Proceedings of the December 12, 2024 Forest Ecosystem Monitoring Cooperative Annual Conference:

Forest Futures: Building Bridges to Shape Strategies Collaboratively

Contents

About the Forest Ecosystem Monitoring Cooperative 3

Proceedings of the December 12, 2024 Forest Ecosystem Monitoring Cooperative Annual Conference: 4

Forest Futures: Building Bridges to Shape Strategies Collaboratively 4

Introduction to the Proceedings 5

Summary of the 2024 Conference Plenary 6

Contributed Talks — Concurrent Sessions 12

Managing for Songbirds 12

Public Perceptions of Forest Management 14

Tree Breeding 16

Assisted Migration and Phenology 18

Forest Soils 20

Building Respectful Cross-Cultural Collaboration with Tribal Nations 22

Recreation and Forest Ecosystems 25

Other Topics in Forest Ecosystems 28

Forest Management and Restoration 32

Northeastern State Research Cooperative Special Session 36

Working Sessions and Panel Discussions 43

Incorporating lingering ash detection into ash/EAB management 43

Informing the development of forest climate change indicator-based tools 44

Understanding climate projections and extreme precipitation events in the context of northeastern forests 45

Implementing Vermont Conservation Design 48

Poster Session 50

About the Forest Ecosystem Monitoring Cooperative

Providing the information needed to understand, manage, and protect the region's forested ecosystems in a changing global environment.

Established in 1990 and ratified in 1996 via a memorandum of understanding between the Vermont Agency of Natural Resources, the University of Vermont, and U.S. Department of Agriculture (USDA) Forest Service, the Forest Ecosystem Monitoring Cooperative (FEMC, formerly the Vermont Monitoring Cooperative) has been conducting and coordinating forest ecosystem monitoring efforts for thirty-three years.

Originally designed to better coordinate and conduct long-term natural resource monitoring and research within two intensive research sites in Vermont (Mount Mansfield State Forest, the Lye Brook Wilderness Area of the Green Mountain National Forest), FEMC efforts have since expanded to capture relevant forest ecosystem health work across the northeastern region with an expanding list of partners from Maine, Massachusetts, New Hampshire, New York, and beyond.

Today, the FEMC funding stems primarily from a partnership between the USDA Eastern Region State & Private Forestry as part of the Cooperative Lands Forest Health Management Program, the Vermont Department of Forests, Parks and Recreation, and the Rubenstein School of Environment and Natural Resources at the University of Vermont. Staff affiliated with the University of Vermont handle the majority of FEMC operations. While FEMC funding primarily supports ongoing monitoring, outreach and data management, contributions by the larger collaborative network are essential to the advancement of FEMC work. Cooperators participate on advisory committees, contribute to the data archive, and share knowledge across the region.

The current mission of the FEMC is to serve as a hub of forest ecosystem research and monitoring efforts across the region through improved understanding of long-term trends, annual conditions and interdisciplinary relationships of the physical, chemical and biological components of forested ecosystems. These proceedings highlight the breadth of activities undertaken by cooperative contributors and demonstrate the potential of large collaborative networks to coordinate and disseminate the information needed to understand, protect and manage the health of forested ecosystems within a changing global environment.

Online at https://www.uvm.edu/femc/
FEMC Steering Committee and State Coordinators – https://www.uvm.edu/femc/cooperative/committees
FEMC staff – https://www.uvm.edu/femc/about/staff

Proceedings of the December 12, 2024 Forest Ecosystem Monitoring Cooperative Annual Conference:

Forest Futures: Building Bridges to Shape Strategies Collaboratively

Published DATE
From material presented at the FEMC Annual Conference
December 12, 2024
Davis Center
University of Vermont
Burlington, VT, USA

Contributing Editors: Alison Adams, Elissa Schuett, Jennifer Pontius

Acknowledgments: The Forest Ecosystem Monitoring Cooperative would like to thank everyone who participated in the planning and production of this conference, from those who coordinated all the details behind the scenes, to our speakers and workshop participants who made the meeting such a success. This conference would not have been possible without the continued support from the Vermont Agency of Natural Resources, the U.S. Department of Agriculture, U.S. Forest Service Eastern Region State and Private Forestry, and the University of Vermont. We would especially like to thank Larissa Robinov, Kyle Lima, Christopher Riely, and Gretchen Nareff for their work on the Annual Conference Planning Committee led by Elissa Schuett, as well as Amanda Mahaffey and Ethan Tapper for designing and leading the keynote address in the opening plenary session. We would also like to thank our invited speakers, working session organizers, and paper and poster presenters for their invaluable contributions. This work was produced in part through funding provided by the U.S.D.A. Forest Service Eastern Region State & Private Forestry.

Preferred Citation: Adams, A., Schuett, E., and Pontius, J. (Eds.) 2025. Forest Futures: Building Bridges to Shape Strategies Collaboratively. Proceedings of the December 12, 2024 Forest Ecosystem Monitoring Cooperative Conference: Burlington, VT, Forest Ecosystem Monitoring Cooperative. DOI: 10.18125/84m2ad. Available online https://www.uvm.edu/femc/CI4/file/info/12272

Introduction to the Proceedings

The Forest Ecosystem Monitoring Cooperative held its 34th annual conference on December 12, 2024. The conference was held in-person at the Davis Center as well as online, making it the third year of offering the conference in a hybrid format. A conference planning committee was formed to define the conference theme and recommend plenary speakers to invite. The committee included Larissa Robinov (New Hampshire Division of Forests and Lands), Gretchen Nareff (Lake Champlain Sea Grant), Christopher Riely (University of Rhode Island), Kyle Lima (Schoodic Institute), Alison Adams (FEMC), and Elissa Schuett (FEMC). The conference theme was Forest Futures: Building Bridges to Shape Strategies Collaboratively. The conference convened a diverse array of speakers and participants to discuss recent advancements in research and management of forest ecosystems, with a particular emphasis this year on building productive and creative collaborations.

The conference offered a collaborative plenary session with ample audience participation; a summary of forest trends across the Northeast presented by Director Alison Adams and updates on recent work by FEMC State Coordinators; a record fourteen tracks for contributed talks, workshops, and FEMC-invited speakers (including for the second time a two-part track for NSRC-funded projects; and a poster session with a panel- and attendee-selected "best poster" award. Kyle Lombard, the new FEMC Steering Committee Chair, opened the conference with introductory remarks, followed by a brief presentation by FEMC Director Adams about the work FEMC has done this year, changes within the organization and its broader network, and what FEMC is looking forward to in the coming year. Alison introduced the keynote speakers, Amanda Mahaffey (US Fish & Wildlife Service Forest Ecologist) and Ethan Tapper (Bear Island Forestry owner and author of How To Love A Forest).

Ethan and Amanda led the audience through a process of self reflection and discussion, accompanied by stories about their own experiences building community in ecological work, to identify key strategies and new ideas members of the audience could pursue in their own work to build strong, more diverse coalitions. The plenary discussion was developed to set the stage for the day by encouraging attendees to connect not only with each other about shared values and inspiration for the work we do, but also with others in their extended communities who may be interested in stewardship and management of forest ecosystems but have not previously been invited to participate. The planning committee identified Ethan Tapper, an award-winning former County Forester in Vermont, now the author of How To Love A Forest and owner of Bear Island Forestry, and Amanda Mahaffey, a strong communicator who is currently a Forest Ecologist with the U.S. Fish & Wildlife Service, as a dynamic pair who could develop and execute an engaging keynote address. Ethan and Amanda guided the audience through discussions with their neighbors about collaboration and communication, paired with stories from Amanda and Ethan's own work. Many attendees shared in the post-conference survey that the keynote address helped establish a more collaborative and congenial tone for the rest of the day.

More than 270 attendees registered for the conference, and 27 attended virtually. The hybrid format once again provided maximum flexibility for attendees, allowing those located further afield to participate in the conference without the additional cost of travel, and also allowing those with health concerns or other considerations to attend. Although most registrants attend in person, post-conference survey responses continue to show strong support for the hybrid event. Post-conference survey responses also indicated that the non-traditional keynote address was appreciated, though some folks had difficulty connecting it to their own work. Sessions on assisted migration and phenology, recreation and forest ecosystems, and building respectful cross-cultural collaborations with Tribal Nations were the most highly-attended sessions.

These proceedings include presentation summaries, abstracts, and outcomes compiled by FEMC staff as a resource for forest professionals from across the region. Additional materials, including presentation recordings, downloadable PowerPoint presentations are available at the conference webpage: https://www.uvm.edu/femc/CI4/cooperative/conference/2024.

Building Bridges

To support the region's forests and address complex challenges like climate change and evolving community needs, we need to connect with stakeholders in new, collaborative ways.

This is most effective when we focus on shared values, which allows us to build trust and create a unified approach to forest management.

This collaborative effort ensures that our strategies are more effective and inclusive, ultimately leading to healthier and more resilient forests.

Summary of the 2024 Conference Plenary

Building Bridges to Support Forest Management Solutions

The 2024 Forest Ecosystem Monitoring Cooperative (FEMC) Annual Conference was a vibrant gathering of forestry professionals, practitioners, experts, and stakeholders, all united by a common goal: to shape the future of our forests through collaboration and innovation. The theme, "Forest Futures: Building Bridges to Shape Strategies Collaboratively," set the stage for an inspiring plenary session that highlighted the power of partnerships in addressing the pressing challenges of forest management.

Ethan Tapper from Bear Island Forestry and Amanda Mahaffey from the US Fish and Wildlife Service were the keynote speakers, each bringing a wealth of experience and passion to the discussion. Ethan, known for his book "How to Love a Forest," emphasized the importance of responsible stewardship and building relationships with people and our forests. Amanda focused on resiliency and climate adaptation, urging the audience to think expansively and collaboratively about the future of our forests.

"Most people are supporters of forest management they just don't know it yet and they don't know it yet because we haven't told them in a way that reaches them and aligns with their values."
~ Ethan Tapper

Relational Communication

One of the key takeaways from the session was the concept of relational communication. Relational communication is a method of connecting with people based on shared values and interests, rather than just facts and figures. This approach is vital in building trust between communities and forest managers because it fosters a deeper understanding and appreciation of forest management practices. By aligning our efforts with the values and concerns of the community, forest managers can create a sense of shared purpose and collaboration. This mutual trust and respect make it easier to gain public support and work together towards healthier, more resilient forests.

Both speakers shared examples of using this relational approach has allowed them to connect with people on a deeper level and share the positive impacts of forest management activities. As a forester, Ethan learned to talk mostly about ecological values like creating underrepresented forest types, managing for songbird habitat or climate resilience and biodiversity. Focusing on these goals worked to win support from many organizations that had previously been litigating to limit forest management activities.

This approach is particularly important in forest management, where the work we do can sometimes seem counterintuitive to the public. Finding and communicating around shared values is a great first step but its also important to share why you are excited about the tools we can use to manage a forest. Making a more personal connection with people and sharing your passion and commitment to these ecosystems serves to deepen trust communities put in you.

Foresters typically want to spend our time working in the woods but we need to be just as excited to talk with people.
~ Ethan Tapper

Amanda shared practical tips for building bridges, starting with the simple act of listening. By asking questions and genuinely understanding others' values and interests, we can create a foundation of trust. Relating to shared values and communicating how our efforts align with their values can make our work more relatable and impactful.

THE BIG QUESTIONS:

How do we communicate the value of what we do in ways that build broad support for forest management?

How can we expand our coalition to reach everyone we need to?

How can we create a forest landscape that is in better relationship with human communities?

Building Bridges: Key Strategies

- **Begin by Listening:** Ask questions to understand others' values and interests. Listen without judgment to build trust.
- **Find Common Ground:** Share points of agreement and communicate how your efforts align with their values.
- **Use Storytelling**: Make your work relatable and impactful by sharing stories that build trust and find common ground.
- **Inclusive Approach:** Emphasize "we" instead of "us/them" to foster a sense of unity.
- **Listening Sessions**: Meet people where they are and address their needs through dedicated listening sessions.
- **Science Exchange:** Aim for mutual learning and sharing of ideas and resources, rather than just delivering information.
- **Engage Diverse Audiences:** Use different communication modalities, such as social media, to reach a broader audience.
- **Celebrate Your Work:** Highlight the beauty and importance of forest management to inspire and engage others.
- **Words Matter**: Avoid inflammatory words. Find ways to say the same thing in a way that doesn't trigger a negative response.

Storytelling, Amanda noted, is a powerful tool in this process that can be important to help find common values. Sometimes simply sharing why you got into the field, or what is special about a forest to you can build trust and provide common ground to work from. Sharing your personal values around a forest invites others to share their own. Combined with actively listening to their stories can help you identify the best way to communicate the science.

"Go out and show how beautiful forest management is. This work is profound and beautiful. ...something we are lucky to be able to do." ~ Amanda Mahaffey

Communities of Practice

Amanda also highlighted the importance of building communities of practice. Amanda shared examples from her work, such as the Women in the Woods network, which brings together women in forestry to share knowledge and support each other.

Building communities of practice is crucial in forest management because it brings together individuals and organizations with shared interests and expertise to collaborate, learn, and innovate. These communities foster a sense of belonging and mutual support, enabling members to exchange knowledge, share best practices, and develop new strategies for managing forests sustainably. By working together, they can address complex challenges more effectively, such as climate change, biodiversity conservation, and community engagement.

Working to develop new communities of practice may be ideal to support your work around specific initiatives or in specific locations. For example, citizen science projects, educational initiatives that involve children and families in forest stewardship activities, community forest working groups that involve residents in decision making and stewardship activities, or establishment of volunteer groups like Adopt-a-Forest Programs can build trust and inform the work you do to manage forests. Find new groups to reach out to. Who has never been asked to join? How can you broaden the coalition? These new collaborative groups bring along their constituency.

This intentional collaborative approach not only enhances the effectiveness of forest management practices but also builds trust and strengthens relationships among stakeholders, leading to more resilient and healthy forest ecosystems.

Women in the Woods

Example Communities of Practice

- **Women in the Woods:** A community that brings together women in forestry to share knowledge and support each other.
- **Foresters for the Birds:** A program that integrates bird habitat conservation with forest management practices.
- **Sustaining Ash:** A community focused on the conservation and management of ash trees in the face of threats like the emerald ash borer.
- **Fire Science Exchange Network:** A network that promotes the exchange of fire science knowledge and practices among forest managers and researchers.
- **Tree City USA**: A program by the Arbor Day Foundation that engages communities in urban forestry management, tree planting, care, and education to enhance urban green spaces.

Words Matter:

How can we talk about forest management in a way that helps people understand without setting off alarm bells?

- Consider what terminology or phrases may best describe the work being done. For example, the phrase "timber sale" does not indicate if the timber cuts are designed to enhance the ecology of the forest. Instead, consider a phrase like "forest stewardship project."

- Focus on terms that align with community needs. For example discussing watershed management will appeal to communities recently flooded by extreme events.

- Emphasize broad benefits. For example, rather than discussing management goals around one species, message the overall improvement to habitats.

A Call to Action

Both of our plenary speakers stressed the need to think more expansively and collaboratively to achieve the forests we hope to have in the future. This involves effective communication and expanding coalitions to share impactful work.

Ethan and Amanda emphasized that this is something we all have to participate in, and concluded their plenary session with a call to action to highlight our need to:

• Build more broad coalitions and identify stakeholders to reach out to;

• Find common values to build common ground;

• Solidify the vision of where we collectively want to go;

• Identify actionable ideas that we can communicate better;

• Celebrate our work sustaining forested ecosystems and the services they provide.

They walked us through a simple reflection to help identify and prioritize actions we can take to think more creatively about collaboration and how we can work to build coalitions based on common values.

Consider the following to guide your own action steps:

~ What is the outcome or change do you want to create?
~ What bridges do we have to build to make this reality happen?
~ What ideas can you act on now to start the process?

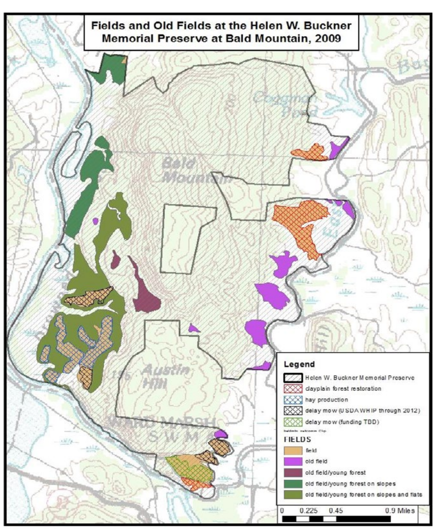
Managing for Songbirds

Managing for young forest habitat in post-agricultural settings to support winged-warblers

Eliza Merrylees, The Nature Conservancy of Vermont; Murray McHugh, The Nature Conservancy of Vermont; Mark LaBarr, Audubon Vermont

Abstract

Abandoned forest-adjacent farmland in Vermont that has begun to transition to early successional shrubland/young forest habitat often supports several bird species whose populations are regionally in decline and are Species of Greatest Conservation Need in Vermont? The Nature Conservancy's Helen W. Buckner Memorial Preserve at Bald Mountain, located in West Haven in the Southern Lake Champlain Valley, includes hundreds of acres of forest-adjacent abandoned agricultural land in various stages of habitat transition. This site has been identified as an important regional stronghold for the suite of shrubland/young forest bird species, chief among them, Golden-winged and Blue-winged Warblers (Figure 1). In an ongoing partnership with Audubon Vermont, The Nature Conservancy actively manages and monitors post-agricultural lands at the natural area to maximize the potential for healthy shrubland/young forest habitat as it continues along a successional path towards mature forest. Future goals include trialling methods for establishing additive high-quality early successional shrubland/young forest habitat on recently abandoned hay fields on the preserve, as current young forest transitions to older forest. Audubon Vermont's participation in the planning and management at the preserve is part of their regional Shrubland Bird Project, which enhances habitat for priority bird species breeding in the shrublands of the entire Champlain Valley.



Map Credits (L to R) © TNC (2009), Eliza Merrylees/TNC (2024)

Figure 1 Survey and restoration sites at Bald Mountain included in the active management of agricultural lands for several bird species.

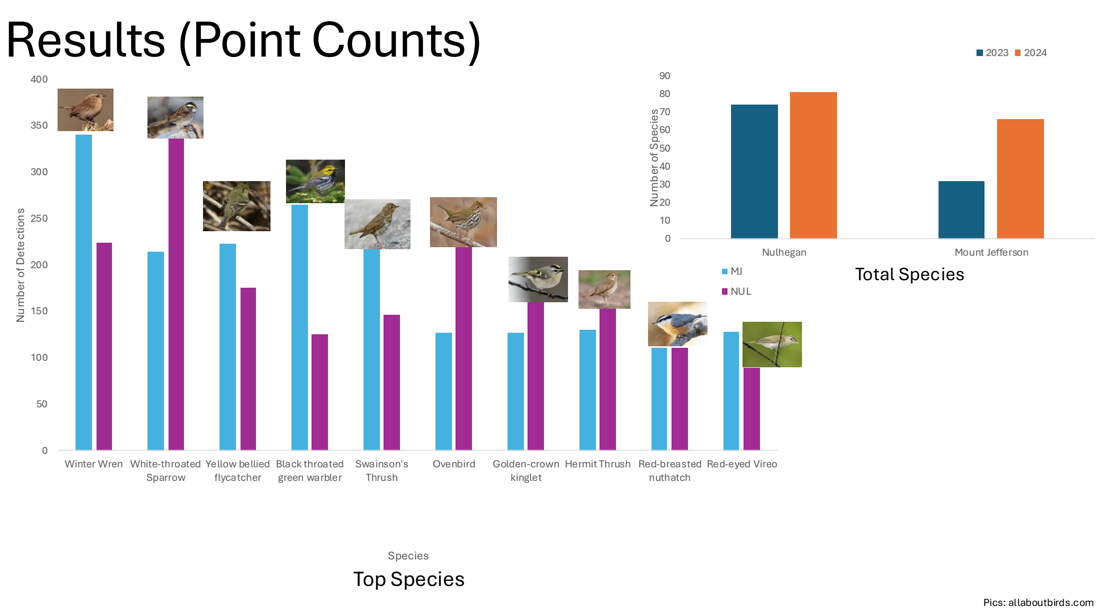
Adaptive silviculture practices and breeding songbirds in the Northeast

Davis Farris Jr., UMass Amherst; Madeline Boyd, Marshall University; Rachel Clich, USWFS, Leighlan Prout, USDA; Alexej Sirn, UNH; Noah Wilson, Vermont DEC

Abstract

Habitat loss is one of the primary factors leading to declines in avian populations. New management strategies such as adaptive silviculture that are used to create more climate adapted forests can increase their complexity, but it's not yet known how they affect the animal species that inhabit them. To better understand how bird communities may be affected by adaptive silviculture practices, we used point count surveys and autonomous acoustic recording units (ARUs) to survey bird species at two study sites in north-central New England (White Mountain National Forest [WMNF] and the Nulhegan Basin Division [Nulhegan] of the Silvio O. Conte Refuge) during the breeding seasons of 2023 and 2024. Nulhegan uses adaptive silviculture techniques in a coordinated effort to increase complexity within homogenous forests, a condition generated from past management, and to increase climate resiliency and adaptation, while no logging has taken place at the WMNF study site for about a century. By comparing these two sites, we hope to build an understanding of how climate-adapted management practices influence forest bird communities in the Northeast. We predicted that bird diversity will be higher in the managed areas due to an increase in habitat complexity and diversity. Our preliminary results support this prediction; avian species richness is higher at Nulhegan than Mount Jefferson, and more species were found at managed sites than unmanaged ones (Figure 2).

Figure 2 Results of breeding bird surveys conducted at the Silvio O. conte Refuge in 2023 and 2024, comparing the effectiveness of different silvicultural techniques.



Worcester Range Management Unit

Oliver Pierson, Vermont Department of Forests, Parks, and Recreation

Abstract

The Vermont Agency of Natural Resources (ANR) recently completed a Long Range Management Plan (LRMP) for the Worcester Range Management Unit (WRMU). The WRMU is located in north-central Vermont in the towns of Elmore, Worcester, Middlesex, Waterbury, and Stowe. It is made up of approximately 18,772 acres and includes five separate parcels: C.C. Putnam State Forest (SF), Elmore State Park (SP), Middlesex Notch Wildlife Management Area (WMA), Middlesex WMA, and Worcester Woods WMA (Figure 3). There was significant public interest in the development of the plan, both during the public scoping in 2020 and when the draft plan was released for comment in late 2023, with over 1300 comments received. Many of the comments did not support some of the ANR's proposed land management classifications and actions for the WRMU, particularly around timber sales, and there were also a range of viewpoints expressed about the merits of expanding recreation in the WRMU. This presentation will describe the process ANR used to develop the plan, solicit comments, consider these comments, and produce a final version of the LRMP, as well as share some lessons learned from the process to be incorporated into future public land management planning efforts.

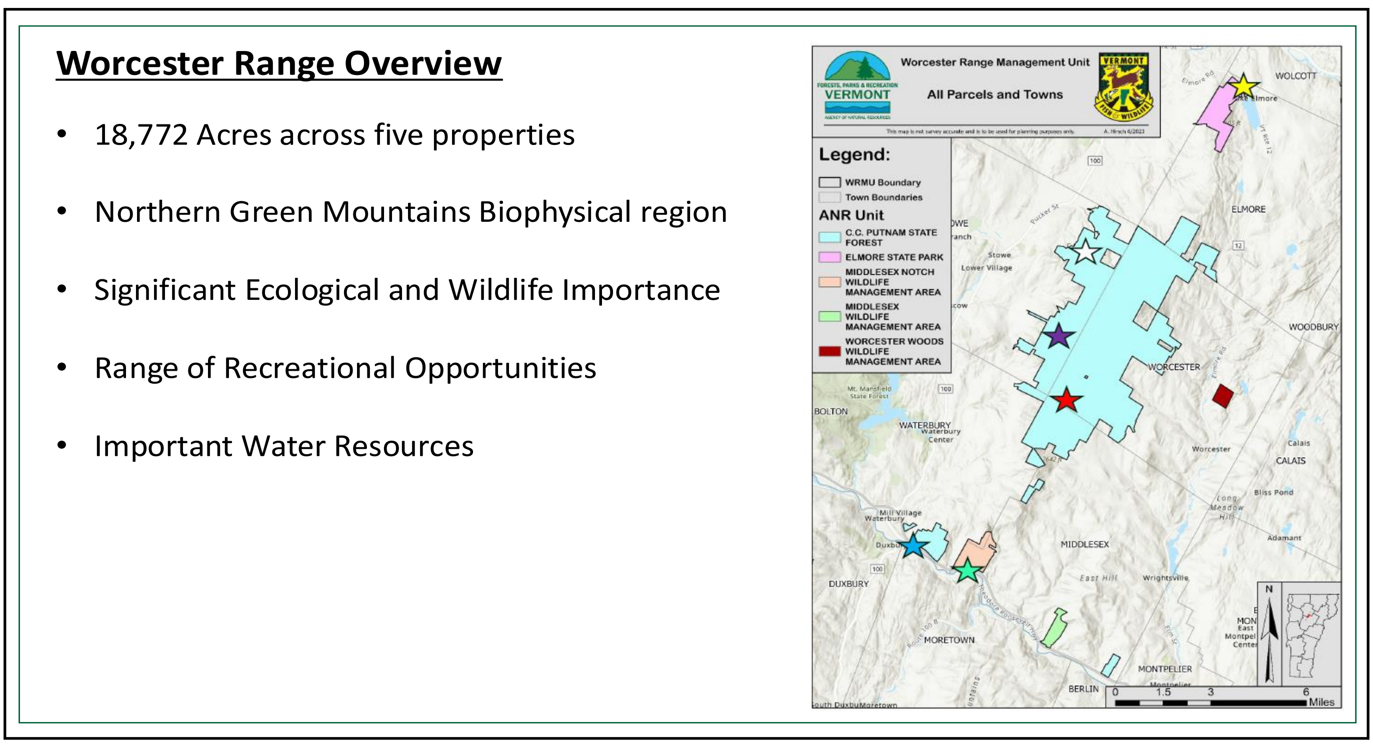


Figure 3 Worcester Range management unit.

I love trees so much, I have to cut them down: The public's perception of a water utility's clear cut and slash wall

Josh Tracy, South Central Connecticut Regional Water Authority

Abstract

South Central Connecticut Regional Water Authority own 21,000 acres of watershed land, managed for high water quality in its reservoirs. Its forestry division has begun incorporating the concept of slashwalls in to its management regime, with two having been completed in 2022. One in particular, located in Seymour, CT, was highly visible to the public throughout the harvest and the wall's construction (Figure 4). Varying degrees of criticism came from groups including local town government, passersby, and budding geologists, for as many reasons as someone can imagine. I will discuss some of the more intriguing interactions and their outcomes.

Figure 4 Seymour, Connecticut clear cut and slash wall.

Tree breeding to support forest resilience: What, why, how

Leila Wilson, U.S. Forest Service Northern Research Station; **Mary Mason**, U.S. Forest Service Northern Research Station

Abstract

Invasive pests and pathogens threaten a growing list of tree species and the ecosystems they occupy. Of elevated concern are floodplains and wetland forests where butternut, American elm, black ash and green ash are all vulnerable leading to loss of diversity, adaptive capacity and resilience (Figure 5). To address this issue, the Northern Research Station (NRS), in collaboration with many federal, state, university and non-profit partners, leads resistance breeding programs for multiple tree species, including green, white and black ash and American elm. The objective of these programs is to develop locally adapted and genetically diverse seed orchards to provide a source of improved seed for restoration of degraded floodplain and wetland habitats. Here we provide updates to the ash and American elm resistance breeding programs with a focus on New England efforts. Testing of lingering green ash and their progeny is showing improved resistance to EAB, while the limited results in black ash show it is different but still has promise for selecting and breeding for resistance. Inoculations to test resistance of 26 New England survivor American elms and their progeny are planned for 2025 (OH) and 2026 (VT). Results will inform which parents to include in New England-based American elm seed orchards.

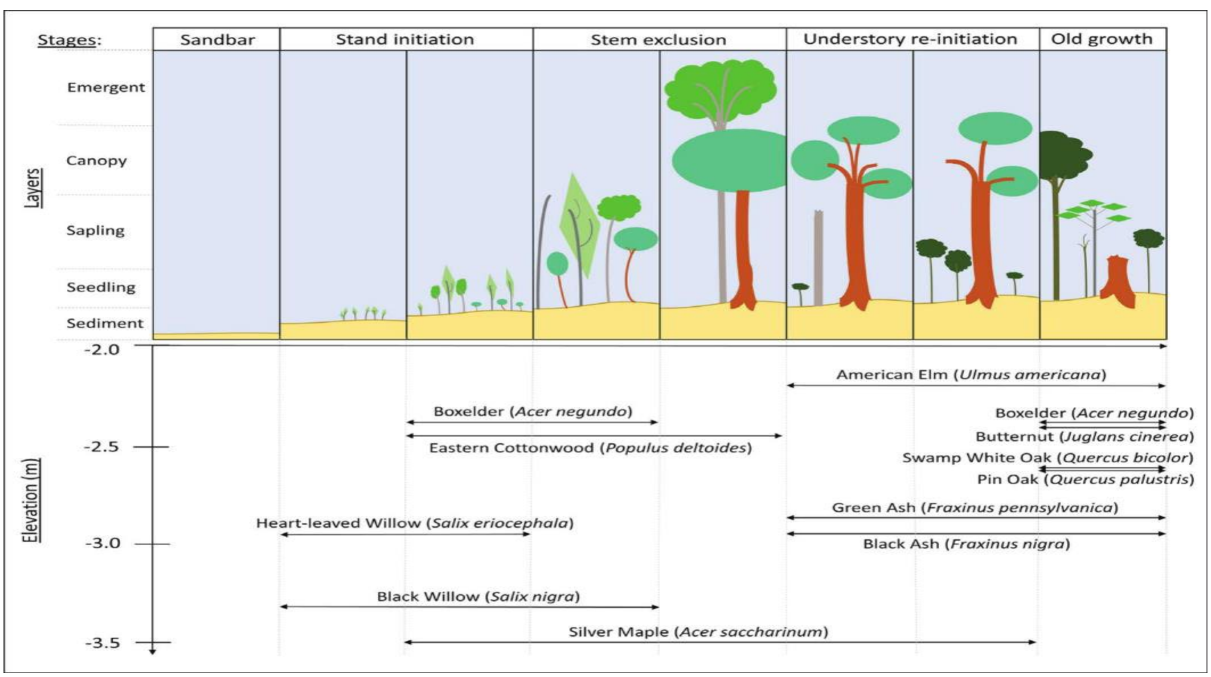


Figure 5 Resistance breeding to support ecosystem resilience, from Marks, Yellen and Nislow. 2021. Northeast Naturalist.

Tree breeding to support forest resilience: Species in detail - ash and elm

Jennifer Koch, USFS Northern Research Station; **Leila Wilson**, USFS Northern Research Station; Kathleen Knight, USFS Northern Research Station; Gus Goodwin, The Nature Conservancy

Abstract

Invasive pests and pathogens threaten a growing list of tree species and the ecosystems they occupy. Of elevated concern are floodplains and wetland forests where butternut, American elm, black ash and green ash are all vulnerable leading to loss of diversity, adaptive capacity and resilience. To address this issue, the Northern Research Station (NRS), in collaboration with many federal, state, university and non-profit partners, leads resistance breeding programs for multiple tree species, including green, white and black ash and American elm. The objective of these programs is to develop locally adapted and genetically diverse seed orchards to provide a source of improved seed for restoration of degraded floodplain and wetland habitats. Here we provide updates to the ash and American elm resistance breeding programs with a focus on New England efforts. Testing of lingering green ash and their progeny is showing improved resistance to EAB, while the limited results in black ash show it is different but still has promise for selecting and breeding for resistance. Inoculations to test resistance of 26 New England survivor American elms and their progeny are planned for 2025 (OH) and 2026 (VT). Results will inform which parents to include in New England-based American elm seed orchards (Figure 6).

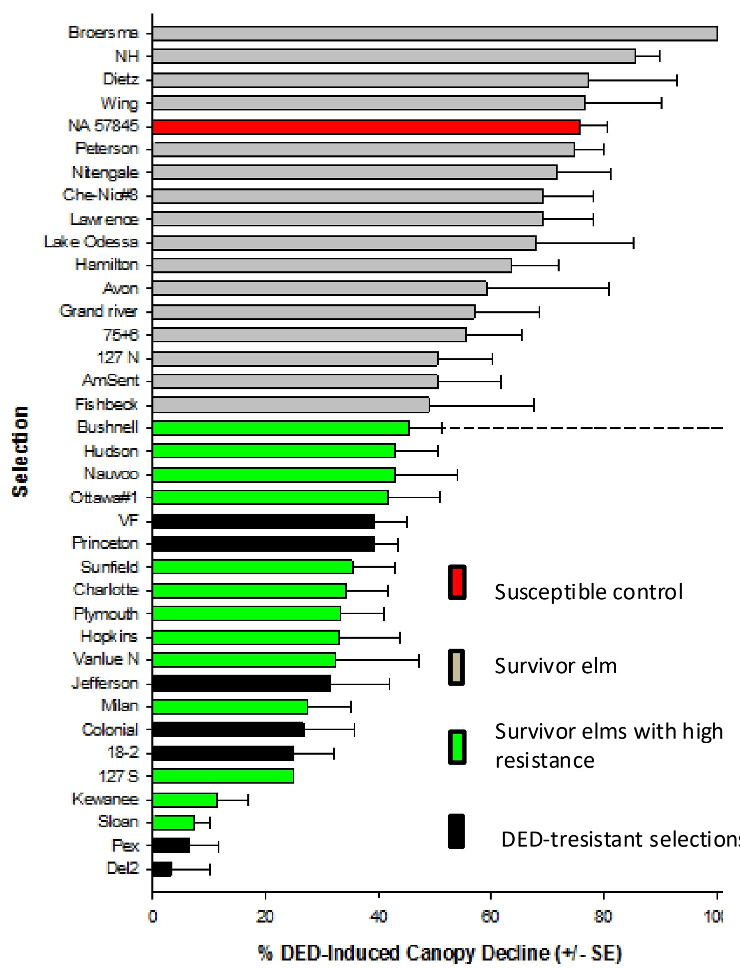


Figure 6 Clones of 29 survivor American elms were planted in complete replicate blocks in Delaware, OH and inoculated with DED 10 years after planting.

Assisted tree migration in northeastern forests: motivations, misconceptions, and applications

Anthony D'Amato, University of Vermont

Abstract

The use of tree planting as a component of adaptation strategies for addressing the impacts of global change on northeastern forests has increased considerably over the past several years. This increased interest has resulted in numerous co-produced adaptation experiments that integrate assisted migration and has motivated broader discussions around the appropriateness of these tactics and associated best practices for their application. This presentation will discuss the current state of assisted migration in northeastern forests, including common motivations, barriers, and misconceptions, and will highlight outcomes of co-produced experiments applying these tactics as part of broader adaptation strategies for sustaining diverse values into the future (Figure 7).

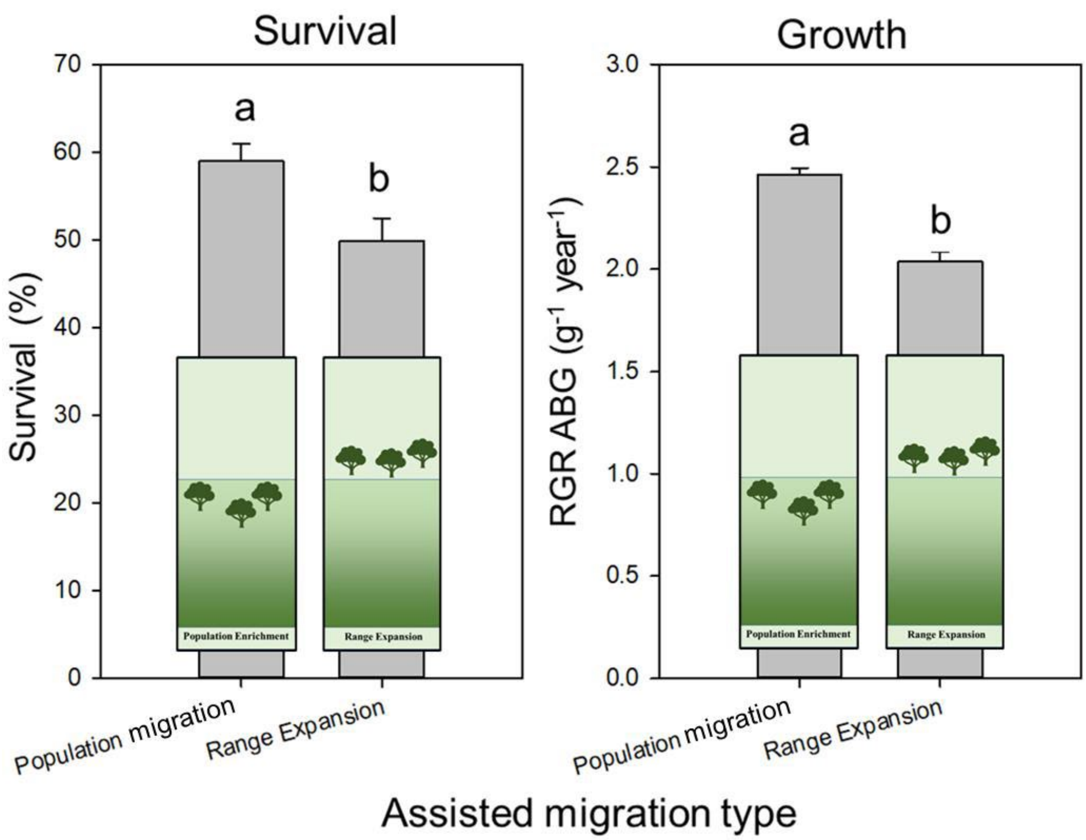


Figure 7 Challenges exist in assisting tree migration, including survival rates of planted trees. 100% survival is not possible, but also not needed. Survival rates of 5-20% of trees for 50 years provide a seed source and genetic diversity that contribute to a diverse forested landscape.

Impacts of early springs and winter warming events on spring phenology and cold tolerance among temperate and boreal tree species

Dr. John Butnor, U.S. Forest Service; Paula Murakami, U.S. Forest Service; Dr. Nicole Rogers, Maine Forest Service; Dr. John Zhang, University of Maine; Dr. Jay Wason, University of Maine; **Laura Pinover**, University of Maine

Abstract

Climate change is increasing the likelihood of earlier springs and winter warming events. These changes can advance spring phenology and reduce cold tolerance, thus potentially threatening tree regeneration if cold temperatures return. However, responses from tree species common in the Northern Forest remain understudied and variable limiting our ability to predict how these events impact regional forests. In this study, we quantified the phenological sensitivity, growth, and cold tolerance of ten tree species to earlier spring and winter warming events and the risks associated with subsequent re-freezing. We exposed more than 300 containerized saplings to single, repeated, or extended warming events at different times of the year. For each tree, we assessed changes in phenological stage (e.g., bud swelling, leaf out), vigor, and cold damage weekly from late February to early May 2024. We also assessed the cold tolerance of each species at three times throughout the experiment in response to warming events by measuring the relative electrolyte leakage of plant tissue. We found evidence that timing of leaf out varied strongly among species and depended on growing degree days accumulated by our warming scenarios. For example, paper birch was consistently the earliest species to leaf out in response to warming whereas sugar and red maple appeared resistant to early warming. We also found that some species lost cold tolerance surprisingly quickly in response to short periods of warming and experienced damage when exposed to subsequent cold temperatures (Figure 8). Our findings suggest that earlier springs and winter warming events may have a highly variable effect on regeneration of Northern Forest trees with the potential to alter competitive dynamics especially if combined with the return to cold temperatures.

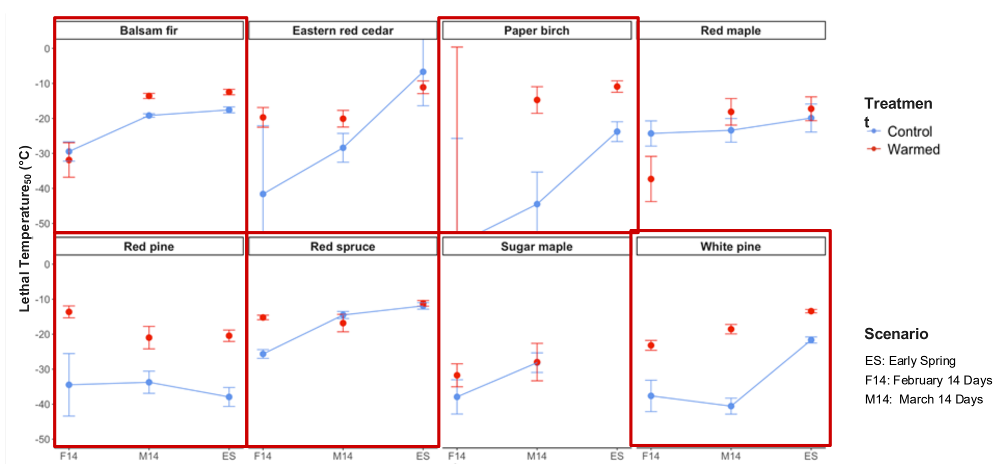


Figure 8 Several species had reduced tolerance to cold following two weeks of warming.

The influence of silvicultural treatments and coarse woody material (CWM) on forest soil carbon storage and sequestration

E. Carol Adair, University of Vermont, Rubenstein School of Environment and Natural Resources; Anthony D'Amato, University of Vermont, Rubenstein School of Environment and Natural Resources; **Caitlin Henry**, University of Vermont, Rubenstein School of Environment and Natural Resources

Abstract

The purpose of this research is to quantify the effect of coarse woody material (CWM) on the amount and form of soil carbon (C), and whether the impact of CWM varies with overstory tree canopy gap size. Objectives include examining (1) the relationship between canopy gap size and soil C, and (2) the proximity to the CWM and the soil C, ammonium, and nitrate. We expect to see increases in soil C with increasing canopy gap size and beneath logs, but declines in nitrogen (N) availability under logs due to microbial immobilization of available N (i.e., ammonium and nitrate). We examined these relationships by collecting soil samples and placing resin sticks in proximity of twelve Acer saccharum logs across a range of canopy openness within the Second College Grant Adaptative Silviculture for Climate Change experiment. Resin sticks are constructed using strips of cation-exchange resin membranes and anion-exchange resin membranes that adsorb ammonium ($NH4+$) and nitrate ($NO3-$) ions, respectively, from soil. We used them to determine soil N availability during peak biomass. Soil samples were collected adjacent/under and 100 cm up- and downslope of each log, to determine how much C is in the soil under and around the logs in the different canopy gaps (Figure 9). Results from this work will be useful for informing management strategies for maintaining and increasing C in forest soils.

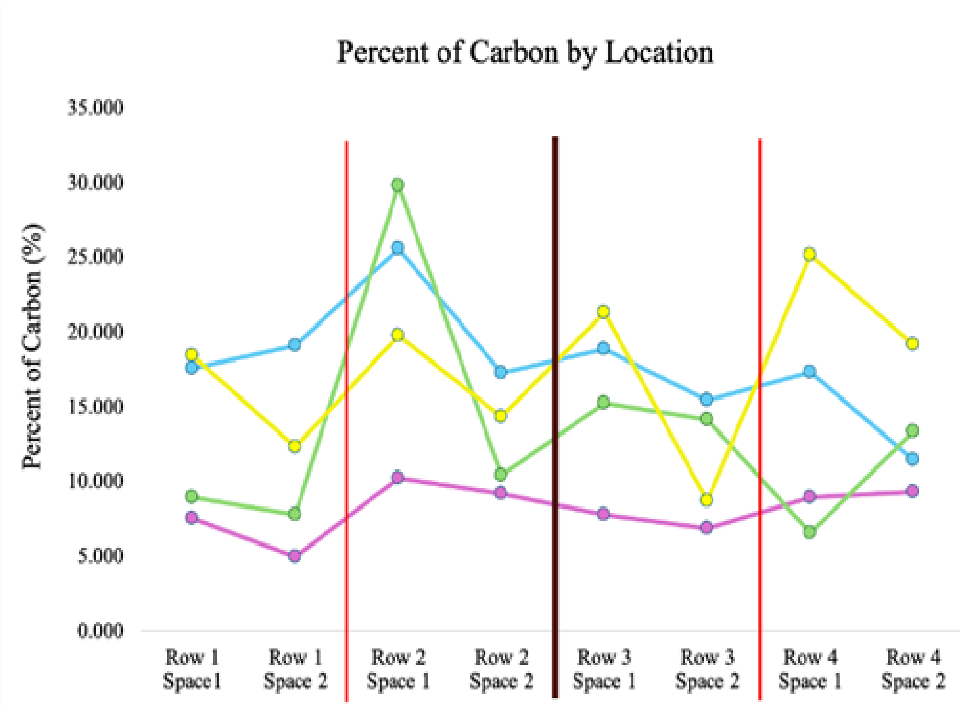


Figure 9 Soil carbon analysis of different canopy gap sizes.

Rooted in resilience: Belowground Variation in the World's Premier Urban Research Forest

Brad Oberle, The New York Botanical Garden; John Zeiger, The New York Botanical Garden

Abstract

Climate change mitigation and adaptation require healthy forests, especially in cities. However, urban forest monitoring lacks an old-growth reference for soil carbon (C). Furthermore, urban soils may pose unique risks with increasingly heavy rainfall, which can remobilize accumulated heavy metals. As the world's first old growth urban research forest, the Thain Family Forest (TFF) at the New York Botanical Garden (NYBG) can provide a unique perspective on long-term urban forest resilience. With its first flora completed in 1898, the TFF provides the longest record of forest dynamics in North America's densest city (Britton 1906). Complementing floristics, ecosystem monitoring began in the 1980s with the Institute for Ecosystem Studies Urban-Rural Gradient project, which determined that the TFF's primeval ambiance belied uniquely urban soil impairment from heavy metal contamination. Systematic soil sampling for carbon and heavy metals brings new insights and partnerships to historic datasets. Aboveground species composition differs starkly from 1938, but both native species diversity and basal area remain similar and weakly correlated with belowground variation in soil bulk density and root distributions (Figure 10). In 1989, at the twilight of the leaded gasoline era, forest soil lead concentrations were 25% of the current EPA action limit. Tracing legacy contamination through the soil and across the watershed partnership with a diverse team of researchers and interns will identify public health risks from planned dam removal and serve as a model for urban stream fish passage projects across the northeast.

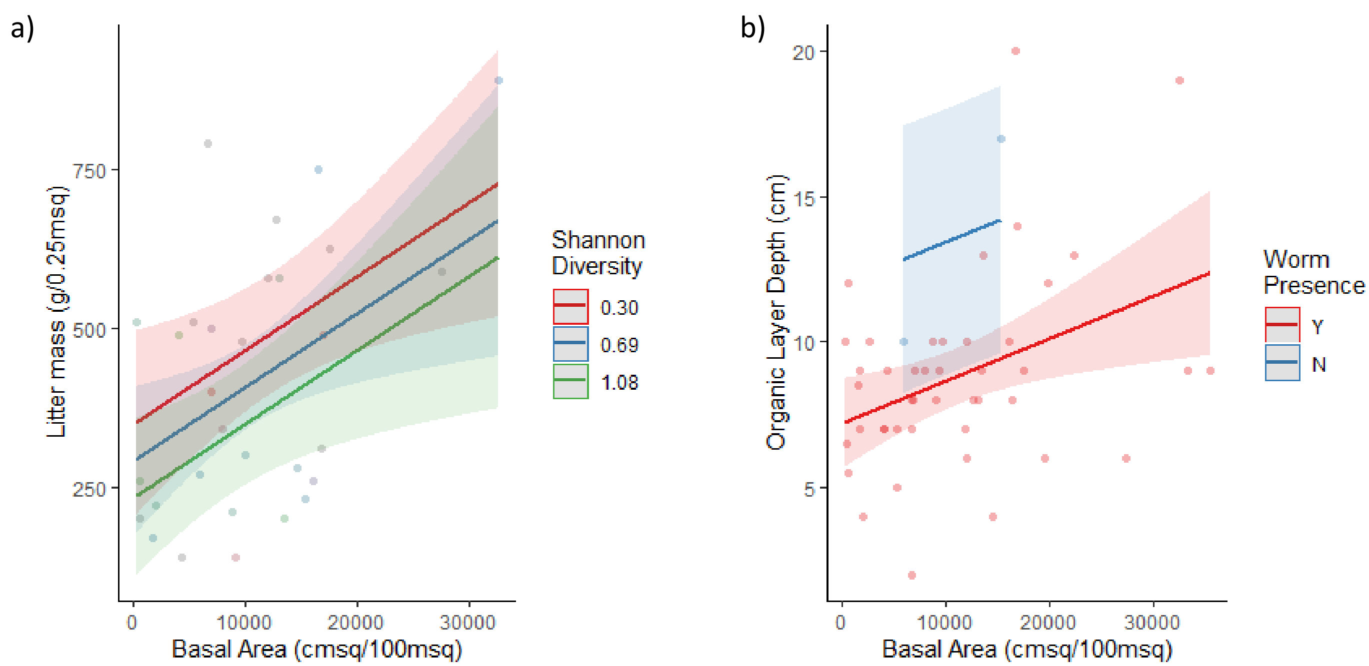


Figure 10 The project object tests relationships between aboveground dynamics and soil carbon variation. a) Litter mass increases with basal area but decreases with canopy diversity. b)Soil organic layer increases with basal area but decreases where worms are present.

Partnership for land in community resilience

Erica Wood, Village of White Mountain, Alaska; SUNY ESF Center for Native Peoples and the Environment

Abstract

This study and subsequent monitoring program, conducted in partnership with the Alaska Native Village of Igiugig in Bristol Bay, Alaska, examines the effects of climate-driven shrubification on a culturally important plant: salmonberry (Figure 11). By integrating Indigenous knowledge and scientific methods, we highlight pathways for co-production of knowledge, land stewardship, and community resilience while supporting Indigenous sovereignty in environmental research and programming.

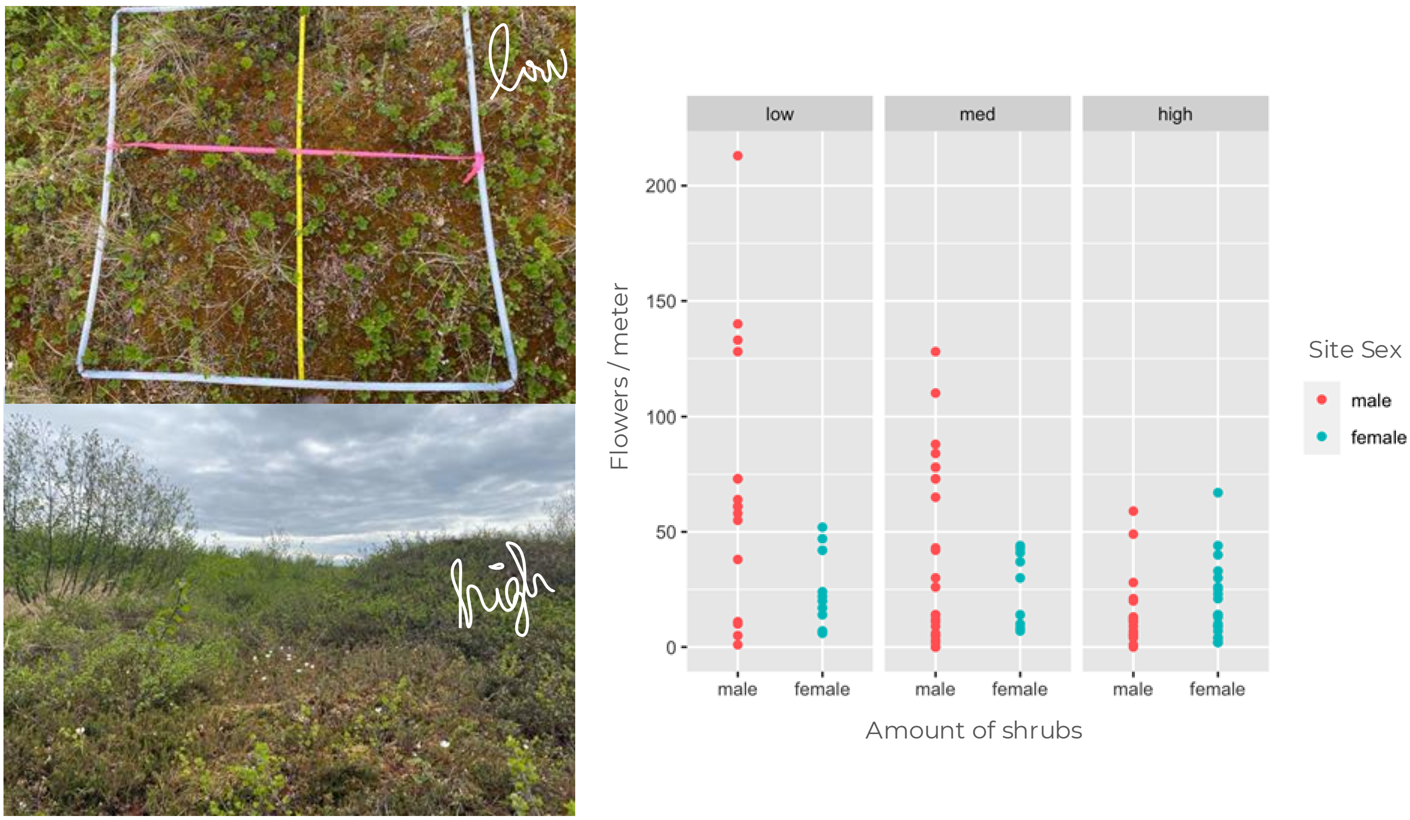


Figure 11 Low, medium, and high shrubbiness results in a sex ratio bias, influencing the variability of salmonberry harvest. Female flowers do not change under different shrubbiness characteristics, whereas fewer male flowers are present in the high shrubiness plots.

Cross-cultural knowledge exchange to advance collaborative forest stewardship

Rachel Schattman, University of Maine; Anthony D'Amato, University of Vermont; Tyler Everett, University of Maine; Darren Ranco, University of Maine; Adam Daigneault, University of Maine; **Rachel Swanwick**, Forest Stewards Guild & University of Vermont

Abstract

Collaborative arrangements help maximize adaptive potential in the face of rapidly changing environmental conditions to achieve cross-boundary stewardship goals. In part, the success of these cooperative efforts stems from their ability to enable exchange or "bridging" across knowledge systems (e.g., western scientific, local, and Indigenous). There is a growing recognition of the benefits of including Indigenous knowledge and community perspectives in environmental collaborations. Yet, there is a need for more context-specific insights to enable equitable collaborative environmental governance and knowledge exchange with Indigenous Nations. To explore this gap, we conducted semi-structured interviews with 22 forest stewards associated with state agencies (n=12) and Wabanaki Tribal Nations (n=10) in present-day Maine (U.S.A). We argue that while different knowledge systems are highly valued and respected by forest stewards across state agencies and Tribal Nations, barriers including western and Indigenous paradigmatic incongruities, inflexible institutional arrangements, and socio-political tensions between the state and Tribes limited cooperation. We recommend recognizing the inherent adaptability and sovereignty of Indigenous Nations, encouraging cross-cultural engagement at the outset of the forest stewardship planning process, and using reflexivity for 'two-way' knowledge exchange. We found that an awareness of these dynamics has the capacity to transform collaborative systems and improve forest stewardship outcomes (Figure 12).

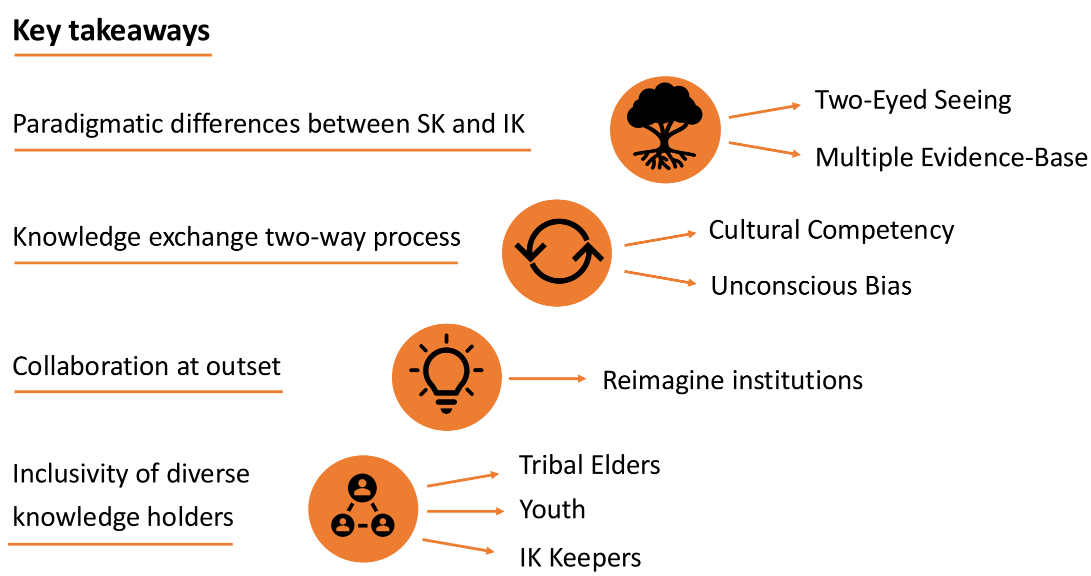


Figure 12 Key takeaways from interviews with forest stewards in state agencies and Wabanaki Tribal Nations in Maine.

Cross cultural collaborations to protect brown ash: Reflections from Wabanakik

Ella McDonald, University of Maine

Abstract

The work of the Ash Protection Collaboration Across Wabanakik (APCAW), based out of the School of Forest Resources at UMaine Orono, unites Tribal Nations and conservationists in an alliance to take action to protect brown ash trees. In the Northeast US, we are in a critical window of time in which land caretakers can collect seed, manage, and monitor healthy ash trees in the face of the dual threats of emerald ash borer (EAB) and climate change before we see widespread tree mortality. This presentation will discuss how our lab centers Wabanaki perspectives on brown ash protection strategies, while organizing the widespread participation of private landowners, conservation groups, and state and federal agencies to follow the ash management recommendations of Tribal Nations. Preliminary results from recent surveys and interviews of APCAW program participants reveal effective strategies for communication around protecting culturally significant species, which have implications for other cross-cultural conservation efforts (Figure 13).

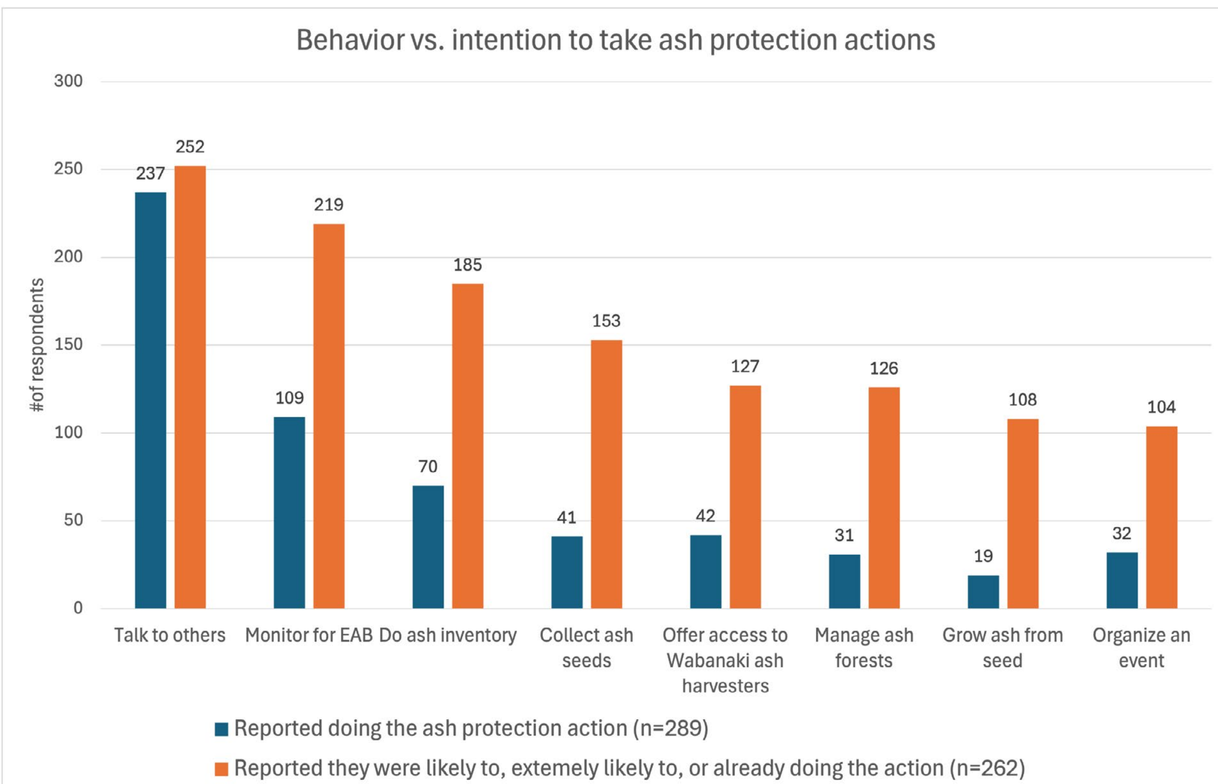


Figure 13 Survey responses showing differences in intention to act and actual behavior.

Recreation and Forest Ecosystems

Recreation impacts on dimensions of northeast regional forest health

Soren Donisvitch, Forest Ecosystem Monitoring Cooperative

Abstract

This project, led by the Forest Ecosystem Monitoring Cooperative (FEMC), analyzed the impact of recreational hiking and biking on forest health across the Northeast USA. Using geospatial data from ForWarn Sentinel products, Strava, iNaturalist, NLCD forest data, and USDA soil surveys, the study examined correlations between recreation, canopy health, soil vulnerability, and wildlife disturbance (Figure 14).

Results showed weak but significant correlations between higher recreational use and slightly reduced canopy health, as measured by NDVI deviance. Soil susceptibility mapping highlighted hotspots of heavy recreation on vulnerable soils, and wildlife analyses revealed increased forest fragmentation near trails.

The project delivered geospatial tools for prioritizing trail maintenance, habitat conservation, and sustainable recreation management. While limited by the absence of field-based data, these resources provide a foundation for informed decision-making and further studies to balance recreation with forest ecosystem protection.

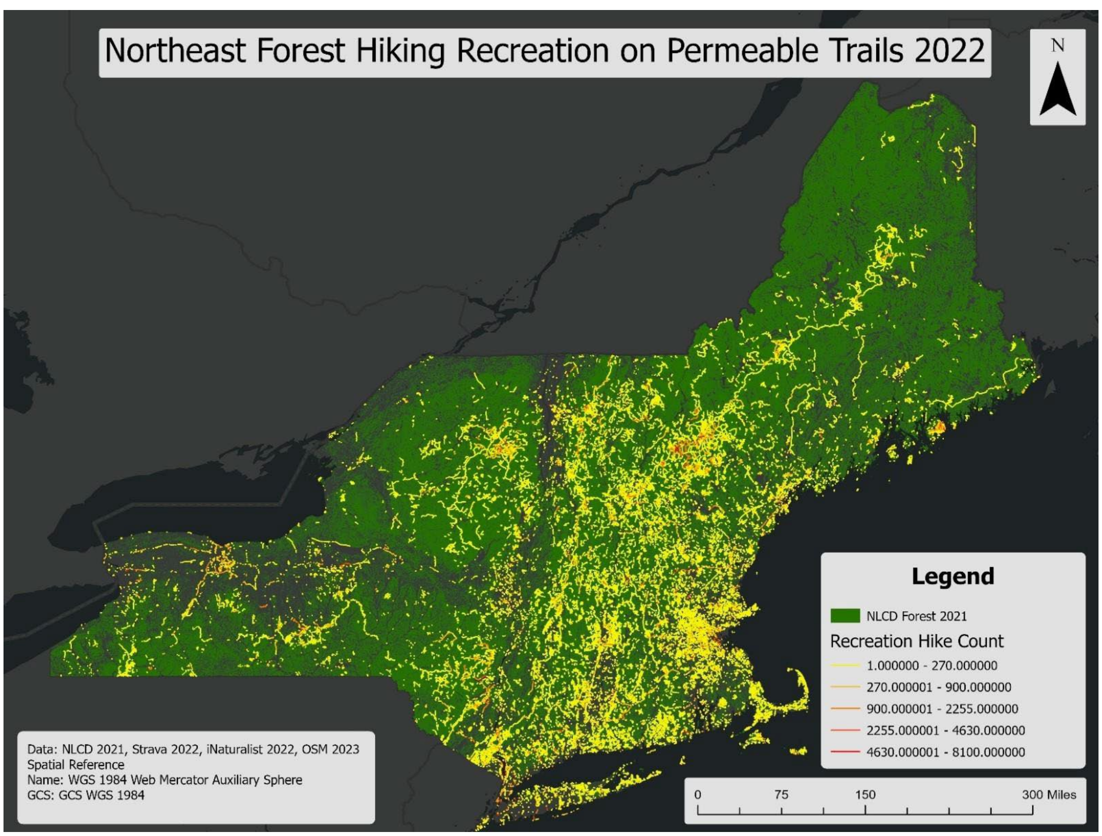


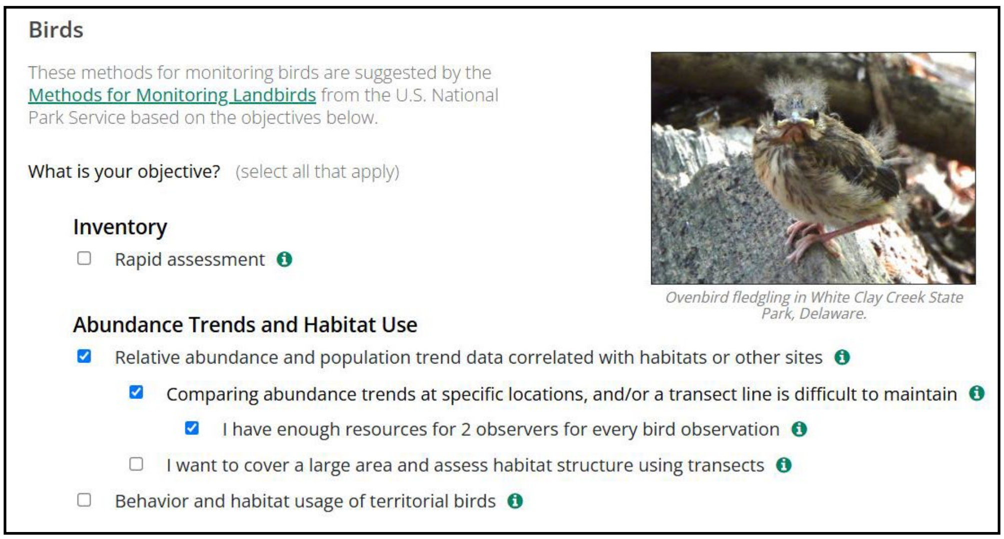
Figure 14 Relative hiking on permeable trails in 2022.

Monitoring for recreation impacts

Elissa Schuett, Forest Ecosystem Monitoring Cooperative

Abstract

FEMC interest-holders expressed a need to better understand how recreation is impacting forest ecosystems. FEMC reviewed available literature and resources, spoke with experts, and formed a working group to identify opportunities to address the community questions. A decision-support tool was developed to aid land-managers in selecting monitoring methods that can be applied to understanding recreation impacts. The support tool allows users to select among different features of a collection of monitoring methods to identify a method that meet the goals of the user (Figure 15). Accompanying this tool is a report that outlines how methods were selected, other considerations to include when developing a monitoring program, and original methods sources. The tool includes methods for studying wildlife; invasive plants; and soil compaction and erosion. This tool complements a second tool developed by FEMC focused on geospatial data, which will be presented in a second talk during this session.



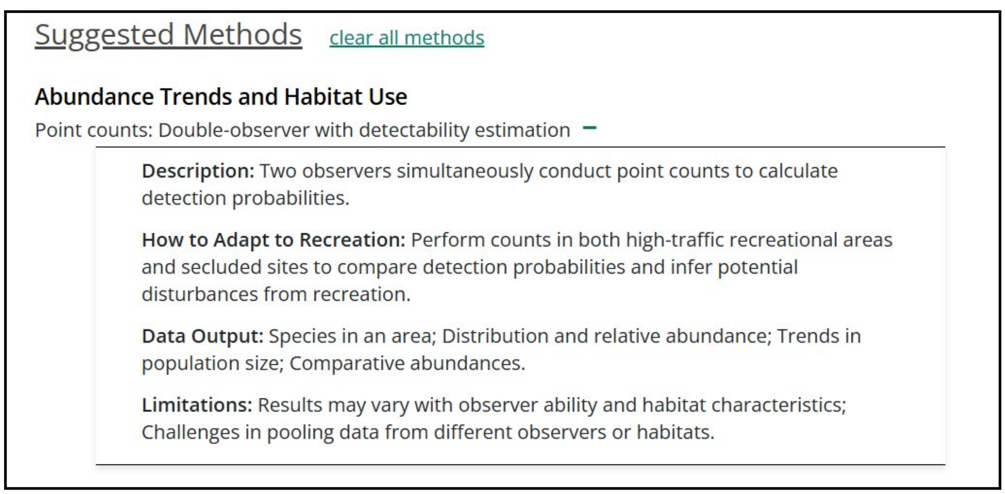


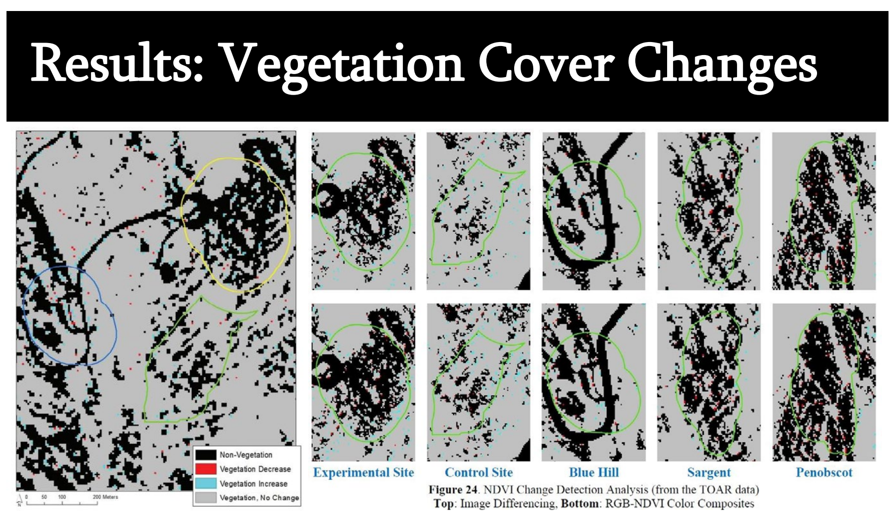
Figure 15 Example of the decision-support tool method selection and output to aid managers in establishing monitoring programs.

Enhancing recreation resource management through remote sensing: Insights from Acadia National Park

Min Kook Kim, Stockton University; John Daigle, University of Maine

Abstract

Researchers have typically emphasized the importance and advantages of remote sensing data and technology for managing recreation resources in various settings. This includes 1) supporting general management through mapping and classification, 2) inventorying the conditions of natural resources, and 3) monitoring changes in those conditions. In this study, we attempted to examine the efficacy of management strategies designed to reduce visitor impacts on vegetation. We utilized a series of high-resolution remote sensing data collected from 2001 to 2007, 2010 to 2018, and 2001 to 2021. The focus was on Cadillac, Penobscot, and Sargent Mountain Summits in Acadia National Park, all of which are popular visitor destinations. Various management actions have been implemented in these areas to mitigate visitor impacts on vegetation. For example, since 2000, indirect management strategies based on Leave No Trace principles and wooden/roped barriers have been employed around the Cadillac Mountain Summit, alongside ecological restoration projects initiated in 2015. In contrast, less intensive management measures, such as pavements and cairns, have been implemented at the summits of Penobscot and Sargent Mountains. Overall, our analysis of changes in vegetation cover revealed consistent patterns across different thresholds and selected spatial extents. Notably, Cadillac Mountain exhibited an increase in vegetation cover, while Sargent and Penobscot Mountain Summits showed declines. These findings provide strong evidence that the active management strategies currently in place at Cadillac Mountain are not only beneficial but also effective in enhancing vegetation cover. Additionally, we highlight the value of utilizing remote sensing data and technology to support informed decision-making in recreation resource management (Figure 16).



	Study 3 (296 reference points)	Study 4-1 Image Differencing (161 reference points)	Study 4-2 RGB-NDVI, Machine Learning (161 reference points)
Overall Accuracy	74.15%	85.09%	86.34%

Figure 16 NDVI change detection analysis at the site locations to demonstrate effectiveness of management strategies.

Eastern Hemlock (Tsuga canadensis) as an alternate host for spruce budworm: Dendrochronological evidence from Maine, USA

Presenter: Rachel Poppe, University of Maine

Abstract

Purpose: Eastern spruce budworm (Choristoneura fumiferana) is a tenacious defoliator of conifer forests in northern New England (USA) and eastern Canada. While its preferred host species are balsam fir (Abies balsamea), white (Picea glauca), red (P. rubens), and black (P. mariana) spruce, spruce budworm is known to feed on alternate hosts as well, including eastern hemlock (Tsuga canadensis). However, the severity, spatial-temporal patterns, and long-term effects of spruce budworm defoliation of hemlock is unclear. Our specific objectives are: (1) Determine the extent to which eastern hemlock has served as an alternate host during documented spruce budworm outbreaks Maine, USA ((Figure 17), and (2) Examine post-outbreak growth and recovery patterns in eastern hemlock. Eastern hemlocks are already threatened by a variety of insect pests including the hemlock wooly adelgid, hemlock looper, and elongate hemlock scale. Understanding how other pests such as spruce budworm could impact eastern hemlock is critical in managing hemlock in face of these compounding threats.

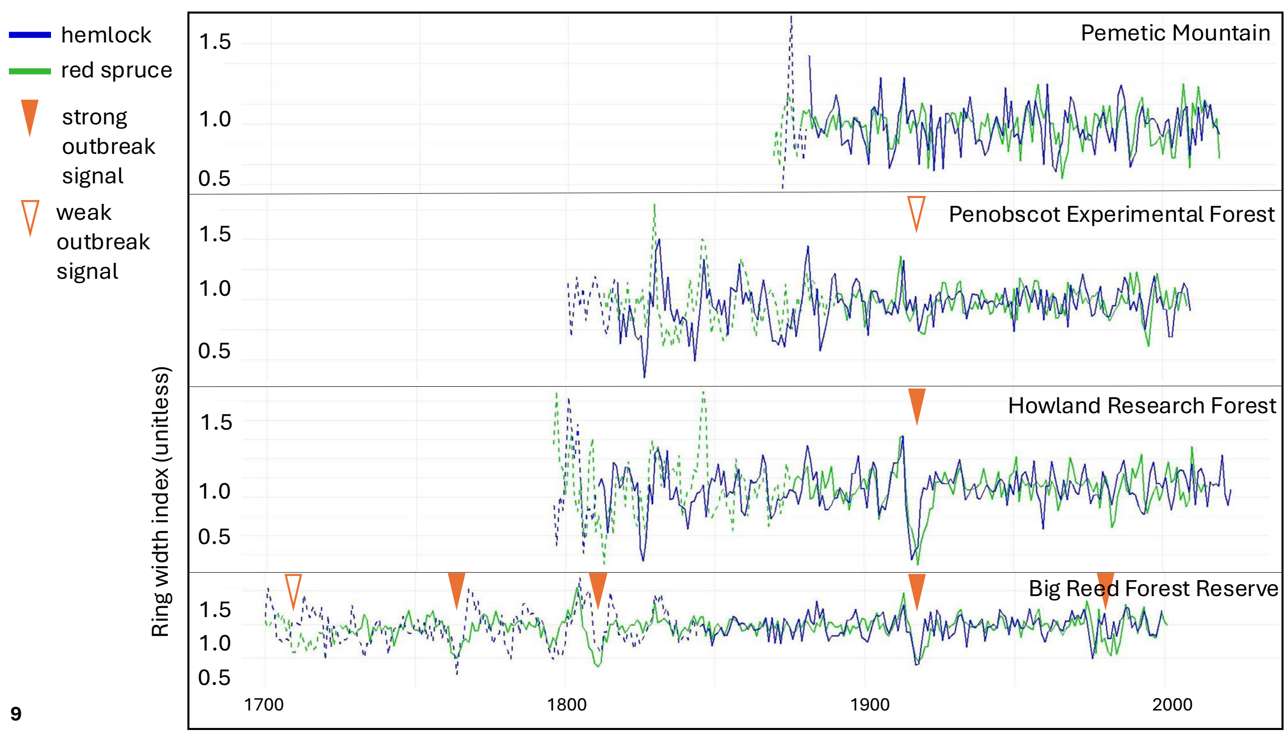


Figure 17 Spruce budworm outbreak signals in red spruce and hemlock at four locations in Maine.

Assessing how effects of browsing by white-tailed deer on tree regeneration vary by species and seedling size across the northeastern USA

Melissa Pastore, USDA Forest Service Northern Research Station; Anthony D'Amato, University of Vermont; **Lucas B. Harris**, University of Vermont

Abstract

Tree regeneration in forests of the northeastern USA is threatened by a number of factors including climate change, non-native pests and pathogens and over-browsing by white-tailed deer (Odocoileus virginiana). Characterizing effects of deer browsing on tree regeneration at regional scales has been challenging due to (a) the need to develop indicators of browsing intensity and (b) the fact that browsing impacts are likely to vary by seedling size yet seedlings are typically tallied within 1-2 broad size classes. We modeled effects of deer browsing and other biotic and abiotic factors on tree seedlings of different sizes for ten common species across New England and New York by leveraging the Forest Inventory and Analysis program's Regeneration Indicator (RI) dataset, which assesses seedling abundance within six height classes. We developed proxies for deer browsing intensity including town-level harvest records, mean snow depth and proportion of nearby non-forest vegetation. These proxies corresponded well with field-estimated browsing intensity from RI plots. Our results suggest that effects of deer browsing varied both by ontogeny and species palatability, with seedlings of less palatable species often benefiting from increased browsing up to a point (Figure 18). Shrub cover often had a positive relationship with gains in seedling abundance, consistent with shrubs protecting seedlings from herbivory. We discuss implications of this work for managing tree regeneration in an era of global change.

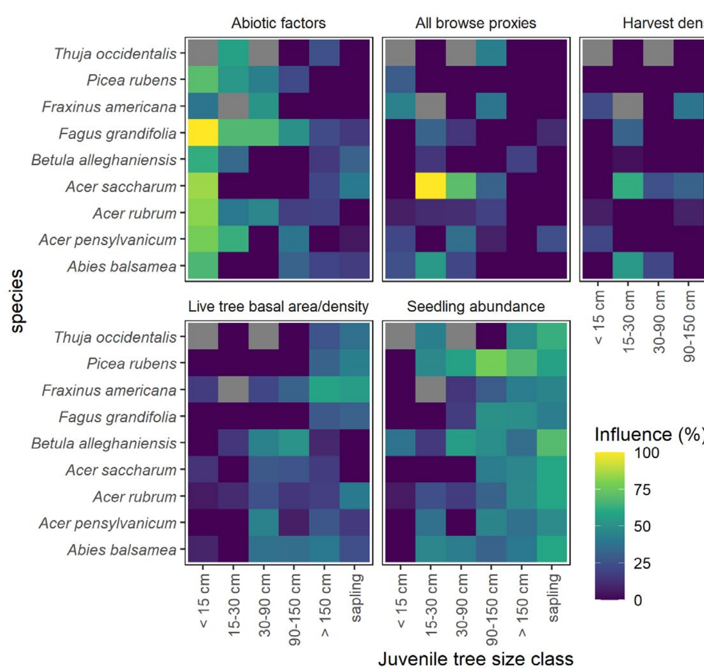


Figure 18 Species level analysis of the influence of browse shows that abiotic factors have a stronger influence than other proxies.

Global Forests - Lessons from Community-based Forest Recreation in Haiti and Connections to Forest Management in Vermont

Jean-fenel Dorvilier, SRDH

Presenter: Julia Pupko, Vermont FPR; SRDH

Abstract

After a summer spent in the mountaintops of Vermont, a Bicknell's Thrush (Catharus bicknelli) has a long journey to reach overwintering grounds in the Caribbean. Once there, it must find forested sites suitable for survival, which may be a difficult task if it arrives in a heavily deforested region. An estimated 90 percent of Bicknell's Thrush overwinter in Hispaniola, the island shared by Haiti and the Dominican Republic. Ongoing degradation and deforestation poses a significant threat to this sensitive species, along with many others.

In Haiti, decades of foreign, expert-led reforestation and agroforestry projects have failed. Conversations with locals and dives into literature will reveal some commonalities of project failure -- lack of local leadership, protectionist models that do not incorporate community needs, and rejection of local land tenure systems, to name a few. Currently, the Global Forest Watch estimates Haiti's tree cover to be between 21.3 and 32 percent, down from the estimated 80 percent forest cover of pre-colonial times. So what can be done?

Sosyete pou Rebwaze Duchity Haiti (SRDH; Society for the Reforestation of Duchity Haiti) is a community-based agroforestry and reforestation organization operating in the mountains of the southern peninsula. SRDH implements accessible reforestation and agroforestry projects in partnership with community, farmers, and other groups. Through the provision of education, training, materials, and support, SRDH facilitates a space to collaboratively replant and manage Haiti's forest ecosystems (Figure 19). Trees and planting sites are selected to address community needs, with an end-goal of sustainably managed forest ecosystems that meet the habitat requirements of endemic, sensitive, threatened, and endangered species, such as the Bicknell's Thrush. Despite limited resources, funds, and continued unrest in Haiti, SRDH has established two community forests, partnered with eight farmers, begun a women's empowerment program, and planted over 12,000 seedlings since 2020.

This presentation will examine forest ecosystem restoration, conservation, and sustainable use through the lens of SRDH's community-based, community-first model. While SRDH operates far from Vermont, our forests are inextricably linked by migratory species like the Bicknell's Thrush. Additionally, lessons from community-based forestry initiatives in Haiti can be applied to local forest management. These lessons and connections provide powerful opportunities for local and international collaborations, ensuring healthy forest ecosystems for all that breathes.

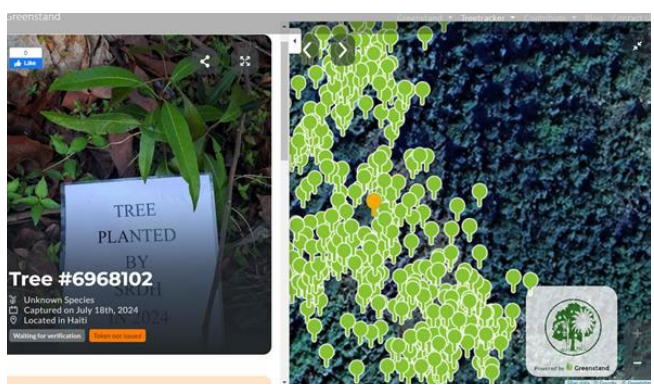


Figure 19 Through education and local engagement, SRDH is supporting reforestation efforts through planting and management in Haiti's forest ecosystems.

Funding trends and research gaps: insights from regional researchers on the current terrain of northeastern forest ecology science

Lydia Roe, Independent contractor hired for this work by Northeast Wilderness Trust

Abstract

In August and September, 30 interviews were conducted with professionals doing forest ecology-related work in the northeastern United States; interviewees were primarily scientists, but also included land managers and those in more policy-oriented or administrative roles. Interviews aimed to gather participants' thoughts in two major areas: one, trends or themes in funding streams available to those doing forest ecology research in the region, and two, knowledge areas in northeastern forest ecology which may be understudied or poorly understood. The top theme to emerge from the first area of inquiry was the presence of a large gap in long-term funding for correspondingly long-term work in northeastern forests. Participants also spoke about the inflexibility of funding in various ways, as well as the relative difficulty or ease of finding money to support specific areas of inquiry (e.g., biodiversity, carbon sequestration, climate change); these findings are presented within the context of a brief review of funding sources in the region. In discussing knowledge gaps, the need to understand more about various disturbances and stressors affecting northeastern forests emerged as participants' top concern, followed by the current lack of basic knowledge of some lesser-known species, particularly fungi (Figure 20). These and additional themes are presented with narrative context drawing on many participants' decades of work in the field.

Category	Subcategories	Subcategory Number of Responses	Category Number of Responses
Disturbances and Stressors	Interaction of disturbances Pests/pathogens Invasive plants Fire Wind	6 6 2 1 1	16
Lesser-Known Species	Fungi (including lichens) General Beetles	9 3 2	14
Other/Miscellaneous	[See report for list]	-	9
Carbon Sequestration	General Soil carbon Old growth	3 3 2	8
Synthesis/Applicability	Integrating data & research Translation to managers	3 4	7
Trees-Other Biodiversity Interactions	-	-	7
Human-Ecological-Landscape	-	-	6
Monitoring	-	-	6

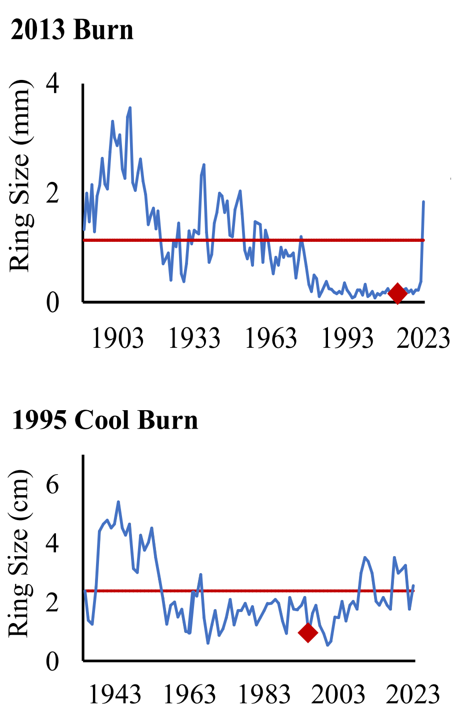
Figure 20 Participants in the interviews identified gaps in knowledge about a number of categories of forest ecosystem health, and also discussed the lack of funding available to fill in these gaps.

Dendroecology reveals successional changes in pitch pine growth Vermont sandplain forests

Sarah Newton, Saint Michael's College; Skyleigh Bickings Saint Michael's College; Jackson Sargent, Saint Michael's College; **Declan McCabe**, Saint Michael's College

Abstract

We conducted this study to determine if controlled burns in Vermont sandplain forests can reset succession, allowing Pinus rigida (pitch pine), an early successional pioneer species, to grow and prevent Pinus strobus (eastern white pine), a late-successional climax species, from overshadowing and dominating the landscape. We measured diameter at breast height (DBH) and increment-core ring length from representative pitch pines at control sites and at 3 sites in Camp Johnson in Colchester, VT, where prescribed burns occurred in 1995, 1998, or 2013. In addition we cored pitch pines at unburned control sites and on the north bank of a beaver pond with southern sun exposure. We tested the hypotheses that pitch pines growing with southern exposure would show consistent growth, that pitch pines under white pine canopies would show reduced growth, and that prescribed burns would reset succession allowing for rapid growth (Figure 21). All three hypotheses were supported by our data sets. Our results confirm white pine domination of the unburned patches across all ages of the lifespan and reduced pitch pine growth later in life. Sun-exposed pitch pines grew consistently with no evidence of reduced growth. Three different prescribed burns in Camp Johnson increased pitch pine growth following a lag time of varying duration. Our data suggest that active management including the use of prescribed burns can reset succession in favor of pitch pines in VT's remaining sandplain forests.



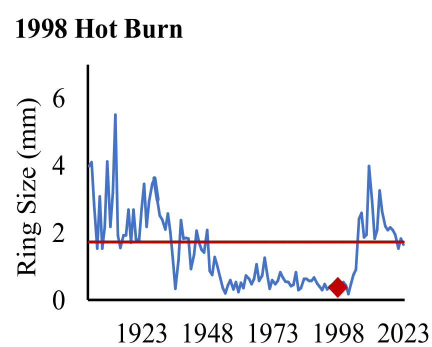


Figure 21 Results show increased growth in pitch pine following prescribed burns.

Natural Dynamics Silviculture in Europe: Application of an Index First Developed in the U.S. Northeast to Compare Natural and Human Disturbances

Rka Aszals, Centre for Ecological Research, Insitute of Ecology and Botany, Vacrotot, Hungary; Dominik Thom, Ecosystem Dynamics and Forest Management Group, School of Life Sciences, Freising, Germany; **William S. Keeton**, University of Vermont, Rubenstien School of Environment and Natural Resources; and Gund Institute for Environment

Abstract

Here we report on an application of concepts first developed in northern New England to forest management across the Atlantic. In Europe, there has long been interest in natural dynamics silviculture (NDS) to provide a full spectrum of seral habitats and structural conditions required by forest biodiversity, including species that are poorly represented in intensively managed forests. However, adoption of NDS has been limited by incomplete understanding of the ranges of variability in disturbance regimes, including frequencies, spatial attributes, and severities. Addressing this constraint in European forest management, we adapted a "comparability index" (CI) that was first developed in the northeastern US (Seymour et al. 2002) to compare natural disturbances and forest management effects (Figure 22). We extended the original concept that included spatial and temporal axes by adding disturbance severity (i.e. tree survivorship or retention) as a third dimension. We populated the model by compiling published data on disturbance dynamics for four major forest types (i.e. spruce, beech, oak, and pine-dominated). Data on silvicultural systems by country and forest type were obtained through an expert-based process employing standardized estimation protocol. The data for both natural and harvest disturbances were visualized in three-dimensional plots indicating ranges for frequency, size, and severity. We developed an algorithm to calculate the index values for bivariate comparisons. The results indicated that natural disturbances are highly variable in size, frequency, and residual structure, but European forest management fails to encompass this complexity. The CI showed the highest congruence between uneven-aged silvicultural systems and key natural disturbance attributes. Even so, uneven-aged practices emulate only a portion of the complexity associated with natural disturbance effects. The remaining silvicultural systems perform poorly in terms of retention, especially, as compared to tree survivorship after natural disturbances. Our results and the CI will help European forest managers to expand their portfolio of silvicultural systems to sustain and conserve forest biodiversity, while providing a broad array of ecosystem services. However, the Index could be used anywhere, including the U.S. Northeast, although down-scaling using more localized data will be important to guide forest management. Accounting for shifts in natural disturbance regimes will be just as important as for any type of adaptive forest management.

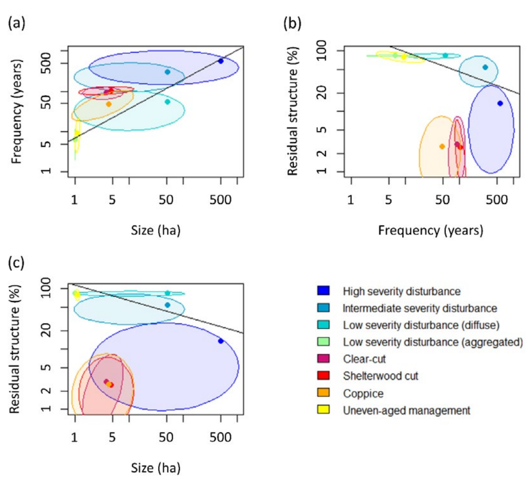


Figure 22 Comparability index for European forests.

Multiple pathways of development in northeastern forests: The role land-use history plays in mature forest structure

Stephen Peters-Collaer, University of Vermont; William Keeton, University of Vermont; Andrew Whitman, Maine Department of Agriculture, Conservation and Forestry

Abstract

Forests across the northeastern US are recovering from land-clearing for timber and agriculture in the 19th and early 20th century. As a result, many northeastern forests are now mature (80 to 150 years old). Traditional models of stand development predict that these mature forests contain a narrow range of structural conditions which has implications for many ecosystem functions. However, these models are based on stands that were completely cleared, while many northeastern forests were only partially cleared and retained legacy structure. Recent research has shown that these legacies, as well as disturbances and management after stand initiation, can alter pathways of stand development and the structures that develop. As such, we expect that the varied land-use history in the region and subsequent light management in many locations has led to a larger range of structural conditions than traditionally predicted. But no research has yet quantified this on a regional scale.

To better understand forest structure region-wide, we collected data on 63 northern hardwood-conifer stands from New York to Maine. All sites were mature with known management and disturbance histories. We analyzed these data with classification and regression techniques to: 1) better quantify the regional range of structural conditions and 2) assess whether different stand initiating disturbances (cleared or partial logging) and differences in subsequent management explain variability in mature forest structure.

Forests exhibited a broader range of structural conditions than predicted by stand development models. In some cases, structural metrics were within ranges typical for old-growth forests. Random forest classification suggested that the most important differences between stands with different land-use histories were aboveground live biomass and the density of large live trees. Differences in these metrics are important for forest complexity and ecosystem function, especially wildlife habitat and carbon storage. Sites that were completely cleared and unmanaged tended to have less old forest structure, with especially low aboveground biomass and the large tree density ($p < 0.05$). These results suggests that stands that initiate from complete clearing and are never managed may be slower to regain critical structural features than stands with alternative development pathways, such as those that were partially logged and retained legacy structure. Stand development pathways in the northeastern US may be more varied than previously understood, with some forests recovering complex, old forest structures more quickly than expected, in part due to land-use history and how that interacts with subsequent management (Figure 23).

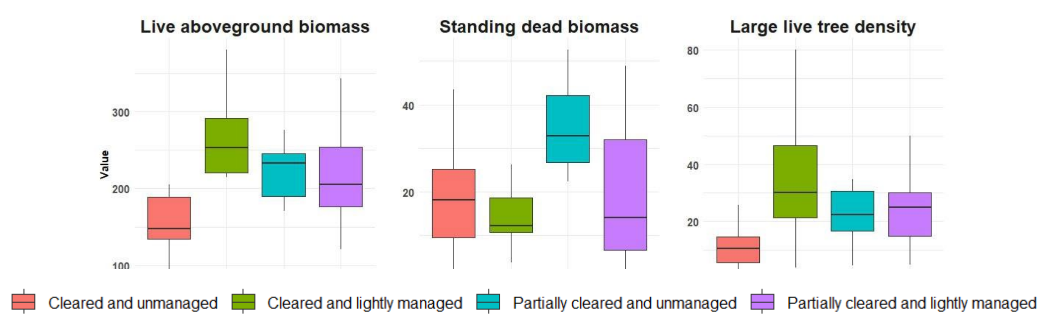


Figure 23 Differences in mature forest structure across forest history groups.

Forest adaptation impacts on micro-climates in lowland spruce-fir ecosystems

Anthony D'Amato, University of Vermont; E. Carol Adair, University of Vermont; Alexandra Contosta, University of New Hampshire; Sarah Nelson, Appalachian Mountain Club; **Grace Smith**, University of Vermont

Abstract

Forests across the northeastern US are recovering from land-clearing for timber and agriculture in the 19th and early 20th century. As a result, many northeastern forests are now mature (80 to 150 years old). Traditional models of stand development predict that these mature forests contain a narrow range of structural conditions which has implications for many ecosystem functions. However, these models are based on stands that were completely cleared, while many northeastern forests were only partially cleared and retained legacy structure. Recent research has shown that these legacies, as well as disturbances and management after stand initiation, can alter pathways of stand development and the structures that develop. As such, we expect that the varied land-use history in the region and subsequent light management in many locations has led to a larger range of structural conditions than traditionally predicted. But no research has yet quantified this on a regional scale.

To better understand forest structure region-wide, we collected data on 63 northern hardwood-conifer stands from New York to Maine. All sites were mature with known management and disturbance histories. We analyzed these data with classification and regression techniques to: 1) better quantify the regional range of structural conditions and 2) assess whether different stand initiating disturbances (cleared or partial logging) and differences in subsequent management explain variability in mature forest structure.

Forests exhibited a broader range of structural conditions than predicted by stand development models. In some cases, structural metrics were within ranges typical for old-growth forests. Random forest classification suggested that the most important differences between stands with different land-use histories were aboveground live biomass and the density of large live trees. Differences in these metrics are important for forest complexity and ecosystem function, especially wildlife habitat and carbon storage. Sites that were completely cleared and unmanaged tended to have less old forest structure, with especially low aboveground biomass and the large tree density ($p < 0.05$). These results suggests that stands that initiate from complete clearing and are never managed may be slower to regain critical structural features than stands with alternative development pathways, such as those that were partially logged and retained legacy structure. Stand development pathways in the northeastern US may be more varied than previously understood, with some forests recovering complex, old forest structures more quickly than expected, in part due to land-use history and how that interacts with subsequent management.

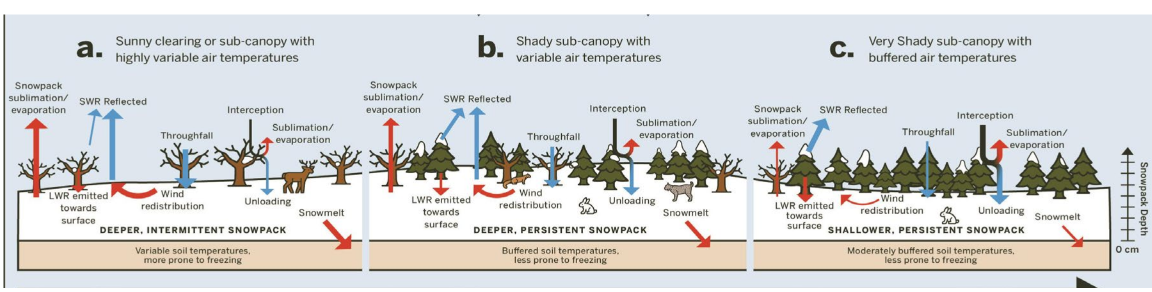


Figure 24 Differences in local micro-climate under varying forest management histories.

Town Forest Census: Carbon, COVID, and capacity building

Cecilia Danks, University of Vermont

Abstract

NSRC researchers with deep knowledge of town forests will provide a complete inventory of community forests in Vermont, a census of Vermont town forests that can be repeated in the future, an updated database with public interface, and an interactive, publicly available map (Figure 25).

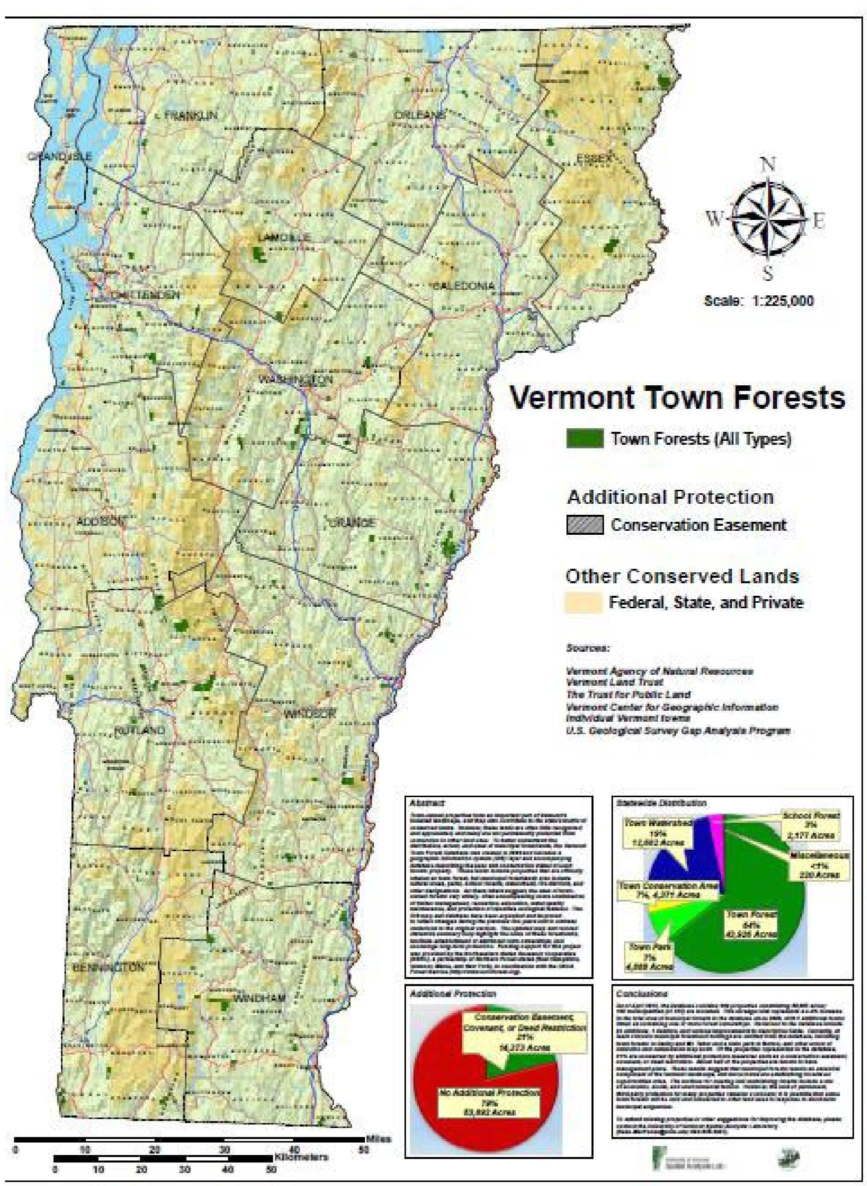


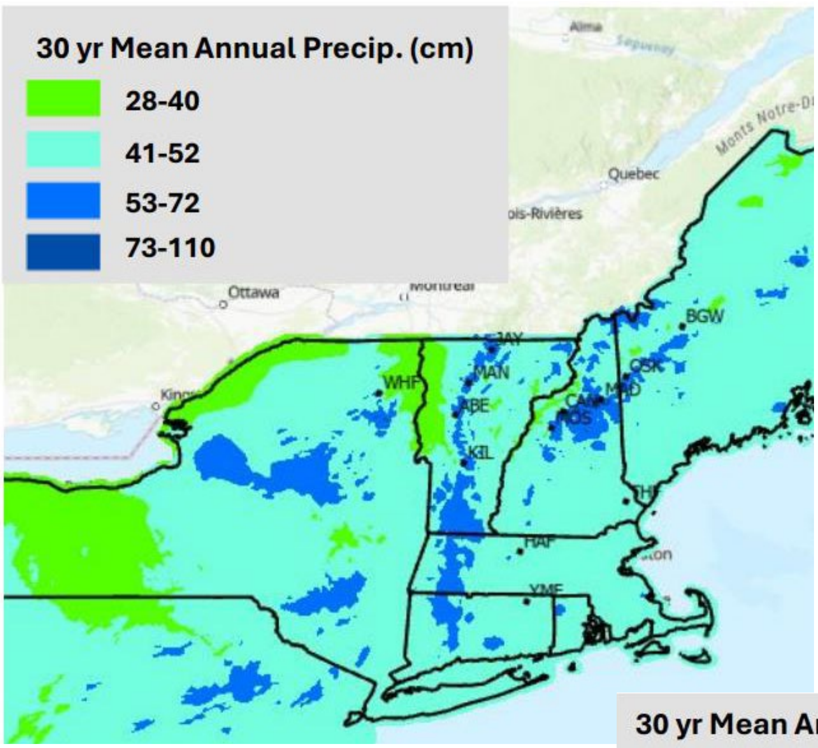
Figure 25 2015 map of the 347 town owned forests in Vermont, consisting of ~68,000 acres.

Using a functional trait approach to inform assisted migration for climate adaptation in the Northern Forest Region

Emily Anders, University of New Hampshire

Abstract

Using a functional trait approach to inform assisted migration for climate adaptation in the Northern Forest Region and Assisted migration: A phenotypic evaluation of species, ecotypes, and drought responses (Figure 26).



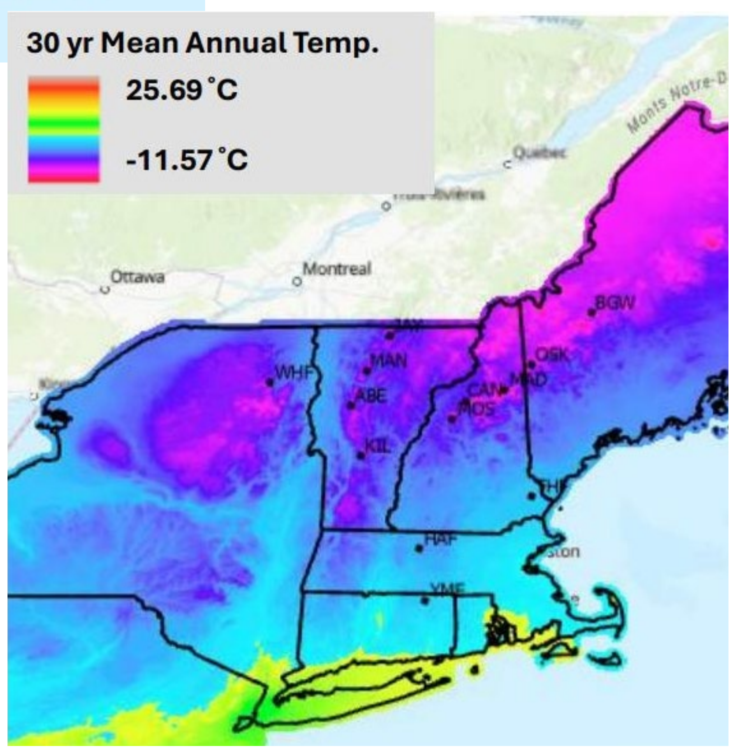


Figure 26 Climate gradients, precipitation (top image) and temperature (bottom image) across sites to inform assisted migration plantings that incorporate functional traits in seed selection.

Assisted migration: a phenotypic evaluation of species, ecotypes, and drought responses

Sam Zuckerman, University of New Hampshire

Abstract

Using a functional trait approach to inform assisted migration for climate adaptation in the Northern Forest Region and Assisted migration: A phenotypic evaluation of species, ecotypes, and drought responses (Figure 27).

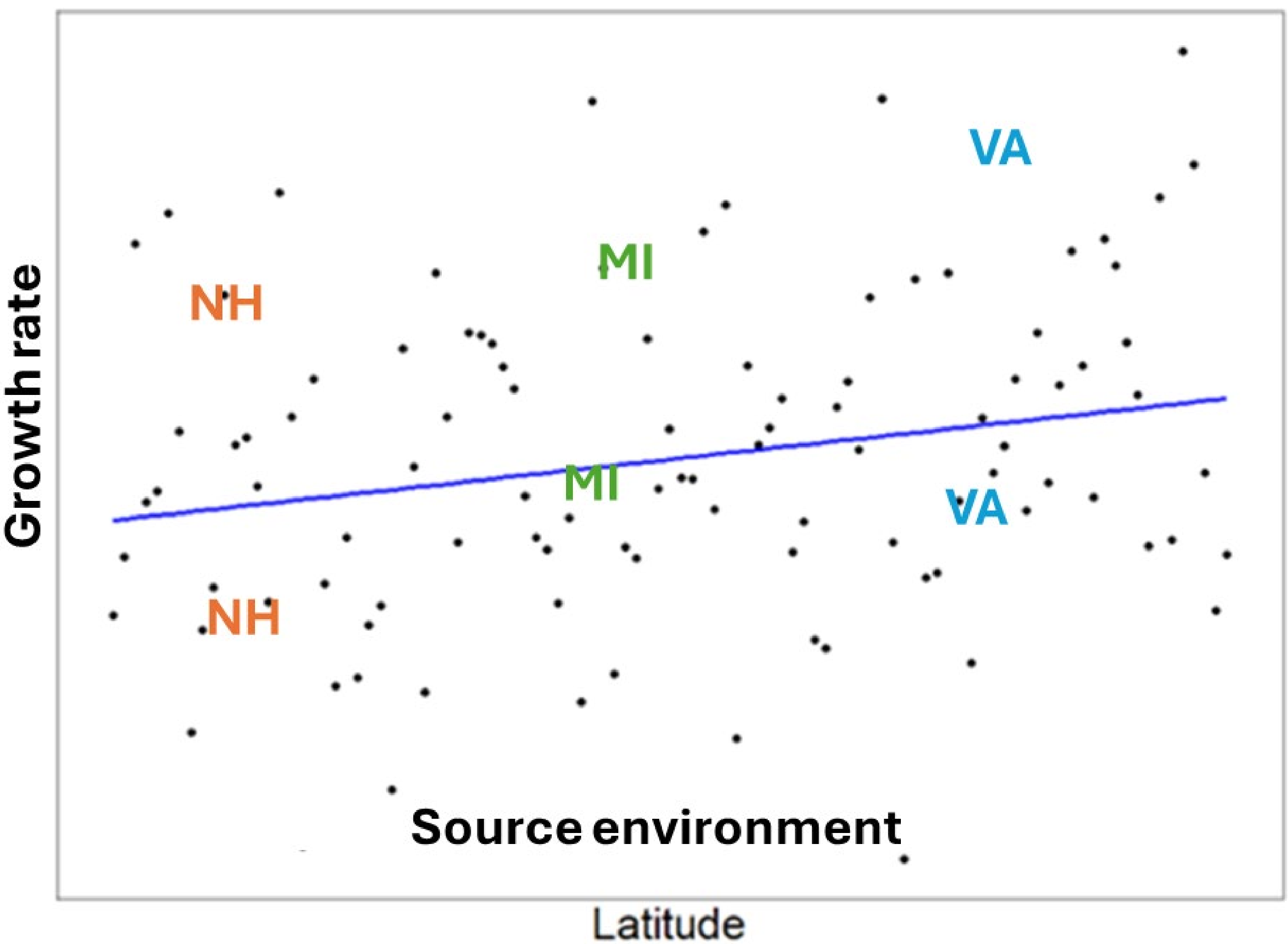


Figure 27 Variability in ecotype performance may contribute to uncertainty in provenance selection

Integrating genetic and ecological data using a new circuit theory approach to measure and map wildlife connectivity across the Northeast

Caitlin Drasher, University of Vermont

Abstract

Comprehensive depiction of wildlife connectivity across the region that can be used to support management decision-making at multiple spatial scales.

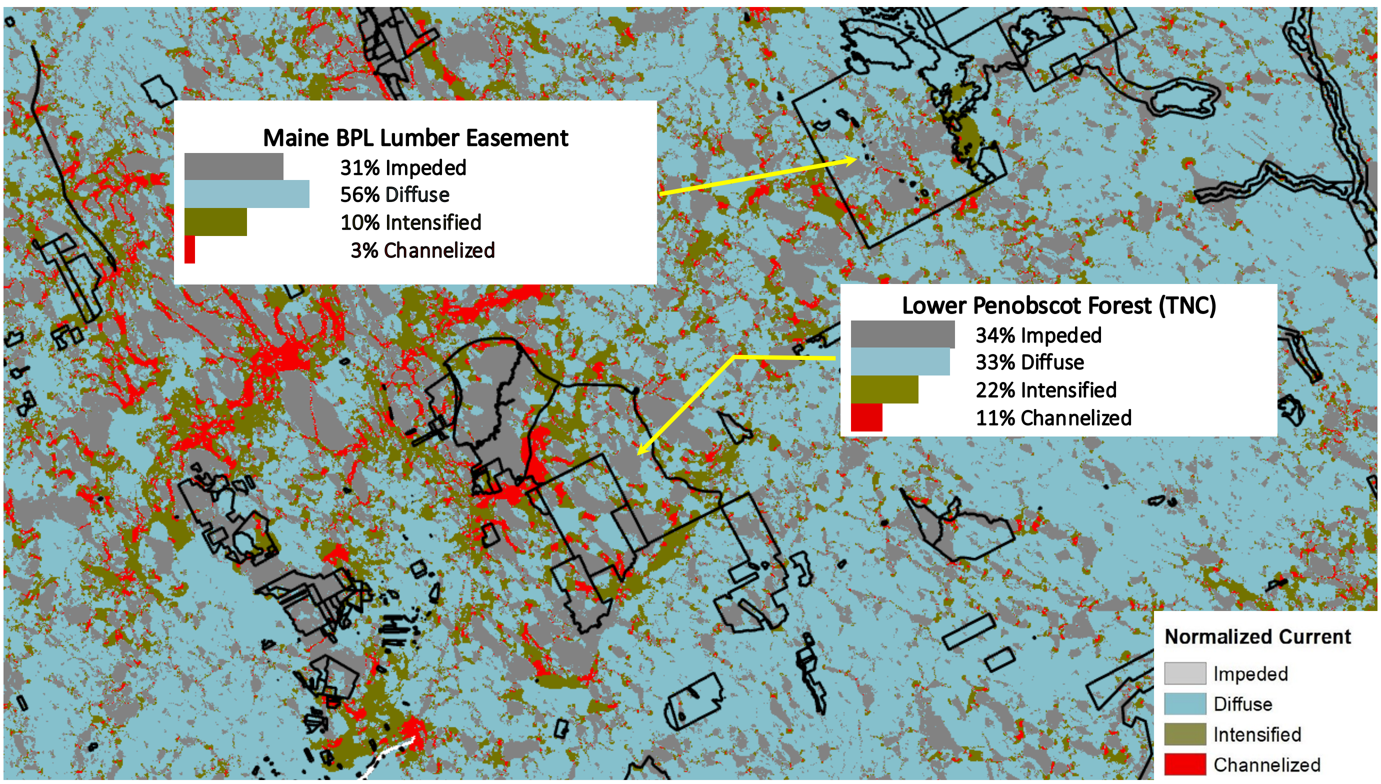


Figure 28 Classifications of current density: compare current to a 'null' model of flow potential (in 'perfect' landscape'. Channelized indicates much greater current than expected; Intensified is a greater current than expected; Diffuse is as much .

Quantifying changes in forest condition, connectivity and resilience in the Northeast using geospatial and remotely sensed data in the Northeast using geospatial and remotely sensed data

Melissa Clark

Abstract

Tool will allow users to quantify the condition of the forest at any location and run scenarios to estimate the impact of various management practices or types of land conversion implemented at specific places.

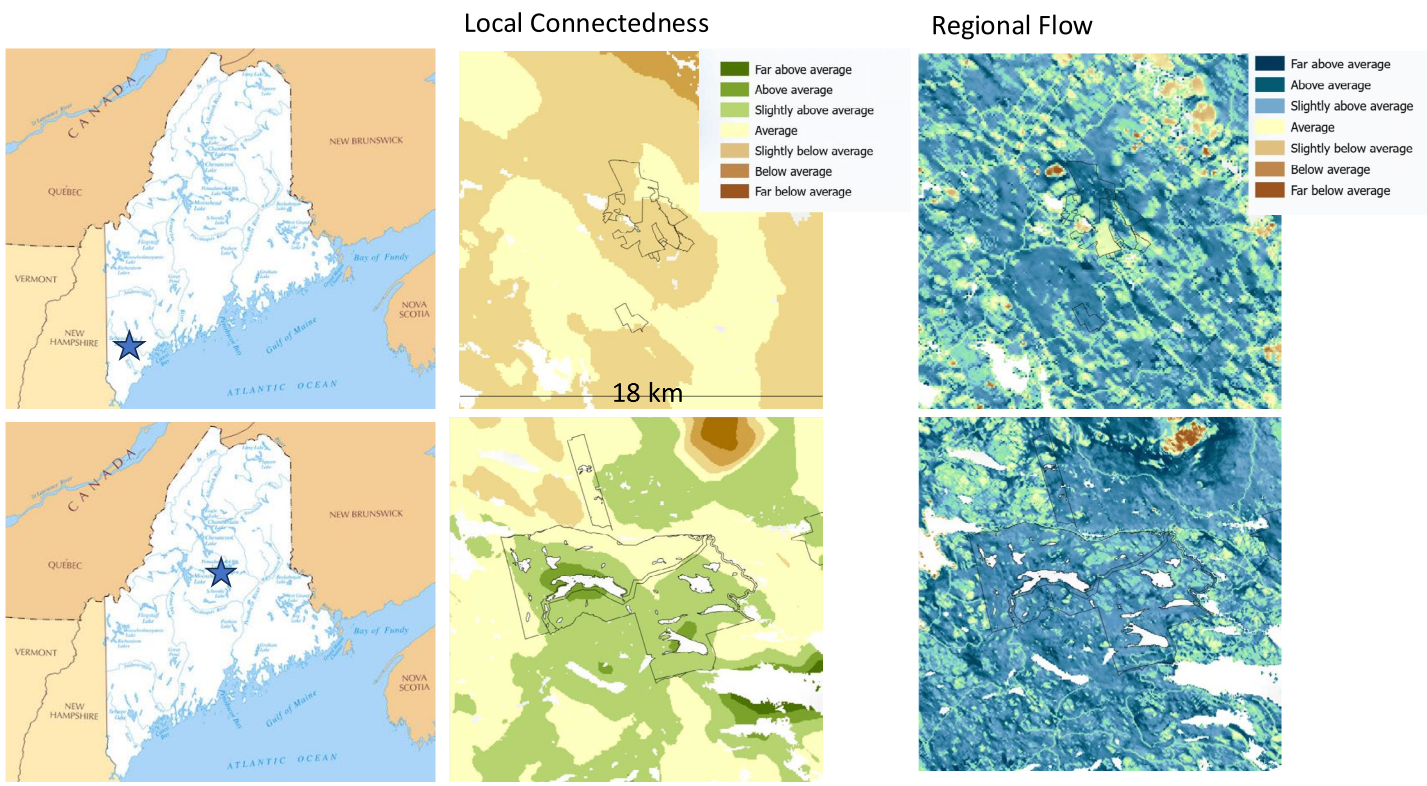


Figure 29 Land connectedness and regional flow at two different locations.

NEBI (Water): Connecting N'dakinna (Land), Bilowagizegad (Climate), and Alnobak (People)

Deni Murray and Kristin Green, University of New Hampshire

Abstract

Project goals: To engage university students in indigenous knowledge and concepts and applicability to watershed and ecosystem science and conservation.

Deni Murray (UNH PhD candidate): Deni led a paper entitled "The environmental responsibility framework: a toolbox for recognizing and evaluating ecologically conscious research" (Murray et al. 2023 Earth's Future. doi: 10.1029/2022EF002964) that describes a framework for researchers to apply to their methods to reduce the environmental impact of research protocols. It is inspired by IRB and IUCAC frameworks which are designed to protect human and animal-based research subjects. The environmental responsibility framework (also know as ER5F) is firmly grounded in the indigenous concept of reciprocity (Figure 30).

Kristin Green (UNH PhD candidate): Kristin's research examines the intersection of indigenous and federal land management practices and perspectives with the objective of identify and defining meaningful collaboration with Tribes in National Forest Planning Processes. Kristin's work leverages principles of cartography and the concept "two-eyed seeing" as a framework to identify meaningful collaboration. Her work was highlighted in AGU's Eos publication: https://eos.org/articles/maps-strengthen-collaboration-between-tribes-and-federal-agencies

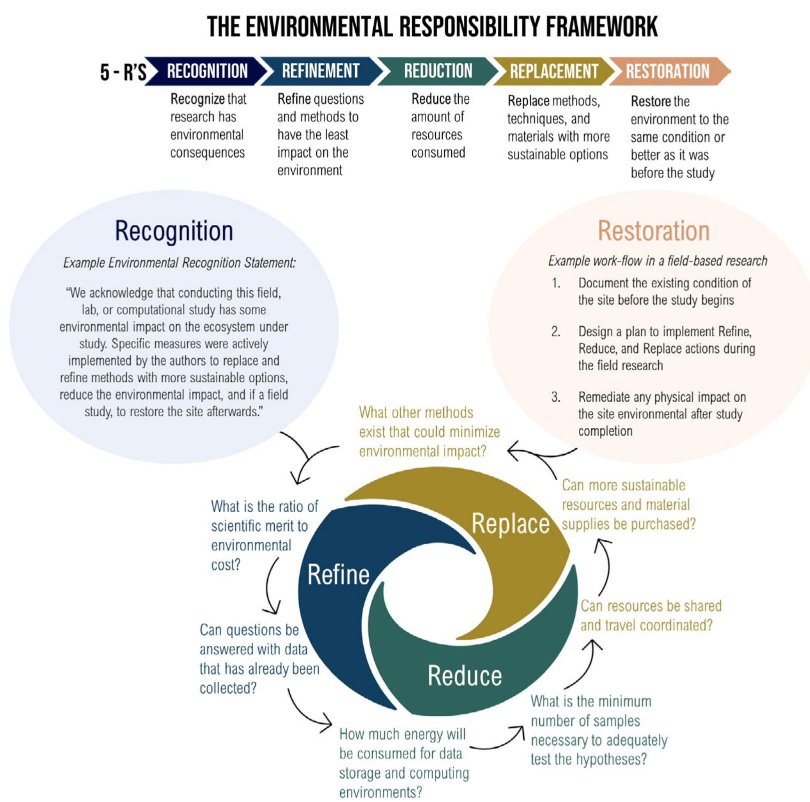


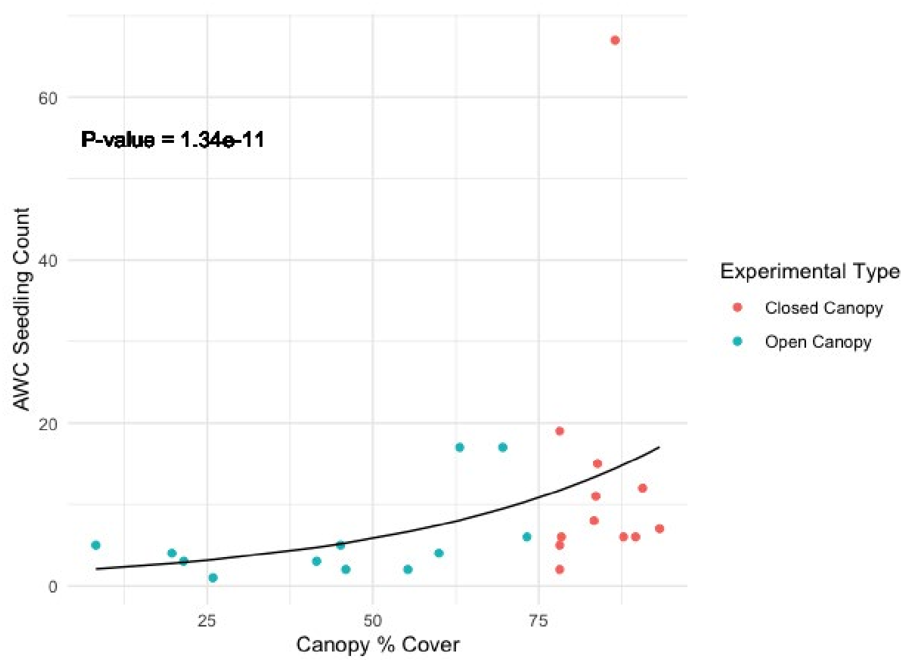
Figure 30 The Environmental Responsibility Framework.

Supporting Abenaki Stewardship of the Ecologically Rare and Culturally Important Atlantic White Cedar Swamp Ecosystem

Gigi Lish, Reece Ciampitti

Abstract

Project goals: Partnership among the Nulhegan Band of the Coosuk Abenaki Nation, University of New Hampshire, Bradford Conservation Commission, Ausbon Sargent Land Preservation Trust, a local landowner, and a local forester to assess Atlantic White Cedar natural regeneration and stand dynamics and establish long-term monitoring plots integrated Indigenous-Western research methods to assess ecosystem health (Figure 31).



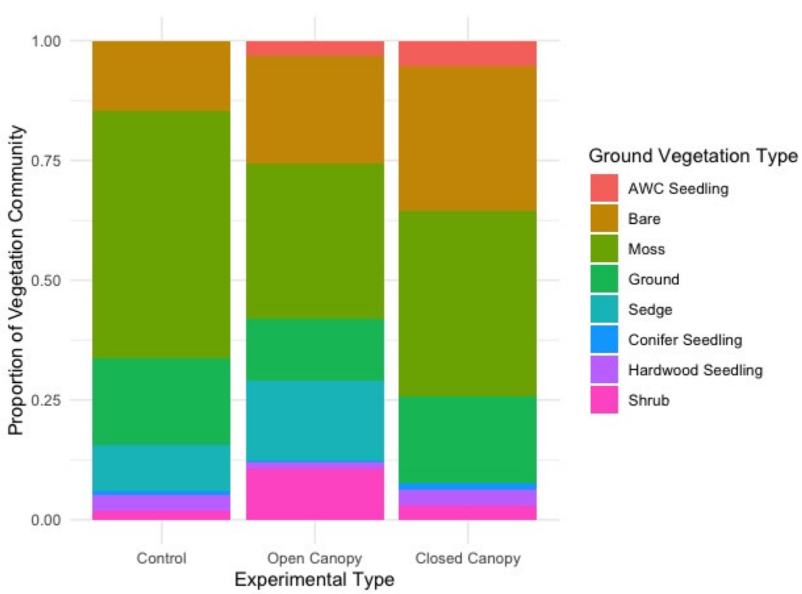


Figure 31 Preliminary results of Atlantic white cedar abundance (top) and vegetation diversity (bottom) under different stand types.

Incorporating lingering ash detection into ash/EAB management

Workshop

Jonathan Rosenthal, Ecological Research Institute

Using material from lingering ash (i.e., trees that meet criteria indicating they likely have some level of heritable resistance) for EAB resistance breeding provides great hope for ash conservation (Figure 32). In this workshop, we will explore how lingering ash detection can be incorporated into the ash/EAB management toolkit and harmonized with other tools such as silviculture, seed collection, biocontrol and insecticide treatment. The presenters developed and lead the Monitoring and Managing Ash (MaMA) program, which relies upon extensive collaboration with land managers, including National Forests, state natural resource agencies, land trusts and other conservation NGOs, and private landowners throughout the region.

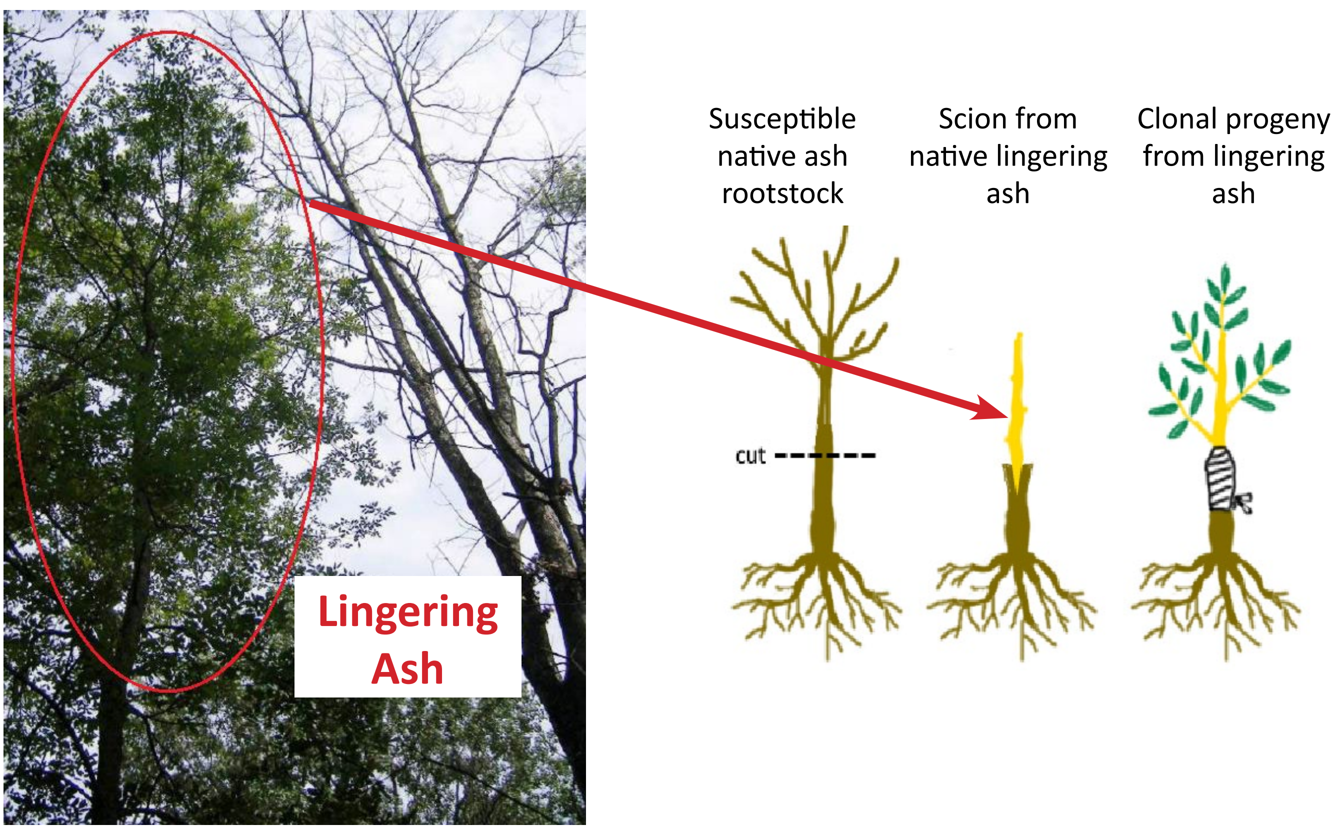


Figure 32 A scion from a lingering ash tree is grafted onto a susceptible native ash rootstock, producing clonal propagation. The progeny from the clone have shown high resistance to EAB.

Informing the development of forest climate change indicator-based tools

Workshop and Discussion

Alyssa Soucy, ORISE Fellow, Northeast Climate Hub

Abstract

Forest climate indicators characterize changes in environmental conditions providing valuable information to increase capacity for adaptation within forests. However, indicators, and more broadly, science and tools developed to aid in decision-making, are not always aligned with user needs. An indicator development process that incorporates user needs throughout can ensure the tools are relevant, applicable, and actionable (Figure 33). The Northeast Climate Hub, Midwest Climate Hub, and Northeast Regional Climate Center are currently developing indicator-based online forestry tools to aid in decision-making. After conducting a series of listening sessions this past summer to identify broad data needs, the research team is now seeking feedback on various indicator-based tools. Specifically, we are exploring the development of tools to address forest health (e.g., pest and pathogens) and extreme weather and climate impacts (e.g., ice storms and extreme precipitation). The working session will provide an opportunity for attendees to (1) learn more about identified needs, (2) discuss specific indicators to address these concerns, and (3) provide feedback for the design of an online tool. The ultimate goal of the working session is to inform tool development such that the product can guide on-the-ground forest management. The audience for this working session includes forest managers, planners, or ecologists who are involved with making decisions on working lands.

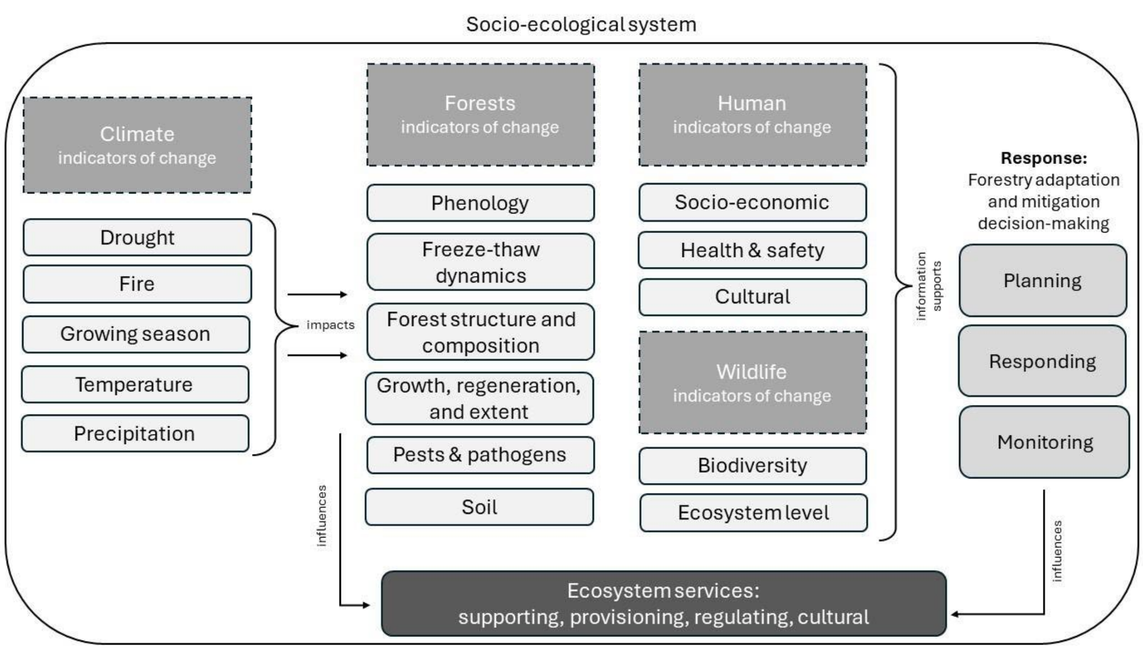


Figure 33 Schematic of how an indicator tool can incorporate different impacts to understand how changes to the system influence other factors in the system.

Understanding climate projections and extreme precipitation events in the context of northeastern forests

Presentations and discussion

Presenters: Jonathan Winter, Dartmouth College; Mattison Brady, Northern Institute of Applied Climate Science; Samantha Myers, Northern Institute of Applied Climate Science; Lesley-Ann Dupigny-Giroux, Vermont State Climatologist and UVM Distinguished Professor; Ali Kosiba, UVM Extension

Abstract

This session will explore up-to-date climate projections for our region, including a discussion of the recent extreme precipitation events and how those fit into project climate regimes and may affect forest health. This session will be structured differently from other concurrent sessions, with a combination of discussion and shorter presentations providing overviews of climate projections and a systems view of climate change, shifting precipitation regimes, and impacts on forests. Session objectives include (1) developing a broader perspective about the interacting factors around climate, precipitation, and site characteristics that contribute to impacts on forests, with examples of what people have been seeing around the region; and (2) identifying information, research, and analysis needs related to the impacts of extreme precipitation events on forests that FEMC and cooperators may be able to pursue.

Jonathan Winter shared information about extreme precipitation events across the Northeast, how extreme precipitation has changed in recent years (Figure 34), and associations between extreme precipitation and damaging floods.

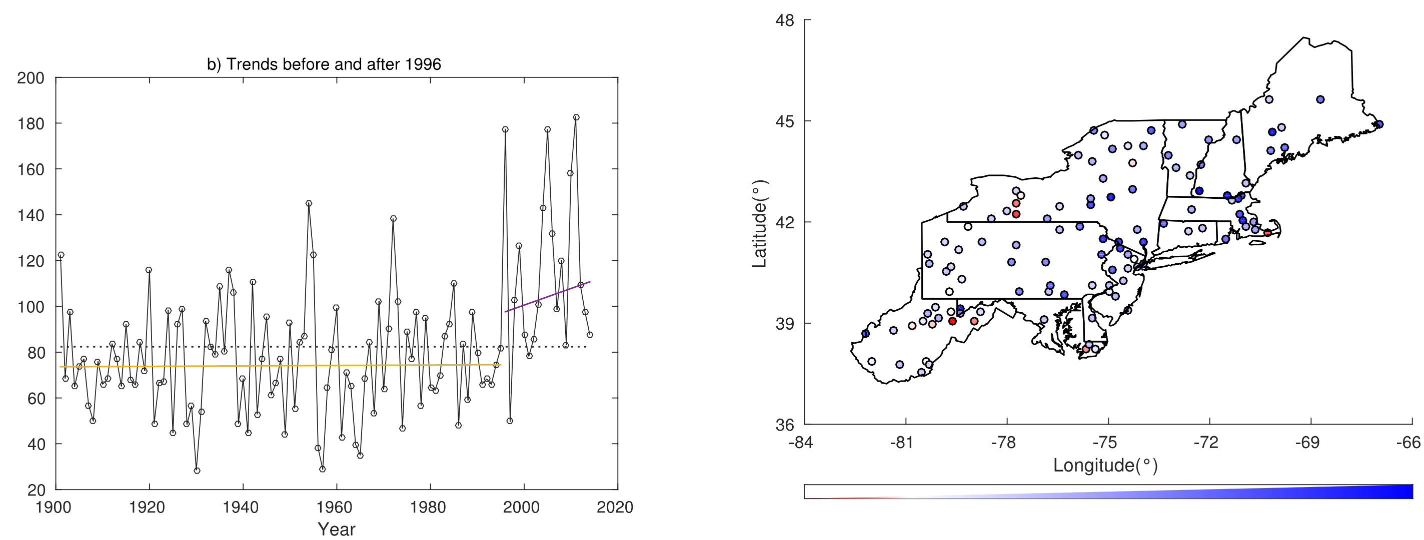


Figure 34 Recent increases in annual extreme precipitation in the Northeast are best characterized as an abrupt shift by 53% after 1996. Stations with increases are distributed throughout the Northeast.

Lesley-Ann Dupigny-Giroux spoke about how climate change is impacting Vermont and the Northeast, providing specific examples as well as projections for future changes. Changing weather patterns and weather extremes are projected, as well as advances in biotic disturbances such as pests and disease. These concurrent stressors contribute to forest health decline (Figure 35).

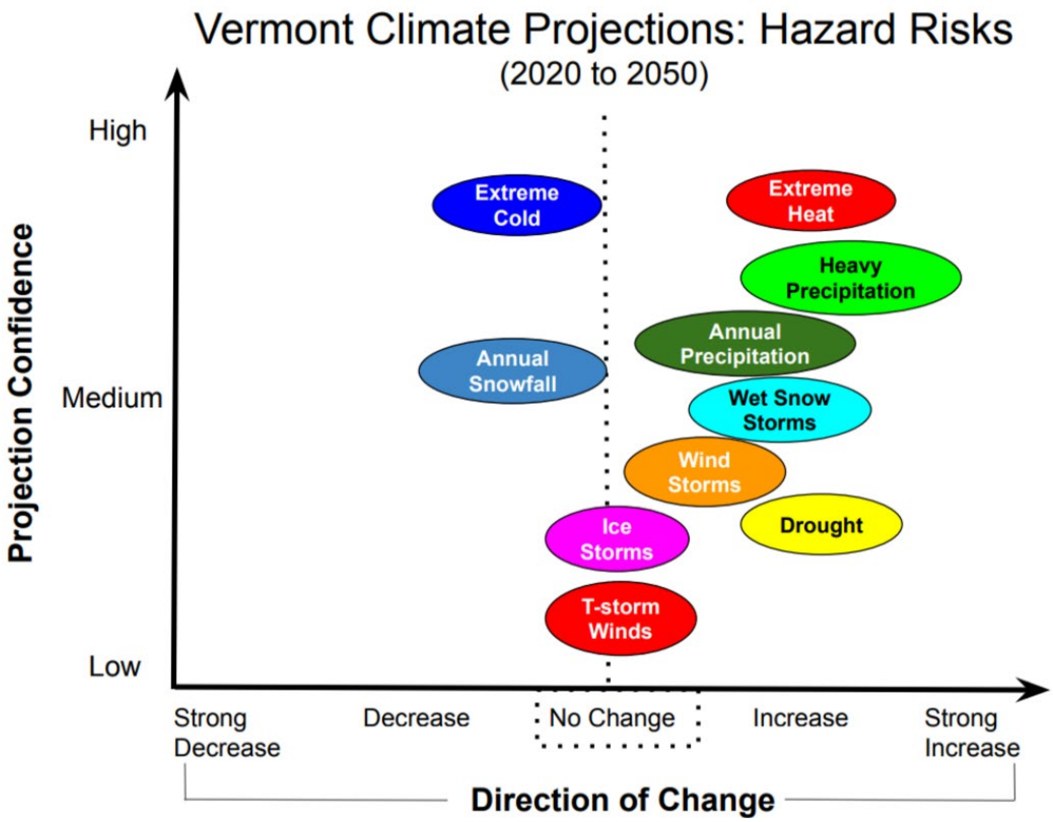


Figure 35 Climate projections in Vermont 2020 - 2050 include increases in heavy precipitation as well as drought, which contribute to concurrent stressors that contribute to forest health decline.

Mattison Brady and Samantha Myers discussed how climate change is contributing to forest vulnerability at both local and regional scales. Local site characteristics such as geophysical, land use history, and vegetation interact with the changes in climate to increase specific risk to various stressors (Figure 36). Regionally, insects and disease are damaging forests and migrating northward, invasive plant ranges are expanding, drought is becoming more frequent, while winters are also becoming warmer. While these stressors are all playing a role in forest vulnerability, diversity of forest conditions across the landscape improves the ability to recover from extreme events.

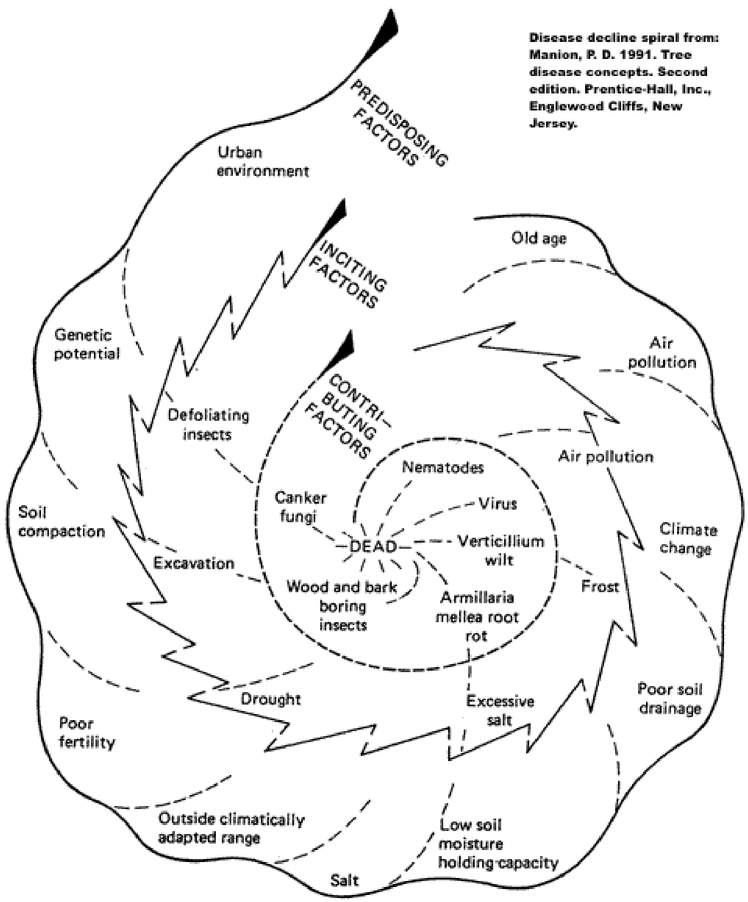


Figure 36 Interactions of climate stress contribute to forest vulnerability, from Manion 1991.

Implementing Vermont Conservation Design

Panel presentation and discussion

Jens Hilke, Vermont Agency of Natural Resources; Gannon Osborn, Vermont Agency of Natural Resources; Bob Zaino, Vermont Agency of Natural Resources; Trey Martin, Vermont Housing and Conservation Board

Session summary

The Implementing Vermont Conservation Design session consisted of presentations given by representatives from the Vermont Fish and Wildlife Department: Jens Hilke, conservation planner; Gannon Osborn, Land Conservation Program Manager; Bob Zaino, Ecologist, as well as Trey Martin from the Vermont Housing and Conservation Board. The session was moderated by Helen Wagenvoord. The purpose of the session was to provide an update on the work being done as part of Vermont Act 59, the Community Resilience and Biodiversity Protection Act, which became law in 2023. The law sets out to formally conserve 30% of Vermont's lands by 2030 and conservation of 50% of the state by 2050.

Jens Hilke provided an outline of how Vermont is approaching the law through the use of Vermont conservation design, which is a science-based vision to sustain the state's valued natural areas, forests, water, wildlife, and plants for future generations. The Biofinder website provides an interactive mapping platform to access data used to identify ecologically important lands when setting conservation priorities (Figure 37). Three scales are considered when employing conservation design: the landscape scale, which includes interior forests and connecting blocks; the natural community scale, which includes biological hotspots; and the species scale, which focuses on rare threatened and endangered species.

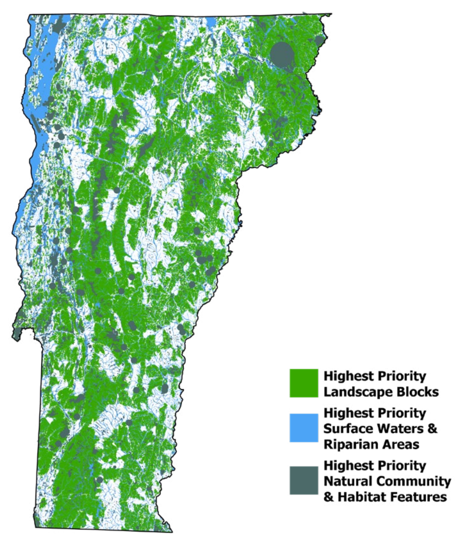


Figure 37 Prioritization of different ecologically most-important lands and waters in Vermont.

Conservation design requires a unified vision across agencies, towns, and organizations in order to be effective and efficient in achieving the conservation goals. Many of the actions are conducted on a local scale. However, the strategic coordination of all of the smaller actions across the state improves the chance that the unified vision will be met across the state.

Gannon Osborn provided background on definitions on what qualifies as conservation and different conservation tools. Several conservation categories qualify under Act 59, including ecological reserve areas, biodiversity conservation areas, natural resource management areas (forest and agriculture). Once priority lands are identified for conservation, the land can be conserved through purchase by a land trust or the use of easements on the land. By creating a priority list of types of lands to conserve, money can more effectively be spent on conserving the ecologically important areas.

An inventory of lands in conservation was conducted to establish the baseline for Vermont in order to determine how to reach the 30% and 50% goals. This inventory is being used to prioritize lands for conservation that contribute to interior forest, connecting forest, and geological diversity blocks. It was highlighted that permanent land conservation is not the only way in which land can be conserved. Using Vermont Conservation Design provides a strategic approach in selecting lands for permanent conservation or determining when another conservation tool is more appropriate. Bob Zaino shared details about these types of forest blocks and the breakdown of conservation status in different regions across the state. Some regions of the state are highly conserved, such as the Green Mountains regions, but other parts of the state have less land in conservation. In considering all of the regions in the state, higher priorities may be placed in regions that do not have as much land in conservation. Overall, Vermont has done a good job of conserving interior forest blocks. However, there are important connecting blocks that need to be prioritized for conservation in order to have the greatest impact on biodiversity (Figure 38).

Tying all of these details together, Trey Martin highlighted the work that has been done to date and the next phase of achieving the goals of Act 59. Using Vermont Conservation Design as a guide, a strategy will be developed to conserve 30% of land in Vermont by 2030 and 50% by 2050. The State of Vermont and Vermont Housing and Conservation Board will continue to work with landowners and municipalities to identify priority lands and determine strategic pathways for conservation. Of importance was the recognition that engagement with communities and incorporating opportunities for continued use and access to conserved lands by different user groups.

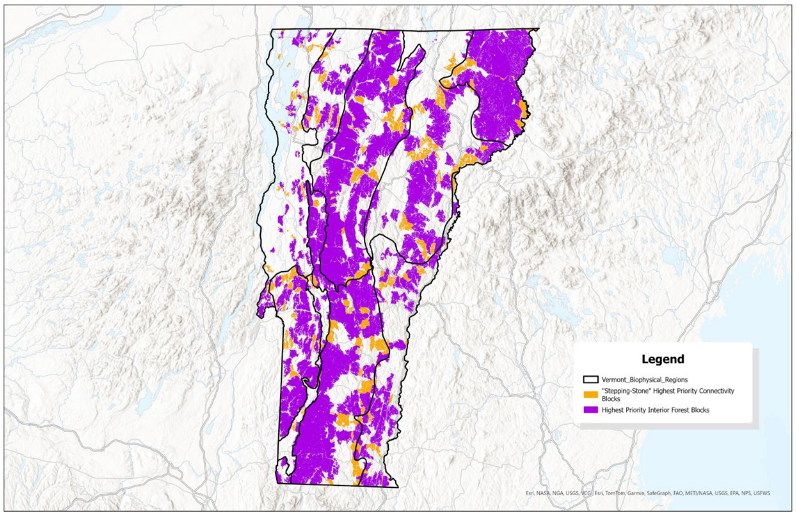


Figure 38 There are high priority connectivity blocks (shown in orange) that are not also high priority interior blocks that are important in linking blocks together.

This session shared background information about Act 59, including an overview of the work that has been done to date. Additionally, presenters highlighted how use of conservation design provides a strategy for identifying priority lands. Implementing a prioritization plan allows for the best use of resources toward conserving the matrix of lands that will contribute the most to biodiversity (Figure 39).

Figure 39 Many land use categories qualify for conservation easements, representing diverse conservation values.

Poster Session

A poster session was held in-person during the event. Posters are included here that were made available.

1. Management and Conservation of Maine's Coastal Spruce Forests for Resilience to Rapid Warming

Colby Bosley-Smith, University of Maine, School of Forest Resources; Rose Gellman, University of Maine, School of Forest Resources; Megan Grega, University of Maine, School of Forest Resources; Emily MacDonald, University of Maine, School of Forest Resources; Gregory McHale, University of Maine, School of Forest Resources; Camilla Seirup, Northeast Temperate Network; Jay Wason, University of Maine, School of Forest Resources; Shawn Fraver, University of Maine, School of Forest Resources; Daniel Hayes, University of Maine, School of Forest Resources; Nicole Rogers, Maine Forest Service; Peter Nelson, Laboratory of Ecological Spectroscopy

2. A simple prototype for assessing plant cold hardiness with differential thermal analysis.

John R Butnor USDA Forest Service, Northern Research Station; Cornelia Wilson, USDA Forest Service; Melike Bakier, Department of Agricultural biotechnology, Faculty of Agriculture, Erciyes University, Kayseri, Turkiye; Anthony D'Amato, University of Vermont, Rubenstein School of Environment and Natural Resources; Charles Flower, USDA Forest Service; Chris Hansen, University of Vermont, Rubenstein School of Environment and Natural Resources; Stephen R Keller, University of Vermont, Department of Plant Biology; Kathleen S Knight, USDA Forest Service; Paula F Murakami, USDA Forest Service, Northern Research Station

3. Northeastern Permanent Forest Land Clearing

Soren Donisvitch, Forest Ecosystem Monitoring Cooperative; Alison Adams, Forest Ecosystem Monitoring Cooperative; Nicholas Aflitto, University of Vermont, Rubenstein School of Environment and Natural Resources; Jennifer Pontius, Forest Ecosystem Monitoring Cooperative, University of Vermont Rubenstein School of Environment and Natural Resources; Matt Rios, Forest Ecosystem Monitoring Cooperative

4. Heat and drought impacts on tree seedling growth and survival

Emily MacDonald, School of Forest Resources, University of Maine; Paige Cormier, School of Forest Resources, University of Maine; Melissa Cullina, Plant Science and Collections, Coastal Maine Botanical Gardens; Bryan Peterson, School of Food and Agriculture, University of Maine; Jay Wason, School of Forest Resources, University of Maine

5. A snapshot of FEMC's Regional Forest Health Monitoring Network: Insights from 2024.

Benjamin Porter, Alison Adams, Soren Donisvitch, Matthew Rios, Elissa Schuett, Nancy Voorhis, Alexana Wolf, Matthias Sirch; Forest Ecosystem Monitoring Cooperative

6. Lingering (resilient) ash detection: a tool for ash conservation

Jonathan Rosenthal, Ecological Research Institute; Radka Wildova, Ecological Research Institute

7. Monitoring and Managing Ash (MaMA): a program that enables lingering (resilient) ash detection

Jonathan Rosentha, Ecological Research Institute; Radka Wildova, Ecological Research Institute

8. Sustaining Ash Partners Network (SAP-Ne)

Rachel Swanwick, Forest Stewards Guild, NE Program Manager

9. Comparing performance of low-cost dendrometers to traditional dendrometers in tracking tree growth in a changing climate

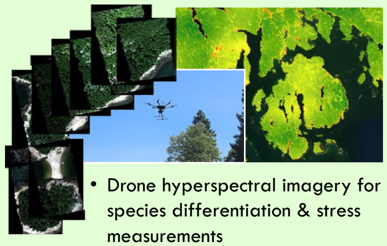
Jordon Tourville, Appalachian Mountain Club; Georgia Murray, Appalachian Mountain Club

Management and Conservation of Maine's Coastal Spruce Forests for Resilience to Rapid Warming

Colby Bosley-Smith[1], Rose Gellman[1], Megan Grega[1], Emily MacDonald[1], Gregory McHale[1], Camilla Seirup[2], Jay Wason[1], Shawn Fraver[1], Daniel Hayes[1], Nicole Rogers[3], Peter Nelson[4]

1. University of Maine School of Forest Resources, 2. Northeast Temperate Network, 3. Maine Forest Service, 4. Laboratory of Ecological Spectroscopy

Where are coastal spruce forests and how 'stressed' are they?



- Drone hyperspectral imagery for species differentiation & stress measurements
- Spaceborne ECOSTRESS sensor for quantifying climate-induced stress

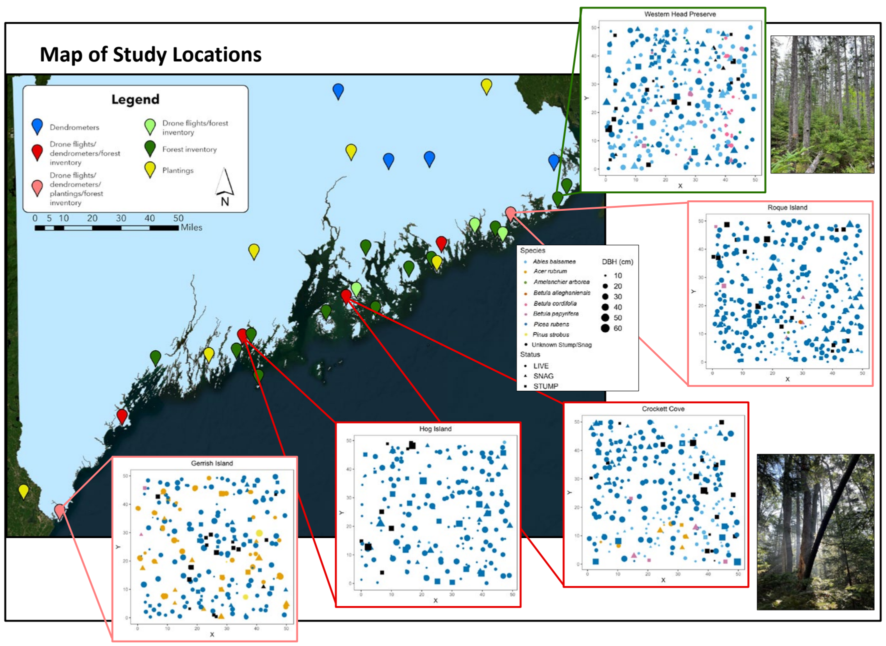
Introduction

The coast of Maine has historically served as a climate refugia for red spruce forests. We hypothesize that rapid warming along the coast make these forests extremely vulnerable to climate change due to low species diversity, limited active management, the species' requirement for cool moist conditions.

How will climate change influence tree regeneration?

- Emergence, growth and survival of 10 species along coastal and inland climate gradients

Map of Study Locations



Can we predict threats to coastal spruce forests?

- Tree-rings to measure annual growth and disturbance history
- 100 automated point dendrometers to measure daily growth and water use
- Microclimate sensors, hemispherical photos, soil nutrient analysis

What management options exist?

Acknowledge Dynamic Equilibrium

- Coastal spruce forests' primary natural disturbance agent remains windthrow
- Manage for age-class and structural diversity across the landscape

Assisted Migration

- If spruce regeneration fails, consider planting predicted "climate winners" to maintain canopy cover

Connect with us!

colby.bosleysmith@maine.edu stand dynamics & tree ring analysis
rose.gellman@maine.edu forest management
megan.grega@maine.edu dendrometer network
emily.macdonald@maine.edu seedling growth and physiology
gregory.mchale@maine.edu hyperspectral imagery

Next Steps

- Link ECOSTRESS to dendrometer-derived tree stress
- Evaluate climate-growth relationships
- Explore connections with other coastal forest ecosystems
- Develop management interventions with coastal land stewards

Acknowledgments

Funding provided by USDA AFRI Grant ME013712945, The University of Maine School of Forest Resources, The Maine Agricultural and Forest Experiment Station, The Forest Ecosystem Monitoring Fund, and Eastern Maine Conservation Initiative.

Special thanks to over 50 coastal cooperators and landowners!

Cold Tolerance Assay Reveals Evidence of Climate Adaptation in American Elm

John R Butnor[1], Cornelia Wilson[2], Melike Bakir[3], Anthony D'Amato[4], Charles Flower[2], Chris Hansen[4], Stephen R Keller[5], Kathleen S Knight[2], Paula F Murakami[1]

[1]USDA Forest Service, Northern Research Station, Burlington VT, [2]USDA Forest Service, Delaware OH, [3]Department of Agricultural Biotechnology, Faculty of Agriculture, Erciyes University, Kayseri, Türkiye, [4]University of Vermont, Rubenstein School of Environment and Natural Resources, Burlington VT, [5]University of Vermont, Department of Plant Biology, College of Agriculture and Life Sciences, Burlington VT

BACKGROUND

American elm (*Ulmus americana* L.) historically occupied the rich, fertile soils of floodplain forests of northeastern and prairie regions of North America. American elm's distribution along waterways has been significantly reduced by Dutch Elm Disease (DED) -- a vascular wilt disease caused by *Ophiostoma ulmi* and *O. novo-ulmi* fungi [1] and vectored by several species of bark beetles. Despite the prevalence of DED, American elm persists throughout its historical range. Rare American elms with resistance to DED have been identified and are being used in breeding programs and horticultural plantings [2].

For elm restoration efforts to be successful, careful attention to climate suitability is critical, especially in cold regions at the northern limit of the species' range. Repeated episodes of winter shoot injury that ultimately impairs production of vegetative and reproductive tissues could limit the success of species restoration in northern New England.

The purpose of this study is to evaluate whether American elm trees are cold-adapted to the climate conditions where they originate, and if that manifests in differences in mid-winter shoot cold tolerance. Understanding this relationship will help inform recommendations for how far north it is possible to move trees without risking tree mortality due to maladaptation to cold temperatures.

VERMONT AND OHIO ELM SAMPLING

VERMONT
DED-resistant trees sampled from the planting in Vermont (University of Vermont Horticulture Research and Educational Center, South Burlington, VT, 44.4287, −73.2046, Figures 1 and 4) were established as part of the National Elm Trial [3] and included clonally propagated commercially available elms designed to test performance in different locations across the country. The geographic origin of these trees is ambiguous, imprecise or **unverified**.

OHIO
DED-resistant trees sampled from a resistance trial planting in Ohio (Westerville, OH, 40.1163, −82.8338, Figures 2 and 3) were established by the U.S. Forest Service, Northern Research Station, American Elm Breeding and Restoration Partnership and provided 11 families of clonally propagated survivor elms from **verified** locations in New England (Figure 3) as well as clonally propagated commercially available elms that serve as resistant controls, but whose source locations are **unverified**.

VERMONT AND OHIO ELM SAMPLING

Figure 1. John Butnor and Chris Hansen collecting elm shoot samples in S. Burlington, VT

Figure 2. Leila Wilson and Mikayla Bailey collecting shoot samples in Westerville, OH.

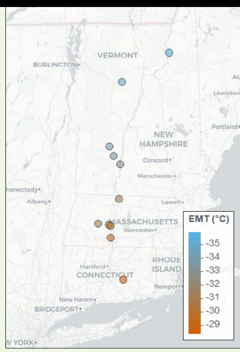


Figure 3. Map of sources for eleven elm genotypes with verifiable locations in New England. The color scale indicates 30-year (1991-2020) extreme minimum temperature (°C) for source location. Ohio source not shown.

Figure 4. UVM Horticulture Center elm, Burlington, VT

COLD TOLERANCE MEASUREMENTS

In January 2023, a total of 11 genotypes from survivor elm trees with verified source locations across a north-south New England gradient as well as a DED-susceptible control (OH) were selected for measures of mid-winter cold tolerance via electrolyte leakage methods (Figure 5) [4]. These genotypes represent a calculated 30-year extreme minimum temperature (EMT) ranging from −35.9° to −27.7° C and a latitudinal range of 40.4° to 44.6° N.

Two additional DED-resistant and commercially available genotypes (of unverified origin), *Valley Forge* and *Princeton,* were collected in both OH and VT [5].

Figure 5. Processing shoot tissue in the laboratory for REL analysis.

COLD TOLERANCE OF NEW ENGLAND SOURCES WITH VERIFIED ORIGINS

The temperature at which 50% of cellular leakage occurred (LT_{50}) was calculated for all genotypes. The mean LT_{50} (+/- s.e.) for each genotype was plotted against source EMT and latitude (Figure 6). Genotypes from colder regions exhibited greater cold tolerance when grown in common garden, indicating genetic variation in susceptibility to mid-winter freezing injury that reflects the gradient in source climate.

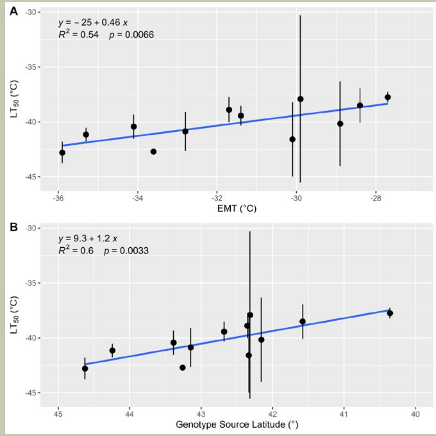


Figure 6. Linear regression of mean LT_{50} values (± s.e.) of 12 American elm genotypes with climate variable 30-year extreme minimum temperature (EMT) of genotype source location (A) and genotype source latitude (B).

COLD TOLERANCE OF COMMERCIALLY AVAILABLE SOURCES WITH UNVERIFIED ORIGINS

Princeton and *Valley Forge,* collected in both VT and OH, were directly compared by genotype and site effects on LT_{50} (Mann-Whitney rank-sum test). There was a significant difference between genotype means, but no difference between site means (Figure 7). During the two months leading up to sampling, winter air temperatures were consistently lower at the VT planting compared to the OH planting except on Dec 23 and 24, 2022 when minimum air temperature in OH was 32.3°C lower than temperatures recorded in VT. Despite air temperature differences, mid-winter cold tolerance measured by REL was not significantly different between sites.

COLD TOLERANCE OF COMMERCIALLY AVAILABLE SOURCES WITH UNVERIFIED ORIGINS

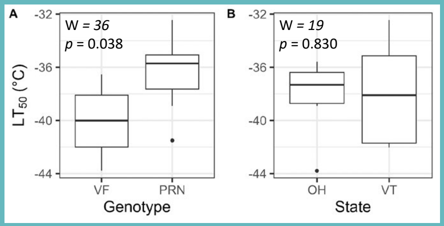


Figure 7. Boxplots of LT_{50} results for genotypes *Valley Forge* (VF) and *Princeton* (PRN)(A) planted in Ohio and Vermont (B). Boxplots display median and interquartile range, with whiskers showing the minimum and maximum of the range, excluding outliers which are indicated with a black dot.

SUMMARY

- American elm genotypes in this study exhibit clonal trait variation consistent with local adaptation to mid-winter conditions as assessed by laboratory cold tolerance methods.
- Genotypes that evolved in colder climates have greater cold tolerance in winter.
- Mid-winter cold tolerance of all New England genotypes was sufficient for survival at the coldest source location in northern Vermont. New research will examine the tolerance of flower and vegetative buds to freeze injury as they de-acclimate in warming spring temperatures.
- Findings suggest that planting American elms too far north from their origin location may result in lower fitness due to maladaptation to current local temperatures.

REFERENCES

1. Brasier, C.M. Ophiostoma novo-ulmi sp. nov., causative agent of current Dutch elm disease pandemics. *Mycopathologia* **1991**, *115*, 151–161. https://doi.org/10.1007/BF00462219.
2. Townsend, A.; Bentz, S.; Douglass, L. Evaluation of 19 American elm clones for tolerance to Dutch elm disease. *J. Econ. Entom.* **2005**, *23*, 21–24.
3. Griffin, J.J.; Jacobi,W.R.; McPherson, E.G.; Sadof, C.S.; McKenna, J.R.; Gleason, M.L.; Gauthier, N.W.; Potter, D.A.; Smitley, D.R.; Adams, G.C. Ten-year performance of the United States national elm trial. *Arboric. Urban For.* **2017**, 43, 107–120.
4. Butnor, J.R.; Wilson, C.P.; Bakır, M.; D'Amato, A.W.; Flower, C.E.; Hansen, C.F.; Keller, S.R.; Knight, K.S.; Murakami, P.F. Cold Tolerance Assay Reveals Evidence of Climate Adaptation Among American Elm (*Ulmus americana* L.) Genotypes. *Forests* **2024**, 15, 1843. https://doi.org/10.3390/f15111843
5. Haugen, L.M.; Bentz, S.E. American elm clones of importance in Dutch elm disease tolerance studies. In *Proceedings of the American Elm Restoration Workshop 2016*; Pinchot, Cornelia C.; Knight, Kathleen S.; Haugen, Linda M.; Flower, Charles E.; Slavicek, Eds; 25-27 October 2016; Lewis Center, OH. Gen. Tech. Rep. NRS-P-174; U.S. Department of Agriculture, Forest Service, Northern Research Station: Newtown Square, PA, USA, **2017**; pp. 109-118.

Northeastern Permanent Forest Land Clearing

Overview

Forests in the Northeastern United States serve as critical reservoirs of biodiversity, carbon storage, and ecosystem services, playing a central role in regional climate resilience and sustainable resource management (Foster & Aber, 2004). Despite their importance, monitoring forest health, detecting deforestation, and differentiating between temporary management disturbances (e.g., shelterwood harvesting, planned rotations) and permanent forest conversion remain ongoing challenges (Hansen et al., 2013; Tropek et al., 2014; Olofsson et al., 2021).

Many existing global and regional land cover products conflate cyclic forest management events with permanent deforestation, misrepresenting forest dynamics and potentially informing misguided policy decisions (Ahmed et al., 2021; Cohen et al., 2022). In the Northeast, where active forest management and natural regeneration after harvest are commonplace, such misclassifications obscure true forest conditions and trends. For instance, clearcutting followed by rapid regrowth is a managed cycle, not permanent forest loss, yet conventional methods often treat these temporary reductions in canopy cover as deforestation (Kennedy et al., 2010; Griffiths et al., 2021). This project addresses these limitations by leveraging higher-resolution (10 m) satellite imagery and time-series analysis to:

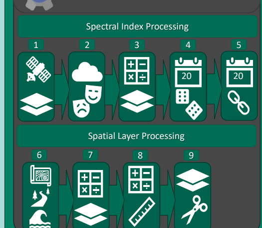
- Generate updated land cover maps focused on Northeastern U.S. forests, reflecting fine-scale spatial heterogeneity.
- Distinguish between short-term, management-related forest disturbances and long-term, permanent deforestation that leads to temporally stable non-forest land covers.
- Incorporate multi-year satellite observations—such as those from the Landsat and Sentinel programs—to track forest regeneration, ensuring that cyclical harvest-and-recovery processes are not mistaken for irrevocable land cover changes (Hermosilla et al., 2022; White et al., 2021).
- Provide a clearer picture of drivers behind permanent forest loss, including urbanization, agricultural expansion, and solar energy installations etc, by identifying true land cover transformations rather than cyclical vegetation dynamics (Hansen et al., 2022; Fagan et al., 2013).

Model Overview

- Data Acquisition & Preprocessing
- Training Data Preparation
- Model Development & Classification
- Time-Series Analysis for Change Detection
- Quantification & Interpretation of Drivers

Data Processing

Processing Visual



Processing Description

1. Filtering and Data Selection: Identify and process regions and times of interest.
2. Cloud Masking: Remove cloud-contaminated pixels.
3. Index Calculation: Generate multiple spectral indices.
4. Temporal Smoothing and Imputation: Apply rolling means to reduce gaps and noise.
5. Annual Composite: Aggregate data to yearly median values.
6. Topographic and Vector Layers: Get the DEM and other vector layers for processing
7. Rasterize: Build and calculate raster layers
8. Compute secondary layers: For layers of distance to features, calculate Euclidean distance raster
9. Clip raster: Clip to northeast

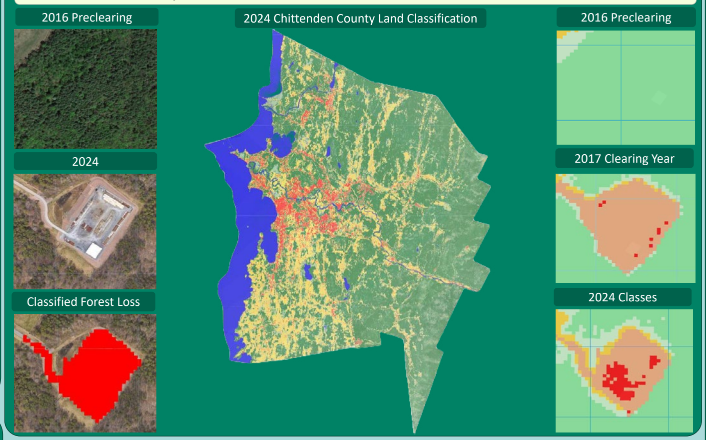
Simplified NLCD Classes

- Forest: Dominated by tall, mature trees (deciduous, evergreen, or mixed). Represents continuous woody canopies.
- Shrub: Characterized by shorter woody vegetation (shrubs, scrub).Includes shrub-dominated wetlands.
- Grass/Crops: Herbaceous vegetation (natural grasslands, pasture, hay, cultivated fields). Incorporates herbaceous-dominated wetlands.
- Urban: Built environments, from scattered housing to dense city centers. Encompasses all development intensities in a single class.
- Water: Open water bodies and water-dominated wetlands. Lakes, ponds, rivers, and flooded areas.
- Bare: Exposed soil, rock, sand, or minimal vegetation cover. Reflects areas with sparse or no plant growth.

Training Data and Classification Methodology

To ensure a high quality, reliable classification, we collected over 5,000 training points relatively evenly distributed across key land cover classes. Using Google Earth Engine (GEE), our team visually interpreted satellite imagery for each year (2016–2024), verifying class assignments following a standardized protocol. We included both stable sites (no land cover transitions) and areas identified as having changed classes, informed by Hansen et al. (2022) forest loss data. Importantly, we did not classify short-term forest harvesting as land cover change, focusing only on lasting transitions such as forest to shrub or urban. This approach allowed us to accurately quantify and characterize meaningful shifts in land cover composition over time.

Example: Chittenden 10m Land Classification 2016-2024

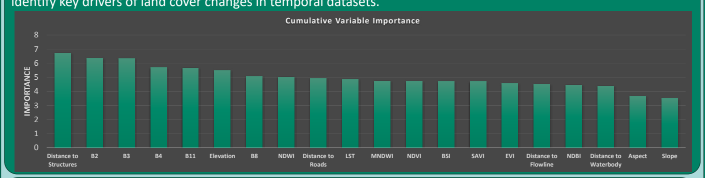


Variable Importance

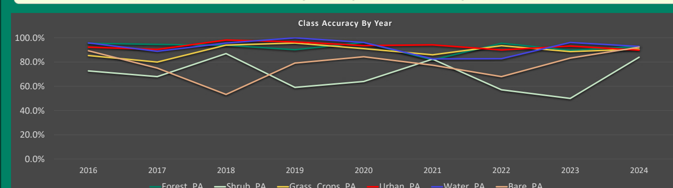
The cumulative variable importance ($IV^{(j)}_{cumulative}$) in land cover classification using Random Forest evaluates the overall contribution of the jj-th predictor variable in explaining the variability of the target classification output (Y) over multiple years. It builds on the conditional expectation function, $\tau(X) = E[Y \mid X]$ which represents the expected value of the target (Y) given the predictors (X). By removing the j-th variable from the predictors (X^{-j}), the importance of this variable is measured as the reduction in explained variance in $\tau(X)$ To capture this effect cumulatively over T years, we define:

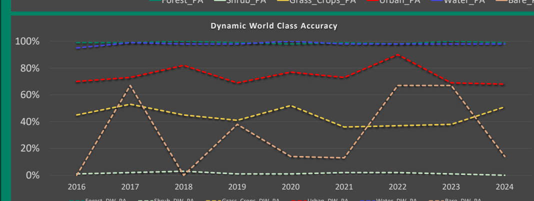
$$IV^{(j)}_{cumulative} = \frac{\sum_{t=1}^{T} E\left[V\left[\tau(X_t) \mid X_t^{(-j)} \right] \right]}{\sum_{t=1}^{T} V[Y_t]}$$

This measure highlights the j-th variable's overall contribution to explaining the output variance across time, helping identify key drivers of land cover changes in temporal datasets.



Classification Accuracy Compared With Dynamic World

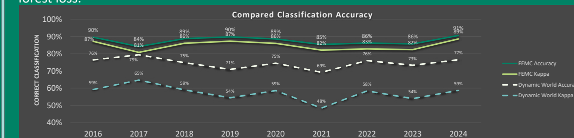




DW Class Code	DW Class Name	Mapped FEMC Code	FEMC Class Name
0	Water	4	Water
1	Tree	0	Forest
2	Grassland	2	Grass & Crops
3	Flooded Vegetation	1	Shrub
4	Crops	2	Grass & Crops
5	Shrubland	1	Shrub
6	Built-up	3	Urban
7	Bare Ground	5	Bare

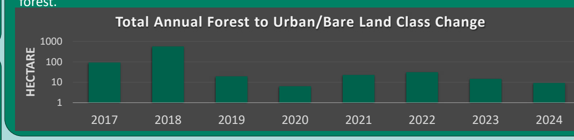
Land Classification Accuracy

The figures comparing accuracy in classes and overall accuracy highlight the superior performance of the FEMC Classification System, consistently achieving over 85% accuracy compared to the variability of Dynamic World (DW), which struggles with transitional land classes. DW nearly fails to classify Shrub while the FEMC model excels at identifying regenerating forests, capturing transitions between forest and shrub more effectively. Forest is the most consistently classified class across all systems, while Urban and Water show moderate accuracy. The FEMC model's ability to classify dynamic land categories demonstrates its robustness compared to DW's limitations. The better the yearly classification, the better the temporal classification of persistent forest loss.



Data Visualization

The data indicate a significant disparity between the Total Forest-to-Urban Change Area and the Total Permanent Forest Loss Area, highlighting differences in land-use dynamics. The Forest-to-Urban/Bare Change Area is substantial at 758.55 ± 19.7 hectares, reflecting conversion of forested areas into urban environments. This underscores urbanization as a major driver of forest cover change. In contrast, the Total Permanent Forest Loss Area is much smaller at 27.29 hectares (3.6%), indicating that while some forest loss is irreversible (e.g., due to development or infrastructure), the overall scale of permanent loss is relatively limited. This distinction is crucial for targeting conservation and reforestation efforts. Where permanent forest loss is the long-term conversion of forest to Urban or Bare for at least 3 consecutive years without regrowth to shrub or forest.



Summary

The process of annual land classification involves filtering Sentinel-2 imagery by region, date range, and cloud cover. A cloud masking function removes contaminated pixels, and key spectral indices such as NDVI, EVI, SAVI, and others are computed. A temporal smoothing technique using a 20-day rolling mean reduces noise caused by cloud gaps. For each year, a median composite of the indices is generated, producing an annual summary image. These annual composites are classified using predefined land classes such as forest, water, agriculture, and built-up areas.

The classification of permanent loss focuses on detecting areas where forest cover has transitioned permanently to non-forest categories like urban areas, agriculture, or bare ground. This involves comparing annual classified layers to identify consistent changes across multiple years. If a previously forested area remains classified as non-forest for several consecutive years, it is labeled as a permanent loss. This approach filters out temporary disturbances such as seasonal clearing or thinned forests, ensuring that only irreversible land-use changes are marked as permanent loss.

Why Are These Data Useful?

- Improved Land Monitoring: Highlight the strengths of the FEMC Classification System in accurately capturing transitions, such as regenerating forests, critical for tracking land-use changes over time.
- Identifying Gaps in Other Models: Show the limitations of models like Dynamic World, particularly its low accuracy for shrub classification, aiding in refining remote sensing methodologies.
- Enhanced Conservation Planning: Provide robust, accurate classifications to support ecosystem monitoring, conservation strategies, and resource management efforts.
- Adaptation for Climate Monitoring: Enable better tracking of dynamic land-cover changes, vital for understanding climate impacts and informing mitigation policies.
- Comparative Model Assessment: Offer a benchmark for assessing the performance of multiple classification systems across various land classes.

Next Steps

- Finalize entire Northeast region models and temporal classification.
- Publication of summary and technical reporting on regional drivers.
- Provide hosting and download capability for land class modeling classification and product layers.

Acknowledgements & Authors

Authors & Contributors: Soren Donisvitch, Alison Adams, Nicholas Aflitto, Jennifer Pontius, Matthew Rios
Data Training: Elissa Schuett, Benjamin Porter, Alexana Wolf, Matthias Sirch, Nancy Voorhis, 2024 FEMC Field Crew

Ahmed, S. E., Franklin, S. E., & Wulder, M. A. (2021). Characterizing forest disturbance and recovery using Landsat time series in Canada's managed forests. *Remote Sensing of Environment, 261,* 112481.
Cohen, W. B., Healey, S. P., Yang, Z., Gorelick, N., & Hermosilla, T. (2022). Disturbance and recovery trends of national forests in the Pacific Northwest U.S. using Landsat time series. *Remote Sensing of Environment, 269,* 112771.
Fagan, M. E., DeFries, R. S., Sesnie, S. E., Arroyo-Mora, J. P., Chazdon, R. L., Sanch n, A. (2013). Land cover dynamics following a deforestation ban in northern Costa Rica. *Environmental Research Letters, 8(3),* 034017.
Foster, D. R., & Aber, J. D. (Eds.). (2004). *Forest in Time: The Environmental Consequences of 1,000 Years of Change in New England.* Yale University Press.
Griffiths, P., Nanni, A. S., & Hostert, P. (2021). Distinguishing forest disturbance from fate: Patterns of forest loss and regrowth in Romania over two decades. *Remote Sensing of Environment, 263,* 112556.
Hansen, M. C., Potapov, P. V., Pickens, A. H., & others (2022). Mapping tree plantations with multisource remote sensing data sets. *Remote Sensing of Environment, 278,* 113120.
Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Townshend, J. R. G. (2013). High-resolution global maps of 21st-century forest cover change. *Science, 342(6160),* 850853.
Hermosilla, T., Wulder, M. A., White, J. C., & Coops, N. C. (2022). Characterizing forest structure change using airborne laser scanning and Landsat time series. *International Journal of Applied Earth Observation and Geoinformation, 108,* 102733.
Kennedy, R. E., Yang, Z., & Cohen, W. B. (2010). Detecting trends in forest disturbance and recovery using yearly Landsat time series: LandTrendr Temporal segmentation algorithms. *Remote Sensing of Environment, 114(12),* 28972910.
Olofsson, P., Woodcock, C. E., & Hughes, M. J. (2021). Monitoring deforestation and forest degradation using Landsat time series. *Current Forestry Reports, 7,* 4762.
Tropek, R., Sedlek, O., Beck, J., Keil, P., Musilov, Z., Storch, D. (2014). Comment on High-resolution global maps of 21st-century forest cover change. *Science, 344(6187),* 981.
White, J. C., Wulder, M. A., Hermosilla, T., Griffiths, P., & Pickens, A. H. (2021). Detecting and attributing drivers of forest disturbance in Canada□s National Forest Inventory plots. *Forests, 12(2),* 134.

Heat and drought impacts on tree seedling growth and survival

Emily MacDonald[1], Paige Cormier[1], Melissa Cullina[2], Bryan Peterson[3], Jay Wason[1]

[1]School of Forest Resources, University of Maine
[2]Plant Science and Collections, Coastal Maine Botanical Gardens
[3]School of Food and Agriculture, University of Maine

Introduction

- Climate change stressors like heat and drought are increasingly threatening regeneration of trees in the northeastern US, particularly those at the southernmost limit of their ranges[1,2].
- First-year tree seedlings are likely extremely vulnerable to changes in climate[3].
- However, we have a very limited understanding of species-specific responses to climate, particularly the extent to which heat, drought, and heat combined with drought will impact survival and growth of first-year tree seedlings in the northeastern US.

Goal

Determine the extent to which heat, drought, and heat combined with drought impact the growth and survival of first-year tree seedlings and explore the physiological mechanisms underpinning their responses.

Methods

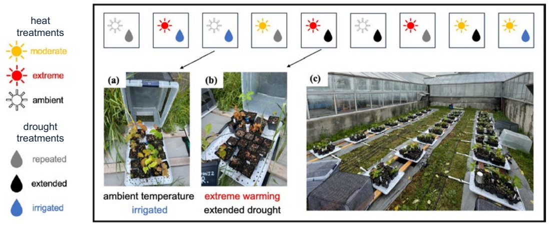


Figure 1. schematic representation of one experimental block with nine combinations of temperature and soil moisture conditions. Examples of (a) ambient, irrigated conditions and (b) extreme heat, extended drought conditions. 27 total chambers were used to replicate each unique treatment combination three times (c).

- We planted seeds of eight tree species individually in containers, which were divided among 27 treatment chambers.

Figure 2. Chamber design used to heat the inside of chambers in both the moderate and extreme heat treatments (left) and ambient treatments (right).

Table 1. List of tree species.

Leaf type	Species
Evergreen needle-leaved species	balsam fir (*Abies balsamea*)
	red spruce (*Picea rubens*)
	eastern white pine (*Pinus strobus*)
	northern white cedar (*Thuja occidentalis*)
Deciduous broad-leaved species	red oak (*Quercus rubra*)
	red maple (*Acer rubrum*)
	sugar maple (*Acer saccharum*)
	black ash (*Fraxinus nigra*)

- Heat treatments lasted 90 days and were crossed with three soil moisture treatments lasting five weeks. Repeated drought chambers received no water for two weeks, which was repeated after a period of full irrigation. Extended drought plants were minimally irrigated for the duration of the treatment.
- We measured start- and end-of-treatment height and vigor. A subset of pots were weighed twice a week to monitor soil moisture. Species-level minimum epidermal conductance (g_{min}) and leaf mass per area (LMA) were measured after drought treatments concluded.

Preliminary Results

- **Survival was significantly lower for balsam fir and red spruce compared to the other species. Generally, we found that survival was lower in response to combined extreme heat and drought than either stressor alone (droughtxheat interaction p-value = 0.038)**

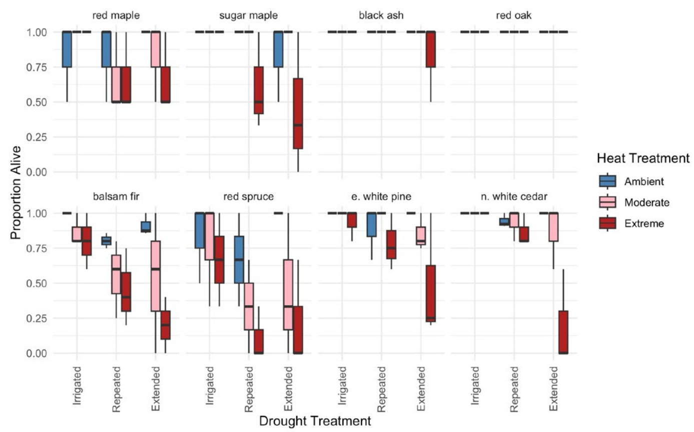


Figure 3. Proportion of surviving seedlings at the end of treatments averaged across chambers. Statistical significance was determined using linear mixed effect binomial model testing for effects of species, drought, and heat on survival.

- **For the seedlings that survived, we found that height differed significantly among species (p-value < 0.001). There were no significant effects of heat or drought on height.**

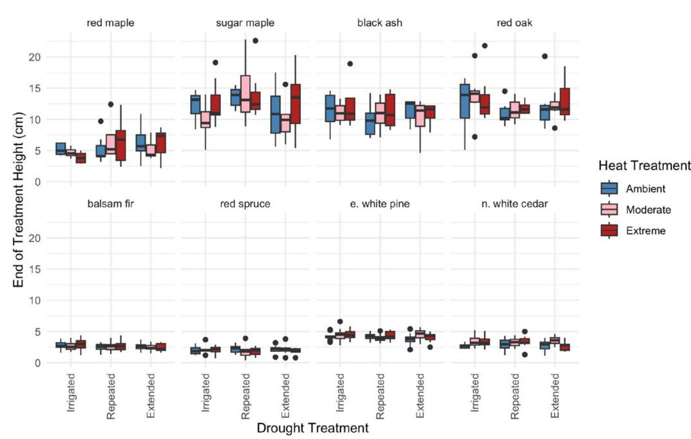


Figure 4. Total height at the end of treatments averaged across chambers. Statistical significance was determined using linear mixed effect model testing for effects of species, drought, and heat on height.

Preliminary Results cont'd

- **We found significant differences in LMA (p-value < 0.001) and gmin (p-value < 0.001) among species. g_{min} of red maple and red spruce were among the highest values, indicating leakier stomata, and the values for red oak and white pine were among the lowest. Generally, red maple and black ash had the lowest LMA, while red spruce and balsam fir had the highest LMA.**

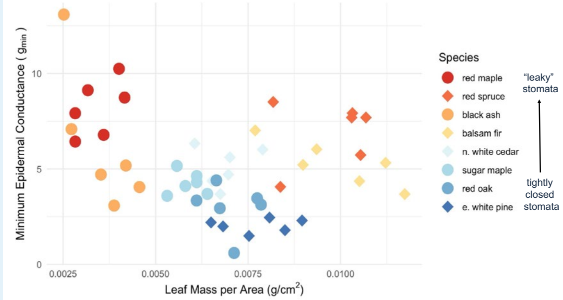


Figure 5. Leaf mass per area (LMA) and minimum epidermal conductance (g_{min}) of our study species. Linear mixed effect model testing was used to determine differences among species. Species are listed according to average g_{min} values.

Discussion

- Boreal conifers were most sensitive to heat and drought effects, and combined drought and heat had more negative effects than either treatment applied independently.
- Drought and heat did not reduce height growth, suggesting that surviving first-year seedlings are able to grow across a range of conditions.
- These results suggest that land managers may want to consider the potential of compounded stressors when there is concern regarding tree regeneration. Additionally, heat waves and higher baseline temperatures associated with climate change may not pose a threat to most first-year seedlings of most species, so long as they have access to adequate soil moisture.
- Next steps:
  - biomass and root:shoot analysis
  - other drought tolerance metrics (e.g., turgor loss point)

Acknowledgements

We would like to thank Brad Libby for his advice and for facilitating the experimental setup and Wason Lab members Megan Grega, Brigid Mrenna, and Laura Pinover for their help. This project was funded by the United States Department of Agriculture's Agriculture and Food Research Initiative (award number 2023-67020-40089) and McIntire Stennis Project Number ME0-42121 administered through the Maine Agricultural and Forest Experiment Station.

References

1. Fisichelli, N. A., Frelich, L. E., & Reich, P. B. (2013). Climate and interrelated tree regeneration drivers in mixed temperate–boreal forests. Landscape Ecology, 28(1), 149–159. https://doi.org/10.1007/s10980-012-9827-z
2. Reich, P. B., Sendall, K. M., Rice, K., Rich, R. L., Stefanski, A., Hobbie, S. E., & Montgomery, R. A. (2015). Geographic range predicts photosynthetic and growth response to warming in co-occurring tree species. Nature Climate Change, 5(2), Article 2. https://doi.org/10.1038/nclimate2497
3. Wright, A. J., Fisichelli, N. A., Buschena, C., Rice, K., Rich, R., Stefanski, A., Montgomery, R., & Reich, P. B. (2018). Biodiversity bottleneck: Seedling establishment under changing climatic conditions at the boreal–temperate ecotone. Plant Ecology, 219(6), 691–704. https://doi.org/10.1007/s11258-018-0827-1

A Snapshot of FEMC's Regional Forest Health Monitoring Network. Insights from 2024

Benjamin Porter[1,2]; Alison Adams[1,2]; Soren Donisvitch[1,2]; Matthew Rios[2,3]; Elissa Schuett[1,2]; Nancy Voorhis[1,2]; Alexana Wolf[1,2]; Matthias Sirch[1,2]

[1]University of Vermont Rubenstein School of Environment and Natural Resources, [2]Forest Ecosystem Monitoring Cooperative (FEMC),
[3] ECO AmeriCorps Program - Vermont Department of Environmental Conservation

Through long-term forest health monitoring in seven (7) northeastern states, the Forest Health Monitoring (FHM) program has observed and analyzed relatively stable health conditions throughout the northeastern forest. However, due to specific damages and diseases, certain species should be continued to be closely monitored and managed, such as American beech, white oak, and white ash.

Introduction

The FHM program of the FEMC has previously conducted long-term monitoring assessments of forest health throughout Vermont since 1990. Expansion in 2022 allowed FEMC to established 194 total plots throughout Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont (Fig. 4). These new sites were primarily co-located at established long-term forest health monitoring plot locations (FIA and CFI), representing the major forest types and geographies on public lands. 2024 marks the third year of monitoring on all plots within our regional 7-state network.

During the 2024 field season, the FEMC FHM crews assessed seedling regeneration, sapling survivorship, and overstory health. Forest health metrics included tree heights, tree diameter at breast height (DBH), vigor, dieback, transparency, defoliation, and discoloration of the forest canopy. Lastly, crews documented special damages for each tree, along with invasive species presence and the degree of browse pressure observed within each plot.

Our primary analyses were focused on several different metrics: Percentage of trees with 'poor vigor' ratings by species in each state (Fig. 2), a temporal analysis of seedling density by species (Fig. 3), the average percent of vigor for each overstory tree species (Fig. 5), and the average dieback for each tree species, categorized by state (Fig. 6).

Plot Layout

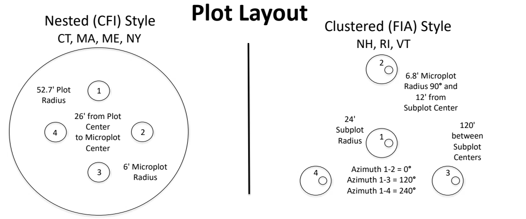


Figure 1. Our nested (CFI-style) (left) and clustered (FIA-style) (right) FHM plots are shown. Our FHM program adopted these to accommodate plot layouts from each state's historical FHM efforts. The nested plots contain an overstory plot (large circle) and four regeneration microplots (small circles at cardinal directions), while the clustered plots contain four subplots and four regeneration microplots, based upon the USFS FIA style plot network.

Results

- While there are a wide range of stressors and vulnerabilities impacting Northeastern forests, data from the 2024 season suggest that the region's forests are overall diverse, vigorous, and healthy. However, there are notable exceptions that we should continue to monitor.
- From the 2024 crown health assessments, we determined white oak (*Quercus alba*), American beech (*Fagus Americana*), and black cherry (*Prunus serotina*) as species of concern. Average vigor ratings for these species were 1.8, 2.1, and 2, respectively (where 1 is healthy and 4 is severe decline) and defoliation ratings were 1.5, 0.6, and 0.9 (where 0 is 0 to trace defoliation, 1 is less than 30% crown defoliation, and 2 is 30-60% defoliation).
- Of live trees measured throughout the plot network, we found that 5,838 trees (92.1%) had vigor ratings corresponding to "healthy" and "light decline" (vigor 1 and 2, respectively) and 499 trees (7.9%) were in "moderate" to "severe decline" (vigor 3 and 4, respectively).
- The overstory trees with the highest average rates of moderate or severe decline were American beech (13.4%), green ash (Fraxinus pennsylvani; 8%), white ash (Fraxinus americana; 7.6%), and white oak (5.1%). Across all species, <3% of total live stems surveyed were determined to be in severe decline.
- Across all live trees, the average fine-twig dieback was 10.7%. American beech had the highest mean dieback at 20.2%, while white ash and Norway spruce had 17.5% and 15.3% mean dieback, respectively (Figure 6).

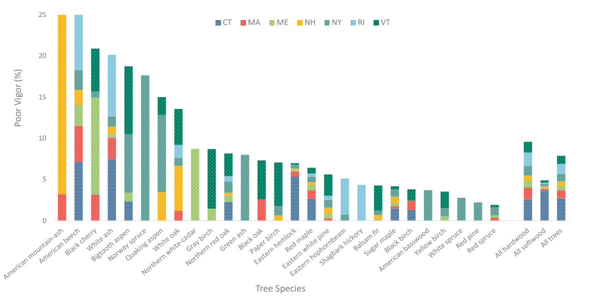


Figure 2. Percentage of trees with a 'poor vigor rating' sampled in 2024 across the seven states in FEMC Forest Health Monitoring plot network where at least 10 individuals of each species were measured. Percent poor vigor is the proportion of live trees per species that were classified to be 'in decline' (vigor ratings of 3 or 4).

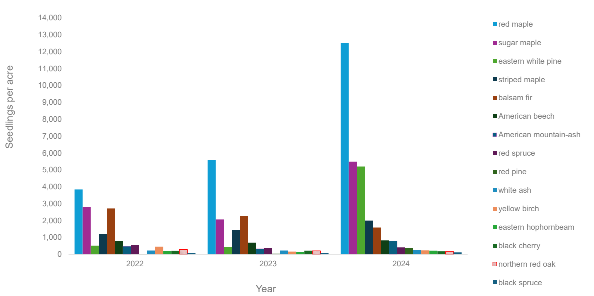


Figure 3. A temporal analysis of the mean seedling density (counts per acre) for each species between 2022 and 2024. Plots consistently visited since 2022 (189 plots) were used in the analysis. Masting by select species could be the cause of large seedling discrepancies.

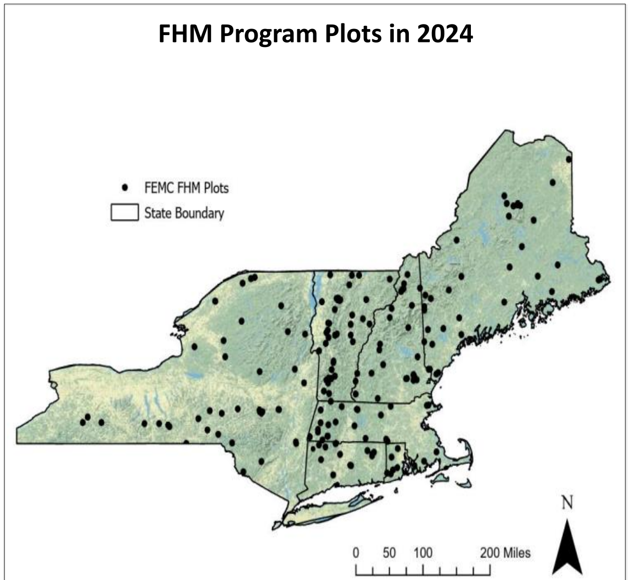


Figure 4. One hundred and ninety-four (194) plot locations were included in the total FHM analysis. As of 2022, our regional states include Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont.

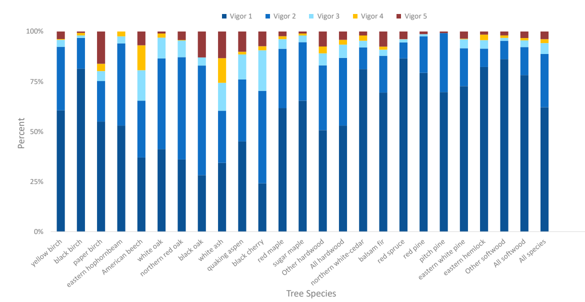


Figure 5. Average basal area (%) of each vigor category (1 is healthiest, 2-4 is increasing decline, 5 is dead and standing) for each overstory tree species. Tree species with relatively high importance (abundance) values were included and only standing trees were included.

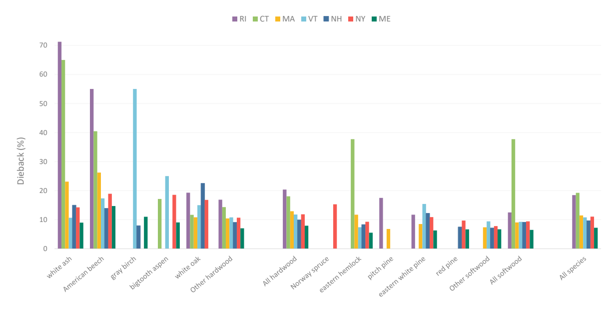


Figure 6. Species with the greatest average crown dieback (%) across seven (7) regional states. Crown dieback is identified as the percent of fine twig dieback and is rated from 0-100% (0% indicating no find twig dieback, 100% indicating complete fine twig dieback). Tree species were included if at least 10 individuals were measured.

Lingering (resilient) ash detection: a tool for ash conservation

Jonathan Rosenthal and Dr. Radka Wildova, Ecological Research institute

What are lingering ash?

Lingering ("resilient") ash are chemically untreated mature (≥4" dbh) trees that retain healthy crowns through peak EAB invasion. They are not trees that merely survive peak invasion nor are they trees that reach maturity after peak infestation ("ingrowth"). Lingering ash have been found for all three widespread Northeastern species: white (*Fraxinus americana*), green (*F. pennsylvanica*), and black/brown (*F. nigra*). Although lingering ash display some resistance, it often is not complete, meaning that even these trees will likely eventually decline. Thus, lingering ash must be found once ash mortality is high enough to reveal them, but not too long afterwards.

Lingering white ash (left) and black ash (right) found in Hudson Valley; photo by R. Wildova.

What roles can lingering ash play in ash conservation?

1. Providing scion for resistance breeding

The USFS EAB Resistance Breeding Project has shown that for green ash, scion (twigs) collected from lingering trees can be grafted to yield replicates that can be used for selective breeding, yielding highly resistant trees. Thus, one role for lingering ash is furnishing scion for resistance breeding.

EAB larva killed by lingering ash; photo by J. Koch.

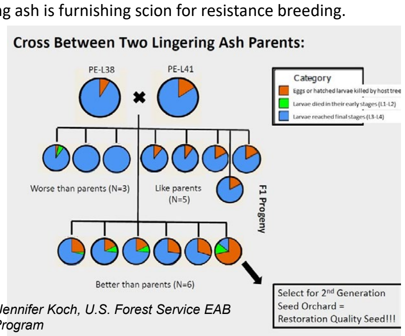


Chart provided by Dr. Jennifer Koch, U.S. Forest Service EAB Resistance Breeding Program

Scion collection from lingering tree (left), photo by J. Rosenthal; clone bank from lingering ash, Cornell Botanic Gardens 5 months after grafting (middle and right); photos by T. Bittner.

Selective breeding has not yet been performed using trees grafted from black ash. However, scion collected from multiple lingering black along with white and green ash by the Monitoring and Managing Ash (MaMA) program in New York have been used to create clone banks, which can be used for selective breeding. As areas long invaded by EAB spread across the Northeast, the number of lingering trees found should increase.

2. Furnishing seeds for resistance breeding

In contrast to untargeted seed collection (especially in areas that haven't reached high mortality), seed collection targeting lingering ash may take advantage of the natural selection that set them apart from the trees that succumbed to EAB (depending upon proximity of other lingering ash to furnish pollen). However, even the resistance of seedlings produced by targeted seed collection will likely be lower than those produced in a seed orchard of confirmed resistant parents. The table below shows how scion collection, targeted seed collection and untargeted seed collection compare with and can complement each other.

	LA scion collection	LA-targeted seed collection	Untargeted seed collection
Advantages	• Takes advantage of natural selection pressure revealing trees with some resistance. • Grafted trees have same level of partial resistance as LA that furnished scion • Grafted trees flower much sooner than trees from seed, enabling early selective crossing.	• May take advantage of natural selection pressure revealing trees with some resistance. • Half of seeds' genes from LA mother, so more likely (depending on whether father a LA) than untargeted seed to produce seedlings with some resistance, but less likely than seeds from two known LA parents. • Captures more genetic variation than scion. • Propagation from seed doesn't require grafting facility.	• Potentially captures greatest genetic variation. • Propagation from seed doesn't require grafting facility.
Disadvantages	• Can (presently) be identified for collection only after high mortality. • Technical expertise and equipment needed for scion collection and grafting.	• Can (presently) be identified for collection only after high mortality. • Because only ½ of seeds' genes from mother, won't reliably produce trees with same level of resistance. • Need seed repository suitable for intended purposes.	• Trees grown from untargeted seeds likely to be largely susceptible (rate varies between species). • Need seed repository suitable for intended purposes.

3. Improving population genetics in situ

To the extent that lingering ash's partial resistance is heritable, and depending upon lingering ash's relative abundance within pollinating distance, they might enable seed produced on-site that reflects selection for resilience.

Another important management tool – let's use it!

By taking advantage of the partial resistance found in many lingering ash, their detection can provide unique benefits. However, it is not a panacea; rather, its impacts can be greatest when combined with other tools. For example, increased resistance and reduced pest pressure (from e.g., biocontrol) can complement each other to reduce EAB's impacts.

How can managers facilitate lingering ash detection?

One way to enable detection is to monitor EAB-induced mortality (through plot establishment or Rapid Ash Mortality Assessments) to determine when it has gotten high enough to reveal lingering ash. Even more important, in addition to setting aside for mortality monitoring, we encourage leaving enough healthy trees untreated and uncut that there will be a reasonable likelihood of some ultimately manifesting as lingering ash. As the table below shows, lingering ash detection needs to be integrated into overall management strategies and includes important tasks even (especially) after almost all the ash have died.

Note: Even if high enough mortality not yet reached to identify lingering ash, if any mature untreated ash are especially healthy when most are dead/declining, these are potential lingering ash, i.e., the pool of trees from which lingering ash can emerge. If possible, refrain from cutting them unless they start to decline.

Tasks for each stage of EAB infestation

Pre-infestation EAB not yet present	**Early infestation** Some EAB signs; mix of healthy and declining trees	**Mid-infestation** Widespread EAB signs; some ash mortality; few healthy trees	**Late infestation** Ash largely dead, with remainder very unhealthy except for *rare* **lingering ash**
Assess ash presence/importance			
Document infestation onset			
Decide which trees to be treated vs. cut vs. left for mortality monitoring/lingering ash detection as part of overall management strategy			
Identify/implement other site-appropriate silvicultural and mitigation (for, e.g., invasive plants, hydrological changes) approaches			
	Identify sites for parasitoid release; conduct releases		
Establish/use **MaMA Mortality Monitoring Plots**; detect when thresholds reached			
		Do **Rapid Ash Mortality Assessments (RAMAs)** in areas with ash mortality; detect when thresholds reached	
		Record, report, protect **potential lingering ash**	
			Find/mark, protect **lingering ash**, report for possible **scion collection**, possibly collect their seed

What should you do if you find possible lingering ash?

- ❑ Report them through the MaMA Lingering Search project. We will work with you to enable taking any subsequent steps that you see fit, including possible scion collection.
- ❑ Protect them from cutting until after scion collected. Then, if it's necessary to cut lingering ash, there at least will already be genetic replicates for breeding.
- ❑ Do not treat them chemically until they've been reported and LA status verified; however, treating them afterwards is encouraged to prolong their in situ persistence.

To find out more about the MaMA program, please visit ***www.monitoringash.org*** *or email us at* ***outreach@monitoringash.org.***

Acknowledgements

Funding provided by the Tree Species in Peril collaborative initiative led by The Nature Conservancy in collaboration with the US Forest Service. Thanks also to MaMA's many partners and participants.

Monitoring and Managing Ash (MaMA):
a program that enables lingering (resilient) ash detection

Jonathan Rosenthal and Dr. Radka Wildova, Ecological Research institute

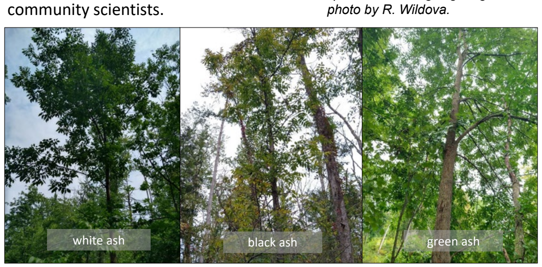
What is MaMA?

Monitoring and Managing Ash (MaMA) is a program of the Ecological Research Institute (ERI) that enables widespread detection of strictly defined **lingering ("resilient") ash**, chemically untreated mature (≥4" dbh) trees that retain healthy crowns through peak EAB invasion. Crucially, they are not trees that merely survive peak invasion nor are they trees that reach maturity after the onset of peak infestation (ingrowth in the aftermath of peak EAB). The U.S. Forest Service EAB Resistance Breeding Project has shown that scion (twigs) collected from them can be grafted to form clone banks and then used for selective breeding to yield highly EAB-resistant native ash.

Developed in 2017 in close consultation with Drs. Jennifer Koch and Kathleen Knight of the USFS EAB Resistance Breeding Project, MaMA has been implemented in Vermont and New York since 2018. It now features prominently in the Tree Species in Peril collaborative initiative led by the USFS and The Nature Conservancy, enabling MaMA to expand throughout New England.

In long-invaded areas of New York, MaMA has already detected 180 lingering ash, including representatives of all three widespread Northeastern species (white, green, black/brown); some of these have furnished material for EAB resistance breeding at Cornell University. MaMA's ability to find lingering ash is based on large-scale data collection along with the integration of lingering ash detection into ash management. Both components are enabled by MaMA's partnerships with agencies, conservation NGOs, researchers, professional land managers, and community scientists.

NYC DEP's invasive species specialist marking lingering ash; photo by R. Wildova.



Examples of lingering ash found in New York; photos by R. Wildova.

Acknowledgements

Funding provided by the Tree Species in Peril collaborative initiative led by The Nature Conservancy in collaboration with the US Forest Service. Thanks also to MaMA's many partners. EAB detection data were provided by NH Dept. of Natural & Cultural Resources, MA Dept. of Conservation & Recreation, VT Dept. of Forests, Parks & Recreation, NY DEC & NYNH iMapInvasives and Maine Forest Service.

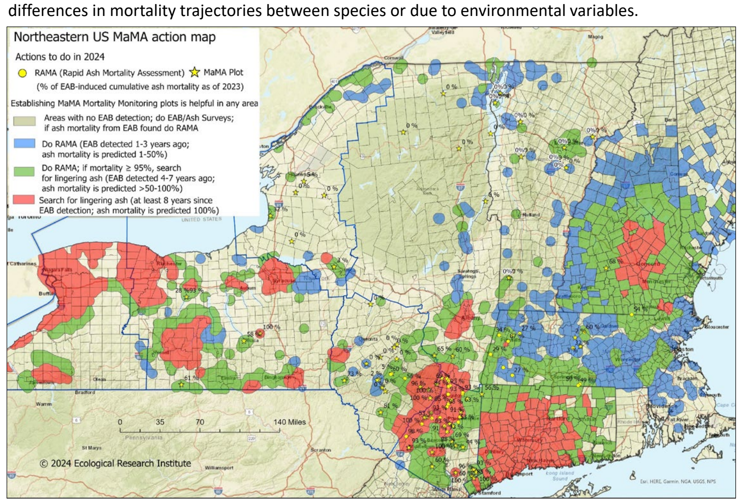
Lingering ash criteria and timing

Based on the criteria of the USFS EAB Resistance Breeding Project, for a tree to qualify as a lingering ash for the MaMA program, it must be a chemically untreated, mature tree (at the time of peak EAB pressure) that retains a healthy crown for ≥ 2years after ≥ 95% of the mature ash in the area were killed by EAB. Thus, finding lingering ash depends upon searching for them in the areas in which this mortality threshold has been reached.

Searching before then will likely produce false positives, i.e., trees that were not yet tested enough by EAB. However, searching too late is also problematic, because: 1) even rigorously defined lingering ash can eventually succumb to EAB or other causes; and 2) post-peak ingrowth can occur, with healthy trees that haven't experienced peak EAB pressure being mistaken for lingering ash. MaMA's "action maps", yielded by data from its projects and other sources, enable looking for lingering ash in the right places at the right times.

MaMA's action maps

MaMA's annually updated action maps show: 1) areas known or projected to be ready to search for lingering ash; and 2) areas needing more data and which MaMA project to use to collect it. The maps are initially created using EAB detection data (mostly from state agencies, but also other sources) along with standard mortality trajectories and spread rates to project when and where 95% mortality will be reached, but they are then refined and updated using mortality and health data collected by MaMA projects. Although the color-coded zones are coarse, MaMA offers guidance in interpreting them to reflect differences in mortality trajectories between species or due to environmental variables.



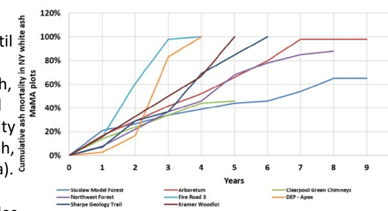
To access MaMA action maps, go to www.monitoringash.org/mama-action-maps; for MaMA project data forms and handouts, go to www.monitoringash.org/data-forms-for-mama-projects.

If you want to find out more about lingering ash and the MaMA program, please visit www.monitoringash.org or email us at outreach@monitoringash.org.

4 MaMA data collection projects

Participants can choose how many and which of these to participate in based on their interest and capabilities and the EAB status in their area; all projects are on **Anecdata**, a platform for rigorous citizen science.

1. Participation in the **MaMA Monitoring Plots Network** comprises monitoring 40 ash until they die. In addition to helping guide the search for lingering ash, data from the plots has revealed considerable variation in mortality trajectories (at least for white ash, for which we have the most data). This variation has management implications, since in some locales die-off is much slower than others. Additionally, we are investigating the extent to which mortality trajectories are influenced by particular environmental variables, which may enable more refined prediction of ash decline rates.



Differences in mortality progression among 8 NY MaMA plots.

2. MaMA Rapid Ash Mortality Assessments (MAMA RAMAs), although less precise than monitoring plots, still helps reveal where and when to search for lingering ash. Unlike the plots, which can be established at sites even before they are invaded by EAB, MaMA RAMAs are only for sites that already have EAB-induced mortality.

3. In areas where EAB has already killed the vast majority of trees, **MaMA Lingering Ash Search** enables reporting trees that meet the strict criteria, as well as negative results of systematic searches.

4. In **MaMA Ash/EAB Surveys**, presence/absence of definitive EAB evidence (and whether any trees with such evidence have died) are reported, complementing state detection data.

Vermont Land Trust crew establishing brown ash MaMA plot; photo by R. Wildova.

Data confidentiality and stewardship

Location data of lingering ash is never made publicly available. Additionally, it is up to the land stewards whether to publicly share the locations of their monitoring plots.

Combining LA detection and seed collection

Those involved in lingering ash detection can put their knowledge to use in seed collection and vice versa. Moreover, seed collection can be targeted at lingering ash. Therefore, we are facilitating connections between these two approaches to ash conservation.

Sustaining Ash Partners Network (SAP-Ne)

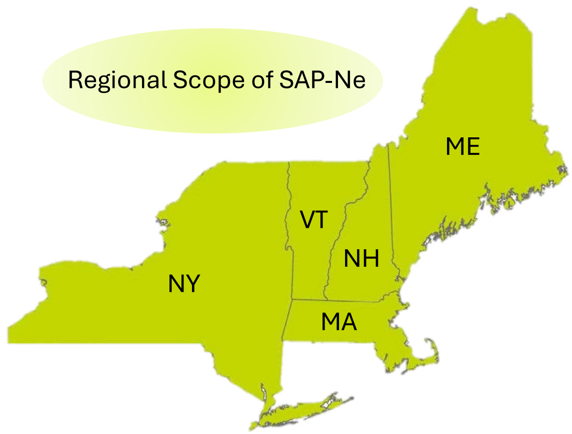
Rachel Swanwick, Forest Stewards Guild, NE Program Manager, rswanwick@forestguild.org

What is SAP-Ne?

Supported through the Forest Stewards Guild and USDA Forest Service Landscape Scale Restoration Program

Our network was established in response to emerald ash borer (EAB) that threatens to eliminate ash from Northeastern forests

SAP-Ne supports a cross boundary regional approach to EAB through training, treatment and outreach- to sustain ash on the landscape for future generations



Including the sovereign lands of federally recognized Tribal Nations throughout the region

Who is SAP-Ne?

A growing network of partners!

SAP-Ne is led in collaboration with the Guild and our partners

Check out some of the network...

SAP-Ne Objectives

1. Elevate cultural values of ash and relationships with Tribal partners
2. Offer workshops and webinars
3. Establish a network of ash treatment demonstration areas
4. Develop a web hub of resources on ash

Want to learn more and get involved?

Visit SAP-Ne's website!

Forest Stewards Guild

Comparing performance of low-cost dendrometers to traditional dendrometers in tracking tree growth in a changing climate

Jordon Tourville[1] and Georgia Murray[1] | 1 - Appalachian Mountain Club

Introduction

- The northeastern United States is experiencing some of the greatest shifts in climate in the US, with warming winters, increased frequency of extreme precipitation events, and severe droughts [1-3].
- Tree productivity is impacted by multiple global change factors, but their impacts may be variable across space [4].
- We are lacking adequate information to connect tree growth and productivity trends across the Northern Appalachian region, which is critical to understand adaptation under future climate scenarios [5-6].
- Broad-scale study of tree growth is limited in feasibility due in part to the high cost of dendrometer instruments - devices that measure the radial growth of tree stems - required to reliably measure these characteristics. However, some cheaper options are starting to come onto the market [7].

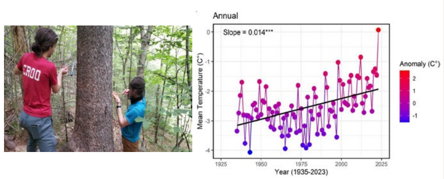


Figure 1: (Left) Traditional methods, such as dendrochronology, to study tree growth across space and time is limited by effort and logistics. (Right) Mean annual temperatures on Mt. Washington, NH, have significantly increased over the last eight decades [1].

The problem

- A large obstacle for consistent measurement of tree growth rates at meaningful scales is the need to use cost-restrictive dendrometers. Low-cost alternative instruments exist, but there is currently not adequate information on the reliability of these devices to support their use in gathering scientific-grade data.

Key questions

- Can we adequately capture and compare intra- annual tree growth patterns with both traditional and low-cost dendrometers?
- Can we feasibly implement a low-cost dendrometer network to measure tree radial growth rates across climate/edaphic gradients and between different age classes of trees and tree species both during summer growing periods and colder seasons.

Methodological approach

Field design:

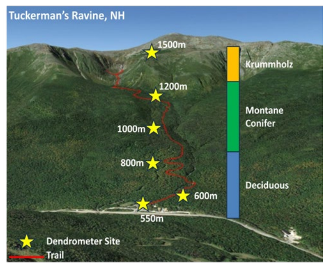


Figure 2 (left):

Dendrometer site placement along the Tuckman Ravine elevation transect.

Figure 3 (right):

Comparison of the traditional expensive Ecomatik (left) dendrometer and the cheaper TOMST (right) point dendrometer on the same trees across an elevation gradient.

Important contrasts:

- Ecomatik vs. TOMST dendrometer measurements
- Large diameter vs. small diameter tree growth
- High elevation vs. low elevation tree growth
- Deciduous vs. conifer vs. krummholz tree growth

Analyses:

Generalized linear mixed models:

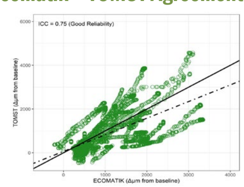
Global: glmer(diff ~ sensor_type + temp + size_class + elevation + (1|tree) + (1|species), family = gaussian

Exploratory comparisons

- T-test + correlations
- Histograms and summary statistics
- Scatterplots

Direct sensor comparisons

Ecomatik + TOMST Agreement:



Reduced Model Results (Generalized linear mixed model):

Fixed effects:

	Estimate	SE	t-value
Intercept	832.44	64.93	12.82
TOMST	**-151.71**	**10.03**	**-15.13**

- TOMST underestimates relative to Ecomatik
- ICC indicates good agreement

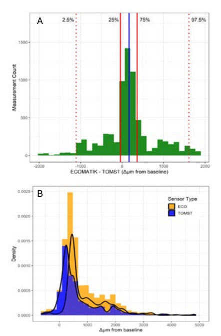
Figure 4 (left):

Comparison of mean daily growth measurements between Ecomatik (x-axis) and TOMST (y-axis) dendrometers. Interclass correlation coefficient (ICC) of 0.75 between the two sensors indicates good agreement. The solid line indicates 1:1 line and dotted line indicates best linear fit.

Figure 5 (right):

(A) Distribution of daily sensor differences between Ecomatik and TOMST units (with 50% and 95% quantiles). (B) Growth measurement histogram for both dendrometer types. Line indicates measurement density distributions.

Ecomatik + TOMST Reliability:



Summary Statistics:

N: 7102
Min: -1947 μm
Q2.5: -1107 μm
Q25: -40 μm
Mean (±sd): 168 (±639) μm
Q75: 361 μm
Q97.5: 1610 μm
Max: 1846 μm
Range 95%: 2717 μm

- Most TOMST + Ecomatik growth measurements fall within ± 1.4 mm; 50% within ± 0.2 mm

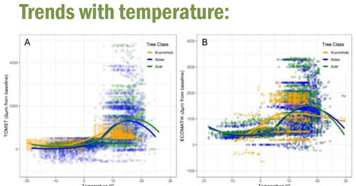
T-Test:

t = -26.588, p-value < 0.001
95% CI: -278 μm to -240 μm
TOMST Mean = 650 μm
Ecomatik Mean = 909 μm

- Ecomatik consistently overestimates tree growth relative to TOMST, magnitude is small

Relationships with covariates

Trends with temperature:



Reduced Model Results (Generalized linear mixed model):

Fixed effects:

	Estimate	SE	t-value
Intercept	703.88	99.47	7.07
TOMST	-162.72	8.90	-18.28
Temperature	**41.14**	**0.42**	**95.74**
Elevation	**-16.44**	**9.11**	**-2.86**

- Temperature (strong positive) and elevation (weak negative) have effects on growth
- Krummholz initiation of growth at lower temperatures than lower elevation trees

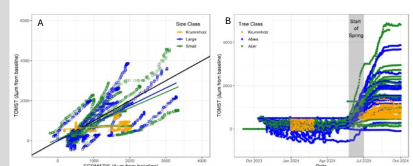
Figure 6 (left):

(A) TOMST tree growth measurements across a range of temperatures partitioned by tree type (krummholz indicates stunted *Abies* at treeline). Colored solid lines indicate loess fits. (B) Ecomatik tree growth measurements across a range of temperatures partitioned by tree type.

Figure 7 (right):

(A) Comparison of TOMST and Ecomatik growth measurements partitioned by tree size class. Solid line indicates 1:1 line. Colored solid lines indicate best linear fits by tree size class. (B) Time series (between October 2023 and October 2024) of TOMST tree growth trends partitioned by tree type (krummholz indicates stunted *Abies* at treeline). Shaded area displays initiation of seasonal tree growth (5/21 – 6/30).

Trends between diameter and tree classes:



Reduced Model Results (Generalized linear mixed model):

Fixed effects:

	Estimate	SE	t-value
Intercept	570.08	78.09	7.30
TOMST	-162.67	8.90	-18.27
Temperature	41.14	0.43	95.74
Large Size	**56.54**	**107.98**	**0.52**
Small Size	**110.38**	**107.98**	**1.02**

- No significant differences in growth between tree size class
- Initiation of tree growth in spring may be good phenological indicator

Conclusions

- Expensive Ecomatik dendrometers tended to significantly overestimate radial growth relative to the cheaper TOMST units, but the magnitude of these differences were small and there was generally good agreement between the two.
- The same overall trends as above were also attributed to different tree species, size classes and sites.
- As expected, radial growth patterns were closely tied to temperature, with threshold responses of the onset of seasonal growth detected with both devices.
- Elevation, was only weakly tied to patterns of seasonal radial growth. Krummholz trees displayed reduced growth compared to all other trees monitored, but experienced growth onset at lower temperatures. There were no detectable differences in growth patterns between large and small diameter trees.

Next steps:

- Examine growth trends across more seasons and include other relevant climate variables, such as accumulated growing degree days (AGDD) and chilling degree days (CDD).
- Test the feasibility of other dendrometer models, particularly those with remote data signaling capability.
- Explore and design methods to establish a dendrometer network across the FEMC monitoring region.

References

[1] Murray, G. L. D., Colgan, A. M., Nelson, S. J., Kelsey, E. P., & Kimball, K. D. (2021). Climate trends on the highest peak of the Northeast: Mount Washington, NH. Northeastern Naturalist, 28(sp11), 64–82. https://doi.org/10.1656/045.028.s1105

[2] Burakowski, E. A., Contosta, A. R., Grogan, D., Nelson, S. J., Garlick, S., & Casson, N. (2022). Future of Winter in Northeastern North America: Climate Indicators Portray Warming and Snow Loss That Will Impact Ecosystems and Communities. Northeastern Naturalist, 28(sp11). https://doi.org/10.1656/045.028.s1112

[3] Janowiak, M.K., D'Amato, A.W., Swanston, C.W., Iverson, L., Thompson, F.R., Dijak, W.D., Matthews, S., Peters, M.P., Prasad, A., Fraser, J.S., et al. (2018). New England and northern New York forest ecosystem vulnerability assessment and synthesis: a report from the New England Climate Change Response Framework project (Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station).

[4] Etzold, S., Sterck, F., Bose, A. K., Braun, S., Buchmann, N., Eugster, W., & Zweifel, R. (2022). Number of growth days and not length of the growth period determines radial stem growth of temperate trees. Ecology Letters, 25(2), 427-439.

[5] Morelli, T.L., Daly, C., Dobrowski, S.Z., Dulen, D.M., Ebersole, J.L., Jackson, S.T., Lundquist, J.D., Millar, C.I., Maher, S.P., Monahan, W.B. and Nydick, K.R. (2016). Managing climate change refugia for climate adaptation. PLoS One, 11(8), p.e0159909. https://doi.org/10.1371/journal.pone.0159909

[6] Rogers, B. M., Jantz, P., & Goetz, S. J. (2017). Vulnerability of eastern US tree species to climate change. Global Change Biology, 23(8), 3302-3320.

[7] Eitel, J. U., Griffin, K. L., Boelman, N. T., Maguire, A. J., Meddens, A. J., Jensen, J., & Jennewein, J. S. (2020). Remote sensing tracks daily radial wood growth of evergreen needleleaf trees. Global Change Biology, 26(7), 4068-4078.

Contact information

For more information, please contact Jordon Tourville:

Email: jtourville@outdoors.org | Website: jordontourville.com