy (blue) represents plots with canopy density < 70%.

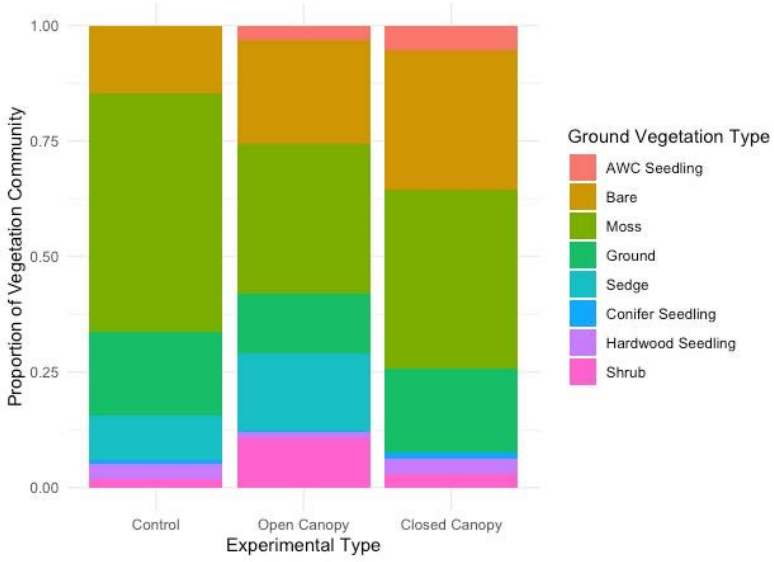


Figure 15: Stacked bar plot of the proportion of major ground cover types across the three plot types: Control (no AWC seedlings), Open Canopy and Closed Canopy (both with AWC seedlings). Source: Ciampitti, R. Investigating the Regeneration of AWC

Signature

The signing party is the official representative and authorized to act for matters related to the above- referenced grant/agreement.

March 25, 2025

Anne Jefferson
Patrick Professor, Watershed Science and
Planning NSRC Director
University of Vermont and State Agricultural College
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The Northeastern States Research Cooperative operates through funding from the United States Congress made available by the USDA Forest Service. The conclusions and opinions in this paper are those of the authors and not of the Forest Service or the USDA.

Appendix A: Products

Scholarly Articles

1. Myers, S. and D'Amato, A. 2024. Adaptation Actions for Northern Forest Ecosystems in New England and New York: Northern Hardwoods. Technology Transfer. Houghton, MI: U.S. Department of Agriculture, Northern Forests Climate Hub. 6 p.
2. Myers, S. and D'Amato, A. 2024. Adaptation Actions for Northern Forest Ecosystems in New England and New York: Mixedwoods. Technology Transfer. Houghton, MI: U.S. Department of Agriculture, Northern Forests Climate Hub. 6 p.
3. Myers, S. and D'Amato, A. 2024. Adaptation Actions for Northern Forest Ecosystems in New England and New York: Spruce-fir. Technology Transfer. Houghton, MI: U.S. Department of Agriculture, Northern Forests Climate Hub. 6 p.
4. Whiting, D. 2025. Nonstructural carbohydrates as a proxy for adaptive capacity and a mechanism for resilience in northern hardwood and mixedwood forests. University of Vermont, Masters' Thesis.
5. Fitch, A. (in review) in is "Mycorrhizal legacy mediates seedling success following timber harvesting in Northeastern forests." Ecological Applications
6. Hicks Pries, C. (in revision). Negative effects of competition outweigh benefits of arbuscular mycorrhizal facilitation for seedling success in a managed temperate hardwood forest. Canadian Journal of Forest Research
7. Das, P., Rahimzadeh-Bajgiran, P., Livingston, W., McIntire, C. D., & Bergdahl, A. (2024). Modeling forest canopy structure and developing a stand health index using satellite remote sensing. Ecological Informatics, 84, 102864. https://doi.org/10.1016/j.ecoinf.2024.102864
8. Timalsina, S., Rahimzadeh-Bajgiran, P., Das, P., Meireles, J. E., & Bhattarai, R. (2024). Monitoring eastern white pine health by using field-measured foliar traits and hyperspectral data. Sensors, 24(18), 6129. https://doi.org/10.3390/s24186129
9. Timalsina, Sudan, "Monitoring Eastern White Pine Health by Using Remote Sensing Assessement of Foliar Traits" (2024). Electronic Theses and Dissertations. 3982. https://digitalcommons.library.umaine.edu/etd/3982

Conferences and Presentations

1. Ciampitti, R. Investigating the Regeneration of Atlantic White Cedar in Bradford Bog, Oral Presentation, Forest Ecosystem Monitoring Conference, 12 December 2024, University of Vermont, Burlington, USA.
2. Lish, G. Conservation easements and contested Indigenous groups: how are New Hampshire land trusts navigating land stewardship and access? Poster Presentation, Turtle Island Indigenous Science Conference, 21 - 23 May 2024, University of Regina, Saskatchewan, Canada.
3. Lish, G. How are New Hampshire land trusts navigating stewardship with contested Indigenous groups? Oral Presentation, Forest Ecosystem Monitoring Conference, 12 December 2024, University of Vermont, Burlington, USA.
4. Forest Inventory and Analyses (FIA) Science Symposium: Toward Tomorrow's Forests Together 2024, November 19-21, 2024; https://research.fs.usda.gov/programs/fia/sciencesymposium#special-journal-issue;

https://whova.com/portal/webapp/fiaaf_202411/ (Access to this site may be restricted); ORGANIZED SESSION: Assessing future forests--Measuring change in the forested wildland urban interface

5. Clark, M. “Quantifying changes in forest condition, connectivity and resilience in the Northeast using geospatial and remotely sensed data”. 2024 Forest Ecosystem Monitoring Cooperative Conference. Burlington, VT.
6. D’Amato, A.W. 2023. Implementing forest adaptation options for Northern Forest ecosystems. Presentation. Forest Ecosystem Monitoring Cooperative Annual Meeting, December 14. Burlington, VT.
7. D’Amato, A.W. and S. Myers. 2023. Implementing forest adaptation strategies for northern hardwood, mixedwood, and spruce-fir forests. Manager Workshop. Forest Ecosystem Monitoring Cooperative Annual Meeting, December 14. Burlington, VT
8. D’Amato, A.W. 2023. Outcomes of Adaptive Silviculture in Northern Hardwood and Spruce-Fir Forests in Northern New England. Presentation. 2023 Granite State Division of SAF Annual Meeting. February 10. Bartlett, NH.
9. D’Amato, A.W., 2023. Field tour of adaptation experiments in VT with project partners. 2023 Forest Stewards Guild Gathering. October 6-7. Greensboro, VT.
10. D’Amato, A.W. 2023. Putting Adaptation into Practice: Overview of General Principles and Approaches. Northeast Silviculture Institute for Foresters Climate Adaptation and Carbon Training. October 12. Leominster, MA.
11. D’Amato, A.W., S. Myers, M. Brady, T. Ontl, C. Woodall, K. Evans, T. Morelli, K. Frecker. 2024. Workshop and tour of Adaptive Silviculture for Climate Change Experiment with Resource Management Staff from Green and White Mountain National Forest. September 10. Second College Grant, NH.
12. D’Amato, A.W. 2024. Putting Adaptation into Practice: Overview of General Principles and Approaches Northeast Silviculture Institute for Foresters Climate Adaptation and Carbon Training. October 17, Randolph, VT.
13. D’Amato, A.W. 2024. Assisted tree migration: motivations, misconceptions, and applications. Presentation. Forest Ecosystem Monitoring Cooperative Annual Meeting, December 12. Burlington, VT.
14. Impacts of extreme climate events on tree regeneration in the Northern Forest. Forest Ecosystem Monitoring Cooperative’s Annual Meeting. December 2024.
15. Benson, S., Murphy, C.A., Charney, N., Eggert, S., Fraver, S., Kenefic, L. Maine’s Secret Clam Flats: The Aquatic Diversity of Northern White-Cedar Forests. Presentation at the Society for Freshwater Science Annual Meeting. Philadelphia, PA 2024. (Oral presentation)
16. Benson, S., Murphy, C.A., Charney, N.D., Kenefic, L., Fraver, S., and S.L. Eggert. 2023. Maine’s Secret Clam Flats: Cedar Forests. USGS Maine Cooperative Fish & Wildlife Research Unit Annual Meeting, Orono, ME. July 2023. (Poster session)
17. Benson, S. 2024. INTERACTIONS BETWEEN TIMBER HARVEST AND THE AQUATIC ECOLOGY OF NORTHERN WHITE-CEDAR (THUJA OCCIDENTALIS) LOWLAND FORESTS. MSc Thesis, University of Maine, Orono, Maine.
18. Das, P. and Rahimzadeh-Bajgiran P., Remotely Sensed Estimation of Live Crown Ratio (LCR) for Eastern White Pine (EWP) Health Assessment”, ASPRS 2024 Geo Week, February 11-13, 2024, Denver, CO, USA.

19. Timalsina, S. and Rahimzadeh-Bajgiran P., Assessing White Pine Needle Damage (WPND) Impact on Eastern White Pine (EWP) Health through Modeling Foliar Traits using Remote Sensing Data, ASPRS 2024 Geo Week, February 11-13, 2024, Denver, CO, USA.
20. Ton. K. UNH NREN Seminar, February 2024.
21. Ton, K. Prescribed fire improves red oak regeneration in northern New Hampshire. Poster presentation, New England SAF, Burlington VT, March 2024.
22. Ton, K. Oral presentation, Annual Hubbard Brook Meeting, Plymouth NH, July 2024.
23. Ton, K. Poster presentation, Ecological Society of America, Long Beach CA, August 2024.
24. Ton, K. Oral presentation, International Oak Symposium, Knoxville TN, October 2024.
25. Ton, K. Oral presentation, UNH ESRC Seminar, December 2024.

Other Products

1. University of New Hampshire Coastal Restoration and Resilience Web Site (Moore Lab): "What's Happening with Atlantic White Cedar?" https://sites.usnh.edu/moorelab/field-updates/field-notes-2024-v2-4/"
2. Project Report: Clark, M., M. G. Anderson. 2024. Geospatial Analysis of Forest Condition and Connectivity in the Northeast U.S. The Nature Conservancy, Center for Resilient Conservation Science. Online Link.
3. Geospatial Datasets: Datasets include extent and characterization of Northern Forest, geospatial forest condition factors, geospatial forest condition index, connectivity for range shifts (local and regional scale) model results, and potential improvement for connectivity for range shifts (local and regional scale) model results. Download Link. View in webtool.
4. Decision Support Tool Under Development. Available February 2025.
5. USDA Forest Climate Hub Manager's Web Guides:
6. Adaptation Actions for Northern Hardwood Forests in New England and New York
7. Adaptation Actions for Spruce-Fir Forests in New England and New York
8. Adaptation Actions for Mixedwood Forests in New England and New York
9. Planting for the Future: Simulating Future Forest Conditions [video]. https://www.youtube.com/watch?v=MJg_RxFglKA
10. Fitch, A. and Legge E. Mycorrhizal fungi and forestry in Northeastern forests. [webinar] https://www.youtube.com/watch?v=PLZutwy5kts
11. IEEE Maine January 2025 Newsletter (https://r1.ieee.org/maine/wp-content/uploads/sites/29/Beacon_January25.pdf)
12. Cassel, A. Fighting fire and fear. Hubbard Brook Ecosystem Study. https://hubbardbrook.org/fighting_fire/
13. Gosling, N. Regenerating Northern Oak Forests Using Prescribed Fire. UNH Today. May 20, 2024. https://www.unh.edu/unhtoday/regenerating-northern-oak-forests-using-wildfire/
14. Brooks, D. UNH researchers wonder if controlled burns really do help red oak. Concord Monitor, Granite Geek. May 21, 2024. https://granitegeek.concordmonitor.com/2024/05/21/unh-researchers-wonder-if-controlled-burns-really-do-help-red-oak/
15. Regenerating Northern Oak Forests Using Wildfire. NH Weekly Market Bulletin. June 5, 2024.

Appendix B: Final Reports

Quantifying Changes in Forest Condition, Connectivity and Resilience in the Northeast Using Geospatial and Remotely Sensed Data

Principal Investigator: Melissa Clark, Center for Resilient Conservation Science, The Nature Conservancy, melissa_clark@tnc.org

Co-Principal Investigators: Mark Anderson, Center for Resilient Conservation Science, The Nature Conservancy, manderson@tnc.org

Project Outcomes

In this project, we developed a decision support tool that combines geospatial measurements of forest condition across the entire geography of the Northern Forests to develop an index of forest condition and from this index measure the impact of condition on local and regional connectivity and identify places on the ground that could most benefit from management to improve forest condition.

Project Summary

To ensure the long-term sustainability of the Northern Forest, land managers, agencies, and conservationists need a way to measure and monitor forest condition at a large scale, assess how its condition and connectivity are distributed across the region, and estimate the impact and benefits of forest management practices. For each major forest type, understanding the distribution of age and size classes, the rates of forest turnover, and the degree of landscape change and fragmentation is essential in determining how individual management decisions accumulate to influence landscape connectivity. Fortunately, the last decade has seen considerable progress in the creation of consistent remotely sensed, time-series datasets that through careful processing and interpretation can be the basis for a new generation of spatially explicit, dynamic maps depicting changes in forest condition.

In this project, we assessed and synthesized geospatial and remotely sensed data on three aspects of forest condition that could be consistently and accurately mapped throughout the region: age and height, turnover, conversion, and fragmentation by human disturbance. We validated the data for each factor with Forest Inventory and Analysis (FIA) data to ensure our models represented observable characteristics of forest stands. Next, we integrated the three factors into a geospatial condition index. Using the continuous results in combination with a kernel model and wall-to-wall Circuitscape model, we explored the implications of forest condition on connectivity to support species establishment and range shifts at both a local and regional scale. The design of the Forest Condition Index was to be able to evaluate geospatial condition attributes individually and combined at the site scale level, but we can make some overall statements by habitat type. Of the matrix forest types, the Northern Hardwood has a slightly better forest condition index than the Boreal Upland Forest; while the Boreal Upland Forest has the least amount of human disturbance, the amount of turnover in this habitat type is much higher than the Northern Hardwood. The forested wetland habitats of Northern Peatland, Wet Meadow/Shrub

Marsh, and Northern Swamp habitats all have the high condition index; these habitats have low forest turnover and low human disturbance. For present day connectivity for range shifts, Boreal Upland Forest had the highest connectivity and also had the highest potential for improved connectivity with improved management, highlighting the importance of this habitat to the Northern Forest. These results are integrated into a user-friendly decision support tool aimed at decision makers and other audiences who would like to explore and understand the geospatial aspects both regionally and locally of forest condition in this region.

Background and Justification

Land managers, agencies, and conservationists have long sought a way to understand how forest conditions are distributed across the Northeast, identify where climate-resilient sites occur, and assess how management decisions impact landscape connectivity. The recently completed "Geospatial Analysis of Forest Condition" decision support tool empowers stakeholders to make these informed decisions.

Methods

For the Northeast Study area we:

- Validated various geospatial individual forest condition metrics.
- Developed an integrated, spatially explicit, geospatial estimate of forest condition.
- Assessed the degree of forest connectivity at two scales (local connectedness and regional flow) while incorporating condition into the estimate.
- Identified areas where improving forest condition could have the largest improvement in connectivity at a local and regional scale.
- Assessed the connectivity of the forest with respect to climate change.

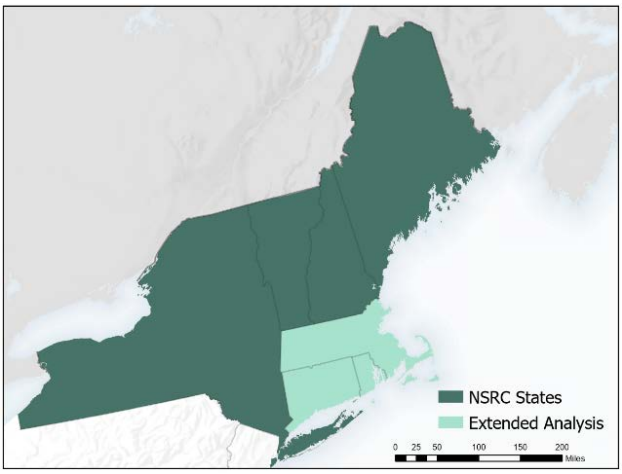

Figure 16: Geographic extent of the project

Key Findings/Accomplishments

The geospatial forest condition index allows site scale characterization of forest condition and connectivity throughout the region.

Some regional trends by forest type can be summarized from the data. Of the matrix forest types, the Northern Hardwood has a slightly better forest condition index than the Boreal Upland Forest; while the Boreal Upland Forest has the least amount of human disturbance, the amount of turnover in this habitat type is much higher than the Northern Hardwood. The forested wetland habitats of Northern Peatland, Wet Meadow/Shrub Marsh, and Northern Swamp habitats all have the high condition index; these habitats have low forest turnover and low human disturbance. For present day connectivity for range shifts, Boreal Upland Forest had the highest connectivity and also had the highest potential for improved connectivity with improved management, highlighting the importance of this habitat to the Northern Forest.

Implications and Applications in the Northern Forest Region

The Geospatial Analysis of Forest Condition web tool will allow foresters, managers, and

conservationists access to continuous geospatial data to characterize forest condition continuously throughout the region. Tool users can zoom in to forests of interest and compare them to other forests. Additionally, for each forest of interest, users will be able to see the contribution of each forest to connectivity and flow for range shifts at a local and regional scale and identify areas where improved condition could result in improved connectivity.

Future directions

The scale and complexity of the analysis took more time than expected, reducing the time for sharing and vetting the tool. Our next step for this project is to present the results, create communication materials, and document case studies, for which we have submitted a pre-proposal for the 2025 round of NSRC funding. Producing science that is used to make decisions requires more than the creation of scientific knowledge and products, but the development of the stakeholders' capacity to use the scientific findings. This next step of communicating and sharing the results of the project and supporting the use of a newly created decision support tool for the results can help with the challenges of navigating management for a variety of potentially competing needs (e.g., wildlife habitat, carbon, resilience).

Products Delivered

Project Report: Clark, M., M. G. Anderson. 2024. Geospatial Analysis of Forest Condition and Connectivity in the Northeast U.S. The Nature Conservancy, Center for Resilient Conservation Science. Online Link.

Geospatial Datasets: All of the datasets created and analyzed in this project are available for download. Datasets include extent and characterization of Northern Forest, geospatial forest condition factors, geospatial forest condition index, connectivity for range shifts (local and regional scale) model results, and potential improvement for connectivity for range shifts (local and regional scale) model results. Download Link. View in webtool.

Decision Support Tool Under Development. Available February 2025.

Conference Presentation: "Quantifying changes in forest condition, connectivity and resilience in the Northeast using geospatial and remotely sensed data". 2024 Forest Ecosystem Monitoring Cooperative Conference. Burlington, VT.

Partners/Stakeholders/Collaborators

This work was guided by a steering committee of scientists from The Nature Conservancy composed of David Fox (Appalachians Program), Jessie Levine (Appalachians Program), Dan Coker (ME), Eben Sypitkowski (ME), Mark Berry (ME), Jeff Lougee (NH), Gustave Goodwin (VT), Jim Shallow (VT), Dirk Bryant (NY), Chris Zimmerman (NY), Andy Finton (MA), and Kevin Ruddock (RI).

Implementing forest adaptation options for Northern Forest ecosystems

Principal Investigator: Anthony D'Amato (University of Vermont, awdamato@uvm.edu)
Co-Principal Investigator: Maria Janowiak (USDA Forest Service Northern Research Station Northern Institute of Applied Climate Science, maria.janowiak@usda.gov)

Project Outcomes

We developed a guide to best adaptation practices for northern hardwood, mixedwood, and spruce-fir ecosystems based on manager and other partner feedback. This guide was developed based on outcomes of adaptation demonstrations, experiments, and operational trials in ME, NH, NY, and VT and include associated case studies linked to the Climate Change Response Framework webpage.

Project Summary

Climate change and the increasing prevalence of non-native invasive insects and pathogens represent some of the most significant challenges facing forest managers tasked with sustaining forest ecosystems across the Northern Forest region. Our project goal was to increase the application of adaptation strategies that confer resilience to climate change and associated invasive pest and disease impacts, while also sustaining critical ecosystem services, including habitat provisioning and carbon storage, and local forest-based economies. Specific project objectives were to: 1) evaluate the outcomes and effectiveness of already implemented adaptation strategies to ameliorate/reduce the impacts of climate change and invasive pests and diseases on the Northern Forest, and 2) co-produce site-tailored recommendations with resource managers on best adaptation practices for anticipated impacts of climate change and invasive species.

Our project leveraged an unrivalled network of stakeholder-developed adaptation experiments and demonstrations in Maine, New Hampshire, New York, and Vermont (> 30 sites total) to generate a comprehensive understanding of the ability of forest adaptation strategies to address emerging forest health and climate change impacts. The structural, compositional, and functional outcomes of adaptation strategies were measured at a subset of these sites to document silvicultural approaches that confer the greatest adaptation potential for northern hardwood, mixedwood, and spruce-fir ecosystems. This included quantifying non-structural carbohydrates of canopy tree species to determine which silvicultural regimes supported tree-level resilience to future stressors. In addition to measuring these trials, we used our sustained partnerships with a wide range of federal, state, Tribal, private, and NGO forestry stakeholders and partners to develop outreach materials, including webpages, factsheets, webinars, and in-person workshops that identified site-tailored, best adaptation practices for northern hardwood, mixedwood, and spruce-fir ecosystems. Short-term benefits for the Northern Forest include management guidance and a broadened community of practice for operationalizing forest adaptation strategies to address emerging threats, with long-term benefits including the ability to sustain the ecological and economic benefits of critically important forest ecosystems despite changing climate and disturbance regimes.

Background and Justification for the project

As the impacts of climate change and invasive insects and pathogens on Northern Forest ecosystems become increasingly clear, forest managers need practical strategies that minimize these impacts and can sustain key forest functions. In some cases, historical management experience and approaches, like thinning to reduce drought impacts or mixed species management to reduce pest outbreaks, may serve as effective near-term strategies to increase the resilience of the Northern Forest to climate. Nevertheless, the lack of historic analogs for forest conditions and dynamics generated by non-native species and changing

climate conditions necessitates the development of more targeted adaptation approaches that explicitly address these threats. General recommendations and frameworks for adaptation have been developed and popularized over the past two decades; however, there is a high level of uncertainty in the management community regarding how to best operationalize these options to match local site conditions and objectives. In fact, a recent assessment of forest manager's adaptation science needs in New England and New York pointed to a lack of real-world examples of adaptation in practice as a key barrier to implementing adaptation strategies in response to climate change and invasive species. Ongoing interview- and survey-based assessments of manager needs led by our team continue to underscore this demand for real-world examples and translation to site-specific conditions.

The Climate Change Response Framework was developed to address these information needs by assisting managers with the integration of climate change considerations into operational management, as well as create a network of adaptation demonstrations to generate local knowledge of adaptation practices. Since 2014, over 100 demonstration projects have been developed in New York and New England to address climate impacts ranging from increasing drought to declining snowpacks as well as current and projected threats from invasive insects, like the emerald ash borer and Asian long-horned beetle. As part of the CCRF, the Adaptive Silviculture for Climate Change (ASCC) experiment was co-designed with regional managers in northern New Hampshire in 2017 to create an operational-scale, statistically robust experiment for evaluating adaptation options spanning a continuum from resisting projected climate change impacts to transitioning forest conditions to those expected to be future adapted.

The proliferation of the abovementioned adaptation demonstrations and experiments in the Northern Forest region over the past decade provides a unique opportunity to address key knowledge gaps that currently limit the application of adaptation practices in the region. Given the potential impacts from climate change and invasive pests and pathogens and the ecological, economic, and cultural importance of forests across this region, there is a significant need for adaptation strategies that reduce risk and sustain forest-dependent industries and delivery of ecosystems services. ***This project directly addressed the NSRC mission by developing science and associated management guidance that can assist with sustaining several forest types that are centrally important to the ecology and economies of the Northern Forest region.***

Methods

We conducted field surveys of forest vegetation conditions across research and demonstration sites established as part the CCRF and the associated Adaptive Silviculture for Climate Change experiment. We specifically focused on summarizing outcomes from sites dominated by northern hardwood, mixedwood, and spruce fir forests (Figure 1). At a subset of sites (n=5), we collected wood tissue samples from overstory red spruce and sugar maple to quantify the impact of past silvicultural treatments on forest

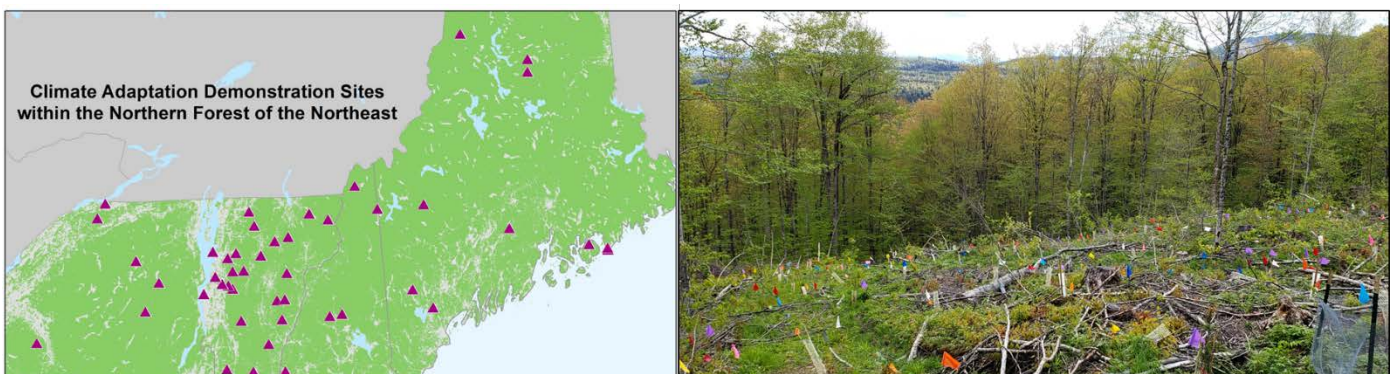

Figure 17: Co-produced adaptation demonstrations and experiments used by this project to summarize adaptation approaches and treatment outcomes across Northern Forest (left). Co-produced adaptation site in northern hardwood forest in northern NH (right).

adaptation potential. Local neighborhood conditions around sampled trees were measured to determine how local density and composition influences adaptive responses in trees.

Outcomes from the field assessments and adaptation demonstrations were summarized and integrated with manager feedback and input on operational considerations associated with the design and implementation of adaptation treatments. This included a manager's workshop at the 2023 Forest Ecosystem Monitoring Cooperative meeting where feedback was solicited from 70 managers to improve adaptation guidance developed by this project. In addition, we solicited and updated adaptation demonstrations created using the NIACS Adaptation Workbook to evaluate broader transferability to conditions across the Northern Forest. The outcomes of our field assessments were integrated with these cooperator inputs to develop a refined suite of best practices for guiding adaptation in Northern Forests that are tailored to specific site conditions, including soils, landscape setting, and forest condition. These guides are now housed on the USDA Climate Hub and also exist as factsheets.

Key Findings/Accomplishments

- Field evaluations of the outcomes of adaptive silviculture strategies on non-structural carbohydrate concentrations in canopy sugar maple and red spruce highlighted the value of density reduction in supporting high tree-level vigor and resilience to future climate stress. This included outcomes of crown-thinning, single-tree selection, and continuous cover irregular shelterwood systems.

- Three manager guides for best adaptation practices were developed by our project team for guiding management of northern hardwood, spruce-fir, and mixedwood forests in the context of climate change and forest health impacts
    - ***Adaptation Actions for Northern Hardwood Forests in New England and New York***
    - ***Adaptation Actions for Spruce-Fir Forests in New England and New York***
    - ***Adaptation Actions for Mixedwood Forests in New England and New York***

- The aforementioned guides allow managers to develop site-tailored adaptation actions that address vulnerabilities tied to overstory composition, regeneration, forest structure, soils, hydrology and infrastructure, and insects and diseases

- Nine adaptation case studies representing NGO, Federal, and State management organizations across the Northern Forest were updated or developed to support the recommendations generated by this project.

Implications and Applications in the Northern Forest Region

This project by design was intended to capture the range of forest conditions and vulnerabilities for northern hardwood, mixedwood, and spruce-fir forests across the Northern Forest Region. By including a wide range of manager perspectives and inputs on the management guidance we developed from this project, we expect the results to have important applications across the region as managers increasingly address the impacts of climate change and invasive insects and pathogens. To this end, we built from and established extensive partnerships with managers across the region and multiple management organizations and companies to ensure the broader application of the management guidance from this project. This included Sean Ross from the Lyme Timber Company, Lou Bushey from Vermont Forests, Parks and Recreation, Jeremy Goetz from the US Fish and Wildlife Service, Chris Zimmerman from The Nature Conservancy-New York, Kyle Burdick from Baskahegan Company, Amanda Mahaffey from the Forest Stewards Guild (and now US Fish and Wildlife Service), and Kevin Evans from Dartmouth

College Woodlands. These broad and diverse partnerships informed the co-production of the research design and associated outreach products to ensure alignment with key management priorities for the region, as well as the relevance of adaptation strategies for diverse forest conditions and ownerships.

Future directions

This work primarily focused on silvicultural activities managers could take to reduce vulnerability to projected changes in climate and disturbance regimes. Nevertheless, there are many other factors constraining managers' ability to sustain diverse values from forests in a changing environment. In particular, most managers pointed to the impacts of extreme weather events on logging activities and infrastructure as a key barrier and source of uncertainty affecting future management. Although we acknowledge these in our guides, there is a great need for decision support tools to assist forest operations and harvest planning in the context of these changing conditions. Likewise, our adaptation guidance captures the current state of perceived climate and disturbance vulnerabilities; however, conditions are continually evolving and introducing novel stressors previously unaccounted for. Beech leaf disease is a prime example of this and was not well established at the time of this project. Future updates to our guidance to address the effects of this novel stressor are critical. Finally, although we covered the three most extensive forest types in the Northern Forest, there are many other ecological, commercially, and culturally important forest types not covered by our guides. Future work to expand this guidance to include other important forest types, such as pine-oak-hemlock and lowland hardwoods, is needed.

Products Delivered

- **Research/technical Reports**
    - Myers, S. and D'Amato, A. 2024. Adaptation Actions for Northern Forest Ecosystems in New England and New York: Northern Hardwoods. Technology Transfer. Houghton, MI: U.S. Department of Agriculture, Northern Forests Climate Hub. 6 p.
    - Myers, S. and D'Amato, A. 2024. Adaptation Actions for Northern Forest Ecosystems in New England and New York: Mixedwoods. Technology Transfer. Houghton, MI: U.S. Department of Agriculture, Northern Forests Climate Hub. 6 p.
    - Myers, S. and D'Amato, A. 2024. Adaptation Actions for Northern Forest Ecosystems in New England and New York: Spruce-fir. Technology Transfer. Houghton, MI: U.S. Department of Agriculture, Northern Forests Climate Hub. 6 p.
- **Theses**
    - Whiting, D. 2025. Nonstructural carbohydrates as a proxy for adaptive capacity and a mechanism for resilience in northern hardwood and mixedwood forests. University of Vermont, Masters' Thesis.
- **Conference presentations**
    - D'Amato, A.W. 2023. Implementing forest adaptation options for Northern Forest ecosystems. Presentation. Forest Ecosystem Monitoring Cooperative Annual Meeting, December 14. Burlington, VT.
    - D'Amato, A.W. and S. Myers. 2023. Implementing forest adaptation strategies for northern hardwood, mixedwood, and spruce-fir forests. Manager Workshop. Forest Ecosystem Monitoring Cooperative Annual Meeting, December 14. Burlington, VT
    - D'Amato, A.W. 2023. Outcomes of Adaptive Silviculture in Northern Hardwood and Spruce-Fir Forests in Northern New England. Presentation. 2023 Granite State Division of SAF Annual Meeting. February 10. Bartlett, NH.
    - D'Amato, A.W., 2023. Field tour of adaptation experiments in VT with project partners. 2023 Forest Stewards Guild Gathering. October 6-7. Greensboro, VT.

- D'Amato, A.W. 2023. Putting Adaptation into Practice: Overview of General Principles and Approaches. Northeast Silviculture Institute for Foresters Climate Adaptation and Carbon Training. October 12. Leominster, MA.
- D'Amato, A.W., S. Myers, M. Brady, T. Ontl, C. Woodall, K. Evans, T. Morelli, K. Frecker. 2024. Workshop and tour of Adaptive Silviculture for Climate Change Experiment with Resource Management Staff from Green and White Mountain National Forest. September 10. Second College Grant, NH.
- D'Amato, A.W. 2024. Putting Adaptation into Practice: Overview of General Principles and Approaches Northeast Silviculture Institute for Foresters Climate Adaptation and Carbon Training. October 17, Randolph, VT.
- D'Amato, A.W. 2024. Assisted tree migration: motivations, misconceptions, and applications. Presentation. Forest Ecosystem Monitoring Cooperative Annual Meeting, December 12. Burlington, VT.

- **Other tangible products**
  - *USDA Forest Climate Hub Manager's Web Guides:*
    - ***Adaptation Actions for Northern Hardwood Forests in New England and New York***
    - ***Adaptation Actions for Spruce-Fir Forests in New England and New York***
    - ***Adaptation Actions for Mixedwood Forests in New England and New York***

Student Involvement

	Names	**Degree Sought**
Post-docs	*Peter Clark*	[redacted]
Professionals	*Samantha Myers*	
Graduate Students	*Tripp Whiting*	*M.S.*
Undergraduate Students	*Teresa Helms*	*B.S.*
Summer students	*Mary Roth*	*B.S.*

Partners/Stakeholders/Collaborators:

- Amanda Mahaffey, Deputy Director, Forest Stewards Guild (currently: US Fish and Wildlife Service)
- Kevin Evans, Forester, Dartmouth College Woodlands
- Lou Bushey, Forester, Vermont Forests, Parks and Recreation, Division of Forests
- Sean Ross, Managing Director, Lyme Timber Company LLC
- Jeremy Goetz, Forester, Silvio O. Conte National Fish and Wildlife Refuge, US Fish and Wildlife Service
- Chris Zimmerman, Forest Restoration Strategy Lead, The Nature Conservancy-New York
- Kyle Burdick, Woodlands Manager, Baskahegan Company

Geographic Location of Project

(30 adaptation demonstrations across ME, NY, NH, and VT were used to summarize adaptation outcomes. The following 5 sites were used for nonstructural carbohydrate sampling from trees).

- Groton State Forest (44.2667° N, 72.2858° W)

- Willoughby State Forest (44.7151° N, 72.0628° W)
- Nulhegan Basin, Silvio O. Conte National Wildlife Refuge (44.7682°N 71.7025°W)
- Dartmouth College Second College Grant (44.9131°N, 71.1073°W)
- Umbagog National Wildlife Refuge (44.7481° N, 71.0739° W)

Leveraged funding

Source:	Amount Received	Direct or In-Direct Contribution?
Dartmouth College Woodlands	$ 139,193	In-Direct

Effects of timber harvesting on the wetland ecology of northeastern lowland forests

Principal Investigator: Christina A. Murphy (USGS ME Cooperative Fisheries and Wildlife Research Unit and the University of Maine: christina.murphy@maine.edu)
Collaborators: Noah Charney (University of Maine, Maine Agriculture and Forest Experiment Station: noah.charney@maine.edu); Shawn Fraver (University of Maine: shawn.fraver@maine.edu); Sue Eggert (USDA Forest Service, Northern Research Station: Susan.Eggert@usda.gov); Laura Kenefic (USDA Forest Service, Northern Research Station: laura.kenefic@usda.gov)

Brief description

We found similar aquatic taxa in harvested and reference stands, dominated numerically by aquatic flies and freshwater fingernail clams and in biomass by clams and worms. Leaf litter breakdown was higher in local depressions 'pits' than elevated, drier 'mounds', indicating that aquatic processes may be important for decomposition in these forests.

Project Summary

Northern white-cedar lowlands in Maine are forest habitats that can remain wetted in localized 'pits' throughout the year and at times much of the forest may be flooded. There remains a gap in the literature as to what types of aquatic biodiversity and processes these forests support and how those are impacted by forest management practices. Our research encompasses harvested and control stands in three working cedar forestlands in Maine. The goal of this research is to expand our understanding of the intermittent wetland habitat and biological processes of northern white-cedar wetland habitats. This includes determining how rates of aquatic leaf litter processing vary between pit and mound microtopographic positions and cataloging the aquatic taxa diversity. We found that aquatic processes appear important in speeding up leaf litter breakdown and that nearly 50 families of aquatic taxa can be found within the wetted pits. We did not find evidence for major changes in composition with harvest, nor for changes in the availability of aquatic habitats as we measured them. Information on the aquatic functioning of these forests will help to inform managers of the processes that drive nutrient cycling and biodiversity and will provide a basis for further research on aquatic ecosystems within these habitats.

Background and Justification

Northern white-cedar lowlands in Maine are forest habitats that are managed as conventional timberlands, though the aquatic biota and processes present within them are often overlooked. Although forests may appear dry during harvest periods, recent data has shown they can remain wetted in localized pits throughout the year and at times much of the forest may be flooded. Even from a terrestrial perspective, impacts of forestry operations on these ecosystems remain poorly understood. Our research encompasses harvested and control stands in three working cedar forestlands in Maine. The goal of this research is to expand our understanding of the intermittent wetland habitat and biological processes of northern white-cedar wetland habitats.

Methods

We used leaf litter bags to assess decomposition rates across treatments. Cedar stakes were deployed, but decomposition rates were too slow for inclusion in this project. We maintained water level logger arrays at all three forested sites in both harvest and reference stands. We developed methods for standard soil sampling to compare taxa and biomass quantitatively across sites and treatments. We also used fixed-time

kick-net sampling. Water samples were collected for nutrient analyses, including pH. We also set up transects to quantify 'pit' habitat availability across treatments.

Key Findings/Accomplishments

Leaf litter breakdown was highly seasonal and significantly higher in wetted 'pits' than drier 'mounds'. We did not see strong evidence for impacts of forest harvest on litter breakdown rates, nor on the aquatic taxa or biomass, though aquatic communities appeared to have higher variability in harvested sites.

Implications and Applications in the Northern Forest Region

Our results suggest that although harvest may influence the overall abundance of aquatic microhabitat across the landscape – which could be important in detrital processing and aquatic biomass at a landscape scale – we found minimal impacts of forest harvest (in this case thinning of cedar) at a microhabitat scale for aquatic biodiversity and processes in the remnant aquatic habitats. This is important to note, as it appears that harvest consistent with our study sites is unlikely to threaten the persistence of aquatic taxa present in a lowland forest plot. We hope to explore questions of scales in the future as noted below.

Future directions

This project has raised questions about how to better quantify wetted areas and the connectivity of these habitats over space and time. We hope to expand this research in the future building off of the current collaborations with foresters and adding LSOG (Late Successional / Old Growth) sites to examine if differences in aquatic habitats occur at larger scales than those studied here.

Products Delivered

- Peer-reviewed publications
  - Three peer-reviewed publications are in draft from this work
- Theses
  - Benson, S. 2024. INTERACTIONS BETWEEN TIMBER HARVEST AND THE AQUATIC ECOLOGY OF NORTHERN WHITE-CEDAR (THUJA OCCIDENTALIS) LOWLAND FORESTS. MSc Thesis, University of Maine, Orono, Maine.
- Conference presentations (including workshops and posters).
  - Benson, S., Murphy, C.A., Charney, N., Eggert, S., Fraver, S., Kenefic, L. Maine's Secret Clam Flats: The Aquatic Diversity of Northern White-Cedar Forests. Presentation at the Society for Freshwater Science Annual Meeting. Philadelphia, PA 2024. (Oral presentation)
  - Benson, S., Murphy, C.A., Charney, N.D., Kenefic, L., Fraver, S., and S.L. Eggert. 2023. Maine's Secret Clam Flats: Cedar Forests. USGS Maine Cooperative Fish & Wildlife Research Unit Annual Meeting, Orono, ME. July 2023. (Poster session)

Student Involvement

	Names	**Degree Sought**
Post-docs		[redacted]
Professionals		
Graduate Students	*Stevie Benson*	*MSc*
Undergraduate	*Kathryn Gatewood*	*BSc (all)*

Students	*Jakob Hallett* *Lee Jones* *Astrid Niles* *Keiara Pham* *Elissa Tuten* *Andrew Brann*	
Summer students	*Additional graduate students and pos-docs provided temporary field assistance for 1-3 days each in the field*	

Partners/Stakeholders/Collaborators

This study included Baskahegan Company and Wagner Corporation as forestry partners, the University of Maine Wildlife, Fisheries, and Conservation Biology Department (who assisted in leaf bag packing and field work), the University of Maine School of Biology and Ecology (water quality), and the University of Maine School of Forest Resources (field sites).

Geographic Location of Project

This study included research sites located in central and Downeast Maine (at the Penobscot Experimental Forest, and in Danforth and Dyer Township.

Trail Forks and Merges: Exploring Social Impacts from Recreational Mountain Biking in Northern Forest Communities

Principal Investigator: Kim Coleman, University of Vermont, Kimberly.coleman@uvm.edu

Co PIs: Bess Perry, Michigan State University, eeperry@msu.edu and Jessica Leahy, University of Maine, Jessica jessica.leahy@maine.edu

Project Outcomes

- Our work demonstrated that user-generated data from sports watches and smart phones can be a powerful tool to inform rural recreation planning.
- Our work revealed that Northern Forest communities who invested in recreation infrastructure as rural economic development are experiencing a range of benefits and tensions.

Project Summary

We conducted a multi-phased research project to investigate the social impacts of the growth of mountain biking in the Northern Forest Region. This included two systematic literature reviews (one of which was completed prior to this grant award period), an analysis of user-generated data from the app Strava, and qualitative analysis of community-level interviews and focus groups. One M.S. thesis sought to address two questions: (1) How usable is Strava data in informing recreation managers about safety, infrastructure, and participation trends in rural areas? and (2) How has the growth of mountain biking recreation affected communities across the Northern Forest region?

To answer the first question, the M.S. student Emily Reinhardt analyzed a case study of Kingdom Trails using user-generated data provided by Strava Metro to better understand the utility that dataset can provide for rural recreation planning. The results demonstrate that user-generated data from Strava have the potential to provide valuable insights on trail usage patterns and intensity across time and space. These data can better inform recreation managers and planners on landscape-level usage patterns, which may be challenging to obtain using traditional methods in a rural context.

To answer the second question, Emily conducted focus groups and interviewers to identify the prevalence of lifestyle seekers as a type of conflict impacting communities across the Northeastern states. She defined lifestyle seekers and how they drive recreational conflict at a broader scale. Traditional frameworks for viewing recreation conflict do not encompass the community-level impacts elicited by lifestyle seekers. Therefore, we propose a new model that incorporates community aspects outside the trail networks comprising of infrastructure, basic needs, and heritage. Rural communities across the Northern Forest region are experiencing similar ramifications due to the growth of mountain biking and this proposed model can be applied broadly.

Taken together, these results provide insight into some of the social impacts associated with the growth of mountain biking in rural communities.

Background and Justification

Nation-wide, mountain biking is growing in popularity. This trend is mirrored in the Northern Forest and intensified during the COVID-19 pandemic. For many rural communities, the growth of mountain biking represents an opportunity to build a new economy centered on forest-based recreation. However,

questions remain about the impact mountain biking has on forests and forest-dependent communities. Our project sought to fill that gap.

Methods

We conducted two Systematic Literature Reviews (see publication list below), an analysis of Strava data, and community-level focus groups and interviews. We had originally proposed to conduct national-level analysis using Twitter data. However, with transitions at Twitter, this became difficult, especially as Twitter is ended the Twitter Academic API. Thus, the research team decided to conduct a regional-level analysis of data from Strava, a social media platform that allows users to track runs, hikes, bike rides, and other activities and share those activities with friends. Strava has 95 million users and is popular with cyclists, including mountain bikers, making it an excellent data source for this project. Further, Strava Metro allows researchers and municipalities to access aggregated data to make informed decisions about the management of transportation and recreation resources.

Key Findings and Accomplishments

We produced two four peer-reviewed publications (three published and one revised and resubmitted), two M.S. thesis, numerous conference presentations and posters, as well as recommendations presented to community partners about management and planning for growth of outdoor recreation in the Northern Forest Region.

Implications and Applications in the Northern Forest

These findings are useful beyond the context of mountain biking and beyond our study area. They are relevant to any rural community considering an outdoor recreation economy as a method of supporting small, rural communities. Town planners, recreation managers, and natural resource professionals should consider our findings, as understanding the range of impacts may help such professionals make more informed decisions. Additionally, scholars will be interested in our findings, in particular our use of a novel data source (Strava) and our contribution of a new regional recreation conflict model.

Products

- Reinhardt**Error! Bookmark not defined.**, E., Coleman, K., Perry, E., Alldred, M., and Leahy, J. (revised and resubmitted) We Have Some Growing Pains": Developing A New Regional Recreation Conflict Model Through Examination of the Growth of Mountain Biking. Submitted to Society and Natural Resources.
- Reinhardt**Error! Bookmark not defined.**, E., Coleman, K., Baran, M., Perry, E., and Alldred, M. (2024) Chasing Informed Decisions: A Research Note on the Potential for Strava to Support Rural Recreation Planning. Submitted to the Journal of Recreation and Tourism Administration. doi:10.18666/JPRA-2024-12457
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Student Involvement

	Names	**Degree Sought**
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	Katelyn Kuklinski	M.S.
	Luke Briccetti	M.S.
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	Madison M Janes	M.S.
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Undergraduate Students	Allison McCurdy	B.S.

Partners/Stakeholders/Collaborators

- Maura Adams and Joe Fox, Northern Forest Center

- Abigail Long, Kingdom Trail Association
- Joshua Tauses, Town of Carrabassett Valley
- Katheryn Wrigley, Vermont Department of Forests, Parks and Recreation
- Carolann Ouellette, Maine Office of Outdoor Recreation