# 2020 FEMC ANNUAL CONFERENCE PROCEEDINGS

# 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 twenty-nine 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, the Massachusetts Department of Conservation 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, the bulk of FEMC activities are accomplished by "in kind" contributions provided by the larger collaborative network.

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 Partnership Committees – https://www.uvm.edu/femc/cooperative/committees

FEMC staff – https://www.uvm.edu/femc/about/staff

VERMONT AGENCY OF NATURAL RESOURCES

The University of Vermont

USDA FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

# Proceedings of the December 17-18, 2020 Forest Ecosystem Monitoring Cooperative Annual Conference:

## *Revealing a Changing Forested Landscape: Where we have come from, what we have learned, and what is next in long-term ecosystem monitoring*

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Contributing Editors: Elissa Schuett, John Truong, James Duncan, 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 Dr. Lesley-Ann Dupigny-Giroux, Dr. Laura Kenefic, Dr. Brittany Mosher, and Dr. Alexej Siren for their work on the Annual Conference Planning Committee, as well as Dr. Kate Miller and Dr. Charles Driscoll for their work in developing the plenary session and curating talks; Peter Church, Director of Forest Stewardship for the Massachusetts Department of Conservation and Recreation and FEMC Steering Committee Chair for moderating the morning plenary; and Nancy Mathews, Dean of the Rubenstein School of Environment and Natural Resources for providing financial support to graduate students; and our session moderators, Matthias Sirch, Alyx Belisle, and Emma Gwynn. We would also like to thank our invited speakers, workshop 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.

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# Introduction to the Proceedings

The Forest Ecosystem Monitoring Cooperative held its 30th annual conference on December 18 and 19, 2020. The conference was held as a virtual event due to the coronavirus pandemic. The conference theme was ***Revealing a Changing Forested Landscape: Where we have come from, what we have learned, and what is next in long-term ecosystem monitoring***. The conference explored the major findings of key monitoring programs, shared research discoveries and how the ecosystem has changed, and identified future opportunities and innovations in monitoring.

The conference, held as two half day sessions (Thursday and Friday mornings) offered two plenary sessions, six tracks for contributed talks, a facilitated group session, and a poster session. Opportunities for networking were limited, but people were able to engage with the speakers by asking questions in Zoom (the online platform used for the conference). Peter Church, the FEMC Steering Committee Chair opened the conference with introductory remarks. Each morning also had a plenary speaker, introduced by FEMC Director Jim Duncan. Dr. Kate Miller, a quantitative ecologist with the National Park Service's Inventory and Monitoring Program shared findings from long-term monitoring of forests on National Park properties, with a focus on invasive plants, regeneration, and impacts of climate change. Dr. Charles Driscoll, a Distinguished and University Professor from Syracuse University, discussed monitoring of atmospheric deposition conducted at Hubbard Brook Research Forest.

In addition to the two plenary sessions, each day offered concurrent contributed talk sessions, with three tracks each day: Forest Pests & Diseases, Disturbance & Stressors, Tools & Technology, Wildlife, Long-Term Monitoring, and Forest Ecosystems. A total of 19 presenters shared their research and monitoring findings from across the region. A poster session also offered presenters the opportunity to share information about research or an organization as a flash talk; attendees then had the opportunity to join the presenters in break-out rooms to discuss the poster. A listening session was also hosted by FEMC to discuss upcoming strategic planning that will help define the next five years for the organization. At the conclusion of the two-day conference, FEMC Principal Investigator Dr. Jennifer Pontius provided closing remarks.

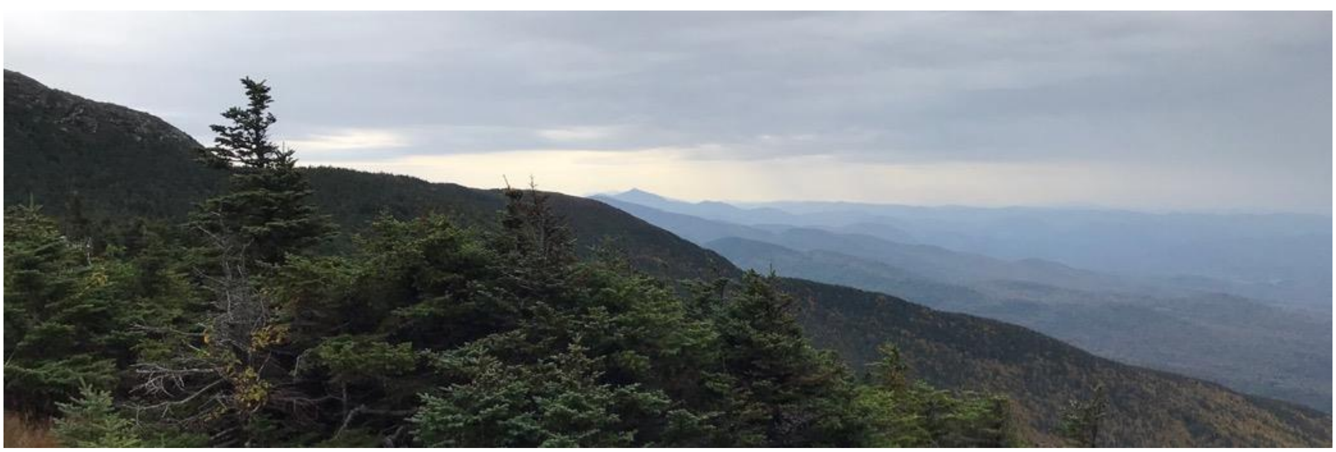
While the conference was not a typical in-person event with opportunities to meet colleagues over coffee or in the hallway from across the region, the virtual platform did allow for participation from people who might otherwise not be able to attend due to travel constraints and poor weather conditions. Follow-up surveys suggested support for hybrid in-person/online events in the future to allow for accessibility from attendees across the region. Identifying opportunities for greater networking and engagement in the online platform was also encouraged.

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/cooperative/conference/2020

# Revealing a Changing Forested Landscape: Where we have come from, what we have learned, and what is next in long-term ecosystem monitoring

A conference planning committee was formed to define the conference theme and recommend plenary speakers to invite. The committee included Dr. Lesley-Ann Dupigny-Giroux, Dr. Laura Kenefic, Dr. Brittany Mosher, and Dr. Alexej Siren. Several sessions were held to discuss the conference theme, using guidance from the 2019 post-conference survey to focus on using the 2015 long-term monitoring in Vermont theme to expand to covering the region. Members were interested in the opportunity to consider how long-term monitoring can be used to advance experimental research and unexpected findings can become evident with a long-term record. The selected theme was "***Revealing a changing forested landscape: Where we have come from, what we have learned, and what is next in long-term ecosystem monitoring."***

The plenary discussion was developed to learn about long-term monitoring being conducted across the region and identify ways in which long-term ecosystem monitoring provides our community with the means to explore data trends and discover changes happening across the forested landscapes of the Northeast. While manipulation and experimentation are not conducted in monitoring programs, the outcomes from monitoring often provide the basis for new research questions and innovation in techniques and methodology. The 2020 FEMC Conference explored the major findings of key monitoring programs occurring across northeastern forests, shared research discoveries and how the ecosystem has changed, and identified future opportunities and innovations in monitoring.



# Summaries of Plenary Sessions

## Forest health monitoring in eastern national parks: lessons learned and future concerns

DR. KATE MILLER

Kate Miller is a Quantitative Ecologist with the National Park Service's Inventory and Monitoring Program (NPS I&M), which conducts long-term monitoring in national parks to help inform management decisions. Kate leads long-term forest monitoring in 20 national parks from Virginia to Maine and freshwater wetland monitoring in Acadia National Park. Kate also develops tools for analysis and visualization, such as a power analysis for fixed-plot data, ecological indicators of forest and wetland condition, and R-shiny based visualizers. Kate received her BS in Natural Resources from Northland College, and MS and PhD from the University of Maine's School of Biology and Ecology.

Monitoring forest lands is essential to effectively managing long-term forest health. A thorough understanding of the plants, animals, and ecosystems of a landscape and the stressors that affect those natural resources is important to developing a strategic approach to maintaining and improving ecosystem health. Current causes of stress to eastern U.S. forests include invasive plants, deer browsing, forest pests, and changing conditions as a result of climate change.

Dr. Kate Miller conducts long-term forest monitoring on National Park properties as part of the National Park Service's Inventory and Monitoring Program. The program began as an initiative to identify natural resources on National Park properties, and has since transformed into a monitoring program that collects data from long-term plots. From this data, Dr. Miller and the Northeast Temperate Network team are able to make science-based management decisions to address specific needs of a park. The approach is important for National Parks, but can also be applied to non-Federal lands to improve forest health across the region.

The National Park Service mission is to conserve natural and historic objects for the enjoyment now and for future generations. To serve this mission, National Park lands have greater protections, including restrictions on hunting and logging. With the long-term data from the monitoring program, there is evidence that these protections have resulted in forests with greater diversity and more biomass than forests on land surrounding the parks.

The monitoring program has also identified current and potential future stressors that can lead to forest ecosystem decline. National Park properties across the region have several types of invasive plant species. These invasive species are a threat to forest ecosystem health both on National Park properties and off (Figure 1).

*Figure 1 Growth of invasive plants were monitored on National Park lands for over ten years.*

Lessons from the National Park monitoring program can be extended to lands that do not have as many use restrictions or protections. Forest lands across the eastern U.S. are experiencing many stressors. The NPS I&M program uses methods based on the U.S. Forest Service Forest Inventory and Analysis program to monitor and evaluate forest health. Long-term monitoring on other properties around the region can be compared to NPS data and complementary strategies can be implemented to support healthy forest ecosystems. Forest lands across the region are also experiencing stresses related to invasive plants, forest pests, and deer browsing.

*Figure 2 Impacts of deer browse on forest understory.*

Dr. Miller’s plenary provided valuable understanding of the challenges forests are facing currently as well as future potential challenges as a result of climate change and regeneration debt. Future forests may not be composed of the same mix of tree species as a result of fewer seedlings and saplings that contribute to forest regeneration. Some of this is due to invasive plants, some to pests, and some due to deer browse (Figure 2).

Additionally, many climate change models suggest that conditions are changing in which species from farther south are moving northward. This implies that forest types will change, however, while habitat conditions might be more suitable for southern species, it is unlikely they will be able to disperse to the more northern regions (Figure 3). This may result in forests being lost or overtaken by invasive plants unless planting plans to manage forests are put in place.

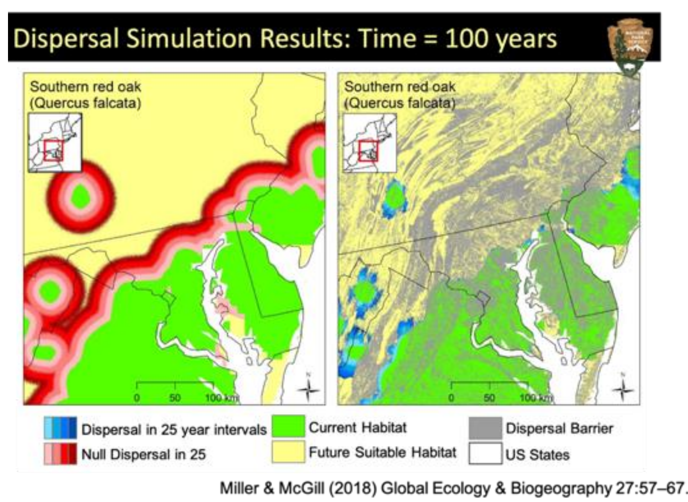



*Figure 3 Dispersal barriers may limit expected range expansion of plant species under changing climate conditions.*

The NPS I&M program is an example of the importance and value of long-term monitoring in order to identify and implement best management practices. Without the complete understanding of the resources available and how they are changing over time, management plans may be out of sync with what is needed. Using monitoring methods that can be easily compared across programs is valuable to having a complete picture of the forest landscape across the eastern U.S. region.

# Effects of Changing Atmospheric Deposition and Climate on the Structure and Function of a Northern Forest: Long-Term Measurements and Experiments from the Hubbard Brook Experimental Forest, NH, USA


DR. CHARLES DRISCOLL

Charles T. Driscoll is a Distinguished and University Professor at Syracuse University, Syracuse NY USA. Driscoll's scholarly work addresses the effects of disturbance on forest, urban, freshwater and marine ecosystems, including air pollution (acid and mercury deposition), land-use, and climate change. Current research focuses on: recovery of eastern forest watersheds from acidic deposition; co-benefits of carbon dioxide emissions controls from power plants; ecosystem restoration; ecosystem response to changing climate; harmful algal blooms; and atmospheric deposition, watershed and surface water transport and transformations, and biotic exposure of mercury. Driscoll has been designated as a highly cited researcher. Driscoll has testified at US Congressional and state legislative committee hearings, and has served on local, national and international committees pertaining to environmental management and policy. He is a member of the National Academy of Engineering and a fellow of the American Association for the Advancement of Science.


Long-term monitoring has been a hallmark of the Hubbard Brook Experimental Forest in New Hampshire. The site was originally established in 1955 to understand the impact of forest harvesting on water supply in New England. Long-term monitoring at Hubbard Brook has not only led to documentation of acid rain in North America in the 1960's, but has provided the baseline information to study the impacts of climate change on northeastern forests.

Dr. Charles Driscoll has conducted research at the Hubbard Brook Experimental Forest throughout his career, contributing to studies and monitoring of air pollution, acid deposition, and climate change. Following the implementation of the Clean Air Act and subsequent amendments and rules, air pollution and associated acid rain noticeably declined in the United States. This program of air quality management has improved forest and aquatic ecosystem health in the Northeast. Without the long-term monitoring datasets from Hubbard Brook and other research stations, much less would be known about the recovery of the forests, streams, and wetlands.

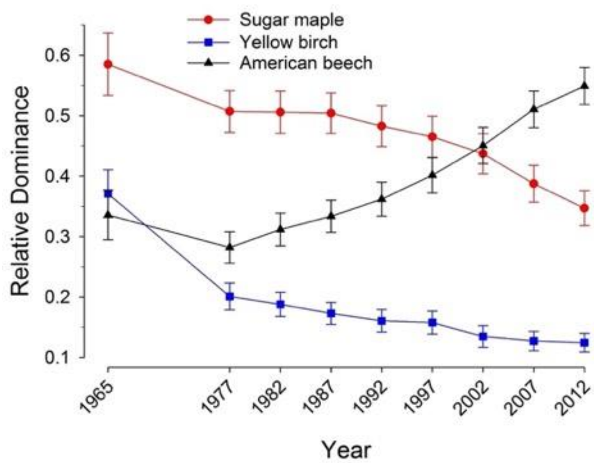



*Figure 4 Sugar maple has shown poor growth in recent years.*

Acid rain caused a loss of positively charged ions, or cations, from soils. Nutrient cations, like calcium, are important for tree health; the soils not only lost nutrient cations available for trees, but also calcium was leached from the foliage of some tree species. Red spruce and sugar maple have been particularly impacted in the northeastern forests, with declining growth and regeneration as well as increased winter freeze injury due to loss of calcium from needles (Figure 4).

Not only has monitoring and research conducted at Hubbard Brook provided valuable insights in recovery from acid rain, but also early signs of impacts due to climate change. As the climate warms, red spruce have shown an improvement, despite the impacts as a result of acid rain. Red spruce are particularly susceptible to winter freeze injury, but with a warming climate, fewer extreme freeze events are expected to occur (**Error! Reference source not found.**). However, sugar maple is not recovering in the same manner, with growth and regeneration still impacted by the acidic soils and calcium leaching.

As evident from other studies, as the climate warms, shoulder season temperatures are becoming more variable, as is annual precipitation amounts. However, precipitation is occurring more frequently in summer months and less as winter snowpack. These changes are impacting the vernal transition from frozen soils to rapidly warming in the spring, creating a greater gap in time between last day of snowpack and first day of full canopy (Figure 5). It is not yet known what implications this gap will have on the ecosystem.

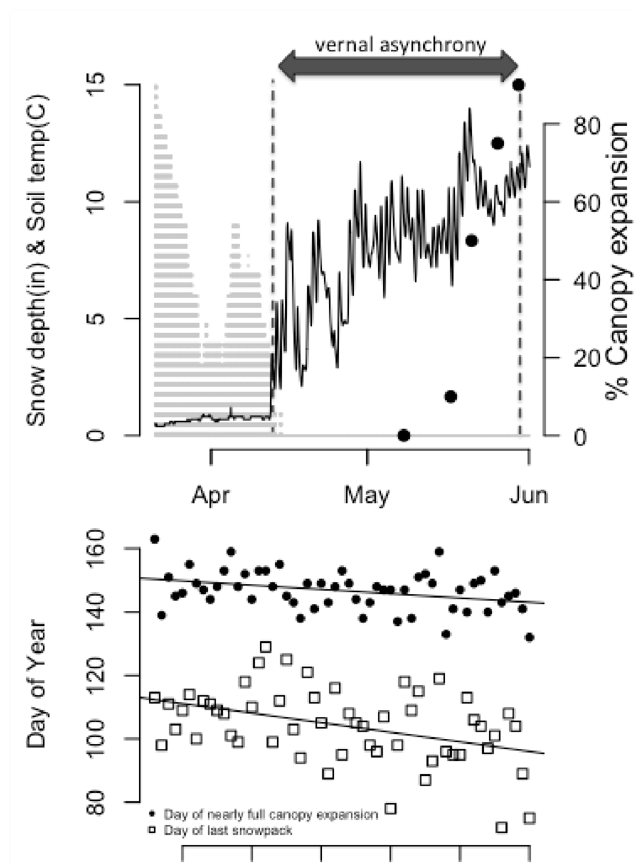



*Figure 5 The period between end of snowpack and end of tree canopy expansion is increasing, potentially leading to vernal asynchrony.*

The long-term monitoring conducted at Hubbard Brook provides valuable data to understand the regional impacts of acid rain as well as climate change. This long-term monitoring also provides the valuable foundation to develop research hypotheses and conduct experimental manipulations.

# Abstracts from Contributed Talks

## *FOREST PESTS & DISEASES*

**Trait variation and long-term population dynamics of the invasive Alliaria petiolata (garlic mustard) across three forest microhabitats**

Kristina Stinson[1], **Laura M.S. Hancock[1]**

[1]University of Massachusetts Amherst

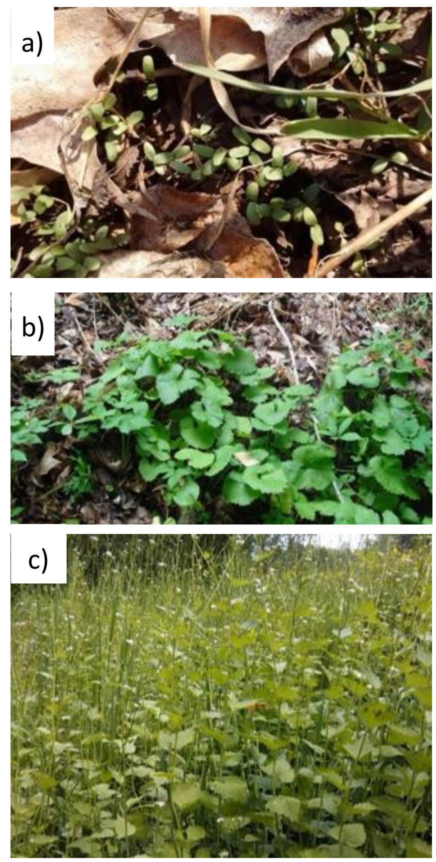



*Figure 6 Life stage of A. petiolata, garlic mustard: a) seedling; b) rosettes; c) reproductive adult plants*

Long-term population dynamics across heterogenous environments can be a major factor in determining species' ability to expand their ranges and persist in novel environments. Whether and how the relative performance of populations in different microsites over time impacts invasion into new microsites is poorly understood. Though largely restricted to disturbed semi-shaded microhabitats in its home range, the invasive herb garlic mustard (Alliaria petiolata) successfully invades intact forest understories in its introduced range, where it is known to impact above and below ground community composition. We conducted long term field surveys to evaluate trait variation, biomass allocation, and long-term population demographics of A. petiolata growing at the forest edge, within the intact forest understory, and in the intermediate transition zone between the two. Our results show that adult plants in the edge were taller and branchier, produced more fruits, and had higher total and reproductive biomass than plants in the intermediate and forest microhabitats. Over time, seedling density remained highest in the edge microhabitat compared to the forest and intermediate microhabitats, which had similar densities. Reproductive adult densities were similar among all microhabitats at the beginning of the study, but a decade later, all microhabitats exhibited a decline in the number of adult plants they supported. Populations in the intermediate microhabitat displayed the steepest decline in reproductive adults but supported more adult plants than the forest microhabitat. Populations in all microhabitats were predicted to grow ($\lambda>1$) at the onset of the study, and a decade later declines in population size were only predicted in the forest understory ($\lambda<1$). The edge and intermediate populations were still growing ($\lambda>1$) at the conclusion of the study. Since edge and intermediate patches had higher densities of adult plants which produced the most fruit and had larger reproductive biomass, it appears that the edge populations, and possibly the intermediate populations, have sustained the low-density forest populations through source-sink dynamics at our study sites. Eradication of garlic mustard populations in edge microhabitat could thus be an effective management strategy for reducing populations in the forest microhabitat.

**Impacts of Emerald Ash Borer Management on Northern Hardwood Forest Dynamics in New England**

**Hanusia Higgins**[1], Anthony D'Amato[1], Nathan Siegert[2],

[1]University of Vermont, [2]United States Forest Service

*Figure 7 Examples of treatment scenarios to mitigate Emerald Ash Borer.*

As non-native forest pests disperse across the United States, the emerald ash borer, Agrilus planipennis (EAB), has emerged as one of the most costly and destructive invaders. In response to EAB, forest management practices including pre-salvage logging, "phloem reduction" (large ash removal), and strategies to improve future ash regeneration have been implemented to meet economic, ecological, cultural, and safety objectives. Although many studies have quantified EAB's destruction of ash trees (Fraxinus sp.), less is known about the effects of the management response to this pest. In summer 2020, we measured forest structure and composition at sites across New England that represent a variety of approaches to mitigating EAB's destruction. We present preliminary findings on the range of ash removal treatments and consequences for regeneration and forest composition. This work will highlight effects of the response to EAB to guide management decisions and understand the broader impacts of this invasive pest.

**Hits, Misses and Incoming: A review of Federal and state pests of concern**

**Judy Rosovsky**[1]

[1]VT Agency of Agriculture, Food and Markets

This talk will provide a quick review and update on pests, including diseases, of national import that came through or near VT this past year, and one or two that may be coming our way. There is recent new information about spotted lanternfly biology and how will affect VT; Emerald ash borer potential deregulation and biocontrol release; elongate hemlock scale in northern VT and Asian Giant Hornets, aka 'murder hornets' are on the brink of establishment in WA. COVID may be affecting some regulatory processes and we have had several diseases narrowly miss VT, for now. And how will climate change affect these, if at all?

*Figure 8 Several invasive pests that are of concern in Vermont and the Northeast. a)* Ralstonia *symtoms on geranium, b) Sudden Oak Death, c) Asian Long-Horned Beetle.*

## *DISTURBANCE & STRESSORS*

### Red Pine Decline in Vermont

**Savannah Ferreira**[1], Emily Meacham[1]

[1]State of Vermont

*Figure 9 This monitoring site in Groton State Forest was established in 2019 to study the decline of red pine across Vermont.*

Red pine (Pinus resinosa) has been in a noticeable state of decline across Vermont for the past several years. Previously, foliar shoot blight pathogens such as Diplodia sapinea, Sirococcus conigenus, and Pestalotiopsis spp. have been found to contribute to this decline in central Vermont in 2019. To try and determine if this declining pattern and fungal complex are homogenous across the state, 12 red pine health monitoring sites were established in 2020 to annually observe crown health and tree decline. Monitoring sites were divided evenly among 4 geographical regions: Northeast (NE), Northwest (NW), Central (C), and Southern (S) Vermont. At each of the 12 monitoring sites, 4 permanent plots were established, each with a fixed radius of 35ft. All red pine within the plots were tagged and azimuth, location, diameter at breast height (DBH), and crown position were all measured and recorded. Crown metrics including live crown ratio, crown density, dead shoots and location, crown transparency, needle discoloration, and resinosis and location were observed and recorded for each tree. This year, 10 out of the 12 total plots were destructively sampled to assess foliar pathogens and insect stressors. Crown metrics as described above were observed on the sampled tree before felling. Standard red pine health metrics for an asymptomatic, open-grown red pine were established as having a crown density of 50%, dead shoots of 10%, crown transparency of 30%, and discoloration of 10%. Average crown density for the destructively felled and sampled trees were 45%, 5% less than standard; average dead shoots were 17%, 7% higher than standard; average crown transparency was 34%, 4% higher than standard; and average discoloration was 17%, 7% higher than standard. Felled red pine trees were micro-sampled on the main bole at DBH and symptomatic branches in the canopy with a sterile bone marrow biopsy tool, and symptomatic needles and cones were also harvested from the canopy. Needles and bark plugs were surface disinfested with a 1:9 commercial bleach: water solution (bark plugs for 14 minutes, needles for 3 minutes), and plated on potato dextrose agar with antibiotics. Fungal isolates were identified and subcultured as they appeared. Fungal isolates were identified based on morphology, and a representative subset has been sent out for PCR to confirm morphology identification. Across all sites, Diplodia sapinea was observed in both needle and branch tissue. Insect pests observed included signs of pine weevil gall (Podapion gallicola, 9/10 plots), pine needle scale (Chionaspis pinifoliae, 9/10 plots), and sawflies (9/10 plots). To determine how these insect stressors and pathogens have impacted growth over the past few years, cross-sections were taken at the base of live crown (BLC) and diameter at breast height (DBH) from the 10 sampled trees. This winter, FPR staff will be conducting tree-ring analysis to quantify any growth reductions these complexes may have caused.

**Extreme Weather Changes and Implications for Forest Health**

**Jason Shafer**[1], Kevin Cronin[2]

[1]Northern Vermont University, [2]Northview Weather

*Figure 10 Tree damage following a wet snow storm.*

This presentation will highlight results from a long-term examination of extreme weather trends across Vermont and their possible impacts on forests. Extreme weather such as ice, wind, and snow storms and their yearly, decadal, and long-term trends will be described. This work is being conducted with support from electric utilities to understand how climate change affects long-term planning for the electric grid. Dynamical downscaling of two climate simulations through 2050 examining the frequency and intensity of extreme storms (wet snow, ice, and wind) will be described. This work has direct application to forests as weather-caused power outages are predominantly caused by tree conflicts in right of ways. Speculation on the implications for long-term forest health and resilience to catastrophic storms will be shared.

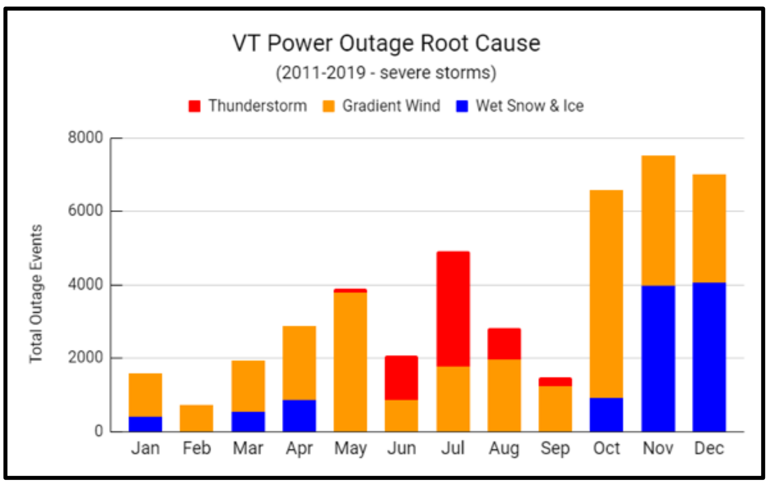



*Figure 11 Severe storm days were defined as at least 100 or more outage events statewide (n=169) - about 18 days per calendar year. Most storm events do not produce catastrophic forest damage.*

**And now for something completely different...Climate change effects on forest fire hazards in the wildland-urban-interface of Bhutan**

**William Keeton**[1], Lena Vilà Vilardell[2], Dominik Thom[3], Choki Gyeltshen[4], Kaka Tshering[5], Georg Gratzer[2],

[1]Rubenstein School of Environment and Natural Resources, University of Vermont, Burlington, Vermont, USA

[2]Institute for Forest Ecology, University of Natural Resources and Life Sciences (BOKU), Vienna, Austria

[3]Ecosystem dynamics and forest management group Technical University of Munich, Germany

[4]National Biodiversity Centre, Thimphu, Bhutan

[5]Institute for Conservation and Environmental Research, Bumthang, Bhutan

With the United States coming out of one of the worst fire seasons in history, there is increasing urgency around adaptation through fire restoration and fuels treatment, particularly within the Wildland-Urban-Interface (WUI) where human lives and infrastructure are most at risk. Understanding climate vulnerabilities are central to this response, and it is informative for forest managers to compare with similar efforts abroad. In the Himalayan Mountains of Bhutan, for example, fires play a formative role in blue pine (Pinus wallichiana) ecosystems but are also changing with shifting land-use patterns. Our research has investigated the climatic, social, and ecological drivers of fire behavior and risk. The most recent study examined fire hazards in the WUI, focusing on two valleys in Bhutan (Thimphu and Jakar) where expanding human settlements and infrastructure, including cultural sites of global significance, are surrounded by blue pine forests. Data characterizing fuel profile and other risk factors were collected from 102 field inventory plots. We then applied FlamMap, a spatially-explicit wildfire simulation model, to simulate forest fire behavior under four climate scenarios. Climate scenarios were based on climate change projections for the Himalayas (symbolizing scenarios of monsoon failures and warmer temperatures) and built with extreme values of temperature and relative humidity from the years 1996 to 2017. The FlamMap output indicators used for assessing fire behavior were flame length, rate of spread, crown fire activity, burn probability, and fire size. After integrating FlamMap output into a common fire hazard index, we created a fire hazard map showing the areas most susceptible to forest fires. FlamMap predicts a likely two-fold increase in fire hazards in the WUI for both study areas due to climate change. The capital city of Thimphu has greater fire hazards than Jakar; fire hazards are spatially variable over both study areas. Our results highlight parallels between increasing forest fire hazards in the Himalayan Mountains and those unfolding in western North America. Results can be used to better plan suburban development to minimize fire risks in the WUI, plan fire restoration treatments, allocate firefighting resources, and otherwise adapt forest management efforts in the face of climate change. Certainly the methodological approach is also relevant to predicting climate-fire vulnerabilities in parts of the Northeast, such as oak-pine forest types in southern New England.

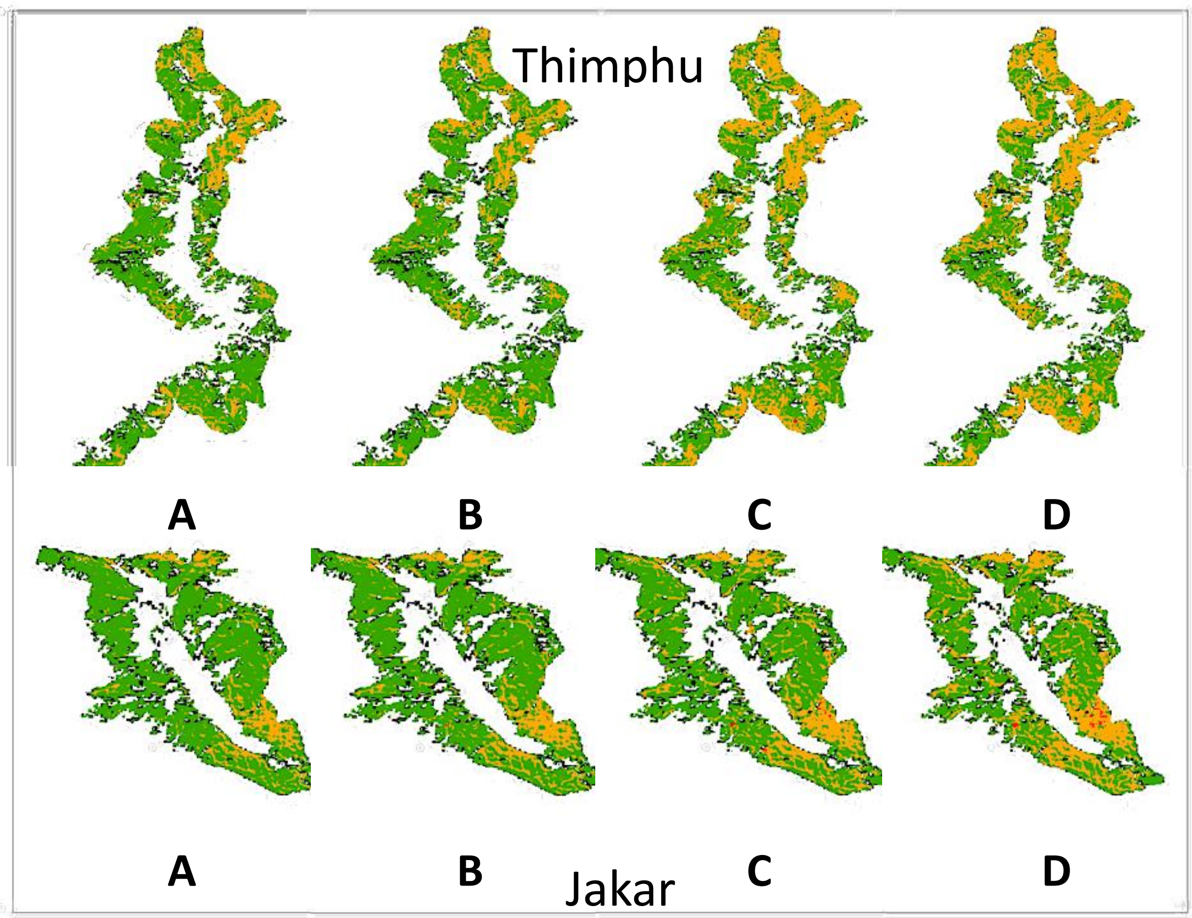




*Figure 12 With the construction of the fire hazard map we were able to determine the regions that are more prone to fire in each area. Under all scenarios most part of both valleys is categorized as having a "moderate" fire hazard.*

## Spruce DRIED: Density Reduction and Imposed Extreme Drought

**Kelly French**[1], Heidi Asbjornsen[2], Shawn Fraver[1], Laura Kenefic[1,3], David Moore[2], Matthew Vadeboncoeur[2], Jay Wason[1]

[1]University of Maine

[2]University of New Hampshire

[3]USFS

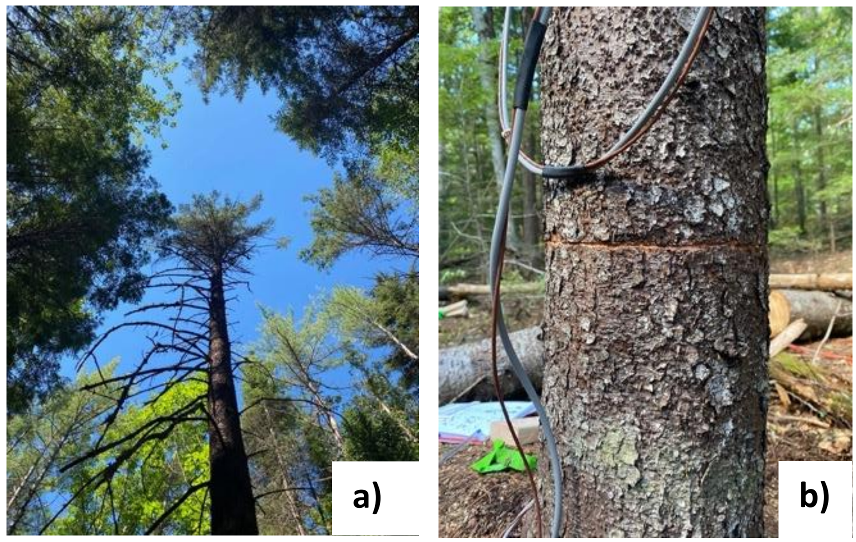



*Figure 13 Project treatments: a) thinning, b) phloem girdled.*

Climate change is expected to drive increased temperature, vapor pressure deficit (VPD), and frequency of drought, even in the mesic forests of the northeastern United States. Importantly, many northeastern trees are not tolerant of warmer temperatures or drought, potentially increasing their vulnerability to even minor changes in climate. Thinning forests reduces competition for water and can reduce drought effects. However, thinning may also have negative impacts as it can increase canopy temperature and exposure of residual trees. The goal of this study was to test how thinning and extreme drought influence the water relations of red spruce (Picea rubens), to better inform management of this species with climate change. We created a factorially designed novel experiment to manipulate competition (by thinning) and water availability (by severing sapwood) for eight suppressed spruce trees (breast-height diameters 16-26 cm). We monitored tree water use, water potential, relative water content, leaf photochemistry, stomatal conductance, and microclimate from June through November 2020. We found limited impacts of thinning on tree water use. However, thinning increased light availability (+70% canopy openness), daily maximum temperature (+2.46°C), and daily maximum VPD (+0.64 kPa) compared to non-thinned controls. These environmental changes lead to more negative mid-day leaf water potential for 3 weeks, and the transition to high-light conditions lowered the photosynthetic efficiency of leaves by 5-17% for the rest of the growing season. The experimentally imposed drought led to rapid reductions in sap flow that were proportional to the amount of sapwood severed. Trees experiencing an extreme drought (100% reduction in sap flow), surprisingly showed no clear signs of water stress for 12 weeks. However, these trees had significantly reduced stomatal conductance, lower mid-day leaf

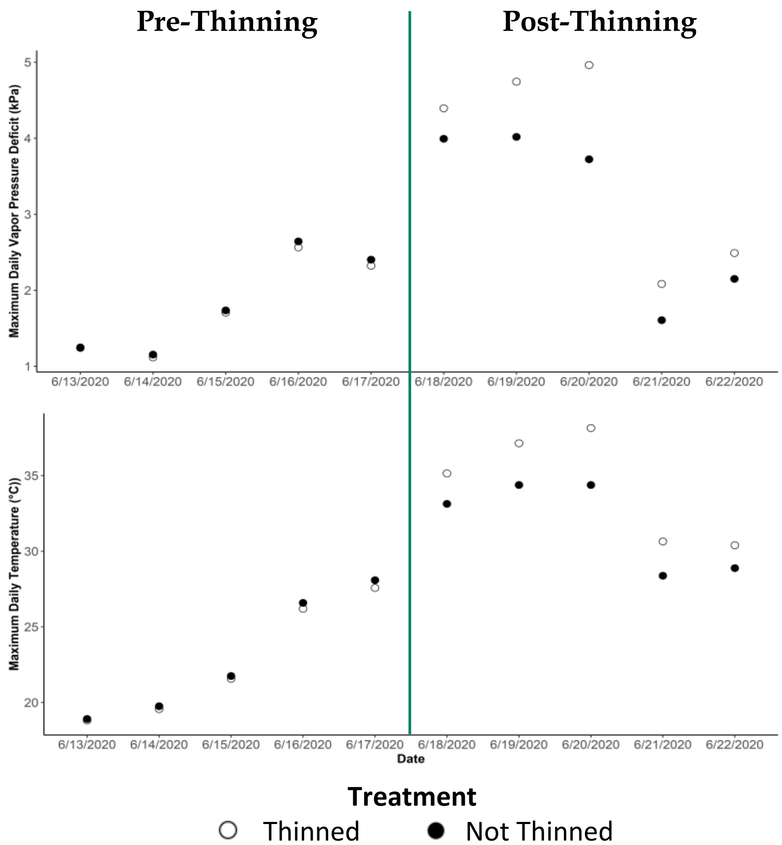



*Figure 14 Thinning Drives Increased Temperature and Vapor Pressure Deficit*

water potential, and lower trunk-wood relative water content compared to the controls, suggesting reduced photosynthesis to favor water conservation. This research suggests that although thinning did not influence whole-tree water use, the rapid transition from low- to high-light conditions negatively impacted photosynthesis and carbon relations. Red spruce appears to be relatively resistant to the extreme drought with a very conservative water use strategy. Also, trees that experienced 60-73% reductions in sap flow due to partial sapwood severing did not show signs of water stress for the duration of the experiment, suggesting even a small area of intact sapwood is sufficient to support the species' water transport needs. Importantly, this conservative water-use strategy likely comes with a major opportunity cost for carbon gain, as the tightly closed stomata limit photosynthesis. These novel findings advance our understanding of potential climate change impacts on red spruce, and how silvicultural practices may mitigate or exacerbate the effects of future climates.

## *Tools & Technology*

### Modeling Moose Habitat Suitability by Age, Sex, and Season in Vermont, USA based on GPS Radio-collar Data and Lidar Imagery

**Joshua Blouin**[1,2], Jacob DeBow[1,2], Elias Rosenblatt[1,2], Cedric Alexander[3], Katherina Geider[3], Nicholas Fortin[3], James Murdoch[2], Therese Donovan[1,2],

[1]U.S. Geological Survey, Vermont Cooperative Fish and Wildlife Research Unit,

[2]Rubenstein School of Environment and Natural Resources, University of Vermont

[3]Vermont Fish and Wildlife Department

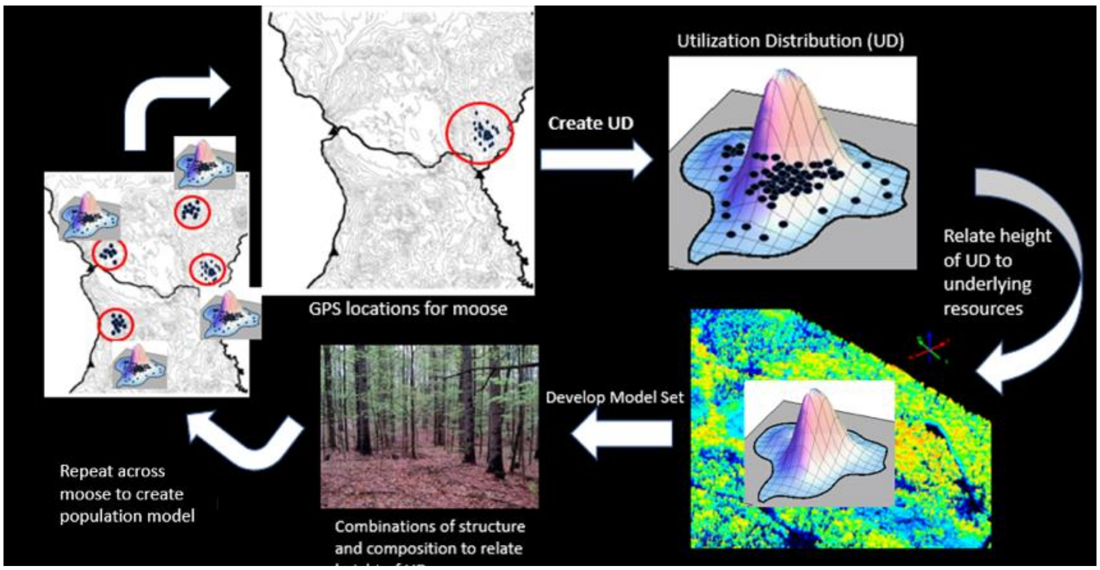



*Figure 15 LiDAR mapping was used to identify suitable moose habitat across Vermont.*

The moose (Alces alces) population has experienced unprecedented declines along the southern periphery of its range, attributed in part to winter tick (Dermacentor albipictus) epizootics. Direct management through hunter harvests has been suggested to reduce moose density and the number of ticks on the landscape, while indirect habitat management may be used to improve the status of the population and health of individuals. We combined more than 41,000 moose locations collected from radio-collared individuals (n = 74), recent land cover data, and high resolution, 3-dimensional lidar data to develop Resource Utilization Functions that link home range use to habitat conditions by age (mature and young adult), season (dormant and growth), and sex. Across analyses by sex, season, and age, the top resource utilization function models included both composition (as measured through the National Land Cover Database) and structure variables (as measured through lidar), and significantly outperformed models that excluded lidar variables. Generally speaking, female moose actively used areas with proportionally more regenerating forest (i.e., forage < 3.0m) and canopy structure (>6.0m), while males actively used more high elevation, mixed forest types. The resultant maps of habitat suitability provide a means of informing management activities (e.g., the restoration or alteration of habitats to benefit moose) and policies around land use that can contribute to population recovery.

**Plots to Pixels to Policy: The Intrepid Journey of a Wall-to-Wall Forest Carbon Monitoring and Assessment System**

**Chris Williams**[1]

[1]Graduate School of Geography, Clark University, Worcester, Massachusetts, USA

Forests are recognized as a key component in nature-based solutions for mitigating climate change, with co-benefits across a portfolio of ecosystem services. Thus, U.S. state and regional land managers and policymakers seek actionable information to aid in the design, implementation and evaluation of plans to put these carbon management opportunities into play. This presentation introduces a national-scale forest carbon monitoring and assessment system (NFCMS) that serves as a baseline inventory for greenhouse gas reporting and as a tool for assessing local to regional climate change mitigation opportunities in the forest sector. The method synthesizes FIA yield curves, remote sensing of biomass and disturbances, and a carbon cycle model to quantify baseline drivers and trends in forest carbon stocks, emissions and uptake at a wall-to-wall 30 m resolution. We highlight state-level carbon stock and flux trends, expected future carbon sequestration, and the role of harvest removals across New England plus New York. We also assess the potential climate benefits of avoided deforestation, reforestation, and sustained forest growth and utilization across the region. Concluding discussion examines challenges that remain in preparing the scientific basis for informed decision making about the global climate benefits achievable in the forest sector.

**Using electrical circuit analysis to map landscape connectivity for wildlife in Vermont: Implications for transportation planning and mitigation**

**Caitlin Drasher**[1], James Murdoch[1]

[1]University of Vermont

Landscape connectivity is important for the persistence of wildlife populations, allowing for genetic exchange and access to resources needed for population growth. The natural landscape is becoming progressively fragmented by human development, impeding the ability of species to move between habitats. Understanding how wildlife move throughout the landscape in response to land cover and human development variables is critical for mitigating the negative impacts of fragmentation on populations. We are using electrical circuit theory to model and map the movement of terrestrial mammals throughout Vermont. This approach treats the movement of wildlife as the flow of electricity through a circuit, while incorporating wildlife occurrence and species-specific landscape resistance data to determine probable movement paths. Resulting maps indicate areas where wildlife movement is being concentrated, and these areas may be targeted for conservation and mitigation efforts to improve landscape connectivity. Our analysis specifically seeks to mitigate the impact of roads on wildlife populations by determining which

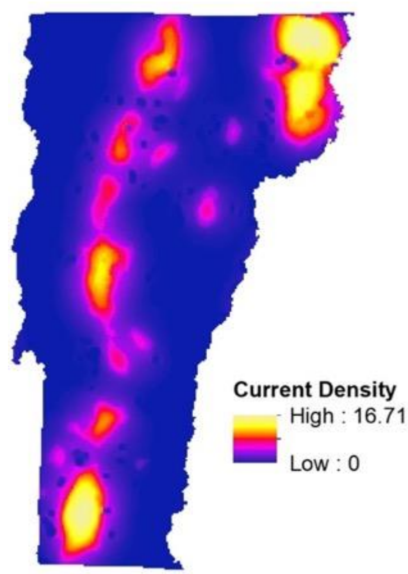



*Figure 16 Wildlife movement flow opportunity for marten.*

transportation structures are located in critical connectivity areas for wildlife. This information will be incorporated into a broader Terrestrial Organism Passage Screening Tool, used by transportation managers to make decisions on improving structures to promote wildlife use. We will discuss the use of circuit theory modeling to identify important connectivity areas in the landscape, and how this information can be used to improve transportation infrastructure to increase permeability across road networks. This project is in collaboration with the Vermont Agency of Transportation, The Nature Conservancy in Vermont, Vermont Fish and Wildlife Department, and University of Vermont.

**Monitoring Stream Connectivity with Trail Cameras**

Christopher Bellucci[1], Mary Becker[1], **Melissa Czarnowski[1]**, Corinne Fitting[1]

[1]Connecticut Department of Energy & Environmental Protection

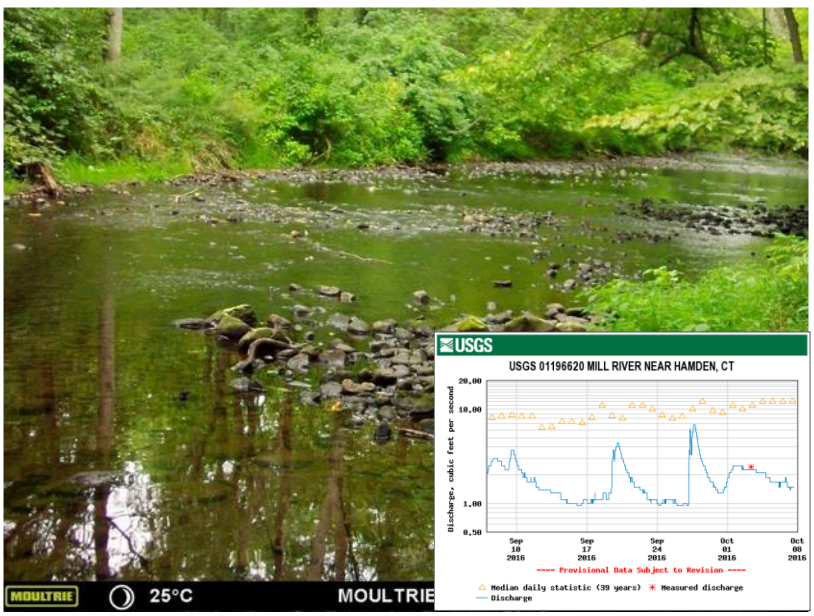



*Figure 17 Trail camera photo of a connected stream with the stream gauge data for comparison.*

Stream connectivity is important for the ecological health of the stream and downstream waters. In this study, we use the term stream connectivity to mean hydrologically connected pools and riffles that link stream habitat along a longitudinal continuum (upstream to downstream), while also recognizing the lateral dimension (connection to flood plain) and vertical connection to groundwater. There are thousands of man-made structures (i.e. dams, culverts, surface and groundwater withdrawal locations) in Connecticut which negatively impact stream connectivity and can result in aquatic habitat fragmentation. Cost-effective techniques are needed to assess human alteration to streams in order to prioritize management actions to restore stream connectivity. We developed a method to characterize stream connectivity using commercially available trail cameras that cost less than approximately $500 per deployment (Figure 17).

We developed a six-category system to describe the variations in stream connectivity observed using the trail camera images. We then used the categorical data to calculate metrics that quantify stream connectivity. To pilot this approach, we evaluated reference locations with minimal anthropogenic influence on stream connectivity in comparison with stream reaches likely to be impacted by nearby groundwater wells. We found that metrics derived from trail camera images were useful to quantify stream connectivity (Figure 18). We anticipate that the methods outlined herein is a useful stream connectivity assessment tool that can be effectively communicated to scientists and non-scientists. All source code and data for this project are freely available and open source at: link https://github.com/marybecker/streamconnectivitymetrics.

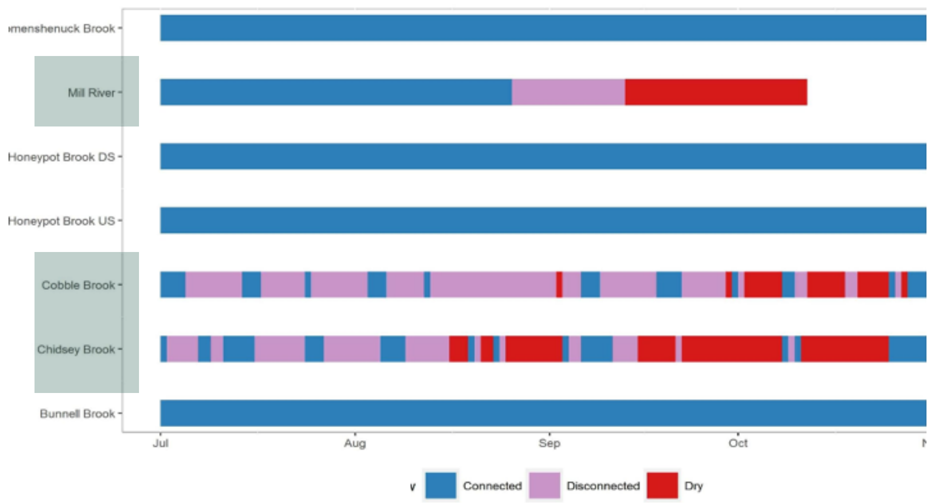



*Figure 18 Connected, disconnected, and dry categories assigned to seven streams using trail camera photos.*

## *WILDLIFE*

**Moose Habitat Selection and Fitness Consequences During Two Critical Winter Tick (Dermacentor albipictus) Life Stages in Vermont, USA**

**Joshua Blouin**[1,2], Jacob DeBow[1,2], Elias Rosenblatt[1,2], James Hines[3], Cedric Alexander[4], Katherina Gieder[4], Nicholas Fortin[4], James Murdoch[2], Therese Donovan[1,2],

[1]U.S. Geological Survey, Vermont Cooperative Fish and Wildlife Research Unit,

[2]Rubenstein School of Environment and Natural Resources, University of Vermont

[3]USGS Patuxent Wildlife Research Center

[4]Vermont Fish and Wildlife Department

Moose (Alces Alces) are a charismatic species that has been in decline across much of their southern range. In New England, USA, the reduction has been attributed, in part, to winter tick (Dermacentor albipictus) infestations. Winter ticks tend to be fairly immobile throughout all life stages, and therefore their distribution patterns at any given time are shaped largely by the occurrence of moose across the landscape during the peak of two critical time periods; fall questing (when ticks latch onto a moose, which coincides with the rut) and spring drop-off (when engorged female ticks detach from moose and lay their eggs in leaf litter). We used recent land cover and lidar data within a dynamic occupancy modeling framework to estimate first-order habitat selection (use vs non-use) of female moose (n = 74) during the questing and drop-off periods. Patch (1 km2) extinction and colonization rates during spring drop-off periods were strongly influenced by habitat and elevation, but these effects were diminished during the questing period when moose were more active across the landscape. In the spring drop-off period, patches where colonization was high and extinction low (highest probability of female moose occupancy) had higher proportions of young (shrub/forage) mixed forest at greater elevations. We evaluated the fitness consequences of individual-based habitat selection (second-order habitat selection during the tick questing period) by comparing Resource Selection Functions (RSF) for 5 females that successfully reared a calf with 5 females whose calf perished. Second-order habitat selection analyses showed adult female moose whose offspring perished selected patches during the questing period that matched the first-order selection during the spring drop-off period. In contrast, adult female moose whose offspring survived selected areas with proportions of young deciduous habitats, as well as higher proportions of mature (canopy) evergreen forests and wetlands at lower elevations, i.e., their second-order habitat selection patterns deviated from the overall patterns illuminated by the multi-season occupancy analysis. Our model coefficients and mapped results define "hotspots" that are likely encouraging the deleterious effects of the tick-moose cycle (Figure 19). Knowledge about the composition and structure of these hotspots may influence more direct (i.e. hunter harvest) and indirect (i.e. conservation, modification, or formation of habitats) management decisions.

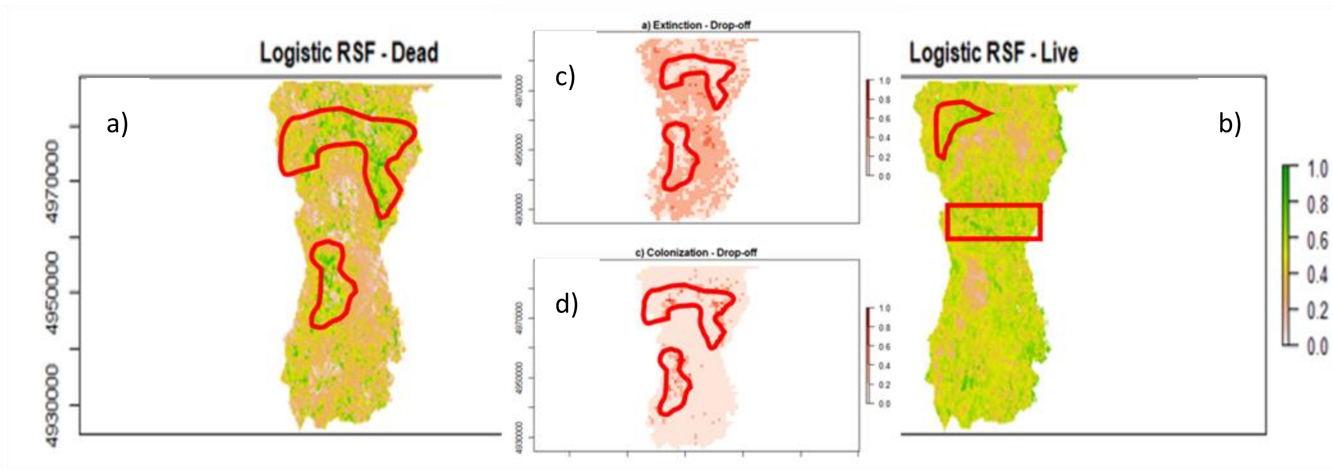



*Figure 19 Areas where moose calves a) died and b) survived as well as locations with tick c) extinction and d) colonization.*

**Community trends in forest bird abundance within northeastern National Parks**

Jeffrey Doser[1], **Aaron Weed[2]**, Elise Zipkin[3], Kathryn Miller[2], Andrew Finley[1],

[1]Department of Forestry, Michigan State University

[2]Northeast Temperate Inventory and Monitoring Network, National Park Service

[3]Department of Integrative Biology, Michigan State University

Since 2006 the Northeast Temperate Inventory and Monitoring Network (NETN) of the National Park Service, with the assistance of local partners and a large volunteer base, has conducted annual monitoring of forest birds in nine national parks located from Maine to New Jersey. In this study, we estimated trends in bird abundance and the effects of local forest structure on their abundance from this monitoring program using a novel hierarchical model that accounts for imperfect detection. A multi-species, multi-region removal sampling model was developed that shares information across species and parks to enable inference on rare species and in sparsely sampled parks. The model indicated that trends in bird abundance over time varied widely across parks, but species and guilds showed similar trends within the same park. The analysis indicated significant declines in bird abundance at three parks (Acadia National Park and Marsh-Billings-Rockefeller and Morristown National Historic Parks (NHP)) and significant increases at three others (Saratoga NHP and Roosevelt-Vanderbilt

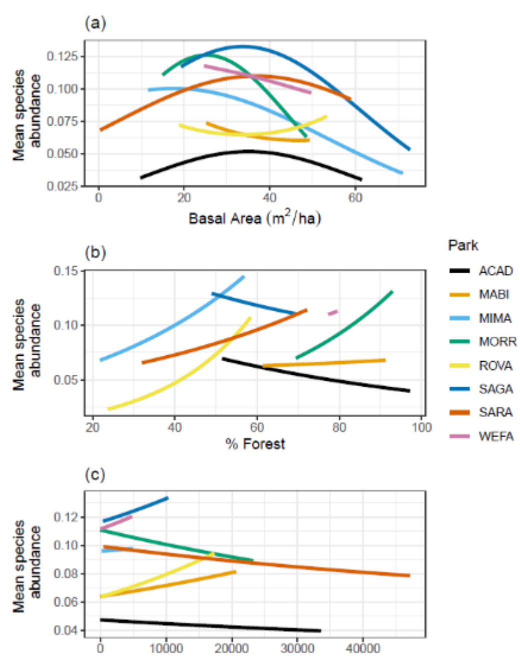



*Figure 20 Effects of forest structure on mean species abundance (from Boser et al., in review, Ecol. App.).*

and Weir-Farm National Historic Sites). Unfortunately, the fastest declines over time in bird abundance occurred in the bird communities reflective of higher ecological integrity (i.e. parks with more forest specialists). Bird abundance was most strongly associated with local forest cover (% forest within 1km around sites) but was also related to basal area and regeneration (Figure 20). The consistency we observed in trends within a park suggests that local forest condition may have a broad and consistent effect on the entire bird community and further analyses are needed to determine the driver(s) of these trends.

### Lady Beetles of Vermont: Invasions, Extirpations, and Recent Discoveries from Community Scientists

**Julia Pupko**[1,2], Kent McFarland[1],

[1]Vermont Center for Ecostudies

[2]ECO AmeriCorps

Many studies in North America have reported that lady beetle (Coccinellidae) species assemblages have undergone dramatic changes over the past 50 years, likely due to the introduction of exotic lady beetle species. Some native lady beetles may now be extirpated from parts of their range. Despite these alarming trends, lady beetles have been little studied in Vermont following the publication of a checklist and county record project that was completed in 1976. We digitized historic and modern lady beetle records from literature, museum collections, and crowd-sourced databases to assess the current status of lady beetles in Vermont (Figure 21). Of Vermont's 33 native species, ten have not been recorded since the completion of the 1976 checklist. In 2015, three of the species that remain missing from Vermont were designated as "species of greatest conservation need" in New York: Two-spotted Lady Beetle (Adalia bipunctata), Nine-spotted Lady Beetle (Coccinella novemnotata), and Transverse Lady Beetle (C. transversoguttata). The Nine-spotted Lady Beetle was recently declared "Endangered" in Canada. These designations emphasize the urgency for mapping Vermont's lady beetle species.

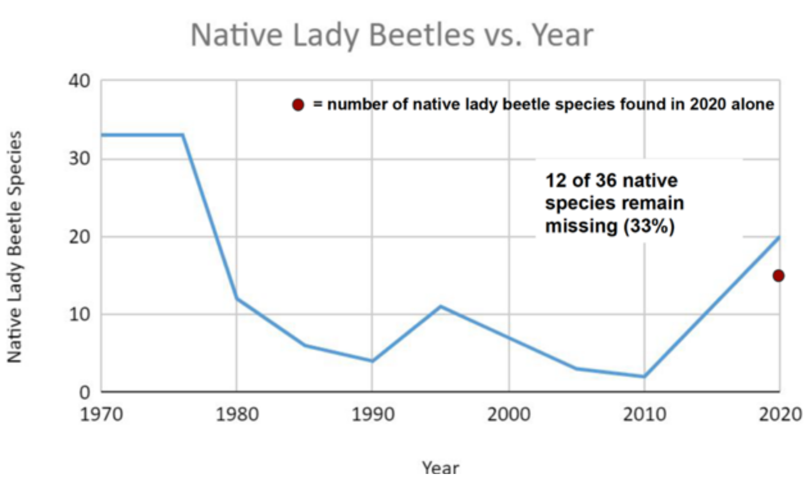



*Figure 21 Number of native lady beetles found in Vermont annually.*

In 2020 we piloted the Vermont Lady Beetle Atlas, which will be expanded throughout the state in 2021. This project is modeled after other successful projects with the Vermont Atlas of Life as well as the Lost Ladybug Project at Cornell University, which successfully found two species of lady beetle previously thought to be extinct in New York. Using a citizen science framework will allow for a greater chance of discovering more missing lady beetles while engaging Vermonters of all ages in science and natural history. We have already had great success with volunteer data: volunteer community scientists have recently rediscovered three species that had previously been lost for over 40 years. Additionally, volunteers have discovered three new species for the state.

While understudied and difficult to find, several species of lady beetle are vital to Vermont's forest health. Due to the critical pest control role played by lady beetles in Vermont's ecosystems, it is important to understand how these species are faring in Vermont so conservation measures can be implemented if needed before it is too late.

## *Long-Term Monitoring*

**The applications and utility of a unified continuous forest inventory network in Northeastern United States.**

**Soren Donisvitch**[1], Jennifer Pontius[1], Anthony D'Amato[1], Jim Duncan[1], Alexandra Kosiba[2], Aaron Weiskittel[3]

[1]University of Vermont, Rubenstein School of Environment and Natural Resources

[2]State of Vermont, Department of Forest, Parks and Recreation

[3]University of Maine

There are numerous continuous forest inventories (CFI) that have recorded forest conditions across the Northeastern United States for the past several decades. Although these efforts have often been focused on a limited geographic domain or set of forest conditions, integration of multiple, long-term inventories provides a unique opportunity to inform regional forest management and scientific applications. The NEFIN project was developed as a collaborative effort led by the FEMC to create a truly unified and application-driven database (Figure 22). This presentation will provide an overview of the infrastructure and preliminary results of standardization across a subset of programs and demonstrate the potential utility of this new network for research on the region's forests. From regional forest stand dynamics to localized growth and yield curves, this comprehensive data resource will provide forest land managers and researchers an instrumental tool in furthering the study and monitoring of forests in the Northeast.

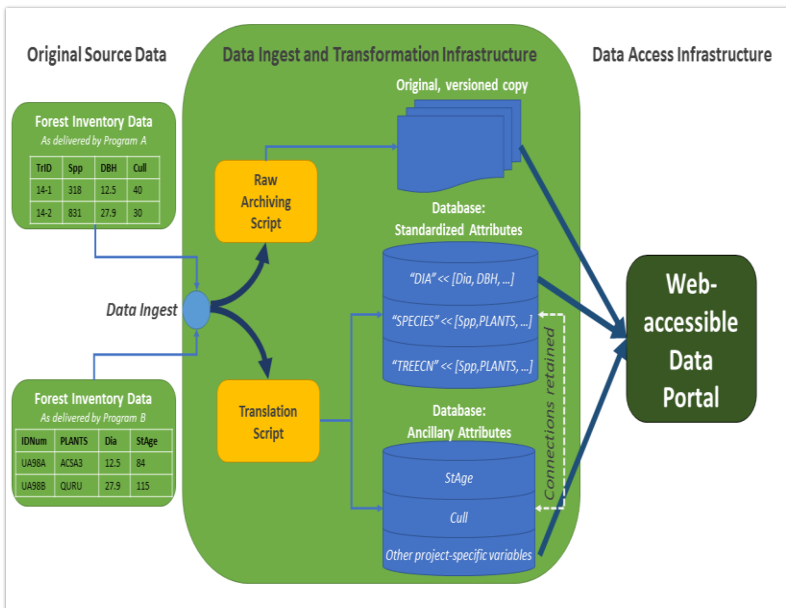



*Figure 22 Data processing to make accessible in a web portal.*

**Variability in forest conversion rates and drivers across a diverse socio-ecological landscape: a Vermont Regional Planning Commission case study**

**Jennifer Pontius**[1], James Duncan[1], Alison Adams[1,2],

[1]University of Vermont, Rubenstein School of Environment and Natural Resources,

[2]University of Vermont Gund Institute

Much work has been done to understand the pressures that development places on the forested landscape, but most studies cover broad geographic regions heavily weighted towards urban expansion patterns. We set out to understand how the drivers and rates of forest conversion differ across the landscape by examining historical changes in forest cover across 13 smaller Planning Commission Regions across the state of Vermont (Figure 23). Our objectives were to: (1) quantify and map historical changes in forest cover, (2) identify spatial correlates associated with forest conversion to development and (3) examine how rates and drivers of forest loss differ across the landscape. Historical analysis shows a pattern of decreasing forest area and increasing fragmentation metrics across the region, although rates of change vary spatially and temporally. The most highly ranked drivers of forest conversion were related to proximity to roads, but the class of road differs across planning regions. Other population and topographic variables were important in different regions, indicating the differential nature of development pressures across heterogeneous socio-ecological landscapes. This study highlights the importance of using smaller scale models to understand the drivers of forest conversion in order to best inform local planning and sustainably manage important forest resources.

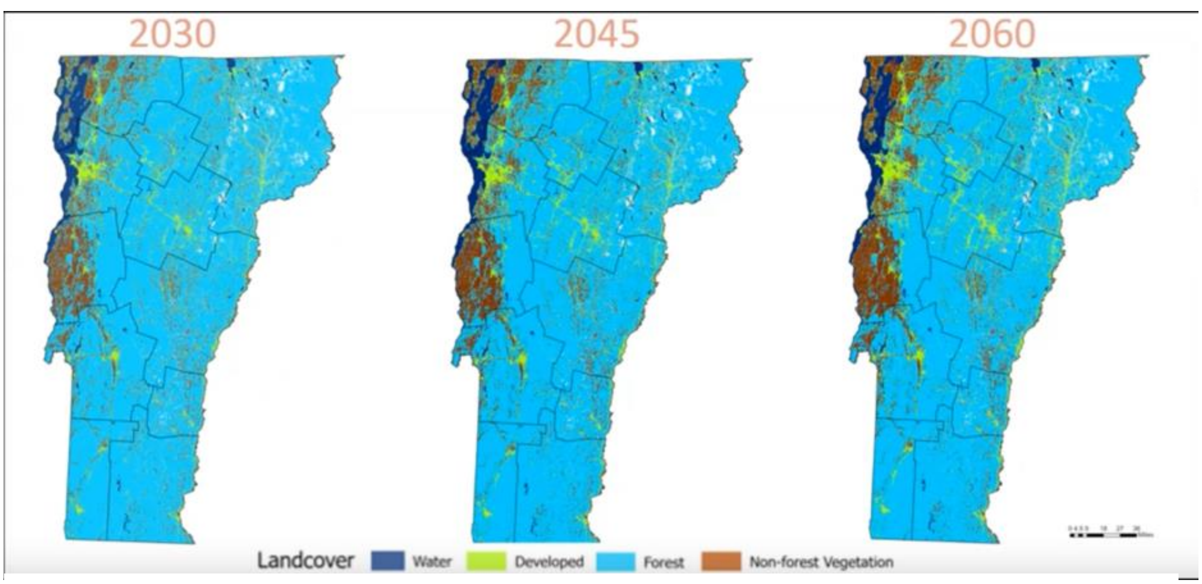



*Figure 23 Drivers of historical forest conversion were used to develop models for risk of future conversion.*

**Completing the Life Cycle of Trees: Northern Forest Dead Wood and Tree Regeneration in the Context of Forest Resource Assessments**

**Christopher Woodall**[1]

[1]USDA Forest Service

Strategic scale assessments of forest resources are often focused primarily on live tree (sapling to sawtimber populations) attributes such as diameter distributions and species composition. Missing from these assessments are the "tails" of the tree life cycle including regeneration (i.e., birth) and dead wood (i.e., death). Comprehensive assessments of such tails of the tree life cycle may refine our understanding of the future forest (i.e., tree seedlings) and carbon/structural/habitat implications (i.e., standing and down dead wood). Starting in ~2012, the Forest Inventory and Analysis program of the USDA Forest Service, began a northern region wide inventory of tree seedlings and downed dead wood as a compliment to the standing tree inventory which now enables evaluation of live tree dynamics in the context of these tails of their life cycle (Figure 24). The initial results of these "cradle to grave" inventories in the context of a comprehensive assessment of northern forests will be presented.

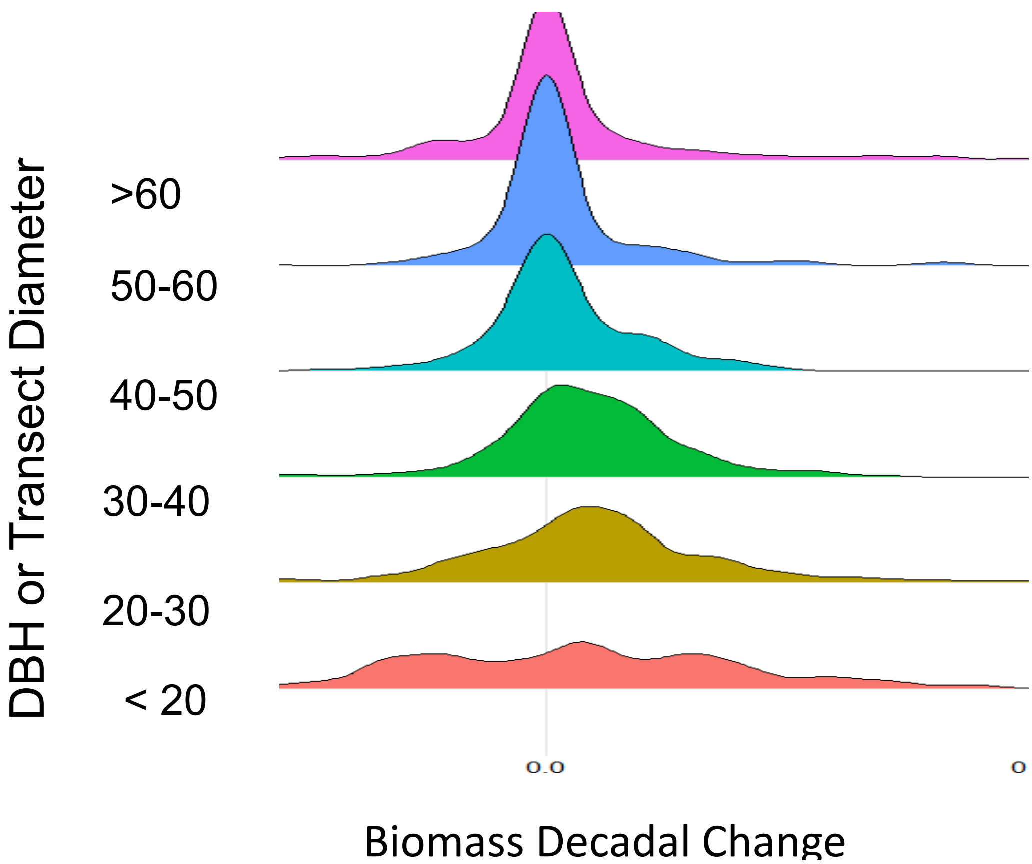



*Figure 24 Decadal change in DBH of downed dead wood from sites across the U.S.*

## *Forest Ecosystems*

### Forests to Faucets 2.0

**Rebecca Lilja**[1]

[1]USDA Forest Service

Forests to Faucets 2.0 builds upon the national Forests to Faucets (2011, https://www.fs.fed.us/ecosystemservices/FS_Efforts/forests2faucets.shtml) by updating base data and adding new threats including wildfire, invasive pests, and future stresses such as climate-induced changes in land use and water quantity. The project assesses subwatersheds across the US to identify those important to downstream surface drinking water supplies as well as evaluate a subwatersheds natural ability to produce clean water based on its biophysical characteristics: percent natural cover, percent agricultural land, percent impervious, percent riparian natural cover, and mean annual water yield.

### The FEMC Sampler: New releases of regional data and tools from the Cooperative in 2020

**James Duncan**[1]

[1]Forest Ecosystem Monitoring Cooperative

Did you miss the launch of an FEMC tool, or always mean to go back and catch that webinar to learn more about what we're up to? Get the digest version by attending our 2020 retrospective on some of the big regional tools and data releases from the year past in bit-sized servings. We will touch on resources for tracking forest regeneration, the economic threats to urban forests from pests, new spatial data compilations connecting forest cover and water quality, and data rescued and in need of rescuing, as well as some of our state projects around clearcut tracking, forest health monitoring and trailhead invasion risk (Figure 25). We promise no more than 15 slides and at least one good joke, so take this chance to find out a little about a lot, and get connected to quick links and resources to learn more after the session.

*Figure 25 Four FEMC developed tools available for use.*

# Facilitated Sessions

**FEMC LISTENING SESSION: HELP SHAPE THE FUTURE OF THE COOPERATIVE**

The Forest Ecosystem Monitoring Cooperative turns five next year, and 2021 represents 30 years since the founding of the Vermont Monitoring Cooperative. With the FEMC set to expand again in its work and complexity, we invite all collaborators, from founding members to the newly interested, to join a listening session to share their hopes for the Cooperative and help shape its future in the years ahead. Through a series of guided breakouts and group discussions, this session will focus on what the environmental monitoring and assessment agenda of the Cooperative should include going forward, how best to leverage FEMC for the support of monitoring efforts in the region, and identifying the current and pressing needs in long-term monitoring of change of our large and diverse community. The outcomes of this session will be used to directly inform the FEMC's 5-year strategic planning session that begins in January, 2021, so please join us at this important moment in the evolution of your Cooperative!

**Summarized notes from the breakout room discussions:**

*Breakout session 1: What are the needs of a regional cooperative?*
*Group 1*

- Incorporate community scientists so monitoring initiatives come from community stakeholders
- Facilitate communication
- Prioritize efforts – identify the most pressing issue and keep a regional focus on it
- Engage with communities on common grounds across the region (between scientists and citizens)
- Share and assist in infrastructure approaches to make data sharing easier
    - Provide documentation on best practices
    - Provide training
    - Provide assistance in bringing disparate or old systems to something more uniform
- Facilitate conversations across cooperative members
    - This is a bigger part of what the cooperative does
    - Create and facilitate more opportunities for sharing, collaborating
- Facilitate connection across the community
- Standardize across multiple efforts
    - Cross communication between steps on the web of ecological practitioners
- Socially and professionally connect people
- Act as a data hub
    - Provide easy access to keep policy and decision makers informed on forest issues
- Build on existing tools to integrate into management and add to for relevancy to management
- Draw in private lands – how do we monitoring them?
    - Provide protocols and data collection systems the smaller groups can use to then feed back into the larger system

*Group 2*

- Can a group help standardize across the various efforts. So much is happening in parallel
- Can we better bridge the gap between monitoring and research work/funding/feedback (take methods developed by research and apply/promote them more widely
- Promotion of best management practices for practitioners.
- Identifying gaps and needs (for example BMPs for invasive plants)…. connection to action on the ground
- Connecting from research to practitioners and land owners Both trickle up and trickle down. Can we promote more social media. COVID as a silver lining to reach more people. Chittenden Country Forester Ethan Tapper.
- Finding ways to connect people (socially and professionally).
- Types of issues a regional cooperative should work on:
- Invasives – plants and pests/pathogens
- Sufficient data to represent the landscape, ecozone and ownership types

*Group 3*

- There is a power of group with FEMC - ability to reach broad audience
    - Provide framework – protocols, data collection tools
- VT is too big to focus efforts (VT Family Forests Networks) – focus on specific portion of state to connect people who love the place – using citizen/commoner science
    - Relates to what public lands are doing – what are private lands doing differently?
    - Closer to home to make a platform for action
- Cooperative that can understand how we are with the landscape – more wild forest in Vermont
    - Monitor how we are doing on carbon sequestration, water quality – relate monitoring to what is actually happening on the land.

*Breakout session 2: What is FEMC doing now that it should absolutely keep doing? Are there opportunities that FEMC has missed in the recent past? What other successful efforts should be studied for potential lessons? What was a successful outcome of the recent past?*

*Group 1*

- What is one thing FEMC is doing now that it should absolutely keep doing?
    - The conference and the connection - highlight
        - Catch up with what's happening

- Are there any opportunities that FEMC has missed over the recent past?
    - Engaging non academics/manage, citizens science and private land
    - Private lands!
        - Engaging public in the conference
    - Leaving out social sciences
    - Potentially missing diversity in conversations on what we want to know because of our focus on a particular approach to science. Who's questions get asked/heard and who's don't

- What other successful efforts or models from the recent past should be studied for potential lessons?

- Bring different aspects of forest ecosystems together
    - Holistic approach/synthesizing knowledge in a comprehensive document
        1. Easily interpretable/accessible
        2. Don't know who else would lead initiative besides FEMC

- What was a successful or useful outcome from the FEMC over the recent past?
    - Data archiving! One of the better organized data repositories out there
    - Broad picture research - regional data synthesis
    - Visualization tools - opens up to different users/interactive

- Continuing to create opportunity to connect - the CONFERENCE
- Pulling the science together
- Leadership to take technical stuff and make it available
- More sessions like the conference - collect the science and have discussions
- Conference
- Hub for data collection and architecture
- Comparability piece as a missed opportunity. Things that could have been useful but aren't because of different methodologies
- Data rescue
- Staying connected initiative as model.
- Keep expanding - connecting people outside of the state
    - Cognizant to make connections within states as well
- Missed: FEMC working to figure out how to support more citizen science - QAQC protocols to provide
    - Working more to provide funding opportunities
    - More accessibility (virtual model is doing that )
- Reports about things that are happening across the states - **connect people who are monitoring the same things**
- Monitoring work is awesome (connectivity)
- Conference is successful in bringing all folks together in conversation (agencies, university la
- Missed: increase collaborative flavor/approach for research (inclusivity throughout process)
- Positive: data archive, conference
- Missing: engaging policy makers and publicER - bringing protocols to public (citizen science/community protocols).
- Larger network of monitoring cooperative/venues across the nation?
    - Could FEMC potentially help facilitate this in some way (
- Collaborate with LTER & NEON
- In going regional, don't lose site of the local
    - Connecting with human communities where are doing monitoring
- **Pulled from Chat: I'm noticing that Environmental Justice hasn't come up much in this conversation, but my experience is that the absence of talking about it, is when environmental injustice in research work is most likely to be perpetuated. So that's where my question lies. Who are we really representing, and who gets to ask and participate in our questions?**

*Group 2*

What can we learn and draw from over the past few years

Keep doing or do more of:

- **Expanding** is important … keep doing it (geographically and thematically, organizationally) How do we coordinate beyond New England …… Go bigger: Connect with LTER and NEON … but also smaller (sustainability is local) pilots within regions.
  - Expand access (2 days instead of 1 for conference and web access to draw in more people from farther out)
- Focus on interagency networking to avoid pigeonholing ... **Facilitating connections within each state** (like VT has with UVM)
- **more easy access (remote access)**
- More dissemination of tools and increase utility (what type of tools…. synthesis or just data aggregation)
- **Floodgate QAQC to support citizen science** to boost monitoring data ….. increase quality of the data we collect
- Support collaborative groups to **identify new funding internal/**external

*Group 3*

- Lots of brainstorming over the years – sometimes things on the list come from people doing the work. FEMC takes the idea without reaching back to where the idea came from - lost some of the collaboration in transition - Want to be inclusive throughout

- keep monitoring and keep the data available to all the tiers – invaluable – beginning of standardizing and managing resources for all

- To have regional/local contacts to get handle on challenges facing – very relevant

- adaptive management – science-based management is used at all levels
  Using adaptive management allows for private landowners or others to set up plots, researchers don't have to be the only ones involved - this can build cultural knowledge of people working in forests.
- biophysical classifications at multiple scales in sub regions can provide ecological potential – what benefits can be provided, what are the interactions due to weather – think we need this kind of a framework to take from regional to local and local to regional – don't see a binding biophysical framework in FEMC work and overarching hypothesis of outcomes. By using a biophysical framework, a baseline can be established to help understand as a result of climate change. There is utility of phenology information collected over time – have something to measure against
- FEMC helps knit environment together in more cohesive way – as things change – we still know the baseline within a given zone (north-facing v. south-facing) to appropriately communicate and respond on a regional basis – bigger job than FEMC on its own, but FEMC could be part of this bigger picture
- Can't speak to much to the past, but last year there was a lot of talk about outreach and getting info out to managers, users, policy-makers, etc – RI really needs that – they don't have the resources, but need to know about the cooperative tools available
- Continued emphasis on the importance of communication – conference is big success to connect researchers with on-the ground managers

*Group 4*

- Successes
  - Hub for bein gable to support data collection and architecture
  - Conference
  - Untapped data resources
  - Data rescue
- Missed opportunities
  - Not making things comparable
- Things to learn from
  - D'Amato grotnon project- permanent plots
  - Stayin gconnected initiative

# Poster Presentations

**Moderator: Elissa Schuett (FEMC)**

The poster session was held online. Each presenter had an opportunity to share the topic of their poster in a flash talk. Following all presentations, break-out rooms were opened for each presenter to have more intimate discussions and answer questions from attendees. Nearly 100 people attended the session. Posters can be viewed at: https://www.uvm.edu/femc/cooperative/conference/2020/content#posters

**2020 FOREST ECOSYSTEM MONITORING COOPERATIVE REGIONAL PROJECTS**

**Pia Ruisi-Besares**[1], Matthias Sirch[1], Emma Tait[1], John Truong[1], James Duncan[1], David Gudex-Cross[2], Jennifer Pontius[1]

1Rubenstein School of Environment and Natural Resources, FEMC

[2]SILVIS Lab, U. of Wisconsin

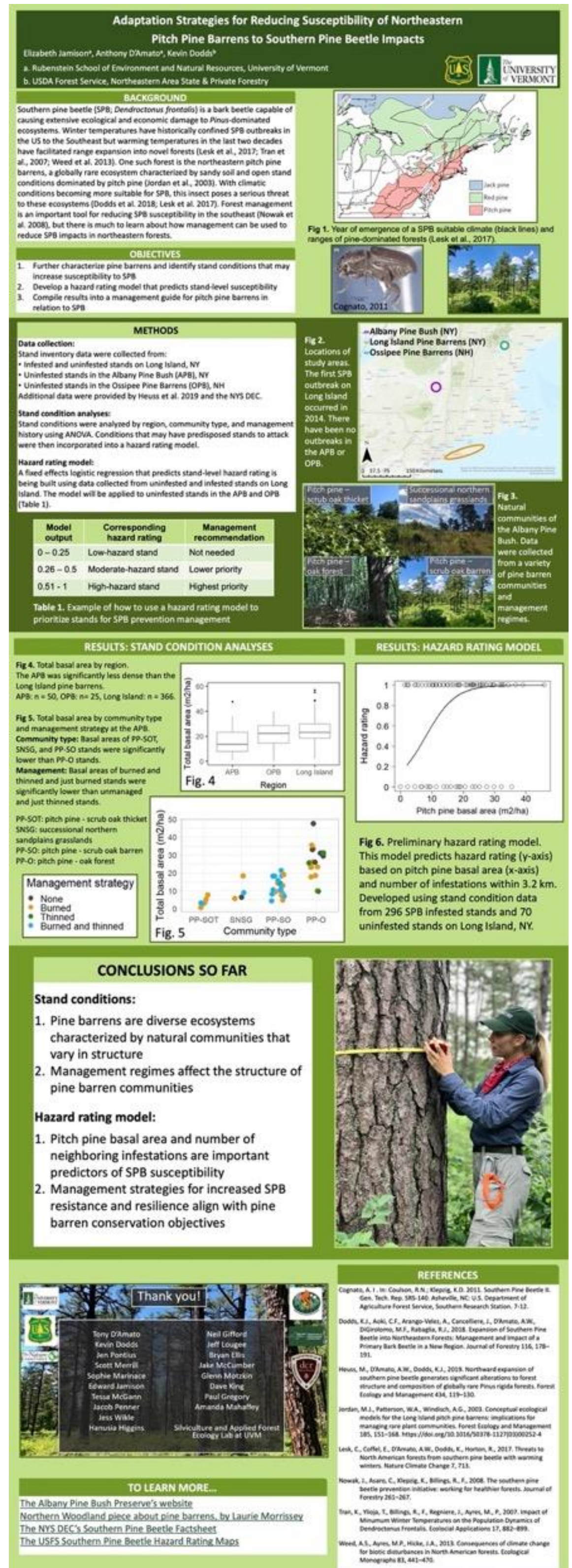
Every year the Forest Ecosystem Monitoring Cooperative (FEMC) develops regional projects on selected topics determined by the FEMC Steering Committee with input from the FEMC State Partnership Committees. In past years, the FEMC has built tools and products that allow forest managers and researchers to better understand and coordinate monitoring efforts relating to forest health. This year, the FEMC has begun development on two new regional projects: 1) Monitoring and Communicating Changes in Forest Disturbance Regimes, and 2) Monitoring Northeastern Forest Indicators for Signs of Climate-Driven Change. The FEMC has also continued work on its long-term Forest Health Monitoring Program, expanding its network beyond Vermont to include plots in the rest of New England and New York. In October 2020, the FEMC completed its 2019 regional project Forest Water and Water Quality.

**ADAPTATION STRATEGIES FOR REDUCING SUSCEPTIBILITY OF NORTHEASTERN PITCH PINE BARRENS TO SOUTHERN PINE BEETLE IMPACTS**

**Elizabeth Jamison**[1], Anthony D'Amato[1], Kevin Dodds[2]

[1]Rubenstein School of Environment and Natural Resources, University of Vermont

[2]USDA Forest Service




Southern pine beetle (SPB; Dendroctonus frontalis) is a highly aggressive bark beetle of great ecological and economic significance. It is native to the southeastern United States, Mexico, and Central America where it causes extensive mortality in Pinus-dominated ecosystems. Warming winter temperatures over the last two decades, however, have facilitated outbreaks in northeastern pitch pine (Pinus rigida) barrens such as the Central Pine Barrens of Long Island, NY and the New Jersey Pine Barrens. With range expansion expected to continue, SPB presents a serious threat to this globally unique ecosystem. Forest management is an important tool for reducing SPB susceptibility in the southeast, but there is much to learn about how management can be used to reduce SPB impacts in northeastern forests. This ongoing study aims to develop tools for the prioritization of highly susceptible stands for informed SPB prevention management in this newly invaded region. Using stand inventory data collected from infested and uninfested stands on Long Island, NY, conditions predisposing stands to attack have been identified. These conditions are being incorporated into a hazard rating model that will predict stand-level susceptibility to SPB. The model will be applied to uninfested stands in the Albany Pine Bush of NY and the Ossipee Pine Barrens of NH to identify susceptible stands and prioritize areas for adaptive management. Lastly, results will be complied into a management guide for pitch pine barrens in relation to SPB. This work will have applications in minimizing the impact of the range expansion of SPB into northern pine forests and promoting the development of healthy pine barren ecosystems.

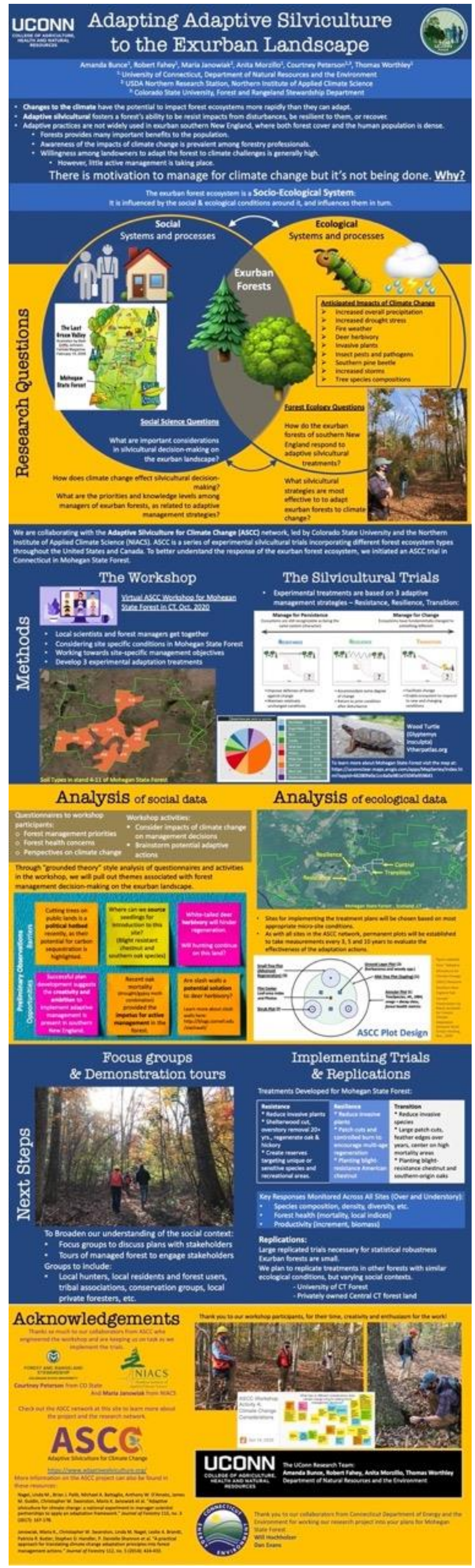
## ADAPTIVE SILVICULTURE ON THE EXURBAN LANDSCAPE

**Amanda Bunce**[1], Robert Fahey[1], Thomas Worthely[1], Anita Morzillo[1], Courtney Peterson[2], Maria Janowiak[3]

[1]University of Connecticut, Department of Natural Resources and the Environment

[2]Colorado State University, Forest and Rangeland Stewardship Department

[3]USDA Forest Service, Northern Institute of Applied Climate Science




The temperate deciduous forests of the Northeast are valued globally as a carbon sink and a source of forest products and for a myriad of ecosystem benefits important to local populations. Changes to the climate are affecting forests and have the potential to do so more rapidly than the ecosystems can adapt, resulting in substantial loss of species richness and diversity. Climate adaptive forest management practices, which increase the resiliency of forest ecosystems, could be valuable tools in southern New England to protect the ecosystem and meet forest management objectives in the region. Awareness of climate change and the negative impacts on forest ecosystems is prevalent among forestry professionals, and willingness among landowners and managers to adapt the forest to the associated challenges is generally high. However, any action is mostly passive, suggesting forest managers are motivated to manage for climate change but are not doing so.

To better understand forest management on the exurban landscape, we recognize southern New England forests as socio-ecological systems - landscapes shaped by interacting social and ecological process and conditions. The success of forest management activities in the region is necessarily impacted by the socio-ecological context of the exurban landscape. Our study aims to improve our understanding of 1) local forest response to adaptive management and 2) the social context surrounding decision-making for climate adaptive forestry practices.

We are collaborating with the Adaptive Silviculture for Climate Change (ASCC) network, led by Colorado State University and the Northern Institute for Applied Climate Science (NIACS). ASCC is a collaborative effort to establish a series of experimental silvicultural trials across a network of forest types throughout the United States and Canada. Site-specific treatments are co-developed among local scientists and natural resource professionals according to local conditions and tailored to meet site-specific management objectives, while at the same time aligned under a common framework for answering questions about how different forest types will respond to management and the future climate.

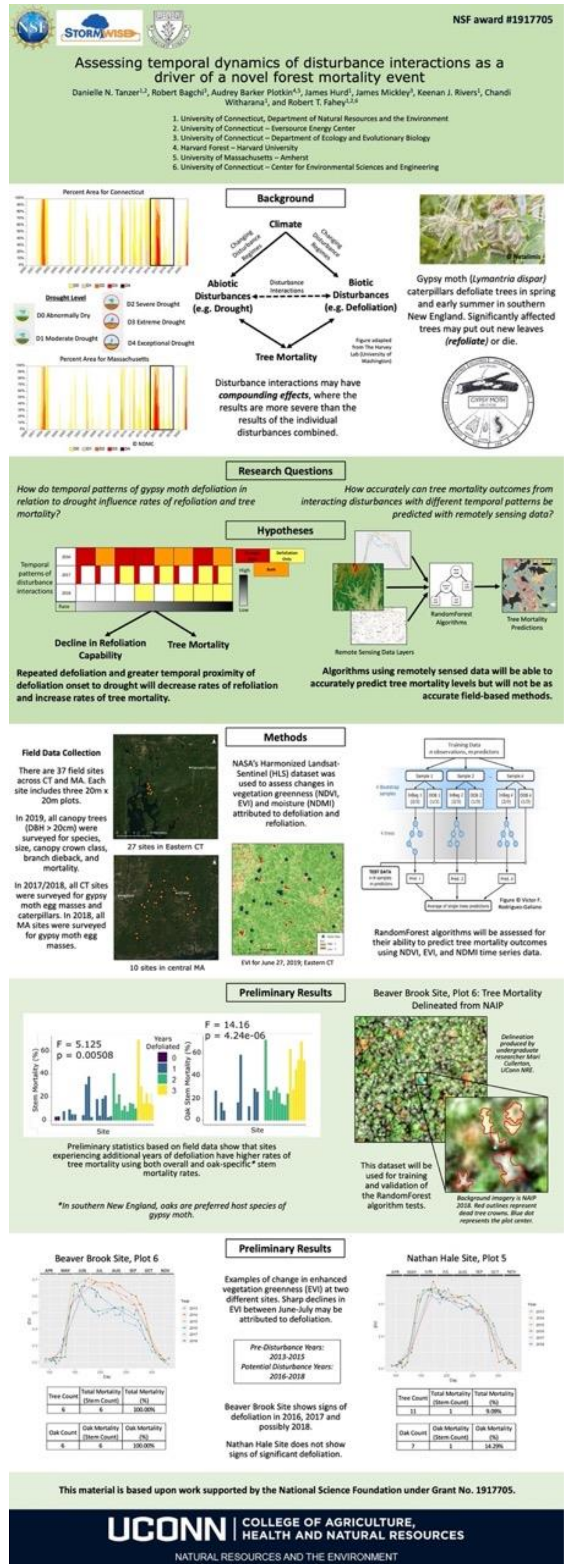
We use the ASCC protocol to develop adaptive forest management treatment plans for a forest in Connecticut. The ASCC protocol allows local stakeholders to organize their own strategy - a method that improves resiliency of the plan - while steering them towards a plan that improves resiliency of the ecosystem in turn. We study the social aspect of the exurban socio-ecological system with a thematic analysis of the treatment development process, while the silvicultural treatments themselves will improve our understanding of the use of these adaptive practices in the region. The long-term nature of a silvicultural trial will also allow us to follow social processes - using site tours and interviews with stakeholders - as the ecological process respond to silvicultural treatments.

**ASSESSING TEMPORAL DYNAMICS OF DISTURBANCE INTERACTIONS AS A DRIVER OF A NOVEL FOREST MORTALITY EVENT**

Danielle Tanzer[1], Robert Bagchi[1], Audrey Barker Plotkin[2], James Hurd[1], James Mickley[1], Keenan Rivers[1], Chandi Witharana[1], Robert Fahey[1],

[1]University of Connecticut

[2]Harvard Forest, University of Massachusetts - Amherst




The frequency and severity of disturbances in forested ecosystems are expected to increase under climate change, potentially driving substantial increases in disturbance interactions. Interactions between disturbances can result in compounding effects on forest growth and mortality, but the influence of temporal patterns on disturbance interaction outcomes is not well understood. Southern New England has recently experienced an unprecedented tree mortality event related to severe drought in 2016 and widespread gypsy moth defoliation from 2016-2018. Our objectives were to assess how defoliation severity and timing (relative to drought) influenced stand growth and tree mortality outcomes and to predict tree mortality outcomes using remotely sensed data. We sampled 27 study sites across eastern Connecticut and central Massachusetts from existing sampling locations with field-based assessments of gypsy moth defoliation, caterpillar populations, and egg mass counts. At a site level, remotely sensed imagery was used to characterize within-season patterns of defoliation, vegetation response, and mortality timing and extent.

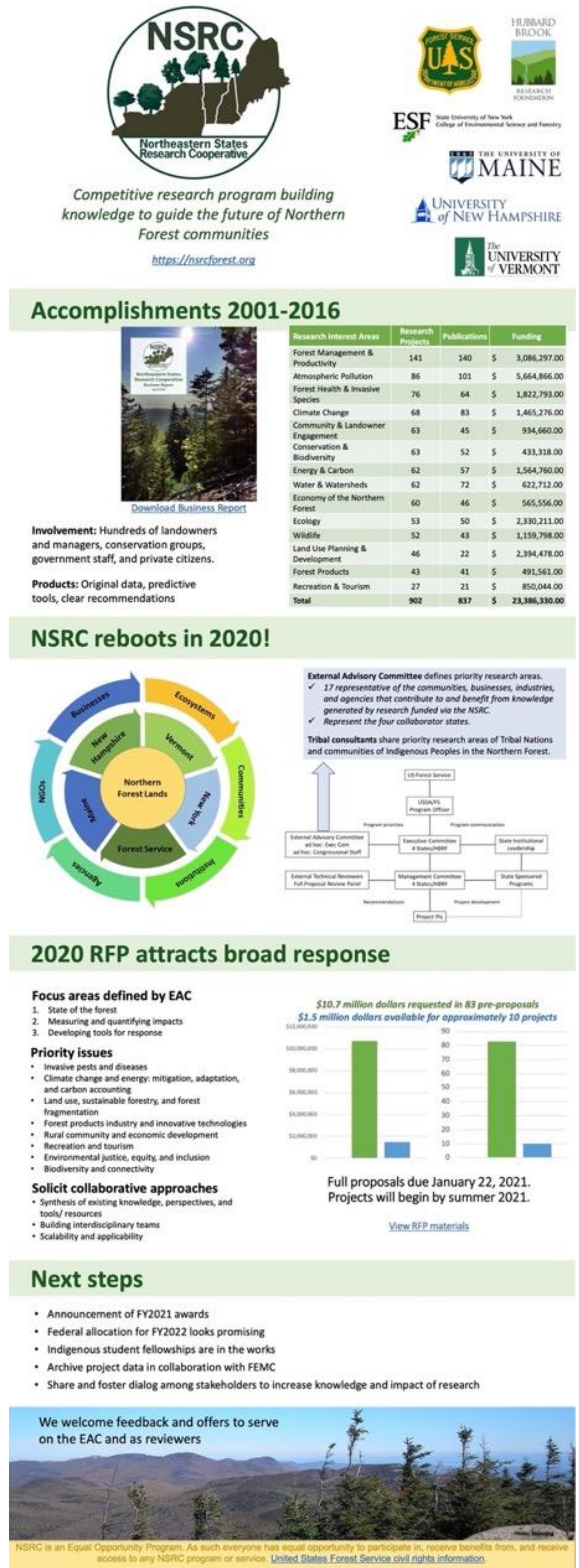
Based on remote sensing image time series analysis, existing study sites were classified into six classes describing the temporal pattern of gypsy moth defoliation - none (3 sites), 2017 only (13 sites), 2018 only (2 sites), 2016 and 2017 (2 sites), 2017 and 2018 (3 sites), and all 3 years (4 sites). Field observations indicated that 81% (22 of 27) of sites experienced tree mortality, with overall mortality rates ranging from 3-70% and oak mortality rates ranging from 11-90%. Both overall and oak-specific mortality rates varied significantly among defoliation timing categories based on analysis of variance (p = 0.024 of overall mortality and p = 0.002 for oak-specific mortality), with significantly greater mortality in sites undergoing multiple years of defoliation. Additional analysis and tree mortality prediction modelling using random forest algorithms are ongoing. Results of this study will further understanding of the effects of temporal patterns of interacting disturbances on tree mortality and stand productivity, as well as our capability to predict tree mortality outcomes from interacting disturbances.

**NORTHEASTERN STATES RESEARCH COOPERATIVE 2.0**

Breck Bowden[1]

[1]University of Vermont, Rubenstein School of Environment and Natural Resources, Northeastern States Research Cooperative

Northeastern States Research Cooperative will share information and opportunities related to the relaunch of NSRC to 1) summarize what we have done since the NSRC went into hiatus, 2) highlight the big changes we've made, 3) summarize the 2021 RFP response, and 4) outline what we hope to be future opportunities.

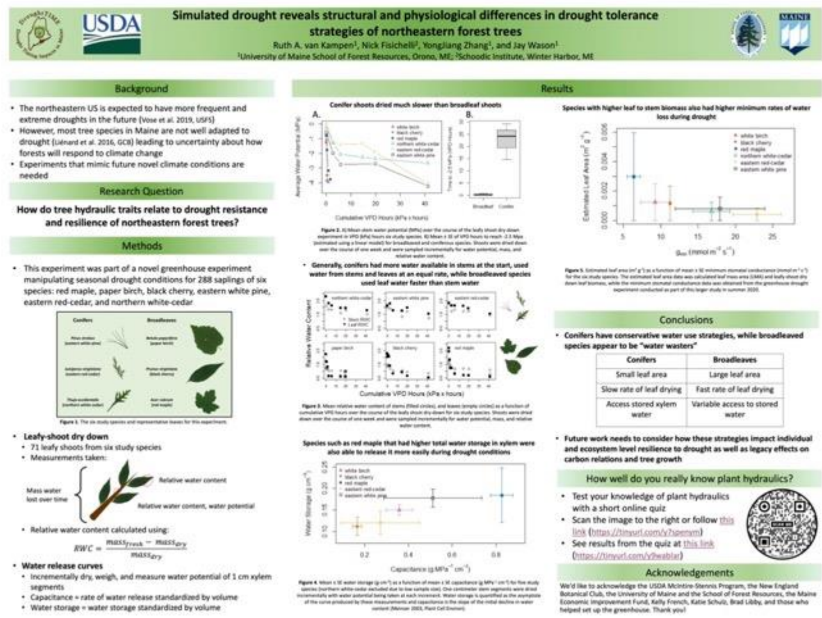


## SIMULATED DROUGHT REVEALS STRUCTURAL AND PHYSIOLOGICAL DIFFERENCES IN DROUGHT TOLERANCE STRATEGIES OF NORTHEASTERN FOREST TREES

Ruth van Kampen[1], Nicholas Fisichelli[2], YongJiang Zhang[1], Jay Wason[1]

[1]University of Maine

[2]Schoodic Institute




Climate change is expected to lead to novel environmental conditions in the northeastern United States. Therefore, experimental studies that mimic these conditions are crucial to understand the potential impact on the forest. The goal of this research was to determine how tree hydraulic traits relate to drought resistance and resilience of northeastern forest trees. We used experimental dry downs of leafy shoots to assess how structural and physiological adaptations of each species relate to water use during drought. This experiment was part of a novel greenhouse experiment manipulating seasonal drought conditions for 288 saplings of six species (Acer rubrum, Prunus serotina, Betula papyrifera, Pinus strobus, Juniperus virginiana, and Thuja occidentalis). A total of seventy-one leafy shoots from the six species were subjected to an experimental bench-top dry down to simulate extreme drought. We found that broadleaved species dried rapidly and used water stored in leaves without accessing water stored in stems. In contrast, conifers dried much more slowly, were resistant to changes in water potential, and took twice as long as the broadleaved species to desiccate. The clear division between fast-drying broadleaved species and slow-drying conifer species was further supported by morphological and physiological traits of leaves and stems. Broadleaved species had higher minimum rates of water loss on a leaf area basis, more readily released water in leaves during drought, and had lower leaf to stem biomass ratios. Interestingly, A. rubrum, a species widely perceived to be a climate change winner, seems to release stored water from stems quite easily but has high initial water storage. On the other hand, P. serotina is slower to release water from stems and has low initial water storage. Understanding that tree species in northeastern forests have opposing strategies that confer varying degrees of drought resistance and resilience will be key to managing these species as their suitable habitats shift with climate change.

Forest Ecosystem Monitoring Cooperative



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