CFRU

2025 ANNUAL REPORT

CFRU & REPORT BACKGROUND

Founded in 1975, the Cooperative Forestry Research Unit (CFRU) is one of the oldest industry/university forest research cooperatives in the United States. We are composed of 35 member organizations including private and public forest landowners, wood processors, conservation organizations, and other private contributors. Research by the CFRU seeks to solve the most important problems facing the managers of Maine's forests. The CFRU is a core research program of the Center for Research on Sustainable Forests at the University of Maine.

The CFRU is an applied scientific research organization. As scientists, we favor metric units (e.g., cubic meters, hectares) in our research; however, the nature of our natural resources business frequently dictates the use of traditional North American forest mensuration English units (e.g., cubic feet, cords, acres). We use both metric and English units in this report. Please consult any of the conversion tables that are available on the internet if you need assistance.

Citation: Smith, R. K., (Ed) 2025. Cooperative Forestry Research Unit: 2025 Annual Report. Center for Research on Sustainable Forestry, University of Maine. Orono, ME. 56 p.

COOPERATIVE FORESTRY RESEARCH UNIT

A Core Program of the Center for Research on Sustainable Forests

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CFRU YOUTUBE PAGE

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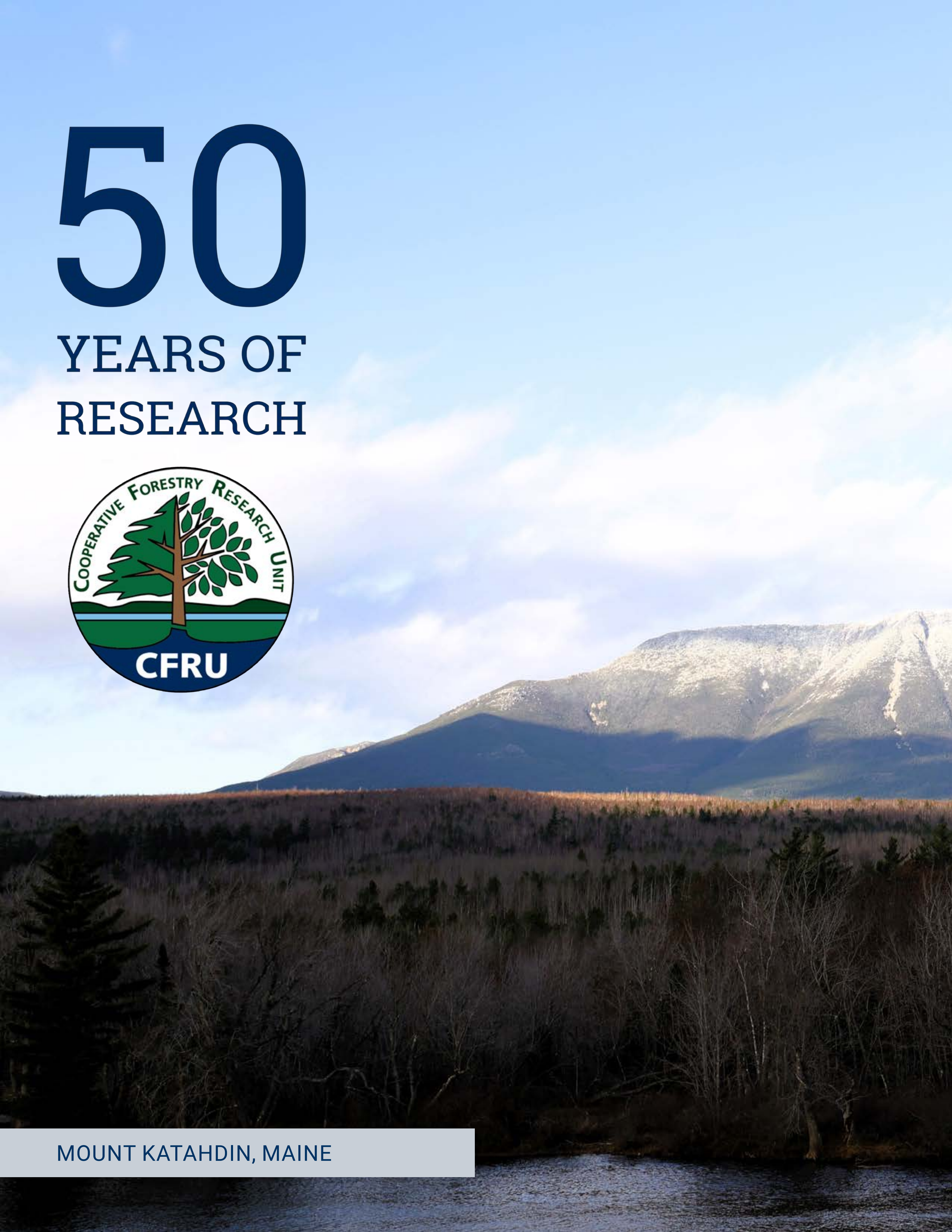
CONTENTS

50 YEARS OF RESEARCH

Cooperative Forestry Research Unit
CFRU



MOUNT KATAHDIN, MAINE

PROGRAM MANAGER'S LETTER

CFRU 2025 Fall Field Tour

Dear CFRU Members,

The Cooperative Forestry Research Unit has put on another solid year of growth and in doing so, has reached its 50th anniversary. I like to think of our research history thus far somewhat like the growth rings on a tree. We can look back and see which years were humming with field experiments, which years focused heavily on monitoring and protecting endangered species, which years our control account was healthy enough to dream up and install long-term field research networks, many of which still exist today, and which years may have seemed more quiet outwardly, but were paced by months of reporting, listening sessions, meetings, and trying like hell to put operational research to work in the hands of our foresters, entomologists, loggers, citizen scientists, students, and perhaps even you, reader.

In 2025, we focused heavily on evaluating our processes and procedures for our RFP, requests for proposals, and how we assess new research ideas as a cooperative. In the fall we held a listening session with our members and research community, and in the spring we hosted an educational public forum for spruce budworm and early intervention strategy. As we neared this momentous anniversary, we were busy reflecting on the importance of our relationships with our members. We're so grateful to those of you who volunteered to be on a CFRU subcommittee, hosted students for internship shadowing, installed a MASN prescription on your lands, or just sent an email to check in on how things at the CFRU were going.

Research kept steady momentum throughout the year. In FY2025, we supported 14 research projects! From nanoliters of vernal pool sampling, to a 3 foot branch samples from the top of a balsam fir for monitoring spruce budworm, our researchers work is being used more and more everyday by our forestry community.

We couldn't be a cooperative without all of our parts and people. Thank you to our members, old and new, for supporting Maine's commitment to stewarding our forests through asking questions and following the research, no matter how long it may take. Thank you to our scientists and researchers who have listened to our problems and helped inform solutions based on our needs and our resources at hand. You have shaped our forests arguably as much as those who manage it on the ground. Thank you to all of our staff and students throughout the years, there are far too many of you to name here. Being the small staff that we are, and have been, I hope you know who you are and how much of an impact you have had on this place.

With gratitude,

Regina Smith (she/her)
Program Manager, Cooperative Forestry Research Unit

DIRECTOR'S LETTER

The Cooperative Forestry Research Unit (CFRU) has reached its 50th anniversary, a milestone that I find both humbling and inspiring. Founded in 1975, the CFRU is one of the oldest industry and university forest research cooperatives in the United States, and the fact that it remains vibrant, relevant, and growing after five decades speaks volumes about the commitment of our membership and the enduring importance of the questions we seek to answer. This is a moment to celebrate, but also to look forward and consider how we collectively position the CFRU for the challenges and opportunities ahead.

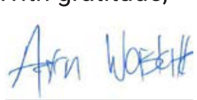
This past year brought both significant accomplishments and some unexpected challenges. On the research front, the long awaited Northern Conifer Silviculture Guide completed its draft stage in summer 2025 following a comprehensive effort involving more than two dozen experts and practitioners from across the region. This guide represents years of collaborative work and will be an invaluable resource for managing the more than seven million acres of northern conifer forest in Maine and the broader Northeast. Unfortunately, federal government restructuring and associated shutdowns delayed some deliverables and forced the cancellation of a planned field workshop at the Penobscot Experimental Forest, which will be rescheduled in 2026 at no cost to the project. These disruptions serve as a reminder of the importance of having organizations like the CFRU that can provide continuity and stability for forest research regardless of the federal funding landscape.

The MASN continues to be a cornerstone of the CFRU's field program, with ongoing long term measurements, new installations, and an increasing number of projects that draw upon the network's data. The creation of a harmonized MASN inventory database represents an important step toward making these valuable datasets more accessible and useful for researchers and managers alike. Meanwhile, the spruce budworm monitoring program continued to track concerning increases in L2 populations, particularly in northwestern Maine, and new remote sensing tools for defoliation detection are being developed to complement ground based monitoring. The expanded focus on habitat and biodiversity through projects on wood turtle movement ecology, bird communities as management indicators, and environmental DNA for species monitoring reflects the breadth of issues that our membership cares about and the CFRU's ability to address them.

I also want to highlight an important development at the national scale. In December 2025, the NSF Industry University Cooperative Research Center for Advanced Forestry Systems (CAFS), which has been a core program of CRSF alongside the CFRU, will formally graduate from NSF sponsorship and transition into its fourth phase as an independent entity. CAFS has been a tremendous platform for multi scale forest research and I am proud of the role that CRSF has played in supporting its growth over the years. The transition to Phase 4 presents exciting new opportunities for how CAFS and the CFRU can continue to complement each other in serving the forest sector.

The continued success of the CFRU is made possible by the dedicated work of our staff, including CFRU Program Manager Regina Smith, Research and Internship Coordinator Eric McPherson, Financial Manager Leslee Canty Noyes, and Communications Coordinator Meg Fergusson. I also want to recognize the hard work of the 2025 CFRU summer field crew, who put in long days under challenging conditions to maintain research grade measurements across the state. Lastly, I remain grateful for our 35 member organizations whose collective investment of over $500,000 annually makes this work possible. As we celebrate 50 years, I am confident that the CFRU's best days are still ahead.

With gratitude,



Aaron Weiskittel
Director, Center for Research on Sustainable Forests
University of Maine

CHAIR'S LETTER

Dear CFRU Members and Partners,

The year 2025 marks a significant milestone for the Cooperative Forestry Research Unit: 50 years of collaborative forestry research. Founded in 1975, CFRU is one of the oldest industry and university forest research cooperatives in the United States, and for five decades it has brought together landowners, researchers, and practitioners to address the most pressing challenges facing the management of Maine's forests.

This annual report highlights a productive and wide-ranging year of applied research shaped directly by CFRU members. In 2025, CFRU supported projects spanning silviculture, forest health, remote sensing, carbon, and biodiversity, reflecting both the complexity of today's forest management decisions and the strength of CFRU's cooperative research model. Outcomes from these projects directly influence and improve decision-making in the ever shifting field of forestry for our members and the region.

Long-standing investments continued to deliver value in 2025. The Maine Adaptive Silviculture Network (MASN) advanced as a statewide, operational-scale research platform, supporting long-term measurements, new installations, and multiple CFRU-funded projects using MASN data. Work in planted spruce systems, commercial thinning response, mixedwood management, and northern conifer silviculture contributed new insights to adaptive management and future decision-support tools.

CFRU also made substantial progress in applying remote sensing and geospatial technology to forestry. Projects in enhanced forest inventory, statewide high-resolution land cover and forest type mapping, and pest-induced damage detection demonstrated how emerging data sources can complement field measurements and improve efficiency and scale for forest monitoring.

Forest health research remained a critical focus in 2025, particularly in response to the accelerating spruce budworm outbreak. CFRU-supported work expanded monitoring capacity, improved defoliation detection models, and contributed directly to management planning through Maine's Early Intervention Strategy. Such efforts were hugely successful due to the hard work of many CFRU members and state and federal agencies.

None of this work would be possible without the commitment of CFRU's members. In fiscal year 2025, contributions from private and public landowners, forest products companies, conservation organizations, and other partners supported a diverse research portfolio and the students, staff, and infrastructure needed to carry it forward. Just as importantly, member engagement—through data sharing, site access, technical input, and collaboration—remains central to CFRU's success.

At the heart of the CFRU over the past 50 years are the people who have sustained it. We are deeply grateful to the faculty, research staff, coordinators, technicians, and administrators whose dedication and expertise have guided CFRU's work since its founding. We also extend particular thanks to the many students, interns, and field crew members who—through countless hours in the woods, laboratories, and offices, have built and maintained the long-term datasets that are central to CFRU's impact.

As we celebrate 50 years of CFRU, we also must look ahead. Forest managers face increasing uncertainty from climate change, forest pests, shifting markets, and evolving societal expectations. CFRU's cooperative model grounded in long-term datasets, applied science, and trusted partnerships positions it well to continue delivering research that is both rigorous and relevant to the forests of Maine, and all of us that depend on them for our livelihoods and wellbeing.
Sincerely,

Steve Tatko

Chair, Cooperative Forestry Research Unit

STAFF

Regina Smith, Program Manager, Cooperative Forestry Research Unit

Aaron Weiskittel, Director, Center for Research on Sustainable Forests

Leslee Canty-Noyes, CFRU/CRSF Administrative & Financial Coordinator

Eric McPherson, CFRU/SFR, Research and Internship Coordinator

Meg Fergusson, CRSF Outreach and Communications Specialist

FOREST LANDOWNERS & MANAGERS

Acadian Timber Corp.
Appalachian Mountain Club
Baskahegan Company
Baxter State Park, SFMA
BBC Land, LLC
Clayton Lake Woodlands Holdings, LLC
Downeast Lakes Land Trust
EMC Holdings, LLC
Fallen Timber, LLC
Fresh Timber, LLC
Frontier Forest, LLC
Irving Woodlands, LLC
Maine Bureau of Parks & Public Lands
Maine Forest Service
Maine Inland Fisheries & Wildlife
Manulife Investment Management
Mosquito, LLC
New England Forestry Foundation (NEFF)
Pleasant River Lumber Co.
Prentiss and Carlisle Company, Inc.
Presley Woods, LLC
Robbins Lumber Company
Sandy Gray Forest, LLC
Seven Islands Land Company
Solifor Timberland Inc.
Sylvan Timberlands, LLC
The Conservation Fund
The Nature Conservancy
Tree-Star Timberlands
Wagner Forest Management
Weyerhaeuser

WOOD PROCESSORS

SAPPI North America

CORPORATE & INDIVIDUALS

David B. Field
Forest Society of Maine
Huber Engineered Woods, LLC
LandVest

EXECUTIVE COMMITTEE

Chair - Steve Tatko, Appalachian Mountain Club
Vice Chair - Nava Tabak, Baxter State Park, SFMA
Financial Officer - Eugene Mahar, LandVest
Member-at-large - Jeremy Miller, American Forest Management (*BBC Land, LLC*)

ADVISORY COMMITTEE

Acadian Timber Corp. – Jody Jenkins
American Forest Management (BBC Land, LLC) – Jeremy Miller
Appalachian Mountain Club – Steve Tatko
Baskahegan Company – Laurie MacElwain
Baxter State Park, SFMA – Nava Tabak
Downeast Lakes Land Trust – vacant
Forest Society of Maine – Jake Metzler
Huber Engineered Woods, LLC – Jake Metzler
Huber Resources Corp. (Fallen Timber, LLC/Solifor LLC/Pressley Woods, LLC) – Trevor London
Irving Woodlands, LLC – Ked Coffin
LandVest (Clayton Lakes Woodlands Holding, LLC/EMC Holdings, LLC/Falcon Lodge, LLC) – Eugene Mahar
Maine Forest Service – vacant
Maine Bureau of Parks and Lands – Mike Pounch
Manulife Investment Management – David Smith
Northern Hardwoods Research Institute – Gaetan Pelletier
Pleasant River Lumber Co. – vacant
Prentiss and Carlisle Company, Inc. – Karin Belanger
Robbins Lumber Company – James Robbins
SAPPI North America – John Ackley
Seven Islands Land Company – Ian Prior
The Conservation Fund – Brian Schneider
The Nature Conservancy – Amanda Farris
Tree-Star Timberlands, LLC – Stephen Pollis/Louis Villeneuve
Wagner Forest Management – Mike Jurgiewich
Weyerhaeuser – Ben Dow

LEAD & ASSISTANT RESEARCHERS

Jeanette Allogio (MSc), University of Maine
Rajeev Bhattarai (PhD), University of Maine
Erik Blomberg (PhD), University of Maine
Ken Bundy (MA), Center for Research on Sustainable Forests, U. of Maine
Noah Charney (PhD), University of Maine
Matthew Chatfield (PhD), University of Maine
Adam Daigneault (PhD), University of Maine
Quin Daly (MS), University of Maine
Sequoia Dixson (MS), University of Maine
Shawn Fraver (PhD), University of Maine
Erin Grey (PhD), University of Maine
Anthony Guay (MSc), University of Maine
Daniel Hayes (PhD), University of Maine
John Kabrick (PhD), USFS
Keith Kanoti (MSc), University of Maine
Laura Kenefic (PhD), USFS
Claire Kiedrowski (BS), Maine GeoLibrary
Anil Raj Kizha (PhD), University of Maine

Benjamin Knapp (PhD), University of Missouri
Kasey Legaard (PhD), University of Maine
William Livingston (PhD), University of Maine
Libin T.Louis (PhD), University of Maine
Eric McPherson (MF), University of Maine
Angela Mech (PhD), University of Maine
Mike Premer (PhD), University of Maine
Parinaz Rahimzadeh (PhD), University of Maine
Patricia Raymond (PhD), Quebec Ministry of Forests, Wildlife and Parks
Skylar Roach (MSc), USFS
Nicole Rogers (PhD), Maine Forest Service
Amber Roth (PhD), University of Maine
David Sandilands (MSc), University of Maine
Josh Sherrill (MSc), PRT Growing Services
Erin Simons-Legaard (MSc), University of Maine
Regina Smith (BS), Cooperative Forestry Research Unit
Neil Thompson (PhD), University of Maine at Fort Kent
Lance Vickers (PhD), University of Kentucky
Jay Wason III (PhD), University of Maine
Aaron Weiskittel (PhD), University of Maine
Justin Whitehill (PhD), North Carolina State University

PROJECT PARTNERS

Department of Wildlife, Forestry, and Conservation Biology
Hancock Lumber
Maine Agricultural and Forest Experimental Station
Maine Department of Environmental Protection
Maine Department of Transportation
Maine Library of Geographic Information
Maine Natural Areas Program
Maine Woodland Owners
New England Forestry Foundation
New Hampshire Division of Forests and Lands
NOAA Office for Coastal Management
Northern Forest Conservation Services, LLC
Oregon State University
Passamaquoddy Forestry Department
Penobscot Experimental Forest
Penobscot Nation, Department of Natural Resources
Rangeley Lakes Heritage Trust
School of Forest Resources
Stephen Phillips Memorial Trust
SUNY College of Environmental Science and Forestry
Tribhuvan University, Institute of Forestry, Nepal
U.S. Fish and Wildlife Service, Umbagog National Wildlife Refuge
U.S. Forest Service, Eastern Region State, Private, and Tribal Forestry
U.S. Forest Service, Green Mountain National Forest
U.S. Forest Service, Massabesic Forest
U.S. Forest Service, National Forest System, Enterprise
U.S. Forest Service, White Mountain National Forest
University Forests
University of Maine Advanced Computing Group
University of Maine Fort Kent
University of New Brunswick
USDA Forest Service, Northern Research Station FIA Program
Western Maine Conservation

COLLABORATORS

Janet Atoyan ,RI-INBRE Molecular Informatics Core, University of Rhode Island
Paula Blanco-Ortiz, Cornell Wildlife Health Lab, Cornell University
Anna Buchanan, Davey Tree
Samara Davis, Yale University
Andrew Finley, Michigan State University
Cheryl Frederick, Center for Wildlife Studies
Brian Heath, North Carolina Forest Service
Kristine Hoffmann, St. Lawrence University
Sean Horan, Goodfellow Forestry
Victoria Hunter, Michigan Technological University
Alyssa Kaganer, Cornell Wildlife Health Lab, Cornell University
Jacob Kubel, Natural Heritage & Endangered Species Program, Massachusetts Division of Fisheries & Wildlife
Bethany Muñoz, Bethany Muñoz Delgado LLC
Zachary Olinger, Virginia Forest Service
Skylar Roach, USFS
Mark Stoeckle, Program for the Human Environment, The Rockefeller University
Sudan Timanlsina, Spruce Budworm Lab
Lindsay Ware, Center for Wildlife Studies
Justin Whitehill, North Carolina State University
Jenna Zukswert, USFS

STUDENTS

Sam Aali (BS), UMaine
Lila Beck (MSc), UMaine
Ashley Carter (MSc), UMaine
Danielle Cook (BS), UMaine
Sarah Costa (BS), UMaine
Reg Clarke (BS), UMaine
Adrian Elliot (BS), UMaine
Meaghan Erlebach (BS), UMaine
Helena Gawlowski (BS), UMaine
Harrison Goldspiel (PhD), UMaine
Alyssa Kuskowski (BS), UMaine
Garrett Laffler (BS), UMaine
Tyler Locke (BS), UMaine
Jaidyn Negley (BS), UMaine
Astrid Niles (BS), UMaine
Maeve Noon-Price (MSc), UMaine
Rachel Norment (BS), UMaine
Temitope Olayinka (PhD), UMaine
Ella Raymond (BS), UMaine
Ollie Rice (BS), UMaine
Julia Schneider (BS), UMaine
Elyeah Schweikert (BS), UMaine
Sam Sebasto (BS), UMaine
Peter Serafin (BS), UMaine Fort Kent
Courtney White (BS), UMaine
Tucker Wile (BS), UMaine

INCOME REPORT FY25

FOREST LANDOWNERS/MANAGERS	CONTRIBUTIONS
Irving Woodlands, LLC	$70,074
BBC Land, LLC	$57,062
Weyerhaeuser	$46,948
Clayton Lake Woodlands Holdings, LLC	$44,363
Wagner Forest Management	$43,289
Prentiss and Carlisle Company, Inc.	$43,455
Seven Islands Land Company	$41,619
Maine Bureau of Parks & Public Lands	$25,563
Acadian Timber Corp.	$17,519
Fallen Timber, LLC	$28,118
Solifor Timberland Inc.	$9,991
The Nature Conservancy	$9,641
Baskahegan Company	$8,314
Huber Timber	$7,872
Appalachian Mountain Club	$6,682
Tree-Star Timberlands	$5,380
Manulife Investment Management	$5,249
Downeast Lakes Land Trust	$3,370
EMC Holdings, LLC	$2,363
Pleasant River Lumber Co.	$2,321
Baxter State Park, SFMA	$1,725
Robbins Lumber Company	$1,564
The Conservation Fund	$1,789
Presley Woods, LLC	$1,379
Falcon Lodge LLC	$1,000
New England Forestry Foundation	$1,000
WOOD PROCESSORS	
SAPPI	$23,631
CORPORATE AND INDIVIDUAL MEMBERS	
Huber Engineered Woods, LLC	-
Forest Society of Maine	$1,000
LandVest	$200
David B. Field	$100
TOTAL INCOME IN FY2025:	$512,582

EXPENSE REPORT FY25

PROJECTS BY CATEGORY	PRINCIPLE RESEARCHER	CFRU AWARD FY25
SILVICULTURE		
Maine Adaptive Silviculture Network (MASN)	CFRU	$50,000
Harmonized MASN Inventory database: Curate, analyze, and model inventory datasets for informed decision making	Louis (UMaine Fort Kent)	$34,992
Northern Conifer Silvicultural Guide	Kenefic (USFS)	$0*
Mixedwood Managment: silviculture for hardwood softwood mixtures in Maine	Kenefic (USFS)	$34,290
Silvicultural Systems for Adaptive Planted-Spruce Forests (SSAPSF)	Premer (UMaine)	$37,077
Secrets in the CTRN: Causal factors of thinning response and transfer to adaptive management regimes in Maine spruce-fir forests	Premer (UMaine)	$42,346
REMOTE SENSING		
High Resolution Land Cover and Forest Type Data for the State of Maine	Legaard (UMaine)	$0*
Establishment of effective workflows for pest-induced damage detection and forest health monitoring in Maine by integrating remote sensing technology and field data	Rahimzadeh (UMaine)	$43,395
Using 3-D NAIP data for Enhanced Forest Inventory in Maine	Guay & Sandilands (UMaine)	$44,461
FOREST HEALTH		
Spruce budworm L2 monitoring program in Maine	Mech (UMaine)	$81,226
Understanding white pine's responses to future environmental changes: Developing strategies to reduce damage caused by the white pine weevil	Livingston (UMaine)	$23,100
HABITAT & BIODIVERSITY		
Using eDNA for biodiversity and rare species monitoring	Charney (UMaine)	$22,186
Movement ecology of wood turtles (Glyptemys insculpta) in Maine's working forests	Chatfield (UMaine)	$23,679
Birds as indicators of forest management sustainability in Maine: an evaluation of past surveys and future assessment approaches	Roth (UMaine)	$11,274
ADMINISTRATION		
Administrative budget	CFRU	$278,070[1]

1 * Indicates project is ongoing and a no-cost extension was provided.

MAINE ADAPTIVE SILVICULTURE NETWORK (MASN)

ERIC MCPHERSON, COOPERATIVE FORESTRY RESEARCH UNIT & SCHOOL OF FOREST RESOURCES

PROGRESS REPORT

ABSTRACT

The goal of this long-term CFRU managed study is to examine alternative silvicultural approaches for improving rotation length productivity and value of mid-rotation stands in Maine. The main objective of this project is to establish a network of operational scale study installations distributed across the state in all combinations of mid-rotation softwood, mixedwood, and hardwood stands of good, medium, and low site quality.

PROJECT OBJECTIVES

Once established, this network will serve as a field laboratory, where on an operational scale silvicultural treatments can be compared, productivity and costs of multiple harvest methods can be quantified, data will inform and improve growth and yield models, predictions of remotely sensed forest inventory attributes and habitat quality can be validated, and the effects of forest management on wildlife habitat can be quantified.

KEY FINDINGS/ACCOMPLISHMENTS

2025 was another busy year for MASN with long-term measurements continuing, supplementary data gathering and CFRU funded projects using data. The CFRU summer crew completed the postharvest measurement on AMC Mooresville and an overstory measurement on the most topographically diverse site, Wagner Stetsontown, in western Maine. Along with the continuous measurements, data was gathered on crown width at the AMC Mooresville site to help validate remotely sensed forest structure measurements. Wheatland Geospatial Lab also completed a postharvest aerial imagery reconnaissance flight of the AMC Mooresville site, providing a high resolution DEM and RGB imagery.

Talks are continuing with Baskahegan to implement treatments at their site with the hopes that these will resume this summer. The SFMA Hinckley Brook site received a full preharvest inventory and that data will be used to help inform the ongoing conversations about treatments to be applied.

Along with long-term measurements, the CFRU summer crew and Research Coordinator cored the dominant species in the Delayed Harvest blocks of 6 sites (Wagner Stetsontown, Weyerhaeuser Mayfield, CLWH Oxbow, SILC Nashville Plantation, JDI Saul's Brook and SILC T13R15). This was done to get an estimate of stand age which will be an important metric for research projects going into the future. The Research Coordinator also worked with landowners to get estimates of site history as another data point for researchers to use.

MASN DRIVES NEW CFRU PROJECTS

Interest from researchers in MASN has increased in recent years. Three CFRU projects are currently utilizing MASN as a key research component:

BIRDS AS INDICATORS OF FOREST MANAGEMENT SUSTAINABILITY IN MAINE: AN EVALUATION OF PAST SURVEYS AND FUTURE ASSESSMENT APPROACHES

- ARUs were deployed on 4 sites over the summer: AMC Mooresville, SILC T13R15, JDI Saul's Brook and CLWH Oxbow.
- ARU deployment will continue to rotate through the sites into the future.
- PIs are using data collected from on the ground observations and Autonomous Recording Units (ARUs) to relate silvicultural practices to bird populations

HARMONIZED MASN INVENTORY DATABASE: CURATE, ANALYZE, AND MODEL INVENTORY DATASETS FOR INFORMED DECISION MAKING

- The database is finished and will be shared with cooperators and researchers for use and feedback.

MIXEDWOOD MANAGEMENT: SILVICULTURE FOR HARDWOOD–SOFTWOOD MIXTURES IN MAINE

- Data was used in analysis of mixedwood forest management in Maine. Specifically looking at silvicultural treatment effects on saplings and regeneration.

FUTURE PLANS

- Complete installation of Baskahegan Brookton site.
- Continue long-term measurements.
- Work with Baxter State Park SFMA to identify and implement treatments.
- Support projects currently using MASN data.
- Manage and add to the database as necessary.

ACKNOWLEDGEMENTS

We would like to thank the CFRU membership for their continued support of this long-term research network. We would like to thank the researchers who have utilized our data for current/future projects and who frequently make themselves available to discuss and provide critical input on research design.

Lastly, this project would not be possible without the hard work of our summer field crews. They worked long, especially hot days in the summer of 2025 with an exceptional eye to collecting research grade measurements. Thanks to our Field Crew Leader, Sam Sebasto (SFR, 2026), for returning to the CFRU for a second summer in a row. We appreciate all of the work you do for us, in and out of the field. Thanks to Reg Clarke (SFR, 2026) and Isabella "Bella" Pfankuch (SFR, EES, 2028) for putting in the long days and hard work. We wish Reg the best of luck after graduating this spring and happily welcome Bella back as 2026 Field Crew Leader.

GEOGRAPHIC LOCATION OF PROJECT

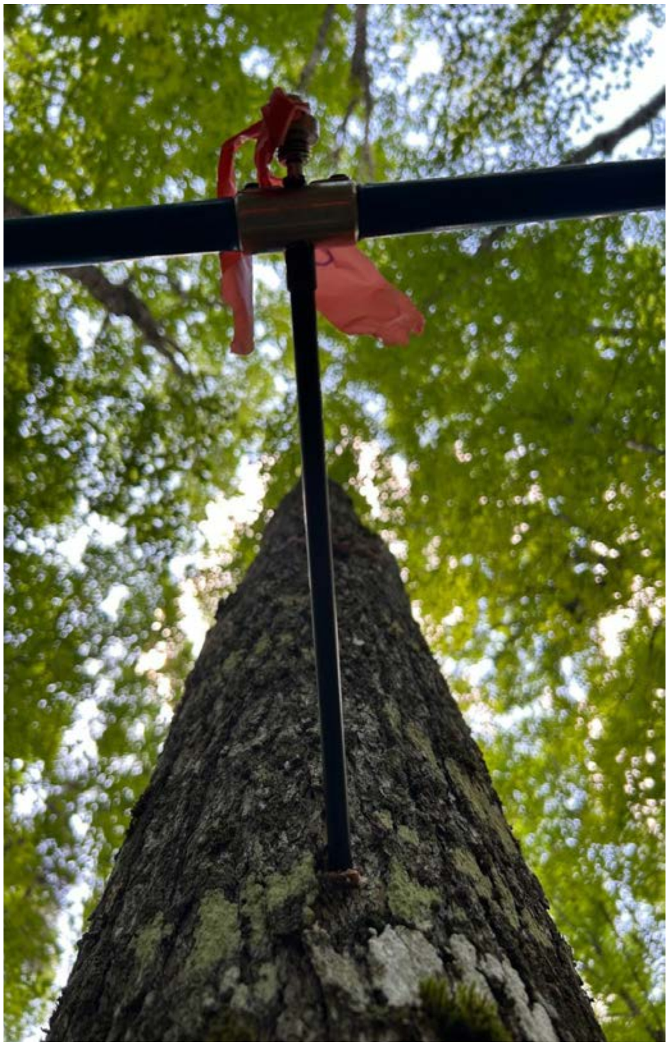
Maine, on select CFRU member lands. Locations and additional site details can be viewed in ArcStory.

PARTNERS, STAKEHOLDERS, & COLLABORATORS

The CFRU membership and the researchers who utilize our data for collaborative research.

EXTERNAL/MATCHED FUNDING SOURCES

Funds from Dr. Sydne Record totaling X.



Photos left to right: Dominant species cored on MASN sites in 2025, the 2025 CFRU Field Crew

HARMONIZED MASN INVENTORY DATABASE: CURATE, ANALYZE, AND MODEL INVENTORY DATASETS FOR INFORMED DECISION MAKING

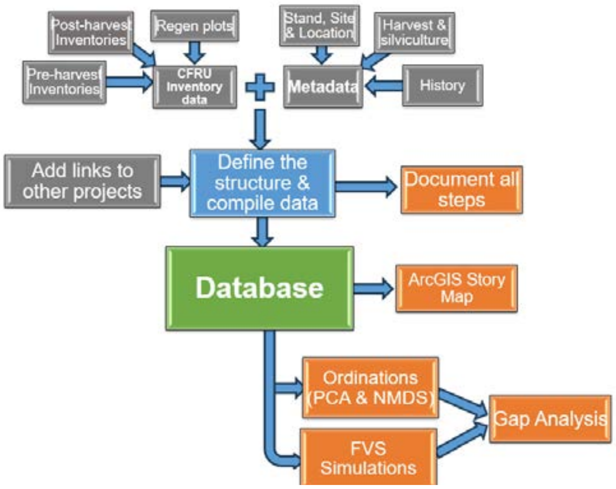
LIBIN THAIKKATTIL LOUIS, ASSISTANT PROFESSOR OF FORESTRY, UMFK (PI)
ERIC MCPHERSON, RESEARCH & INTERNSHIP COORDINATOR, CFRU, UMAINE
ANIL RAJ KIZHA, ASSOCIATE PROFESSOR OF FOREST OPERATIONS & FORESTRY PROGRAM LEADER, UMAINE

ABSTRACT

Long-term data from permanent field plots is foundational to decision-making in various aspects of forestry including silviculture, operations, and management, as well as growth and yield modeling. Data gathered from permanent, long-term plot studies cannot be substituted with data gathered from temporary plots because the longer time scales provide an in-depth understanding of tree growth trends and environmental variations from seedling to harvest (Weiskittel et al 2011). Historically, long-term data collection initiatives involving permanent field plots have been subject to inconsistencies in plot maintenance, data collection protocols, and data curation, which complicate data analysis (Kershaw Jr et al 2016). Permanent plot data collection initiatives generate tremendous amounts of data over a long-time scale, which must be reliable and archived in a consistent format to confer the largest benefits to forest managers and researchers. Hence, we propose creating a harmonized database incorporating multi-year data collected from all Maine Adaptive Silviculture Network (MASN) study sites. The primary objective of the project will be to define the structure and add key metadata from internal and external data sources. We will document every step in creating the database so that future data can be added in a similar way. The project will also analyze trends in data that can inform future decision-making and communicate findings to stakeholders at CFRU. The results from the project will help answer questions related to the effectiveness of management, growth trends, and responses of various silviculture prescriptions, and inform policy maker's future decision making.

PROJECT OBJECTIVES

- Compile inventories (pre- and post-harvest) from all MASN sites with the data on trees and regeneration into a harmonized database that is Findable, Accessible, Interoperable, and Reusable (FAIR-compliant; Wilkinson et al 2016).
- Document the entire processes involved from data collection and curation procedures to entering data and metadata to the database such as, structure and function of the database attributes, data collection procedures, archival formats, and links to internal and external metadata (e.g., satellite and Lidar), and link the existing ArcGIS online Story map to the new database.



- Explore MASN site data for patterns, relationships, trends, and gaps using inferential and comparative statistical methods and communicate the results to CFRU members.
- Exploration will include growth simulations with the Forest Vegetation Simulator, multivariate analyses, and gap analysis.

APPROACH

- The project will gather the various inventory data collected by the CFRU from MASN sites and compile as a database in suitable platforms (e.g., Microsoft access). The structure of the tables and links will be properly defined so that adding new metadata or managing the existing database will be clear for the future database managers. Along with the inventory data from the MASN sites, the database will have other meta data such as GPS location, harvesting methods, silviculture prescription, links to external sources, other CFRU projects in the site etc.). The database structure will be defined at the plot, stand, and location levels and the accumulation of various metadata for the respective levels will be defined.
- The project will also define access for various stakeholders such as CFRU members, UMaine researchers, and the general public. The CFRU members will have complete access to the ArcGIS story map and the database, including the plot, stand, and location level inventory data, all metadata including the links to other CFRU or internal projects

(based on availability). There will be limited access for UMaine researchers and the general public in the database which will also be defined in the structure of the database and will be properly documented.

- Growth simulations: Standardized comparisons of stand growth projections among silvicultural prescriptions and forest types will be performed using the online FVS application (Forest Vegetation Simulator; Dixon and Keyser 2008, Kuehne et al 2022).
- Multivariate analyses: Ordination statistics such as principal component analysis (PCA), nonmetric multidimensional scaling (NMDS) and graphical vector analysis (GVA) will be applied to identify patterns and trends among data at site, prescription, and plot levels (Shipley 2021, Wildi 2017). Variables such as prescription, stand, site, operational characteristics, and other metadata will be used for analyzing patterns. These approaches will identify optimal combinations of forest management practices that are associated with desired outcomes, such as increased tree growth rates and biodiversity. GVA and post hoc analyses will be used to rank order the relative importance of different combinations of variables. We will share with CFRU members an interpretation of these analyses enumerating specific forest management recommendations (e.g., which trees to plant in which environments to maximize growth).
- Gap analysis: Growth simulations and multivariate analyses will reveal gaps in the MASN plot data and elucidate new research questions. For example, FVS may identify additional variables needed to strengthen model predictions, or multivariate analyses may reveal meaningful relationships among forest management and growth variables that apparently lack bio-physical basis (and thus merit mechanistic exploration). Remedying gaps and exploring new questions may warrant gathering additional types of data and/or refining data collection protocols. Based on these simulations and statistical analyses, we will provide CFRU members with a list of salient questions and recommended data collection actions.

KEY FINDINGS/ACCOMPLISHMENTS

- Comprehensive Forest Inventory Database: Developed a relational database with 12 interconnected tables to capture all aspects of forest inventory data, enabling efficient data management and analysis across multiple measurement types (overstory, saplings, regeneration, CWD).
- Automated Forestry Metrics Calculation: Implemented automatic calculation of key forestry metrics (BAPA, TPA, stumps per acre, seedlings per acre) through SQL queries, transforming raw field data into actionable information for forest managers.
- Treatment Effect Analysis Capability: Designed the database to compare pre- and post-treatment conditions through metrics like QMD Ratio and % BA Removed, allowing for quantitative evaluation of silvicultural practices and their impacts.
- Foundation for Long-Term Monitoring: Established a data platform that supports long-term monitoring of adaptive silvicultural practices in Maine's forests, providing a research foundation that can inform sustainable forest management decisions based on quantitative data.
- Workflow Documentation: Developed comprehensive documentation of the database creation workflow, including SQL code for all queries, step-by-step instructions for recreating the database, and detailed explanations of each process for future database management and expansion.
- Data Curation and Quality Control: Completed thorough data curation and error checking processes to ensure data integrity and reliability, establishing a clean baseline dataset for ongoing research and management applications.
- Involved Undergraduate students at UMFK: The students in the forest inventory and analysis course (FOR332) were assigned parts of the MASN overstory and saplings data which provided hands on experiences for the students. All the students made individual posters and were instrumental in finding inconsistencies and curing the dataset.

FUTURE PLANS

- Statistical analysis: include detailed analysis of the data and summarizing the results based on the gap and multivariate analysis
- Growth Simulations in FVS
- ArcGIS Story map: update the current story map

PARTNERS, STAKEHOLDERS, & COLLABORATORS

Ked Coffin, JDI
Kyle Burdick, Baskahegan
Eugene Mahar, LandVest
Ian Prior, Seven Islands Land Company
Steve Tatko, AMC
Thomas Cochran, Downeast Lakes Land Trust
Mike Treat, Prentiss & Carlisle

NORTHERN CONIFER SILVICULTURE GUIDE

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NICOLE ROGERS, LANDOWNER OUTREACH FORESTER, MAINE FOREST SERVICE

KEITH KANOTI, UNIVERSITY FOREST MANAGER, UNIVERSITY OF MAINE

ERIN SIMONS-LEGAARD, RESEARCH ASSISTANT PROFESSOR, UNIVERSITY OF MAINE

ABSTRACT

The northern conifer forest (spruce-fir and associated species) in Maine and northern New Hampshire, Vermont, and New York is a commercially and ecologically important forest type that supports a robust woods economy. Sustainable management is critical to meeting the needs of landowners and the public. U.S. Forest Service silviculture guides are key resources for managers across the region, but the one for spruce-fir is outdated. This project involved a comprehensive review of available literature, unpublished experiment data, and practitioner experience to co-produce a new silviculture guide for this forest type. Drawing upon more than two dozen experts and multiple long-term studies, we completed and edited a draft of a new guide in summer 2025. The manuscript was reviewed by CFRU members, an advisory panel, and silviculture experts. Next steps include U.S. Forest Service policy review, editing and layout by production staff, and publication on the Treesearch website in 2026.

PROJECT OBJECTIVES

- Produce a new Silviculture Guide for Northern Conifers using a process of co-production through which stakeholders including CFRU members and other forestland owners and managers are engaged in content development.
- Host an in-field workshop for CFRU members and others (scheduled October 2025 but canceled due to government shutdown; will be rescheduled in 2026 at no cost to project).
- Collaborate with partners to disseminate the guide and a companion video (timing contingent on Forest Service processes affected by new Administration's priorities; will be delivered in 2026 at no cost to project).

APPROACH

- Complete literature review, draft table of contents, invite practitioners to advisory panel (completed).
- Gather unpublished data or research results from cooperators and/or extract data from long-term experiments to fill information gaps. Use these to update supporting materials such as density management guides (completed).
- Convene advisory panel to review and revise direction and content of the guide at key steps in the development process (completed).
- Draft the guide, solicit review from practitioners and silviculture experts, respond to reviews, and complete technical editing (completed).
- Host workshop for practitioners (scheduled October 2025 but postponed until 2026 due to government shutdown).
- Submit the guide to the U.S. Forest Service for policy review and formatting, layout, publication, and production of companion video by Communications and Science Delivery Staff (ongoing).

Below - Production Forestry. A drum chopper being used after clearcutting to break up submerchantable trees and logging slash prior to planting spruce seedlings. Courtesy photo by Jake Moore.

KEY FINDINGS/ACCOMPLISHMENTS

Selected findings from the guide include:

- The northern conifer forest is defined in the guide as softwood (S) or softwood-dominated mixedwood (SH) in which spruce species or balsam fir are the most abundant conifers. This forest covers more than 7 million acres in the Northeast and is divided almost equally between S and SH compositions.
- The extent of the northern conifer forest includes the homelands of a number of tribes. Indigenous Knowledge is a form of best available scientific information that can inform sustainable management, and in turn, western science can advance the holistic understanding of tribal co-stewardship. Relationship building with Indigenous people is the basis for respectful and mutually beneficial collaboration on northern conifer management.
- Forest Inventory and Analysis data show that balsam fir volume increased and red spruce volume decreased on plots harvested since 1999, while volume of both fir and spruce species increased on unharvested plots. These data support the results of long-term research, which show that red spruce is the more difficult of the two species to maintain in many harvested stands.
- Soils are an important determinant of site quality for northern conifers and influence the amount of hardwood competition that can be expected. Topographic position is a factor in this relationship and is reflected in spruce-fir habitat types defined in the early 1900s, e.g. spruce flats and spruce-hardwoods. These provide a useful framework for management.
- Northern conifers provide habitat to many wildlife species and other biodiversity values. Old-growth forests, though rare, are useful references for the types of disturbances that favor red spruce over the long term. Key features include low rates of canopy disturbance and abundant deadwood.
- The tendency of spruce budworm to cause greater balsam fir than red spruce mortality during uncontrolled outbreaks historically favored red spruce. Managing for less-vulnerable species, vigorous trees, maintaining mixedwood composition, and using an early intervention strategy can help reduce mortality today.
- When management results in disturbances and stand structural or compositional outcomes that differ from those that confer a competitive advantage to red spruce (e.g., more frequent or intense disturbances, larger canopy openings, less deadwood), silvicultural treatments that focus on retaining and releasing this species at all entries are recommended. New stand density management charts included in the guide, which differ by ecoregion, are useful tools to guide these treatments.
- Projected changes in long-term weather indices suggest that northern conifer forests are vulnerable to changing climate. However, there are a number of management approaches that can be used to increase forest resilience. These can be incorporated into conventional silvicultural systems.
- Ecological or production forestry can be used in northern conifers when ecological values or wood production are paramount. In addition, some of the principles and treatments can be incorporated into silvicultural systems applied for other values, e.g., precommercial thinning to release submerchantable spruce or planting for restoration.
- Where stand conditions have deviated from those desired by landowners, including transition to a hardwood-dominated mixedwood (HS) composition in which red maple or aspen predominate, rehabilitative silviculture can be used. This approach often requires a multi-treatment approach.

The guide consists of two sections. The first is Ecological Background and the second is Silviculture. Each section includes multiple chapters authored by PIs and Co-PIs or invited authors, with supporting case studies that show real-world examples of the concepts discussed. Pairing research findings with perspectives from practitioners will increase the usefulness and relevance of the guide. The following figures, tables, and photos provide examples of the content.

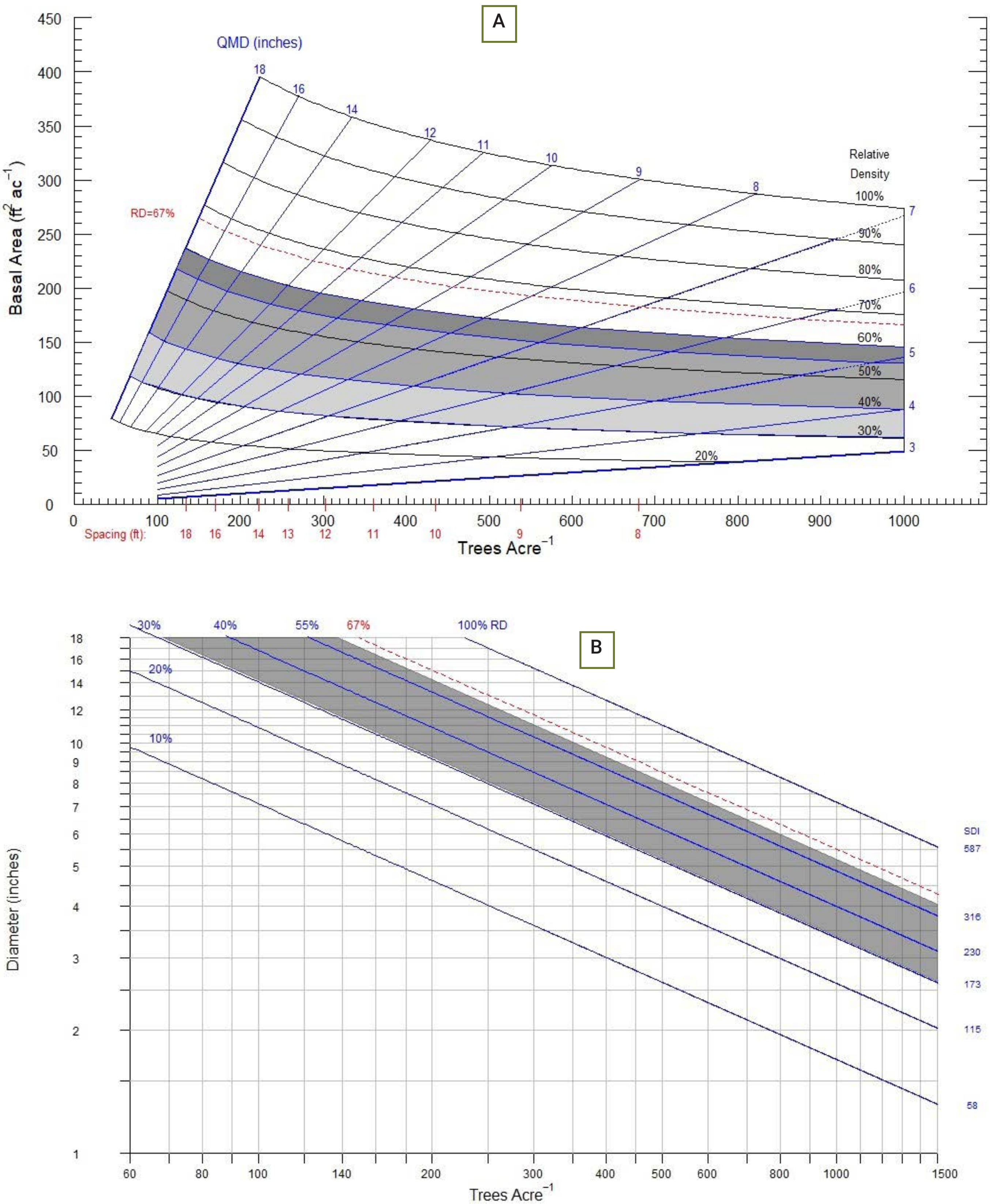

Figure 1. Quantitative Tools. A) Stocking guide. B) Density management diagram. The entire grey zone represents a plausible Zone of Optimal Density (Relative Density from 0.3 to 0.6). The lower (0.3 to 0.4) and upper (0.55 to 0.6) shadings are portions of that zone that have been highlighted or used in different studies. Depending on management objective (e.g., maximizing total biomass or rapid diameter growth), the lower or upper portion of the zone would apply. Diagrams by David Ray and Aaron Weiskittel.

Table 1. State of the Resource. Total forest area and gross stemwood volume (millions of cubic feet) of live trees (greater than 5 inches d.b.h.) estimated by forest type and subtype from Forest Inventory and Analysis (FIA) plots (n = 8,050) across Maine, New Hampshire, Vermont, and New York in 2023. Table by Erin Simons-Legaard.

Forest type[1]	Subtype[2]	Million Acres	Volume (millions of cubic feet)			
			Balsam fir	Red spruce	White spruce	Black spruce
Northern Conifer	S	3.67	1,455	1,942	233	263
	SH	3.62	1,616	1,957	169	83
Other Conifer	S	1.66	140	264	40	43
	SH	4.03	316	465	66	26
Hardwood	HS	9.38	1,079	1,512	129	20
	H	20.6	302	543	34	4

[1]Forest type assignment was determined from relative species abundance based on live aboveground biomass of all trees greater than 1 inch d.b.h. Northern conifer is defined as 50 percent or more softwood with balsam fir, red spruce, white spruce, or black spruce as the most abundant softwood. Other conifer is defined as forest with 50 percent or more softwood and dominated by other conifer species. Hardwood is defined as less than 50 percent softwood.

[2]Subtypes are defined by the relative proportion of softwoods (S) or hardwoods (H) present in the stands. Softwood subtypes (S) have 80 percent or more softwoods, mixedwood subtypes (SH or HS) have between 50 and 80 percent softwoods or hardwoods (respectively), and hardwood substyles (H) have 80 percent or more hardwoods.

FUTURE PLANS

Federal government restructuring and shutdown in 2025 delayed some deliverables. We anticipate that the guide will be published in 2026. The workshop for practitioners at the Penobscot Experimental Forest was scheduled and advertised in October 2025 in collaboration with the CFRU and Maine Forest Service, but was canceled when the Forest Service presenters were furloughed. It will be rescheduled in 2026.

GEOGRAPHIC LOCATION OF PROJECT

Maine, New Hampshire, Vermont, New York

PARTNERS/STAKEHOLDERS/ COLLABORATORS

Acadian Timber
Appalachian Mountain Club
Baskahegan Company
Baxter State Park
Cooperative Forestry Research Unit
Forest Society of Maine
Huber Resources Corporation
J.D. Irving Limited
Landvest
Maine Bureau of Parks and Lands
Maine Forest Service
Maine Department of Inland Fisheries and Wildlife
New England Forestry Foundation
New Hampshire Division of Forests and Lands
Northern Forest Conservation Services, LLC
Passamaquoddy Forestry Department
Penobscot Nation, Department of Natural Resources
Seven Islands Land Company
The Nature Conservancy
U.S. Fish and Wildlife Service, Umbagog National Wildlife Refuge
U.S. Forest Service, Green Mountain National Forest
U.S. Forest Service, National Forest System, Enterprise
U.S. Forest Service, White Mountain National Forest
Vermont Department of Forests, Parks, and Recreation
Vermont Land Trust
Wagner Forest Management

EXTERNAL/MATCHED FUNDING SOURCES

Source:	Amount:	Direct/Indirect:
NSRC	$8,358	Direct
USFS	$35,472	Indirect

MIXEDWOOD MANAGEMENT: SILVICULTURE FOR HARDWOOD-SOFTWOOD MIXTURES IN MAINE

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LANCE VICKERS, ASSISTANT PROFESSOR, UNIVERSITY OF KENTUCKY

ERIN SIMONS-LEGAARD, RESEARCH ASSISTANT PROFESSOR, UNIVERSITY OF MAINE

ABSTRACT

Mixedwoods (hardwood–softwood mixtures) present management opportunities and challenges. While there has been a lot of research on boreal mixedwoods, we have less information about temperate mixedwoods like those in Maine. Yet previous research has shown potential for reduced susceptibility to insects and diseases as well as increased market flexibility, carbon sequestration, climate resiliency, and wildlife habitat diversity in mixedwoods such as spruce–fir–hardwood, hemlock–hardwood, and oak–pine, with benefits varying from type to type. Our team is building on past work on fundamentals of temperate mixedwood management to provide summaries and guidance about mixedwood types managed by CFRU members. This three-year project includes (1) convening regional experts on mixedwood ecology and management for a workshop, (2) summarizing Forest Inventory and Analysis (FIA) and Maine Adaptive Silviculture Network (MASN) data to provide updates on mixedwood status and trends, and (3) developing and publishing a Mixedwood Management guide co-authored by regional experts in English and French with forest-type-specific sections.

PROJECT OBJECTIVES

- Bridge the gap between researchers and practitioners by convening mixedwood researchers for a workshop with CFRU members and others for presentations, discussion, and a field tour
- Leverage FIA and MASN data to refine understanding of mixedwood management by analyzing status and trends of mixedwoods in Maine and in MASN specifically
- Bring state-of-the-art, expert knowledge on mixedwood ecology and management to forestry practitioners in CFRU and elsewhere via a Mixedwood Management Guide to be published in English and French

APPROACH

- Convene researchers and practitioners for day-long workshop and co-production meeting to develop template for management guide (completed, October 2023) (Figure 1).
- Synthesize FIA data to determine status and trends of mixedwoods in Maine in harvested and unharvested stands (completed, April 2025).
- Summarize MASN data to determine near-term effects of silvicultural treatments on forest composition relative to mixedwoods (ongoing).
- Draft guide, solicit review from practitioners and silviculture experts, respond to reviews, and complete technical editing (ongoing).
- Submit the guide to the U.S. Forest Service for policy review and formatting, layout, and publication (planned for 2026).

Figure 1. CFRU members, mixedwood researchers, and others discuss options for mixedwood management at the mixedwood ecology and management co-production meeting and field tour hosted by CFRU and the Appalachian Mountain Club. U.S. Forest Service photo.

KEY FINDINGS/ACCOMPLISHMENTS

- We completed a draft "mixedwood memo" report showing status and trends of mixedwoods in Maine. This was shared with CFRU members for their review and their feedback was incorporated. Descriptive text is in preparation for publication as a technical report (Figure 2).
- More than half (53%) of Maine's forestland has a mixedwood composition, with more mixedwood acres dominated by softwoods than hardwoods (Table 1).
- Almost two-thirds (61%) of Maine forests classified by FIA as northern hardwoods, and one-third (31%) of those classified as spruce-fir, are mixedwoods (Table 2).
- Acres of red spruce and northern white-cedar mixedwoods have declined over the last two decades, with little change in balsam fir mixedwoods and increases in eastern hemlock and eastern white pine mixedwoods (Table 3).
- Compositional transitions (e.g., hardwood to mixedwood) are more common for mixedwoods than for softwood or hardwood stands. More than 70% of hardwood and softwood stands remained in those categories over the last 20 years, while only about half of HS and SH mixedwoods remained in those categories (Table 4).
- These findings and others to be included in the technical report show the extent and dynamic nature of mixedwoods in Maine, and underscore the need for mixedwood-specific management guides.
- Preliminary summaries of MASN data were prepared (Table 5), but missing data and changes in data collection protocol over time limited the analysis we could do. We continue to collaborate with CFRU staff to try to overcome these data challenges.
- Four of the MASN sites with pre- and post-harvest data are mixedwoods: AFM_Grandfalls (SH) and JDI_SaulsBrook, SILC_NashvillePlantation, and Wagner_Stetsontown (HS).
- Partial harvests at the MASN sites generally decreased proportion of softwoods in the overstory, except at SILC_NashvillePlantation.
- The understory (sapling class) was more hardwood than the overstory at most MASN sites, including at CLWH_Oxbow, which had a softwood (S) overstory and mixedwood (SH and HS) understory. With few exceptions, harvesting decreased proportion of softwoods in the understory.
- Assessment of species, regeneration (seedling) data, and remeasurement data (where available) will help to discern trends and clarify compositional outcomes of treatments. Yet the prevalence of hardwoods even at some softwood-dominated sites, and greater proportions of hardwoods in the understory and after harvesting suggest trajectories toward greater hardwood competition in many treatments.
- The in-preparation mixedwood management guide was leveraged to produce a more comprehensive Forest Service-led publication, including a number of temperate mixedwood types in eastern North America. This will elevate the stature and impact of the Maine project at no additional cost.
- We contracted Dr. Bethany Muñoz, a former U.S. Forest Service and Natural Resource Conservation Service scientist, as Project Manager. She is helping to flesh out the content of each section and working with authors to ensure consistency across mixedwood forest types. She serves as a liaison between the Maine authors and those for mixedwood types in other regions, and will coordinate reviews of completed chapters.

SELECTED TABLES SHOWING MIXEDWOOD STATUS AND TRENDS IN MAINE, BY LANCE VICKERS

Table 1. Maine forestland by composition (dbh ≥ 5 inches), 2022.

Composition	Acres	Percent
Hardwood	3,535,826	20%
HS Mixedwood	3,957,578	23%
SH Mixedwood	5,169,176	30%
Softwood	4,814,382	27%
Total	17,478,251	100%

Table 2. Maine forestland by FIA Forest Type Group, 2022.			
Forest Type Group	**Total Acres**	**HS Mixedwood**	**SH Mixedwood**
Northern hardwoods[a]	7,166,805	38%	23%
Spruce Fir	6,000,624	2%	30%
Aspen Birch	1,228,497	37%	34%
Northeastern pines[b]	1,207,056	3%	60%
Riparian hardwoods[c]	408,146	35%	25%
Oak Hickory	402,478	43%	8%
Oak Pine	377,136	30%	66%
Other	174,186	8%	20%
Total	17,478,251	23%	30%
[a]maple/beech/birch, [b]white/red/jack pines, [c]elm/ash/cottonwood			

Table 3. Change in Maine mixedwoods by prominent softwood species, 2003-2022.		
Mixedwood type	**Acres Change**	**Percent Change**
Balsam fir - hardwood	31,640	1.2%
Red spruce - hardwood	-205,277	-10.7%
E. white pine - hardwood	110,894	8.1%
E. hemlock - hardwood	51,925	3.1%
N. white-cedar - hardwood	-282,680	-21.0%
Other	-232,797	-34.8%

FUTURE PLANS

Federal government restructuring and shutdown in 2025, including the departure of co-PI Kabrick from federal employment, delayed some deliverables. We anticipate that the guide will be drafted and ready for practitioner review in 2026.

ACKNOWLEDGEMENTS

We appreciate the support of CFRU and the U.S. Forest Service, Northern Research Station.

PARTNERS, STAKEHOLDERS, AND COLLABORATORS

Acadian Timber
American Forest Management
Appalachian Mountain Club
Baskahegan Company
Baxter State Park
Forest Society of Maine
Huber
Irving Woodlands
Landvest
Laval University
Maine Bureau of Parks and Lands
Maine Department of Inland Fisheries and Wildlife
Maine Forest Service
Manulife
Penobscot Nation, Department of Natural Resources
Prentiss and Carlisle
Quebec Ministry of Forests, Wildlife and Parks
Sappi
Seven Islands Land Company
The Nature Conservancy
University of Kentucky
University of Maine
University of Missouri
U.S. Fish and Wildlife Service
U.S. Forest Service
Wagner Forest Management

GEOGRAPHIC LOCATION OF PROJECT

eastern North America

EXTERNAL/MATCHED FUNDING SOURCES

Source:	Amount:	Direct/Indirect:
USFS	$18,592	Indirect

SILVICULTURAL SYSTEMS FOR ADAPTIVE PLANTED SPRUCE FORESTS (SSAPSF)

MIKE PREMER, UNIVERSITY OF MAINE (PI)
SHAWN FRAVER, UNIVERSITY OF MAINE

ABSTRACT

Forests of the northeast have traditionally been managed with natural regeneration methods. However, uncertainty in future growth conditions coupled with mounting forest health risks has initiated interest in alternative management regimes, including expansion of planted conifer forests. Spruce (Picea spp.) has a rich history of timber commodity supply, generation of non-timber income and ecological services, with potential for rapid C sequestration and long-term storage. This project aims to quantify commodity production, aboveground C dynamics, and soil nutrient status under silvicultural treatments in planted WS forests when compared with naturally regeneration. An experimental network of new research installations is proposed to form baseline measurements of pre-treatment conditions, artificial and natural regeneration dynamics, and site variables. A total of 5 new installations were established in 2024, with plans for 7 additional sites in 2025. Findings will be used to generate predictive, geo-referenced maps of potential vegetative productivity and limiting growth factors.

PROJECT OBJECTIVES

- Quantify aboveground productivity and C sequestration/storage potential of planted WS and naturally regenerating forests across a range of site conditions.
- Test silvicultural treatments to increase productivity of planted WS forests (chemical site preparation)
- Integrate findings with Light Detection and Ranging (LiDAR), remote sensing products, and digital site mapping to generate precision management tools (<30 m) at a regional coverage to aid in decision support for landowners.
- Assess economics of silvicultural treatments (conversion/planting/intensive silviculture) with the aid of G&Y model projections and continued monitoring.

APPROACH

- Experimental sites (n=12 – 6 on JDI ownership, 6 across cooperating landowners) strategically deployed across a gradient in site conditions
- Locations constrained by and coincidental with planned, upcoming harvest activity on cooperator ownership. Within the planted WS plots, seedlings will be planted at a density of 640 trees per acre with 2 site preparation treatments (herbicide, no treatment), for a total of 5 plots per installation, and 60 total plots across the sampling network.
- Samples of forest soils obtained with a slide hammer for archiving and laboratory processing for soil texture and chemistry (Ca, Mg, K).
- Competing vegetation (herbs/shrubs) will be identified and tallied by species (if available) in 4 standard 1m2 quadrats per plot. Soil and vegetation sampling will occur immediately post-planting and annually for the first 3 years, coincidental with tree measurements.
- Utilize a variety of open-source software, processing methods, and statistical analysis across the project, from strategic deployment of experimental installations to final generation of decision support tools for cooperators.
- Leverage site-specific environmental variables (climatic records and digital soil maps (DSM)) and WS productivity, for optimal sampling deployment in the 2024-25 planting seasons. Digital Soil Maps are utilized through past work at the CFRU (Brungard et al. 2019), with additional variables generated by M. Premer (e.g., soil pH, water holding capacity, water deficit index).

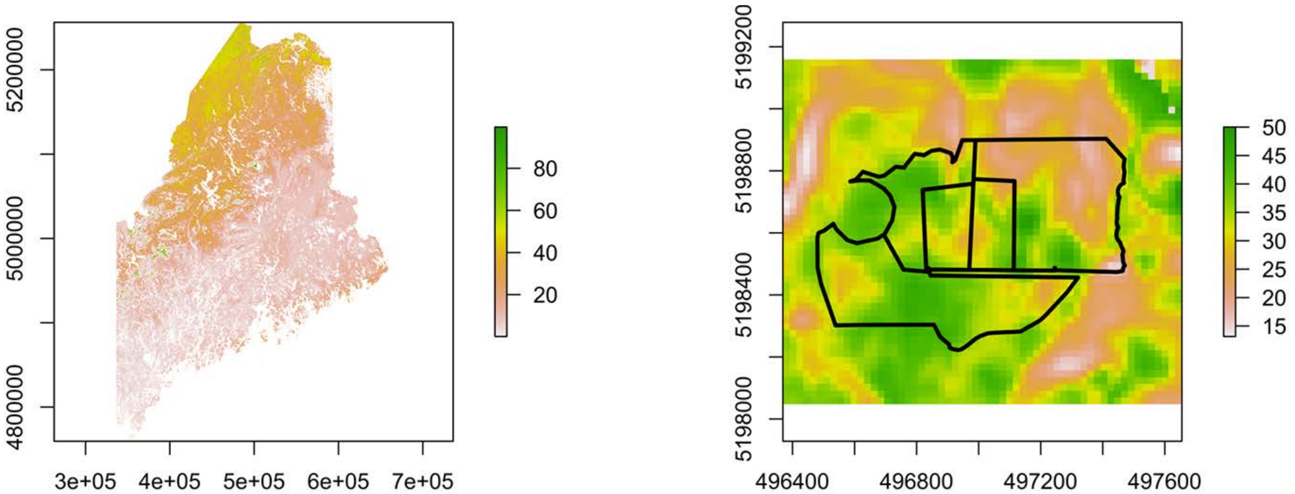
KEY FINDINGS AND

Figure 1. Newly established plot with herbicide application. Pin flags indicate where seedlings are planted.

ACCOMPLISHMENTS

- Five installations established on JDI and Seven Islands Land Company (SILC) managed lands during the 2024 field season for a total of 15 plots. Initial tree measurements taken at each installation including root collar diameter and total height. TMS-4 data loggers installed to measure air and soil temperature and soil moisture, capturing microsite conditions within each installation and treatment (e.g., control, no herbicide + plant, herbicide + plant). Microclimate data retrieved in spring 2025 and sensors redeployed.
- Coordination with both JDI and SILC to establish another three installations in 2026, and four in 2027, completing the study network.
- JDI and PRT comparison trials contributed in-kind from Weyerhaeuser have been generated into a research note provided to the CFRU. Results suggest significantly greater height of JDI seed sources at 7 and 8 years after planting.
- Habitat/Site suitability estimates completed for native spruce species (black, red, white) at 1/5 acre for the entirety of Maine available as raster files (.tif) with accompanying research note (Carter and Premer 2025) – available at https://www.maineforestlab.com/single-project
- Analysis of native spruce species mixtures and risk of weevil damage completed (Carter 2025).

Figure 2. (Below) Statewide estimates of contemporary WS site suitability (0-100) across Maine (left panel-a) and downscaled to a designated planting block and stands (right panel-b) – from Carter and Premer 2025.



(a)

(b)

FUTURE PLANS

We plan to finalize installation of the experimental plots in the next two years (requesting a no-cost extension), while collecting and archiving data from plots established in 2024. While not in the original project proposal, we aim to complete measurements across 10 additional installations planted in 2016-2017 that can provide genetic x environmental comparisons with the experimental plots provided by Weyerhaeuser. We plan to have all supplemental project goals and original research objectives completed by 2027, but measurements will be repeatedly collected, and study findings will be disseminated into the future given available funding.

ACKNOWLEDGEMENTS

We wish to extend our sincere gratitude to Jason Desjardins and the staff at Seven Islands Land Company, Shane Furze, and Trevor London at Huber Resources.

PARTNERS / STAKEHOLDERS / COLLABORATORS

- Ben Dow, General Manager, Northern Timberlands, Weyerhaeuser
- Ian Prior, Senior Inventory and Planning Manager, Seven Islands Land Company
- Trevor London, Senior Marketing Manager, Huber Resources

GEOGRAPHIC LOCATION OF PROJECT

Maine, on select CFRU member lands. Contact CFRU staff for installment locations.

EXTERNAL/MATCHED FUNDING SOURCES

Source:	Amount:	Direct/Indirect:
Maine Agricultural and Forest Experiment Station	$37,250	Direct

SECRETS IN THE CTRN: CAUSAL FACTORS OF THINNING RESPONSE AND TRANSFER TO ADAPTIVE MANAGEMENT REGIMES IN MAINE SPRUCE-FIR FORESTS

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SHAWN FRAVER, UNIVERSITY OF MAINE
JAY WASON III, UNIVERSITY OF MAINE
LAURA KENEFIC, USFS

ABSTRACT

Stand density management through thinning is a common method utilized for production of commodity timber goods and quality improvement. While a rich volume of work from the Commercial Thinning Research Network (CTRN) has examined thinning practices under a variety of treatment timing and intensities, questions remain regarding the influence of site conditions on thinning response (i.e., site productivity). Therefore, quantifying the site-specific limiting factors to growth is imperative to adaptative management strategies and effective silviculture. This project aims to quantify the causal mechanisms of operational thinning response through the integration of tree-ring stable isotopes with high spatiotemporal resolution remote sensing estimates of evapotranspiration across the spruce/fir forests of Maine. Plot measurements and tree cores were collected across 6 CTRN installations in 2024. Preliminary results reveal site-specific thinning response that varies with spruce/fir composition and estimates of water availability. Completion of tree ring processing for isotopes is planned for November 2024.

PROJECT OBJECTIVES

- Quantify the causal mechanisms of stem growth response (or lack of) to variations in thinning intensity, timing, and site variables through sampling and analysis of tree ring stable isotopes (δ13C and δ18O) with long-term CTRN datasets.
- Link remote sensing composite estimates of productivity, (e.g., cumulative monthly timesteps of water availability) with thresholds of thinning response across the hydrologic gradient of the CTRN sites and patterns in stable isotopes
- Test the accuracy, precision, and compatibility of tree and stand reconstruction through stem increment cores with field measurements to form a framework for future sampling efforts.
- Develop regional silvicultural thinning guidelines and geospatial tools of estimated treatment response to aid decision support in commercial forest operations.

APPROACH

- Utilize trees in thinned and control plots in 6 of the remaining CTRN network covering a range of site quality (SI50 = 43-79 ft.), mean annual precipitation

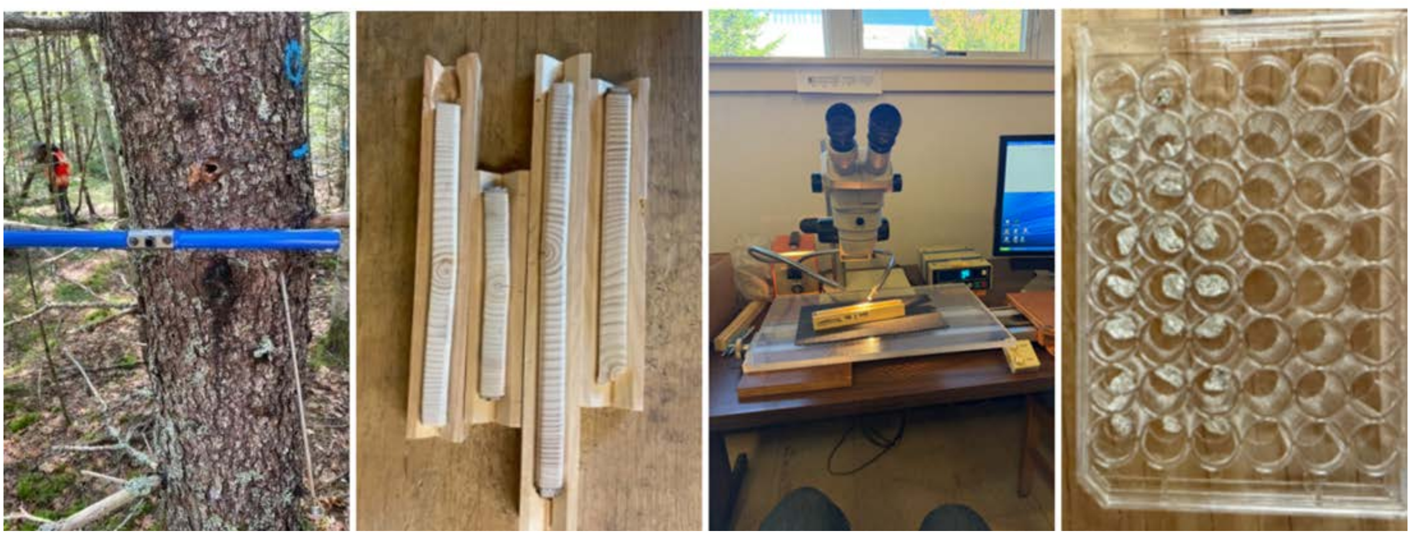

Figure 1. Increment borer sampling at the Penobscot Experimental Forest Installation (far left), the 0.5-inch diameter increment cores mounted for cross-dating at the dendrochronology laboratory middle right, where individual tree rings are ground and processed in the Forest Management Lab at the University of Maine for later analysis at Columbia University (photos courtesy of Lila Beck)

(40-51 in.), and evapotranspiration (5-8 in. water surplus).
- Tree tissue samples of δ13C and δ18O will be composited by tree and at set time intervals -immediately pre-harvest, and 4-8-12-16 years after treatment - for a total of 5 samples of stable isotopes per tree. Samples at the Stable Isotope Laboratory at Columbia University.
- Estimates of evapotranspiration and site water availability (SWA) at each treatment plot generated with geoprocessing software and publicly available monthly climate records. SWA estimates conducted at a monthly time step from 1990 to 2020 to test the influence of average and cumulative SWA since treatment on radial growth response and stable isotope discrimination.
- Integrate tree-level measurements of C assimilation and water use efficiency with high-resolution geospatial estimates of SWA to generate site-specific silvicultural guidelines.
- Integrate tree-level measurements of C assimilation and water use efficiency with high-resolution geospatial estimates of SWA to generate site-specific silvicultural guidelines.

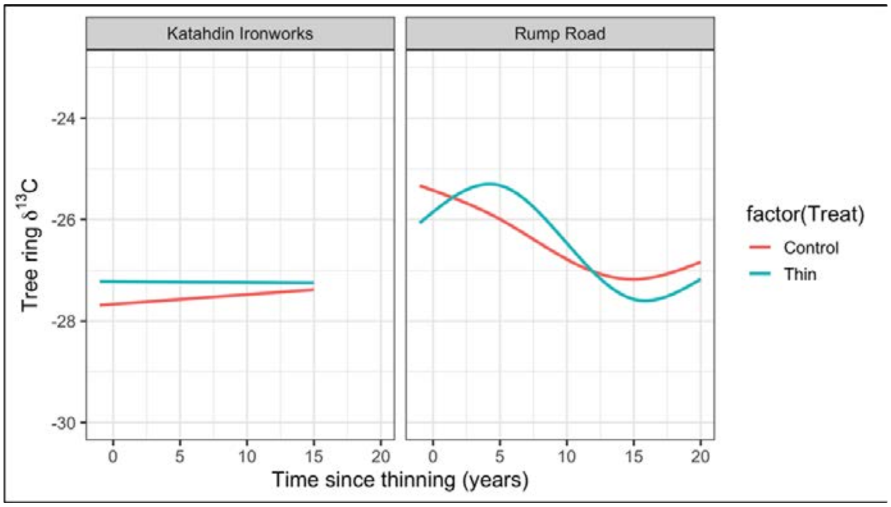

Figure 2. Predicted tree ring δ13C (y axis) by time since thinning (years – x axis) according to treatment, where the red and blue lines correspond to the reference control plot and thinned plot, respectively. Panels illustrate the Katahdin Ironworks (left) and Rump Road (right) experimental installations.

KEY FINDINGS AND ACCOMPLISHMENTS

- Tree cores and plot measurements completed in summer 2024 for 6 Installations (Katahdin Ironworks, Rump Road, Harlow Road, Golden Road, Sarah's Road, Penobscot)
- Cores cross-dated and pre-processed for laboratory submission at Columbia University
- Annual and cumulative Water Deficit (Index) raster layers generated for Maine (1990-2020) at 1/5-acre resolution and available for user download at maineforestlab.com/
- Isotope processing of δ13C completed for 4/6 sites
- Preliminary results reflect the commonly noted "thinning shock" of red spruce immediately after treatment, resulting in stomatal closure (Figure 2).
- Updated yield and financial analysis of CTRN data and site-specific calibration provided by L. Beck

FUTURE PLANS

- Complete laboratory processing of tree rings for submission to Columbia stable isotope laboratory by 12/31/2025.
- Provide a technical transfer workshop and research note of construction of water site water availability estimators
- Provide a technical transfer workshop and research note of site-specific thinning guidelines using digital site mapping products

ACKNOWLEDGEMENTS

We wish to thank collaborators: John Ackley (Formerly Weyerhaeuser, now SAPPI), Ben Dow (Weyerhaeuser), Shane Furze (formerly JDI) Carolyn Ziegra at AMC, Jeremy Miller at AFM, Ian Prior and Jason Desjardins at Seven Islands, and Karl Kreutz at the Climate Change Institute at the University of Maine.

PARTNERS / STAKEHOLDERS / COLLABORATORS

Ben Dow, General Manager, Northern Timberlands
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University of Maine
Jeremy Miller, Regional Technical Manager
American Forest Management
Ian Prior, Senior Inventory and Planning Manager
Seven Islands Land Company
Carolyn Ziegra, Research Forester
Appalachian Mountain Club

GEOGRAPHIC LOCATION OF PROJECT

Commercial Thinning Research Network, Maine.

EXTERNAL FUNDING SOURCES

Source:	Amount:	Direct/Indirect:
CAFS	$28,869	Direct

HIGH RESOLUTION LAND COVER AND FOREST TYPE DATA FOR THE STATE OF MAINE

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ANTHONY GUAY, REMOTE SENSING SPECIALIST, WHEATLAND GEOSPATIAL LABORATORY, UMAINE
CLAIRE KIEDROWSKI, EXECUTIVE DIRECTOR, MAINE GEOLIBRARY (RETIRED)

ABSTRACT

The Maine High Resolution Land Cover project will produce in partnership a multi-resolution set of land cover products for the state, providing an appropriate level of detail for a wide variety of applications. Data development will include a 1-meter land cover product, consistent with NOAA's Coastal Change Analysis Program (C-CAP), and a 10-meter land cover product including C-CAP classes plus detailed forest type categories developed by the University of Maine Intelligent GeoSolutions group, housed under the Center for Research on Sustainable Forests. Both layers will be readily updatable, with planned updates tied to the 4- to 6-year NOAA C-CAP production cycle to reduce future costs. Regularly updated 1-meter and 10-meter layers will provide statewide land cover and forest type data with unprecedented spatial, temporal, and thematic detail. This next-generation, multi-resolution data will support a broad range of forest sector use cases and applied research topics of importance to the CFRU.

PROJECT OBJECTIVES

- Develop a forest typing scheme (approx. 15 forest types) suitable for remote sensing application throughout the state of Maine given available resources and forest stakeholder priorities;
- Develop methods to harmonize 10-meter satellite-derived forest type predictions with new 1-meter land cover data obtained from digital aerial photography and LiDAR;
- Produce and distribute a statewide 1-meter land cover product (17 categories, including natural vegetation, wetlands, and impervious surfaces);
- Produce and distribute a statewide 10-meter land cover and forest type product (the current plan includes 15 forest type categories plus 16 non-forest and disturbed forest categories) (Table 1);
- Develop a data maintenance plan including a 4- to 6-year update cycle coordinated with federal, state, and university programs to reduce future cost.

APPROACH

- Production of land cover and forest type data will be accomplished through a partnership between the NOAA Office for Coastal Management and UMaine IGS. Production and delivery of the 1-meter land cover data will be coordinated by NOAA. Production and delivery of the 10-meter land cover and forest type map will be coordinated between the NOAA Office for Coastal Management and UMaine IGS, with NOAA responsible for aggregating 1-meter land cover categories to a 10-meter grid and IGS responsible for modeling and mapping the condition of forest pixels at 10-meter resolution.
- Methods used to produce the 1-meter data will be consistent with those used to produce the NOAA C-CAP product line [1], and will include a combination of machine learning applied to digital aerial photography and LiDAR, geographic object based image analysis, expert-based rulesets, and manual editing.
- Forest classification will rely on machine learning and geographic object based analysis methods developed by UMaine forest scientists [2-3] and implemented

UPLAND FOREST TYPES (12 CLASSES)		
Aspen Birch	Aspen-Birch mixedwood	Cedar-Black Spruce
Maple-Beech-Birch	Hemlock mixedwood	Hemlock
Oak	Fir-Spruce mixedwood	Fir-Spruce
Red Maple	Spruce-Pine mixedwood	Spruce-Pine
LOWLAND FOREST TYPES (3 CLASSES)		
Hardwood-dominant forested wetland	Mixedwood forested wetland	Softwood-dominant forested wetland
RECENT FOREST DISTURBANCE (1 CLASS)		

Table 1: Proposed forest type and forest disturbance classes for the Maine High Res. Land Cover project, 10-meter land

with software developed in partnership with the University of Maine Advanced Computing Group.

- Forest type predictions will be based on the identification of dominant or co-dominant tree species or species groups (e.g., Populus spp.), obtained from 10-meter resolution predictions of species relative abundance (e.g., percent of total live aboveground biomass). Our proposed forest type scheme includes 12 upland classes (4 hardwood, 4 softwood, and 4 mixedwood classes) and 3 lowland or forested wetland classes (Table 1).

KEY FINDINGS

- Significant improvements were made to machine learning (ML) workflows utilized in areas affected by cloud cover in Sentinel-2 satellite images used for predictive modeling and mapping. Through end-to-end trials conducted in the previous reporting period, we found that areas affected by different combinations of missing data in input satellite imagery needed to be modeled and mapped separately to ensure reliable prediction of species and forest type. Due to extensive cloud cover in northern Maine in particular, this was computationally very costly. During this reporting period, we revised our approach to several aspects of the problem to achieve substantial reductions in computing time, and significant improvements to ML predictions in cloud-affected areas.
- Despite improved predictive modeling in cloud-affected areas, we found that predictions still deviated from surrounding cloud-free areas in many cases. This reflected fundamental limitations to prediction where influential covariates were not available for use. We tested various strategies for achieving further improvement, eventually finding that we could effectively match cloud-affected areas to their surroundings through a local calibration procedure. This was quite effective, but also computationally demanding, given the fact that imagery used for species and forest type mapping included many thousands of individual clouds and cloud shadows. We subsequently devised and implemented an efficient approach to applying local corrections to cloud-affected ML predictions, yielding species and forest type maps that show little to no sign of cloud contamination.
- All Sentinel-2 image processing was completed across northern and southern Maine within this reporting period, following multiple revisions to improve coregistration, haze correction, and topographic correction. Image processing over Downeast and western Maine is in progress.
- We have modeled and mapped 16 species and species groups (Table 2; Figure 1) across northern and southern Maine, as needed for forest typing. These maps will be reprocessed to support integration with 1-meter NOAA land cover data. Missing sections in western and Downeast Maine are under development.
- NOAA completed and released a 1-meter map of C-CAP land cover, made available on the NOAA Digital Coast (https://coast.noaa.gov/digitalcoast/data/) in June, 2025. Prior to this release, we were unable to test the process of merging forest predictions with 1-meter land cover due to difficulties obtaining any suitable trial coverages from NOAA. Following NOAA's release of statewide data, we tested our assumptions about how best to merge layers. We found this to be more difficult than anticipated. We had previously used best-available older layers to define target pixels for forest mapping, and substantial differences between these older layers and the new NOAA data will force us to fully reprocess areas previously modeled and mapped. Due to extensive code development throughout this project, reprocessing maps is, at this point, a largely automated process.
- Statewide cloud-free leaf-on satellite image composites were compiled in preparation for statewide change detection (2016-2021). Reference sample locations were identified for the purpose of training ML models for change mapping. Reference labels (change; no-change) were derived from visual inspection of Sentinel-2 imagery acquired in 2016, 2019, and 2021. ML model training and change mapping will be completed during the next reporting period. Change maps will be integrated with species predictions prior to the final construction of the 10-meter land cover and forest type map. We have since reprocessed species maps across northern Maine and southern Maine (fig). Remaining sections of Downeast and western Maine will be completed during the next reporting period.
- We have completed code required for the cross-validation of species and forest type predictions. A cross-validation strategy is necessary for many species that are present at relatively high abundance on only a relatively small number of FIA plots. And because forest

Individual species	
Balsam fir	Sugar maple
Red spruce	Red maple
Black spruce	Yellow birch
White spruce	Paper birch
Northern white cedar	White ash
Eastern hemlock	American beech
Species groups	
Pine species	Oak species
Poplar species	

Table 2: Species and species groups mapped across northern Maine during this reporting period (10-meter resolution). Species predictions are combined to produce the forest type labels listed in Table 1.

type labels are derived from all species predictions, cross-validation will be applied to forest type predictions as well. We implemented and tested a cross-validation procedure that integrates all species models required for forest type prediction and are ready to apply this procedure once models have been trained statewide.

FUTURE PLANS

- Completion of satellite image processing and data preparation across western and Downeast Maine.
- Completion of statewide species and forest type mapping, including reprocessing of all forest predictions to better align with new NOAA land cover.
- Cross validation of species and forest type predictions.
- Completion of statewide forest disturbance mapping (2017-2021) and integration with forest type predictions and NOAA land cover.
- Public release and distribution of land cover and forest type data products (including complete metadata conforming to ISO standards). Land cover and forest type maps will be distributed directly to the CFRU via the CFRU databank and hosted on the Maine GeoLibrary and NOAA Digital Coast websites.
- Project reporting, including a peer-reviewed publication detailing project partnerships, workflows, outcomes, and maintenance plans.

PARTNERS, STAKEHOLDERS, AND COLLABORATORS

Baxter State Park
Maine Bureau of Parks and Lands
Maine Department of Environmental Protection
Maine Department of Transportation
Maine Library of Geographic Information
Maine Natural Areas Program
NOAA Office for Coastal Management
The Nature Conservancy
University of Maine Advanced Computing Group
USDA Forest Service, Northern Research Station FIA

GEOGRAPHIC LOCATION OF PROJECT

State of Maine (using plot data collected statewide; producing map data statewide).

NOAA C-CAP 1-meter land cover, available on the NOAA Digital Coast (https://coast.noaa.gov/digitalcoast/data/)

EXTERNAL FUNDING SOURCES

External funding for this project year does not include direct or indirect contributions for progress made on project objectives managed by NOAA (totaling $591,000 over the life of the project).

Source:	Amount:	Direct/Indirect:
State of Maine	$42,000	Direct

SBR

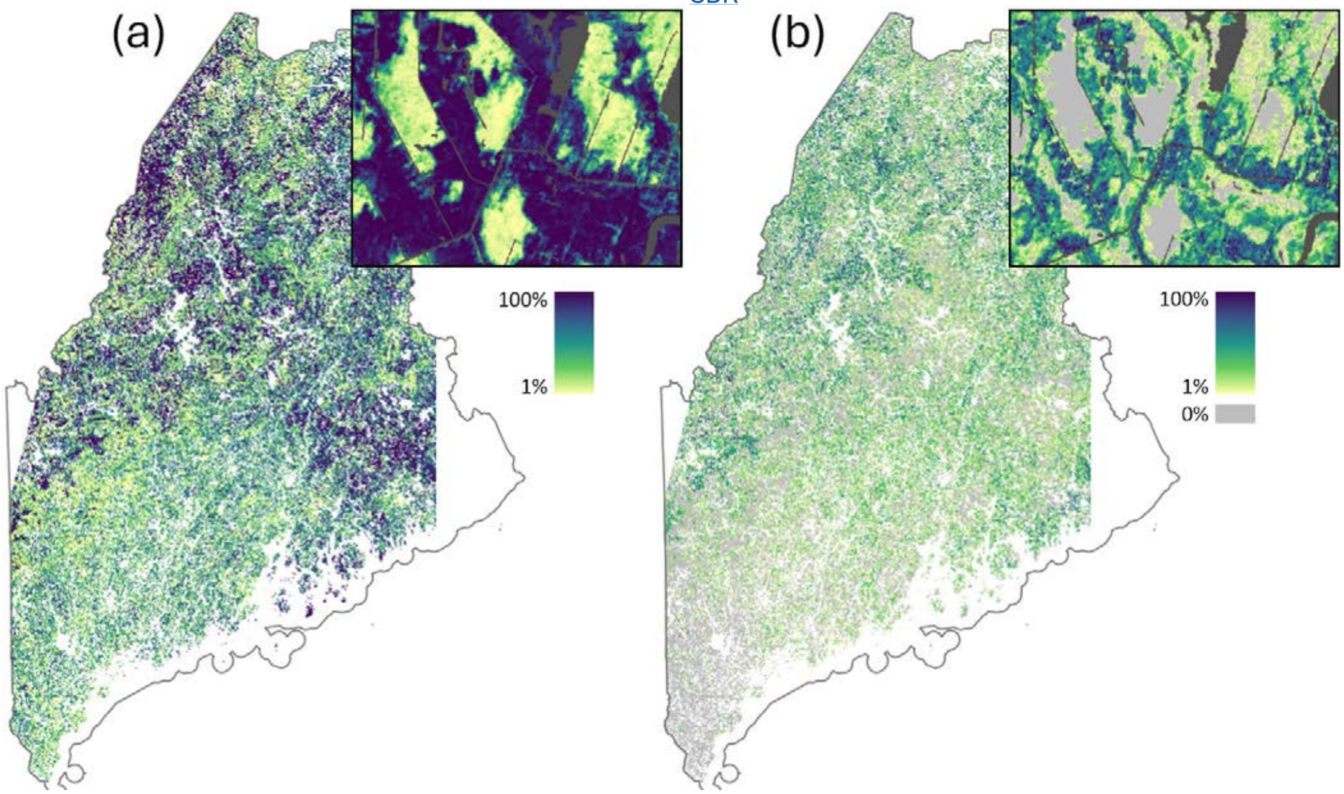

Figure 1: (a) Total softwood and (b) balsam fir relative abundance (percentage of aboveground live biomass) mapped at 10-meter resolution. Background pixels include non-forest derived from existing 30-meter land cover data, which will be replaced with new 10-meter NOAA C-CAP land cover data when available. Missing sections in western and Downeast Maine will be completed during the next reporting period.

ESTABLISHMENT OF EFFECTIVE WORKFLOWS FOR PEST-INDUCED DAMAGE DETECTION AND FOREST HEALTH MONITORING IN MAINE BY INTEGRATING REMOTE SENSING TECHNOLOGY AND FIELD DATA

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ABSTRACT

In the second year of the project, we continued working on improving spruce budworm (SBW) detection models using finer spatial resolution remote sensing data and new field data. Parallel to this project, we also worked on cost-effectiveness of remote sensing technology for spruce budworm monitoring which was mainly funded by an NSF funded project. Firstly, the application of multi-source remote sensing data—PlanetScope (3 m spatial resolution) and Sentinel-2 (10m and 20m spatial resolutions)—alongside derived spectral vegetation indices (SVIs) were evaluated for SBW defoliation detection using defoliation data directly collected from sites in the northern Maine. Three commonly used machine learning algorithms namely, random forest (RF), support vector machine (SVM), and multi-layer perceptron (MLP) were used to model defoliation at the landscape level. Among them, RF delivered the highest accuracy in detecting defoliation. Five models using different combinations of Sentinel-2 and PlanetScope bands were assessed, all producing low modeling errors (high accuracies) compared to the general model developed in Year 1. The best-performing model used Sentinel-2 data at 20m resolution with all bands and SVIs, reducing the modeling error down to 6.1%. The model based on PlanetScope data showed an error of 11.4%. These findings emphasize the importance of the type and resolution of remote sensing data, timing of data acquisition as well as type of field data for model training and modeling performance. Our cost effectiveness analysis also showed that over a 10-year project period, Sentinel-2 imagery emerged as the most cost-effective remote sensing option ranging from $33 to $63/sq km, offering wide spatial coverage and moderate resolution suitable for the identification of defoliation patterns. PlanetScope imagery ranged from $77 to $241/sq km, and unmanned aerial vehicle (UAV) imagery had the greatest variation, from $9,220 to $58,481/sq km.

PROJECT OBJECTIVES

- Comparing the effectiveness of remote sensing data with higher spectral resolution vs higher spatial resolution for modeling spruce budworm (SBW) defoliation.
- Training and validating our models using observed SBW defoliation data at tree level, collected in the field
- Evaluating the performance of different categories of machine learning algorithms namely Random Forest (RF), Support Vector Machines (SVM), and Multi-Layer Perceptron (MLP) for modeling SBW defoliation.
- Evaluating the potential of spectral vegetation indices (SVIs) derived from different satellite data sources to assess defoliation.
- Quantifying the costs of different SBW monitoring methods, including ground and remote sensing approaches

APPROACH

- SBW defoliation detection using PlanetScope and Sentinel-2 imagery
- Study Area and Ground Data: The study was conducted in Northern Aroostook County, Maine, leveraging established partnerships and existing field infrastructure. Defoliation plots were classified into “defoliated” (≥10% defoliation) and “undefoliated” classes based on the ground data research crew collected in the summer 2024.
- Satellite Imagery Collection and Preprocessing: PlanetScope (3m spatial resolution) and Sentinel-2 (10–20m spatial resolution) imagery were acquired for the same defoliation window (early June to late June 2024). Surface reflectance bands were used to compute relevant spectral vegetation indices (Rahimzadeh et al., 208; Bhattarai et al., 2022). We also computed ΔSVIs (i.e., difference between pre- and post-defoliation imagery) to highlight changes in canopy reflectance due to SBW activity. This approach has already been used successfully in prior studies (Rahimzadeh-Bajgiran et al., 2018, Bhattarai et al., 2020, Meneghini et al., 2022).
- Model Development and Comparison and map production: RF, SVM, and MLP algorithms were used to create models separately using PlanetScope and Sentinel-2 derived ΔSVIs. We compared model performance across the three different machine learning algorithms that provided insight into how using different algorithms influence the accuracy of defoliation detection. Using the results from algorithmic comparison, we developed multi-resolution SBW defoliation detection maps that

provide land managers with the information how Sentinel- and PlanetScope data can be used for large-scale landscape SBW assessment.

- Cost effectiveness analysis of remote sensing data, ground sampling techniques, and an integrated monitoring approach for SBW outbreak monitoring
- Data: To conduct a cost-effectiveness analysis of remote sensing technology to understand the tradeoffs of using different monitoring approaches, we specifically focused on three optical remote sensing data including Sentinel-2 satellite imagery, PlanetScope satellite imagery, and the Multispectral imagery derived uisng DJI 3 Mavic unmanned aerial vehicle (UAV). Two common SBW monitoring methods in the region are pheromone trapping and L2 (second instar larvae or the overwintering stage of the SBW) surveys and were considered for this analysis. In addition to SBW population information, these field methods can be used to indirectly estimate SBW defoliation. Note that remote sensing data can provide information on defoliation extent and severity comparable to aerial survey maps that were not available for this project.
- Cost-effectiveness analysis: In this study, the cost and time efforts were collected through expert discussions with remote sensing specialists and forest technicians from the University of Maine, USFS, MFS, and industry partners from Maine's forest community. The costs were estimated for different scenarios (Foster et al., 2024).

KEY FINDINGS/ACCOMPLISHMENTS

- We compared high spatial resolution (PlanetScope, 3m) and high spectral resolution (Sentinel-2, 10m and 20m) satellite imagery for detecting SBW-induced defoliation. Sentinel-2 data at 20m spatial resolution outperformed PlanetScope in defoliation detection, with error rates of 6.1% for 20m and 10.6% for 10 m, compared to 11.4% for PlanetScope. Table 1 summarizes the error rates for various model formulations, while Figure 1 illustrates the corresponding defoliation prediction maps. For more information, please see Bhattarai and Rahimzadeh-Bajgiran (2025).
- Over a 10-year project period, Sentinel-2 imagery emerged as the most cost-effective remote sensing option ranging from $33 to $63/sq km, offering wide spatial coverage and moderate resolution suitable for the identification of defoliation patterns. PlanetScope imagery ranged from $77 to $241/sq km, and unmanned aerial vehicle (UAV) imagery had the greatest variation, from $9,220 to $58,481/sq km. Labor costs are the most influential cost in our study, ranging from 30% for remote sensing approaches, and 80% for field sampling. The integrated remote sensing and field monitoring approach proposed in this study presents a synergistic strategy for effective and timely SBW monitoring, ranging from $141 to $192/sq km. Utilizing this integrated approach leverages both remote sensing and field sampling and combines the benefits that either approach can offer to enhance the efficiency of SBW monitoring efforts, leading to more effective management strategies for mitigating pest outbreaks for forest managers (Foster et al., 2024).

Model	Out-of-bag error
PlanetScope Variables at 3m spatial resolution (Model 1)	11.4%
Sentinel-2 variables at 10m spatial resolution comparable to PlanetScope data (Model 2)	12.1%
Sentinel-2 variables at 20m spatial resolution comparable to PlanetScope data (Model 3)	7.6%
Sentinel-2 variables at 10m spatial resolution (Model 4)	10.6%
Sentinel-2 variables at 20m spatial resolution (Model 5)	6.1%

Table 1. Comparison between the performances of best models for SBW defoliation detection using PlanetScope and Sentinel-2 data at varying spatial resolutions. OOB error: out of bag error.

FUTURE PLANS

We have another manuscript in preparation that we would like to complete and submit to a peer-reviewed journal. We also would like to collect more defoliation data in the field from Northern Aroostook County sites in summer 2026 for future CFRU projects. We would like to use the small remaining funds for these efforts.

ACKNOWLEDGEMENTS

We thank Dr. Neil Thompson for helping us with collecting SBW defoliation data in the field during summer 2024.

PARTNERS/STAKEHOLDERS/ COLLABORATORS

Seven Islands Land Company

GEOGRAPHIC LOCATION OF PROJECT

Northern Aroostook County, Maine

EXTERNAL/MATCHED FUNDING SOURCES

Source:	Amount:	Direct/Indirect:
UMaine Flagship fund	$50,000	Direct

2025 FALL FIELD TOUR, AFM (BBC LANDS)

NAIP EFI: INVESTIGATING THE USE OF NEW 3-D CANOPY SURFACE MODEL DATA FROM THE NATIONAL AGRICULTURAL IMAGERY PROGRAM FOR DEVELOPING ENHANCED FOREST INVENTORIES IN MAINE

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ANTHONY GUAY, REMOTE SENSING SPECIALIST, WHEATLAND GEOSPATIAL LABORATORY, UMAINE

ABSTRACT

The Wheatland Geospatial Lab (WGL) aims to incorporate 3-D photo-based point cloud data sets from the National Agricultural Imagery Program (NAIP) into enhanced forest inventory (EFI) models. We will conduct a series of comparisons between NAIP and LiDAR models conducted at several study areas in Maine where we have access to high-quality remote sensing data paired with field-based measurements for model calibration and validation. The results from this research project will provide CFRU members with information on how, and how well, the new and freely-available statewide NAIP data sets can be used to update and enhance their forest inventory programs.

PROJECT OBJECTIVES

- Produce statewide canopy height model data sets based on NAIP acquisitions for Maine in 2018 and 2021 (completed)
- Investigate the use of NAIP data sets for estimating key inventory variables in Maine forests, and evaluate their accuracy compared to LiDAR-based EFI models.
- Co-produce the data sets and modeling tools with CFRU members to incorporate new and freely-available NAIP data products into their forest inventory programs.

Our vision is that these objectives are a means to extend what has so far been a very valuable partnership between WGL and CFRU into future years ahead. This would facilitate not only the specific research proposed here but also represents an "open" project for more general collaboration on CFRU priority research in remote sensing and geospatial technologies.

APPROACH

- We are comparing and contrasting differences between canopy structure metrics (CHM, CC, RH95, etc.) derived from NAIP to those produced from LiDAR point clouds.
- We are quantifying NAIP model performance (fit, error, bias) in estimating EFI variables (percent softwood, stem density, basal area, volume) compared to LiDAR models that were developed as part of our previous LiDAR EFI case studies.
- We will continue to evaluate the efficiency of the workflows, applicability of the derived products, and other practical considerations for using 3D NAIP products.

KEY FINDINGS/ACCOMPLISHMENTS

- NAIP-based EFI model runs of percent softwood, volume, and stem density were completed for the Penobscot Experimental Forest, Baskahegan Company lands, and the Rangeley Lakes Heritage Trust / Stephen Phillips Memorial Preserve Trust parcels using calibration plot data provided for our previous LiDAR-based EFI case study projects. Visual inspection of predicted metrics, as well as a comparison between internal measures of model performance suggest that NAIP-based EFI models can achieve similar results to those generated from LiDAR-based EFI models (Figure 1).

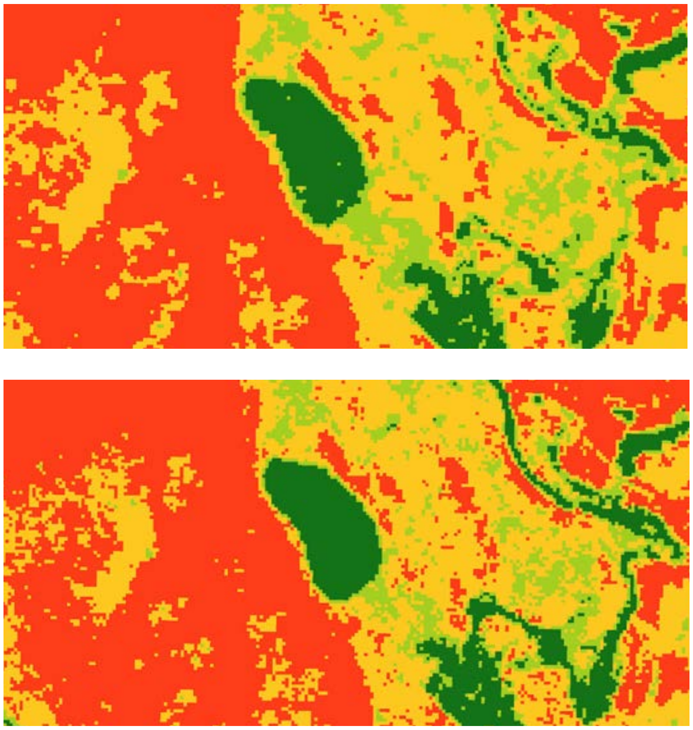


Figure 1. Relative comparison of size classes on a portion of the Stephen Phillips Memorial Preserve Trust generated from 2018 LiDAR (top) and 2021 NAIP (bottom).

FUTURE PLANS

- We are preparing to implement a new modelling framework to our methods to address longstanding modelling challenges relating to our first LiDAR-based EFI project as well as the first iteration of this NAIP-based EFI project.
- We will provide NAIP-EFI prediction map outputs to research partners for evaluation.
- Additionally, we plan to verify research results of NAIP-EFI models at a subset of study sites during the next field season.
- Two workshops are planned for 2026. The first will take place at the NESAF Annual Meeting in March 2026 and a second will be scheduled during the summer of 2026.
- We plan to submit CFRU Research Notes about the interim project status and create video and multi-media content for Wheatland Geospatial Lab and CFRU websites.
- Work on potential research publications will begin, as outlined in our "NAIP EFI" Cooperative Forestry Research Unit Full Research Proposal: Communications Plan, 2023.

ACKNOWLEDGEMENTS

We thank the CFRU members for their support of this project through a financial contribution, data sharing and general interest in this project's research and objectives. Special thanks goes to Seven Islands Land Company, Baskahegan Company, the University Forests, and the Maine Timberlands Charitable Trust for their active participation and strong support. It is very much appreciated and is critical to the WGL's mission of supporting geospatial education, research, and innovation needs of students, forest industry, and natural resource partners in Maine.

Calibration plot data, which is integral to developing our EFI models, has been generously provided by:

- Ian Prior, Seven Islands Land Company
- Kyle Burdick, Baskahegan Company
- Keith Kanoti, University Forests, UMaine

PARTNERS/STAKEHOLDERS/ COLLABORATORS

Andrew Finley, Professor, Department of Forestry, MSU
Seven Islands Land Company
Baskahegan Company
University Forests
Rangeley Lakes Heritage Trust
Stephen Phillips Memorial Trust
Penobscot Experimental Forest

GEOGRAPHIC LOCATION OF PROJECT

Various parcels in Maine. Exact locations available upon request.

EXTERNAL/MATCHED FUNDING SOURCES

Source:	Amount:	Direct/Indirect
MTCT	$21,165	Indirect
NASA	$7,055	Indirect

SPRUCE BUDWORM L2 MONITORING PROGRAM IN MAINE

ANGELA MECH, ASSISTANT PROFESSOR OF FOREST ENTOMOLOGY, UMAINE
NEIL THOMPSON, PROFESSOR OF APPLIED FOREST MANAGEMENT, UMAINE FORT KENT

ABSTRACT

In 2008, spruce budworm (SBW) initiated its current outbreak. With the previous outbreak having caused extensive ecological and economic losses, the ability to identify areas where SBW populations are growing exponentially had become of the utmost importance. The goal of this project was to establish a SBW processing lab in the state to allow land managers in Maine to make time-sensitive decisions about SBW control. This project was initiated in 2021 and we also worked with the Department of Industrial Cooperation at the University of Maine and set up the SBW storefront for processing jobs outside of those associated with the monitoring program, and on October 6th, 2021, the lab officially opened. In August 2022, using CFRU funds as match, the USDA Forest Service awarded PI Mech with a grant to cover ~50% of the processing costs for 3 years. Processing for the 2024 season began September 10th, 2024. Overall, 307 monitoring sites were covered by the program, and 398 sites were purchased; 90 sites were sent to New Brunswick for processing due to capacity issues in Orono. Increased sampling was based on the late-season discovery of hotspots on the Quebec border during the 2023 season. 112 of the 705 total sites submitted in 2024 (16%) were hotspots (compared to 7% of sites in 2023). The maximum average L2 counts for a 2024 site was 132.33 L2s; in 2023, it was 35 L2s. In total, ~307,000 acres were identified as high risk and eligible for EIS; in 2023, ~30,000 acres were identified. All signs indicate a significant growth in Maine's SBW populations.

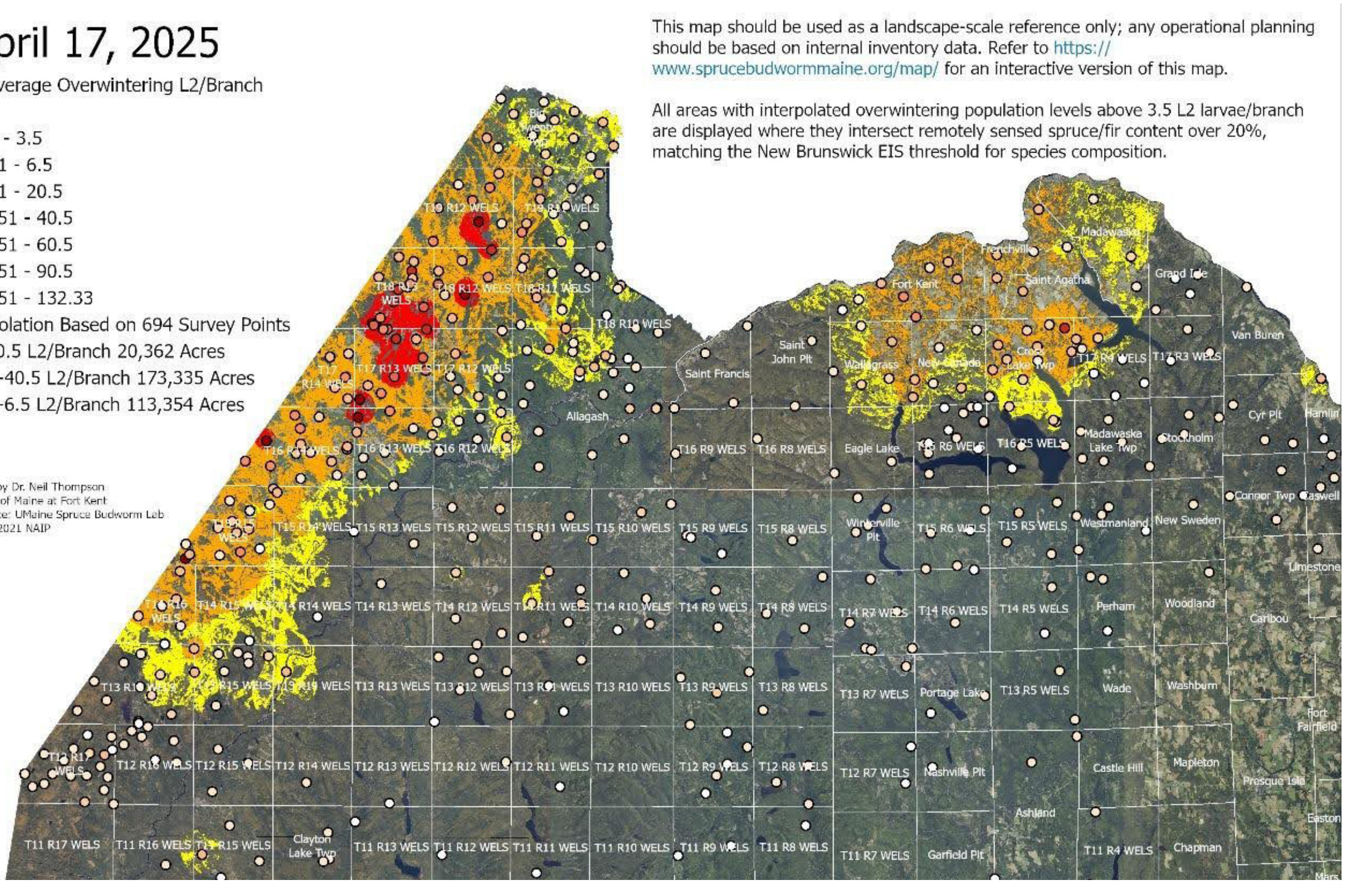


Figure 1. Map of northern Maine showing the locations of hotspot SBW populations. L2 monitoring results (dots) were incorporated into a population model that estimated the population densities between monitoring sites (yellow to red shading). Maps prepared by Dr. Neil Thompson.

PROJECT OBJECTIVES

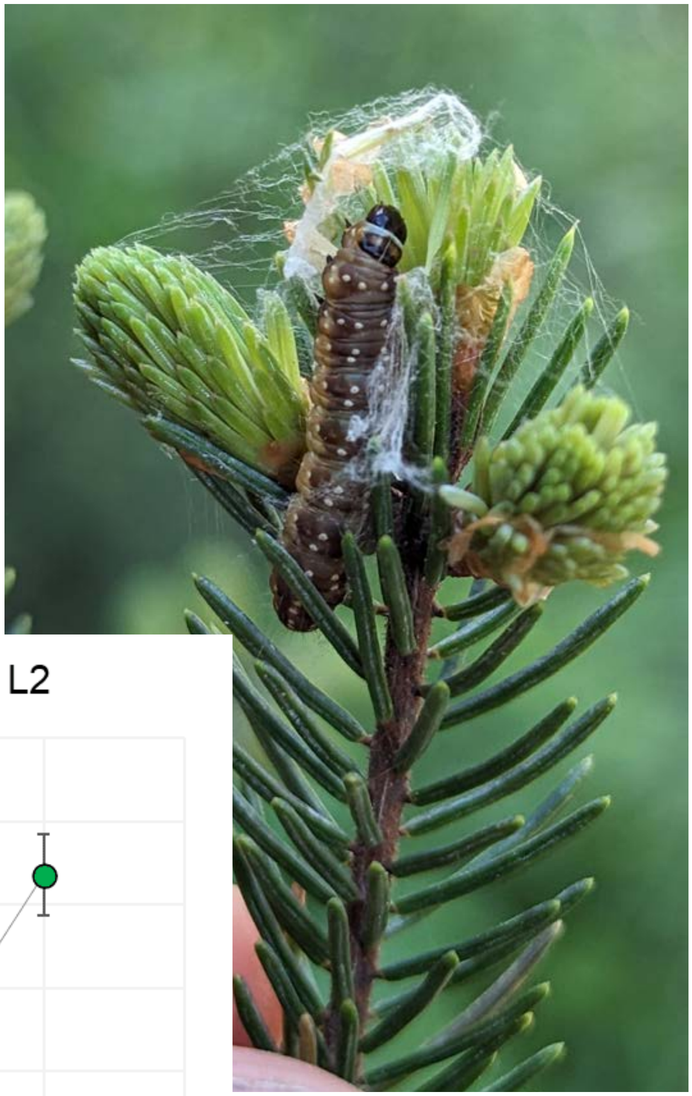
- To establish a SBW processing lab at the University of Maine that would be responsible for determining the L2 counts for 307 monitoring sites across the state.
- To provide a fee-for-service option for landowners to have additional sites processed.
- To provide rapid results for areas that need to make management decisions quickly.

APPROACH

- Sites are ranked based on previous year's L2 counts (avg. 3 branches per site) and proximity to hot spots. Sites in the northern region of the state are at higher risk and are therefore designated as higher priority.
- As branches arrive to the lab, they are sorted and processed based on priority
- Landowners/managers are emailed results biweekly
- The UMaine SBW Lab L2 map is updated weekly and available for public viewing

KEY FINDINGS/ACCOMPLISHMENTS

- Hiring a second full-time staff member for the first half of the processing season allowed the lab to increase the number of processed sites by 87% compared to previous years
- A total of 705 sites (2,115 branches) were processed in the region for the 2024 SBW population estimates; 615 were processed at the UMaine lab
- Two areas of high SBW densities were found; one near Fort Kent and the other along the Quebec border; these high-density areas cover over 300,000 acres (Fig. 1). No other hotspots were found south of these regions
- Although the majority of the sites were in Maine, samples from 3 other states (NH, VT, and NY) were submitted (Fig. 2)
- The average L2 counts per site saw a marked increase. In 2023, the highest site had 35 L2s; in 2024, the highest site had 132.33 L2s. Overall, when looking at the sites that have been a part of the monitoring program for multiple years, the average L2 count for all sites has seen almost a 5-fold increase since 2020 (Fig. 3)
- Final L2 counts from the lab and the map of SBW populations in Maine were used to develop the spray maps used for Maine's Early Intervention Strategy implemented in late May/early June 2025



Above photo: spruce budworm. by Dr. Neil Thompson, UMFK

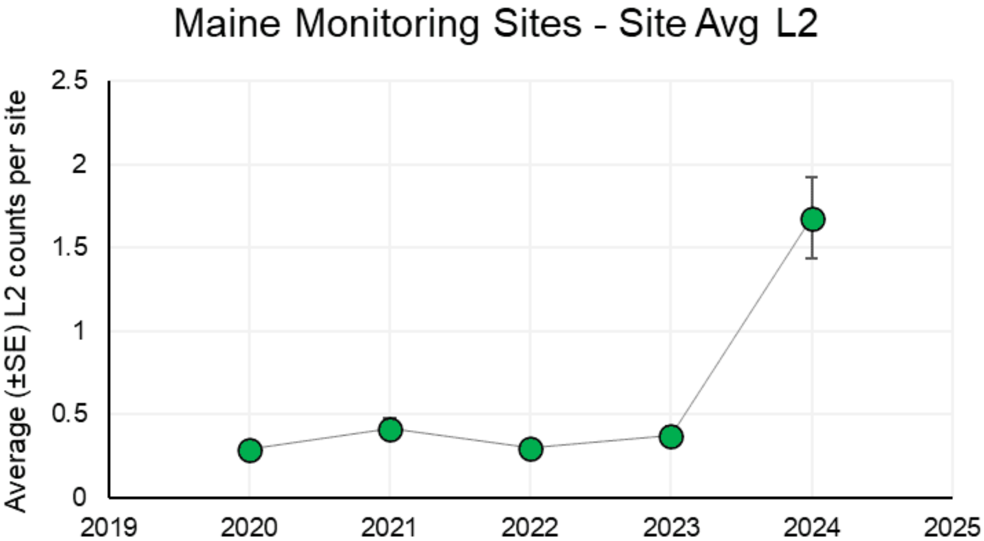


Figure 3. (Above) Average of all spruce budworm L2s per site over the last five years of the SBW monitoring program.

FUTURE PLANS

Increase the SBW Lab's processing capacity by:

- Expanding the lab's usable space in ESL
- Getting a new on-demand hot water system
- Hiring 3 full-time staff members
- Start processing earlier with 50-75 sites pre-collected by Co-PI

&

- Conduct the 2025 processing season's monitoring program
- Estimate the efficacy of the EIS program implemented in June 2025

PARTNERS/STAKEHOLDERS/ COLLABORATORS

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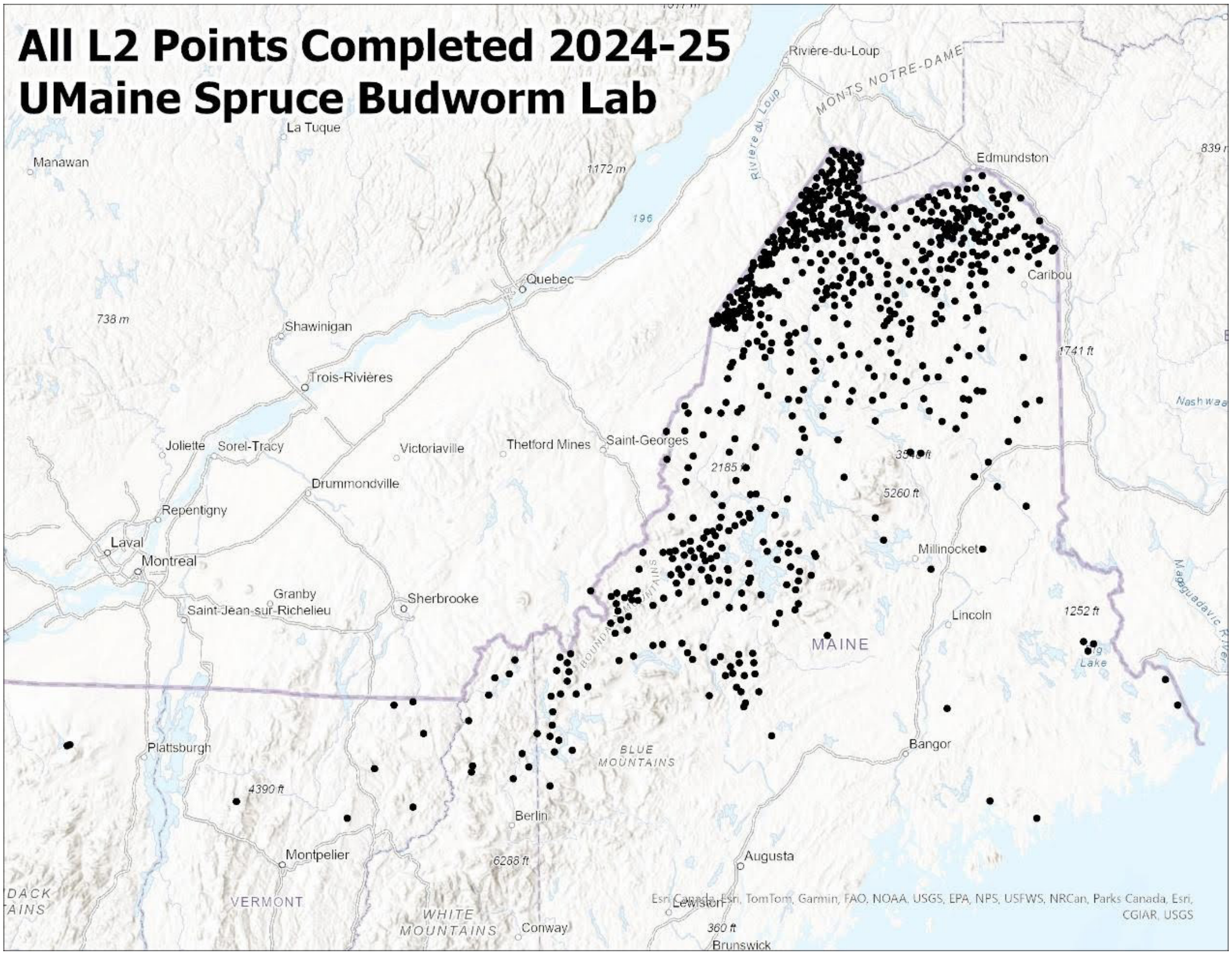
GEOGRAPHIC LOCATION OF PROJECT

Environmental Science Lab at the University of Maine

EXTERNAL/MATCHED FUNDING SOURCES

Source	Amount	Direct/Indirect
USDA Forest Service	$9,128	Direct
MAFES	$15,197	Indirect



UNDERSTANDING WHITE PINE'S RESPONSES TO FUTURE ENVIRONMENTAL CHANGES: DEVELOPING STRATEGIES TO REDUCE DAMAGE CAUSED BY THE WHITE PINE WEEVIL

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ABSTRACT

On the Blue Ridge Plateau in the southern Appalachians, incidence of white pine weevil (WPW) damage is low to non-existent on eastern white pine (EWP). Understanding why these differences occur will provide guidance on how to take advantage of the changing environment to improve EWP growth and health. The key findings of this research were (1) Forest Inventory and Analysis (FIA) supplots in Maine with more than 75% stems of EWP (over 192 stems/acre, 75 plots) all had WPW damage while 32% (533/1,682) of plots sampled with lower levels of EWP (30% average) have no WPW damage. (2) Increasing Water Surplus Index (WSI) a metric of potential evapotranspiration or the amount of water 'leftover' in the system after use by vegetation, is associated with lower WPW damage (more available water, less WPW damage). (3) For field sampling of EWP saplings, 33 of 79 (41%) of the Maine subplots and 14 of 46 (30%) of the Blue Ridge Plateau subplots had observations of WPW damage. When measuring the average percent of trees with WPW damage, Maine's value (13.1%) was more than double the Blue Ridge Plateau value (5.5%). Within the Blue Ridge Plateau, the thin duff layer (0.1 cm average) could be limiting WPW survival and damage compared to the 2.4 cm litter depth in Maine. (4) Three shoot samples of 24 collected in North Carolina had staining of lignified tissue in the primary cortex, but immunohistochemistry was negative for the presence of stone cells that are associated with WPW resistance. All 131 shoot samples in Maine were negative for staining of lignified tissue.To prioritize growing more EWP with less WPW damage, EWP management in Maine could favor growing EWP within mixed species stands.

PROJECT OBJECTIVES

- Assess how environmental factors vary with observed weevil damage on FIA plots in Maine.
- Measure differences between Maine and the Blue Ridge Plateau of Virginia and North Carolina that vary with white pine weevil damage.
- Examine tissue for stone cells from stem tips on white pine in Maine and the Blue Ridge Plateau.

APPROACH

- USFS Forest Inventory and Analysis (FIA) data from Maine plots were used in the analyses.
- Each FIA plot consists of four subplots (1/24th acre). Stem level attributes from the most recent (2019-2023) FIA survey cycle summarized at the subplot level. All live stems greater than or equal to 12.7cm (5 inches) DBH were measured. Stem damage associated with WPW feeding and oviposition was quantified as present or absent. The data was filtered to include only subplots with at least one EWP tree.
- This left a final working dataset of 1,757 subplots in 922 locations including 4,681 EWP trees.
- To capture stand level interactions between trees and saplings, all live stems were retained and stand level attributes such as basal area per hectare (BAPHA; sq. m/hectare), trees per hectare (TPH), relative stand density (RD), and quadratic mean diameter (QMD) were calculated for trees and all stems in addition to EWP Trees.
- All 34 site and climate attributes for the state were obtained from a variety of databases and processed at a 22-m resolution by Mike Premer.
- Stand, site and climate attributes were then joined for each subplot location for a total of 46 attributes
- After initially examining the FIA data for 2019-2023, only 9% of plots across the state had naturally regenerating EWP (285/2960) – therefore we contacted a number of landowners and forest managers to request site locations dominated by EWP saplings. Nineteen field sites were selected in Maine, and 12 were selected along the Blue Ridge Plateau (6 in Virginia and 6 in North Carolina). To be considered for sampling, properties had to have ~50% or more EWP saplings between 1-5m (3-15 feet) tall.
- For field design we modified the FIA ground sampling protocol to account for the difficulty in finding stands with sufficient EWP sapling densities.

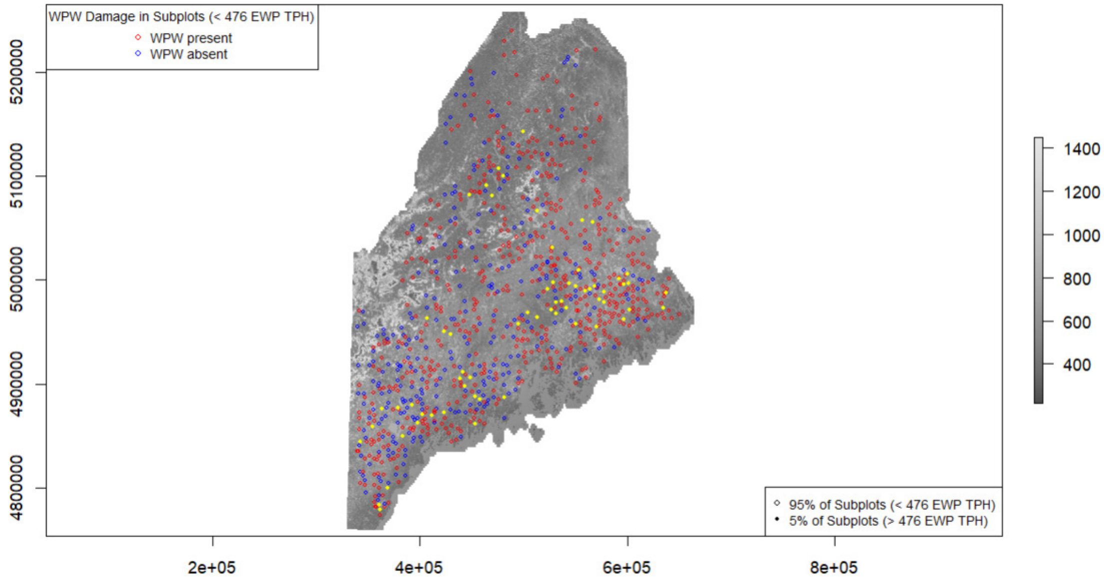

Figure 1. (Above) WPW damage across Maine on subplots with high (yellow) and low values of EWP TPH (red=WPW present, blue=absent) and mapped over statewide values of WSI (mm·m2) (gray shading, lighter=more moisture). Subplots with > 192 EWP trees per acre (476 TPH) (n = 75) are considered high. Subplots with < 192 EWP TPA (n = 1,682) are considered low values.

KEY FINDINGS/ACCOMPLISHMENTS

Analysis of FIA data findings:

- Of the 1,757 subplots in the dataset with at least one EWP, there were 24,493 tree-level observations, of which 4,681 were EWP trees with 3,072 positive occurrences of WPW damage. There were 1,224 subplots (70%) with positive observations of WPW damage and 533 subplots with no WPW damage detected (Figure 1).
- To predict probability of WPW risk for Maine, a Mixed Effects Logistic Regression model was chosen as our framework which incorporates random effects from linear mixed models and can handle binary data – is there weevil or is there no weevil.
- 46 variables assessed
- The selected model shows odds of terminal shoot damage associated with white pine WPW feeding increases for every unit increase of EWP tree/hectare (TPH) and decreases with every unit increase of water surplus index (WSI) (Tables 1 and 2).
- Lower EWP TPH is clearly associated with lower WPW damage (Figure 2).
- Subplots greater than or equal to 476 EWP TPH (=192 stems per acre) or about 4% of subplots (75 subplots) were defined as in the high category, and EWP composed 75% of the stems. All subplots in the high category had WPW damage, with an average of 75% EWP trees damaged per subplot. (Figure 1)
- Subplots below the 95th percentile of 476 EWP TPH were defined as the low category with EWP composing 30% of the stems on average. In the low category, 32% (533/1682) of subplots had no damage, with an average of 61% EWP trees damaged on subplots with damage.

White Pine Weevil Damage in Maine and Blue Ridge Parkway findings:

- Higher WPW damage in Maine (13%) than the Blue Ridge Plateau (5%).
- Probability of NO WPW damage decreases as the % EWP stems decrease
- WPW damage severity increases as duff layer increases from 0.1 cm on the Blue Ridge Plateau to 2.4 cm in Maine.
- Duff layer thickness more limiting to WPW than shoot diameter
- Thinner duff layer in south associated with: Plantation management, warmer winters
- Shoot samples collected in Maine and North Carolina (131 samples) had no staining of lignified tissue in the primary cortex which would indicate the presence of stone cells, while 3 (of 24) trees at separate sites in Virginia had positive staining results. A verification process for stone cells using immunohistochemistry, as used for spruce species, was negative for the collected EWP samples

Management findings:

- The focus of EWP management in Maine has long been geared towards reducing WPW damage for stands dominated by EWP, such as the 4% of the stands that averaged 75% EWP in the FIA dataset (EWP TPA > 192) and the field sites in the sapling study.
- However, percent composition of EWP stems averages 30% in most (96%) of the FIA sampled subplots where EWP TPA is less than 192, and WPW damage did not occur on 32% of these subplots.
- To prioritize growing more EWP with less WPW damage, EWP management in Maine could favor growing EWP within mixed species stands.

KEY FIGURES AND TABLES

Model Iteration	Variables	VIF	AUC	Sensitivity	Specificity	Accuracy	p-value
Mod A	EWP TPH+ dew	1.01	0.9845024	0.9775087	0.843594	0.9317018	0
		1.01					0.0001
Mod B	EWP TPH+ Tmin	1	0.984484	0.9775087	0.843594	0.9317018	0
		1					0.0004
Mod C	EWP TPH+ WSI	1	0.984435	0.9758829	0.8473154	0.9322709	0
		1					0.0195

Table 1. Goodness of fit metrics describing the top 3 models, including VIF, AUC, Sensitivity, Specificity and Accuracy scores. Mod C was selected as the best model. EWP=eastern white pine, TPH= trees/hectare, WSI = water surplus index (involves transperiation and water availability), dew= dewpoint, Tmin=minimum temperature

	Parameter	Variables	Estimate	SE	P-Value	exp (βn)
Mod C	β_0	Intercept	1.1117225	0.4764914	0.020	3.040
	β_1	EWP TPH	0.0606128	0.00504	0.000	1.063
	β_2	WSI	-0.0019589	0.0008372	0.020	0.998
Mod D	β_0	Intercept	0.0383637	0.12833517	0.765	1.039
	β_1	EWP TPH	0.0099069	0.00082606	0.000	1.010

Table 2. Parameter estimates for Models C including the variables EWP TPH and WSI, where exp (βn) is the transformed odds ratio of the parameter estimate. EWP=eastern white pine, TPH= trees/hectare, WSI = water surplus index.

Attribute	Description	Maine Mean (SD)	Blue Ridge Plateau Mean (SD)
STEM & STAND			
Seedling	Seedlings per microplot (stems)	7.3 (13.9)	2.2 (1.5)
Tree	Trees per subplot (stems)	2.3 (2.7)	0.0
Tree.EWP	EWP trees per subplot (stems)	0.9 (1.8)	0.0
n_trees	Saplings per microplot (stems)	187.7 (101.9)	39.1 (23.1)
EWP	EWP saplings per microplot (stems)	78.8 (57.8)	36.8 (23.1)
total.wv	Total saplings with WPW damage per microplot (stems)	11.0 (13.0)	1.8 (1.8)
avg.termdia	Terminal shoot diameter (mm)	5.6 (3.0)	9.7 (2.1)
TPH	Stems per hectare of saplings (stems·ha)	3434.4 (1952.7)	762.2 (415.9)
EWPTPH	EWP stems per hectare of saplings (stems·ha)	1429.1 (1078.4)	698.1 (419.7)
avg.percewp	% EWP per microplot	49.5 (28.4)	92.3 (19.6)
avg.percwv	% of EWP with WPW damage per microplot	13.1 (10.6)	5.5 (5.4)
SITE			
Dufflayer	Mean duff layer (cm)	2.4 (1.1)	0.1 (0.2)
avg.soilmax	30-year average max March soil temperature (°C)	0.3 (0.8)	9.7 (0.4)
CLIMATE			
Julymax	30-year average maximum July mean temp (°C)	26.7 (0.5)	27.1 (0.6)
Janmin	30-year average minimum January mean temp (°C)	-12.5 (0.9)	-4.7 (0.5)
US_Tmax	30-year average maximum temperature (°C)	11.9 (1.2)	17.0 (0.4)
US_Tmin	30-year average minimum temperature (°C)	0.0 (1.1)	5.3 (0.3)
US_PPT	30-year average mean precipitation (mm)	1159.0 (74.9)	1226.7 (129.2)
SGDD	30-year average soil growing degree days above 5°C	2014.32 (233.08)	2910.73 (200.14)

Table 3. Mean and standard deviation (SD) of stem, stand, site, and climate level attributes collected and grouped by Region (Maine and the Blue Ridge Plateau). Data collection occurred at n = 76 subplots for Maine and n = 48 for the Blue Ridge Plateau. Note: The denotation of 'US' within the variables US_Tmax, US_Tmin, and US_PPT represent the 30-year average for those values across the United States (U.S.).

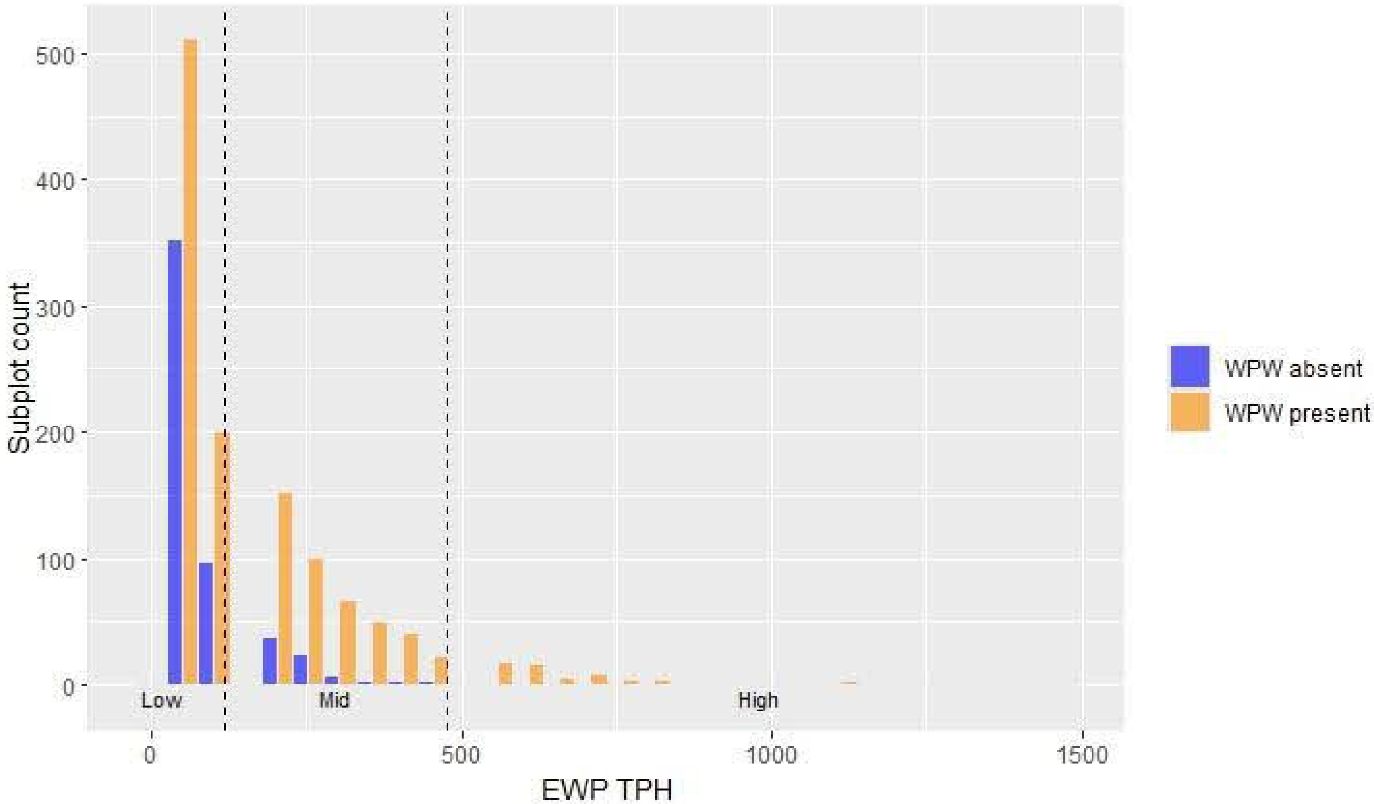

Figure 2: Histogram of EWP TPH (eastern white pine trees/hectare) summarized at the subplot level (n = 1,757). EWP TPH was derived from the USDA Forest Service Forest Inventory and Analysis (FIA) “Data Mart” and classified into percentiles where 119 EWP TPH (48 EWP trees per acre; TPA) marks the 50th percentile and 476 (192 TPA) marks the 95th.

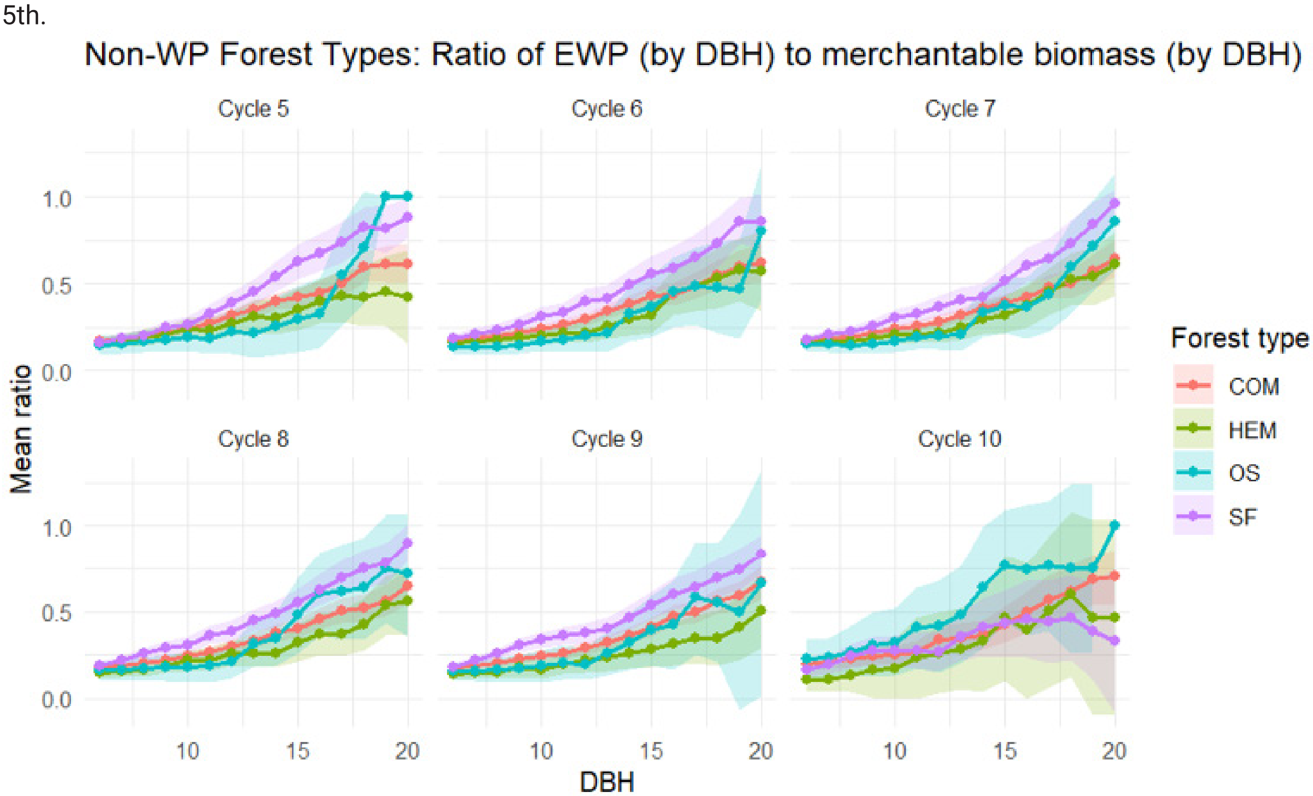

Figure 3. From Dr. Jianheng Zhoa’s analysis. EWP’s relative importance increases with DBH across all non-WP types, indicating that EWP tends to occupy (and persist to) larger size classes. SF shows the earliest and most persistent EWP dominance, while HEM requires the largest sizes for EWP to become dominant. COM and OS are intermediate but differ at small-mid diameters (COM higher than OS).

FUTURE PLANS

Colleagues at UMaine (Dr. Jianheng Zhoa, Dr. Adam Daigneault, Dr. Aaron Weiskittel) have been analyzing FIA data across the state and have made estimates on biomass amounts across the FIA plots across 20 years of FIA data collection in the state. The number of plots with 4 consecutive measurements across 20 years of data collection total 2,980. The plots were divided into 6 forest types based on the majority of stand composition based on biomass; white pine (WP), spruce-fir (SF), other softwoods (OS), commercial hardwoods (CH), and other hardwoods (OH).
Figure 3, shown below, shows a few preliminary results. About a quarter of the EWP biomass is in the WP type. EWP rarely occurs on the OH type. In spruce-fir, EWP biomass begins to exceed SF biomass at about 12 inches DBH. Even in the CH type, EWP biomass begins to exceed the hardwood biomass at 18 in DBH. Even though EWP on the mixed-species sites is at lower numbers, it's biomass accumulation over time becomes a significant component of the stands when EWP is present. As a plus, there is less weevil damage in the mixed-species stands. The status of other EWP pests in the mixed-species stands is not known.

In Maine, future development of the majority of the EWP resource will occur outside of stands dominated by EWP. Current recommendations on EWP management focus on the EWP dominated stands. How forest landowners and managers have dealt with the presence of EWP in the mixed stands is not documented. There is a need to understand the economic, ecological, and silvicultural implications of EWP in mixed-species stands.

In addition, future conditions may be favoring EWP. EWP in the southern Appalachians has nearly twice the growth rate as in the northeastern US. When looking at climate data, summer conditions are similar between the two regions, but winters are warmer, such that soil activity is probably 2 months longer in the southern region. Therefore, warmer winters could favor EWP growth in the future.

I want to share these findings on EWP with scientists, forest land owners, and forest managers in Maine and other states to begin discussions on what we understand about the future of EWP in our forests and what needs additional research.

PARTNERS/STAKEHOLDERS/ COLLABORATORS

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Zachary Olinger, Virginia Forest Service
Brian Heath, North Carolina Forest Service
American Forest Management
Robbins Lumber Company
Irving Woodlands
Maine Woodland Owners
Hancock Lumber
Baskahegan Land Management
Seven Island Land Management
Western Maine Conservation
Massabesic Forest, USFS
University Forest

GEOGRAPHIC LOCATION OF PROJECT

State of Maine
Galax, Virginia
Sparta, NC

EXTERNAL/MATCHED FUNDING SOURCES

Source	Amount	Direct/Indirect
MAFES	$24,000	Both direct and indirect
UM Grad School Tuiton Waiver	$10,000	Indirect

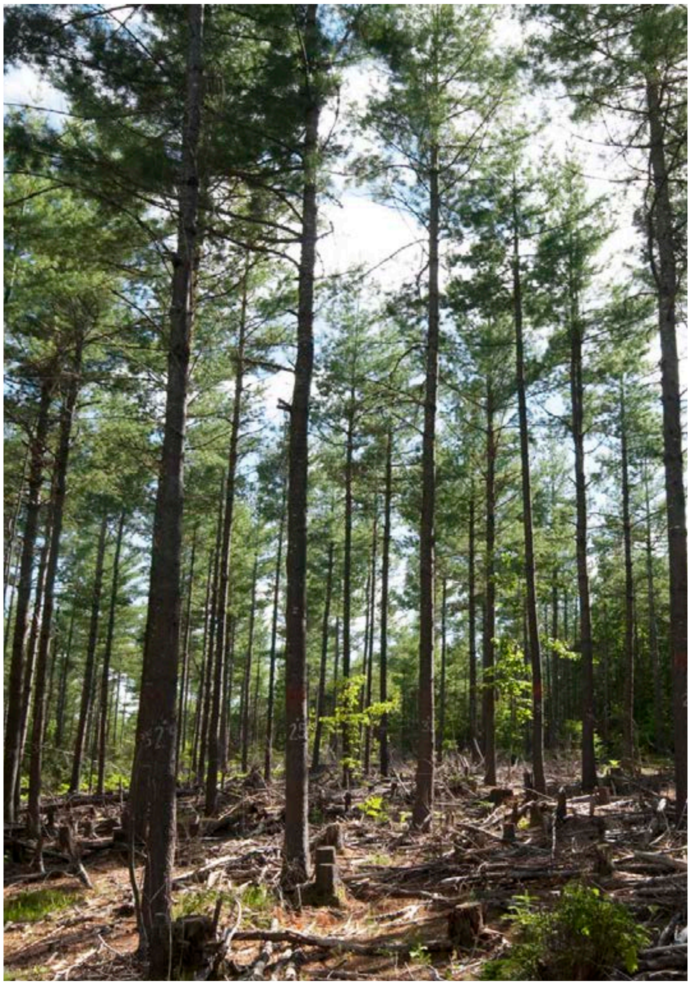

Photo by Dr. Neil Thompson, UMFK

USING EDNA FOR BIODIVERSITY AND RARE SPECIES MONITORING

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ABSTRACT

In the third year of this project, we processed eDNA and conventional wildlife survey data from forested wetlands in central Maine, optimized an eDNA assay for the Blue-spotted Salamander complex (Ambystoma laterale and Unisexual Ambystoma), completed analysis of our pilot eDNA metabarcoding study in forested vernal pools, had one manuscript on trapping methods for pool-breeding amphibians published in the Journal of Herpetology, and submitted two new manuscripts for publication: (1) a note on malformations in Unisexual Ambystoma and (2) a research article detailing ecological insights and methodological considerations for using eDNA to biodiversity in forested wetlands. An essay by PhD candidate Harrison Goldspiel about eDNA and amphibian conservation was also published in UMaine's conservation and sustainability journal Spire. Beyond these research activities, we presented our research at three professional meetings and one community event for the Orono Land Trust. Our research has demonstrated that while eDNA is a powerful tool and may prove to be cheaper and/or more effective than traditional surveys for detecting certain cryptic taxa, no omnibus approach will be effective for all organisms and monitoring objectives. Ultimately, practitioners must reconcile methodological uncertainties, from sampling to sequencing, with monitoring objectives to ensure robustness and cost-effectiveness for any given study.

PROJECT OBJECTIVES

- Review available genetic sequences for Maine fauna and identify missing species
- Compile genetic reference libraries for eDNA monitoring studies
- Assess spatial and temporal variability of eDNA in forested wetlands and examine environmental and sampling limitations on species detection rates
- Develop and validate eDNA assays for rare salamander monitoring in Maine
- Compare eDNA surveys with conventional wildlife monitoring techniques

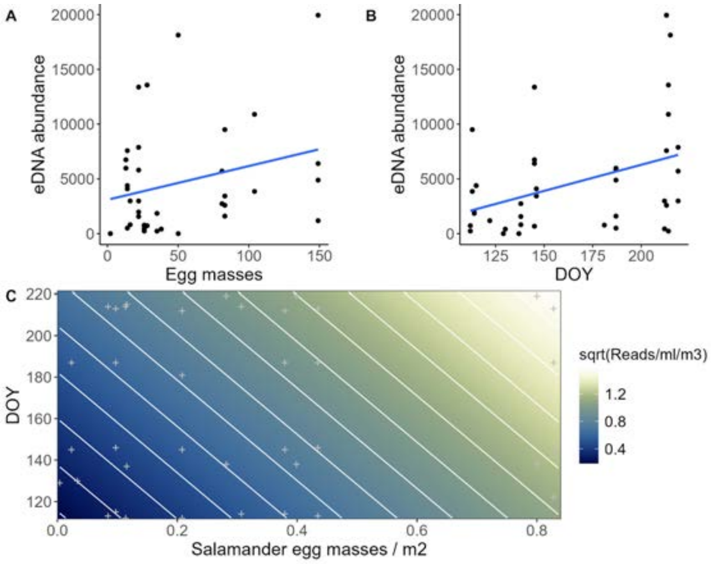
APPROACH

1. Conducted a pilot study in 2020-2021 in eastern vernal pools (n = 12 pools from Indiana, New York, and Massachusetts) to evaluate spatial and temporal components of eDNA study designs. Samples were processed in the lab and sent to the University of Rhode Island for metabarcoding to characterize biodiversity in pools and examine limits of detection.
2. Performed a landscape-scale study of vernal pools and permanent wetlands (n = 31 sites) in central Maine in 2023 using eDNA and conventional survey methods, with the following objectives:
   - Calibrate aquatic eDNA surveys with conventional wildlife surveys for amphibians (funnel trapping, egg mass counts) and birds and mammals (wildlife cameras) in 15 wetlands.
   - Examine how water chemistry, sampling site selection (e.g., water depth, wetland type), and sampling effort (i.e., volume filtered) relate to species detection.
   - Evaluate taxonomic biases of conventional trapping methods for vernal pool indicator amphibians (i.e., Wood Frogs, Spotted Salamanders, Blue-Spotted Salamanders).
   - Identify environmental drivers of Blue-Spotted and Unisexual Salamander co-occurrence in wetlands.
3. Obtained tissue samples and performed mitochondrial sequencing to fill gaps in genetic reference libraries for various non-game species of conservation concern, including fairy shrimp, dragonflies, Ambystoma complex salamanders, and several turtles. These results are summarized in the CFRU Annual Report from FY 2023.
4. Designed and tested >30 species-specific primers and several multi-species primers for rapid identification of salamander populations with eDNA. Collaborated with regional researchers to develop protocols for eDNA monitoring of Blue-Spotted Salamanders, Jefferson Salamanders, and Unisexual Ambystoma.
5. Optimized eDNA metabarcoding protocols for identifying eukaryotes, metazoans, vertebrates, and invertebrates in forested vernal pools.

KEY FINDINGS/ACCOMPLISHMENTS

- eDNA metabarcoding (12S-Riaz vertebrate primers) was effective at detecting and distinguishing different Maine vernal pool amphibians from water eDNA samples and positively correlated with egg mass counts (Figure 1). Metabarcoding had significantly higher detection probabilities than trapping for all species except for pure Blue-spotted Salamanders (Ambystoma laterale) (Figures 2–3). Note: aquatic funnel trapping, while useful for collecting amphibian population data and genetic samples—especially for salamanders and amphibian larvae—is not usually necessary for monitoring breeding activity of species that produce visible and distinguishable egg masses (e.g., spotted salamanders, wood frogs) or calls (e.g., wood frogs). As we observed in our validation surveys, trapping methods themselves can be biased for different species (Goldspiel et al. 2025).
- Our qPCR assay for distinguishing Blue-spotted Salamanders from Jefferson and Unisexual Salamanders was successful on amphibian tissues. We are in the final stages of optimizing this assay for use on eDNA samples, which we expect to be more sensitive and affordable than metabarcoding (or trapping) for monitoring these salamanders of conservation concern in Maine's forests.
- We detected dozens of vertebrate species, including aquatic and terrestrial fauna (fish, amphibians, birds, mammals), from forested wetlands in Maine with eDNA metabarcoding. Universal vertebrate primers (12S-Riaz) displayed discrepancies with traditional field surveys (Table 1), with each method revealing unique components of wildlife communities and camera traps detecting more unique taxa over a continuous four month period. Only waterfowl displayed a positive relationship between eDNA abundance and camera sightings (Figure 4).
- These results highlight the strengths and limitations of eDNA for studying biodiversity in Maine's forests. Species-specific eDNA monitoring approaches may be especially useful and cost-effective for studying a small number (1–3) of closely related species (e.g., Blue-spotted and Unisexual Salamanders), but this approach is dependent on the availability of assays, which can require significant time, labor, and materials to develop for any given species.
- Metabarcoding can vastly improve monitoring capacity for whole communities, but universal vertebrate primers (e.g., MiFish, 12S-Riaz) are heavily biased towards aquatic organisms (i.e., fish, amphibians, waterfowl) when sampling water eDNA from forested wetlands and may carry several unique limitations for practitioners, including (1) incomplete reference libraries and (2) non-differentiated taxa. For example, the following species detected by camera traps either do not have available genetic references or do not have distinct DNA for the 12S mitochondrial region targeted with metabarcoding:
    - Green frog (Lithobates clamitans) shares a sequence with Bullfrog (Lithobates catesbeianus)
    - Mourning dove (Zenaida macroura) shares a sequence with Rock dove (Columba livia)
    - American pipit (Anthus rubescens) shares a sequence with Lapland longspur (Calcarius lapponicus)
    - American crow (Corvus brachyrhynchos) shares a sequence with Common raven (Corvus corax)
    - Cooper's hawk (Astur cooperii has no 12S sequence
    - Tufted titmouse (Baeolophus bicolor) has no 12S sequence
    - Blue jay (Cyanocitta cristata) has no 12S sequence
    - Willow flycatcher (Empidonax traillii) has no 12S sequence
- Researchers and managers should consider using more targeted primers for bird (e.g., MiBird) and mammal (e.g., MiMammal) eDNA surveys. Further study on the feasibility of more targeted metabarcoding approaches is recommended, as using multiple, targeted metabarcoding assays, while potentially more robust, may be prohibitively expensive for monitoring multiple communities in Maine's forests. For example, with this project as a reference, one run of metabarcoding for 100 eDNA samples may cost approximately $1000–1250 for reusable and single-use field sampling equipment, $1000–1250 for single-use lab supplies for DNA extraction and PCR, $1000–2000 for field and lab labor, and $4000 for sequencing facility fees, for a total cost of roughly $7000–8500 (not including other commonly available general lab supplies and labor for bioinformatic analysis). This sample size (n = 100) is approximately how many eDNA samples we collected over four months at our camera trapping wetlands (n = 8 sites). In contrast, material expenses for cameras at these sites amounted to $3300, and labor for image processing (image review, species identification) was approximately $2700, for a total cost of roughly $6000. As we observed, the cost of monthly eDNA metabarcoding surveys can be higher than continuous camera trapping over the same period, but universal vertebrate primers do not appear to offer a corresponding benefit for detection of birds and mammals from aquatic eDNA (though several taxa were exclusively detected with eDNA).

KEY FIGURES AND TABLES



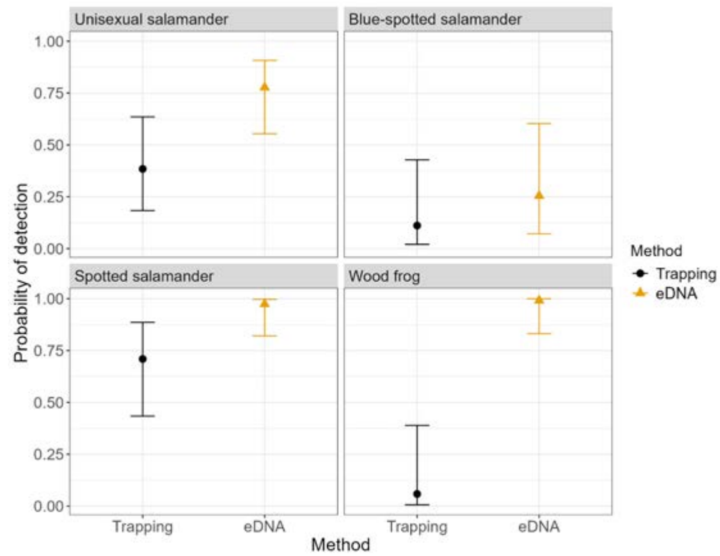
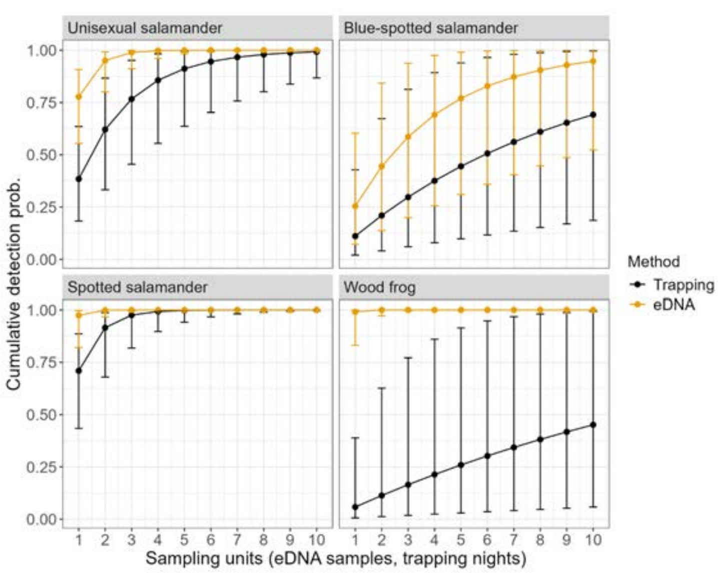


Figure 1. (Above, right) Relationships between Spotted Salamander (Ambystoma maculatum) egg mass counts, eDNA abundance (read counts), and date of sampling (DOY). Both egg mass counts (A) and date of sampling (B) were positively correlated with eDNA abundance of salamanders. The predicted effect of both variables (C) on eDNA abundance (square-root transformed), after scaling for wetland size and volume of water sample, was estimated from a linear mixed effect model.

Figure 2. (Above, left) Probabilities of detecting breeding amphibians from one night of aquatic funnel trapping (12–18 traps per wetland) versus one sample of eDNA.



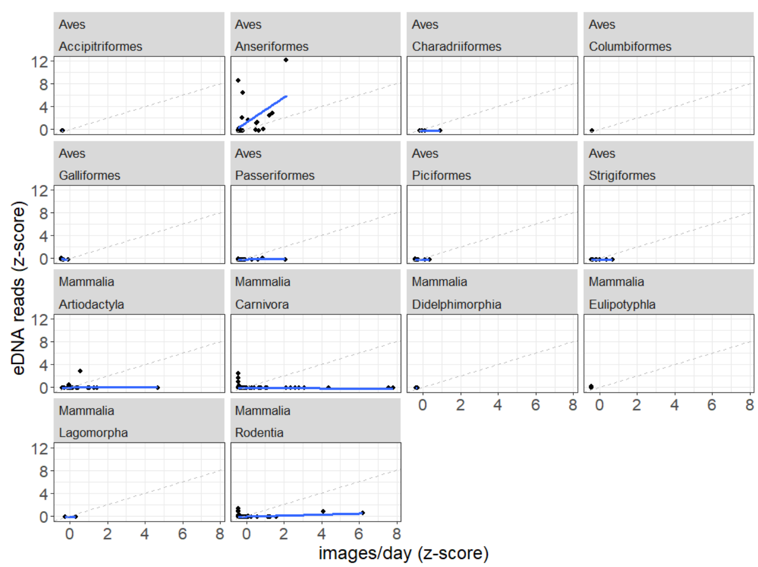


Figure 4. Relationships between eDNA relative abundance (read counts) and camera trap detection frequency (images per day) of bird and mammal taxa.

*To do length, table 1 can be found in the appendix of this report.

Figure 3. (Above, right) Cumulative probability of detecting breeding amphibians with increasing eDNA samples and trapping nights.

FUTURE PLANS

- Complete validation analysis for vertebrate biodiversity datasets from Maine
  - Re-run samples with bird / mammal primers, if future funding available
  - Estimate drivers of eDNA detection (e.g., date, volume, water quality)
- Finalize salamander eDNA assay, run on all samples, and produce manuscript
- Upload all new sequences from voucher specimens to GenBank for public use
- Complete final report, synthesizing all findings from our pilot studies, assay development, and Maine field projects

ACKNOWLEDGEMENTS

We thank the many undergraduate assistants who provided critical help processing lab samples and wildlife camera images during this third year of this project. We are also grateful to several private landowners who provided continued access to wetlands on their property for monitoring.

GEOGRAPHIC LOCATION OF PROJECT

- Orono, ME — 44.8831° N, 68.6719° W
- Old Town, ME — 44.9342° N, 68.6453° W

PARTNERS/COLLABORATORS

- Kristine Hoffmann, Department of Biology, St. Lawrence University
- Jacob Kubel, Natural Heritage & Endangered Species Program, Massachusetts Division of Fisheries & Wildlife
- Alyssa Kaganer, Cornell Wildlife Health Lab, Cornell University (now Penn State)
- Paula Blanco-Ortiz, Cornell Wildlife Health Lab, Cornell University
- Samara Davis, Yale University
- Mark Stoeckle, Program for the Human Environment, The Rockefeller University
- Janet Atoyan, RI-INBRE Molecular Informatics Core, University of Rhode Island

EXTERNAL/MATCHED FUNDING SOURCES

Source:	Amount:	Direct/Indirect:
MAFES	$27,675	Direct
Grey Lab	$188	Direct

Photo above. Harrison Goldspiel, lead PhD student on the CFRU eDNA project, prepares to collect an eDNA sample from a vernal pool in Orono, Maine. Photo by Regina Smith, CFRU

BIRDS AS INDICATORS OF FOREST MANAGEMENT SUSTAINABILITY IN MAINE: AN EVALUATION OF PAST SURVEYS AND FUTURE ASSESSMENT APPROACHES

DR. AMBER ROTH, ASSOCIATE PROFESSOR OF WILDLIFE FOREST MANAGEMENT, SCHOOL OF FOREST RESOURCES AND WILDLIFE, FISHERIES, AND CONSERVATION BIOLOGY (PI)

DR. ERIN SIMONS-LEGAARD, ASSISTANT RESEARCH PROFESSOR IN FOREST LANDSCAPE MODELING, SCHOOL OF FOREST RESOURCES

ABSTRACT

During the summer of 2024, we wrapped up the last forest bird transect surveys across the Maine Adaptive Silviculture Network (MASN) sites. Autonomous Recording Units (ARUs) remained deployed across the surveyed sites and were collected at the end of the season with the help of our MASN partners. During spring of 2025, we developed an ARU deployment protocol with the help of other regional ARU researchers. This protocol guided deployment of 17 ARUs across four of the MASN sites for the 2025 breeding bird season. The ARUs recorded daily around sunrise and sunset throughout June 2025, resulting in over 1,000 hours of audio recordings that will be analyzed in the following year. FY 2026 will focus on data analyzation of the 2017-2024 transect data to assess changes in bird communities with silvicultural treatments and analyzation of ARU data and experiments to assess the efficiency and accuracy of ARUs.

PROJECT OBJECTIVES

- Assess the sustainability of silvicultural treatments through long-term monitoring of bird populations.
- Develop a long-term Autonomous Recording Unit (ARU) survey plan for the continued monitoring of sustainable forestry in the Acadian Forest.
- Integrate new ARU data with past transect survey data.

APPROACH

- Assess transect bird survey data from 2017-2024 from MASN sites. As a metric for forest management sustainability, we plan to assess the forest bird community through various alpha and beta diversity metrics including species richness, diversity, and community dissimilarity and turnover over time.
- In June 2025, run transect and ARU surveys concurrently to assess efficiency and accuracy of the new method and to crosswalk the datasets.
- Develop an ARU deployment and data analyzation protocol with the assistance of other ARU researchers to use for June 2025 deployment and the future.

Photo 1 (Below). ARU deployment at CLWH Oxbow in a Delayed Harvest. ARUs are strapped to small diameter trees or t-posts in the center of the treatment plot.

KEY FINDINGS/ACCOMPLISHMENTS

- We developed an ARU deployment protocol with the help of other ARU researchers (Lisa Venier, Chris Edge, and Sally Stockwell) for continued long-term bird monitoring. ARUs will replace transect surveys going forward. *(ARU protcol available on request and on cfrumembers.org)*
- We deployed 17 ARUs across 4 different MASN sites (SILC T13R15, JDI Sauls Brook, AMC Mooresville, CLWH Oxbow) in 2024. They recorded daily at two times: 30 minutes before sunrise to one hour after sunrise and from sunset to 30 minutes after sunset. They recorded from June 1-30, resulting in approximately 1,020 hours of recordings (60 hours per ARU).
- In addition to the concurrent transect and ARU surveys in the summer of 2024, we conducted experimental sound surveys to assess the maximum effective distance of ARUs for different bird vocalizations in different forest conditions.
- While there was an attempt to run a Forestry for Maine Birds workshop for CFRU members, interest was too low. We plan to find other ways to engage and educate CFRU members with forest birds and ARUs.

FUTURE PLANS

- We will analyze the 2017-2024 transect data to assess changes in bird communities with harvesting among different silvicultural treatments. We plan to submit a paper for publication early in 2026.
- Results from the 2024 ARU pilot deployment will be compared to the transect data from the same year to assess the efficiency of the ARUs and how to best integrate these new data into the current long-term dataset.
- We will determine the best method for analyzing ARU recordings and begin analysis of 2025 data.
- The ARU protocol will be revised to include data management instructions by spring 2026 and updated for ARU deployments in May 2026.

ACKNOWLEDGEMENTS

Thank you to CFRU for continued support and to the MASN partners who have graciously allocated land for experimental silvicultural plots and access for surveys and ARUs. Thank you to the ARU technical team for assistance in developing the protocol; Lisa Venier (Great Lakes Forestry Centre, Canadian Forest Service), Chris Edge (Atlantic Forestry Centre, Canadian Forest Service), and Sally Stockwell (Maine Audubon).

GEOGRAPHIC LOCATION OF PROJECT

Maine, on select CFRU member lands. Locations and additional site details can be viewed in ArcStory.

PARTNERS/STAKEHOLDERS/ COLLABORATORS

- Department of Wildlife, Forestry, and Conservation Biology
- School of Forest Resources
- Maine Agricultural and Forest Experimental Station

Maine Adaptive Silviculture Network Partners, specifically:

- American Forest Management
- Appalachian Mountain Club
- Baskahegan Company
- Clayton Woodland Holdings, LLC
- J.D. Irving
- Manulife Investment Management
- Seven Islands Land Company
- Wagner Forest Management
- Weyerhaeuser

EXTERNAL/MATCHED FUNDING SOURCES

Source:	Amount:	Direct/Indirect:
UMaine	$28,060	Direct

MOVEMENT ECOLOGY OF WOOD TURTLES (GLYPTEMYS INSCULPTA) IN MAINE'S WORKING FORESTS

MATTHEW CHATFIELD, ASSOCIATE PROFESSOR OF EVOLUTION AND ECO-HEALTH, SCHOOL OF BIOLOGY AND ECOLOGY, UNIVERSITY OF MAINE

SEQUOIA DIXSON, MS, ECOLOGY AND ENVIRONMENTAL SCIENCES PROGRAM, UNIVERSITY OF MAINE

ABSTRACT

The wood turtle (Glyptemys insculpta) is a Species of Greatest Conservation Need in the most recent version of the State's Wildlife Action Plan and is currently under review for listing on the U.S. Endangered Species Act. The working forests of northern Maine are thought to support relatively intact populations that may be critical to the long-term persistence of the species. Managing for a variety of habitats that includes foraging, basking and nesting areas may improve wood turtle conservation efforts and help reverse population declines. In early 2023, we were awarded funds from the USFWS Wildlife Conservation Initiative (WCI) to conduct a two-year study on the population and movement ecology of wood turtles on forested lands. Building on the WCI-funded study, the goal of our project is to provide a detailed understanding of movement patterns and habitat selection of wood turtles on Maine's forestry lands. Conserving this species relies on cooperation between foresters and researchers to help create a well-informed and evidence-based approach to improve forest management practices for this species. Specifically, the objectives for the project are to: (1) extend our existing project through 2026 and (2) expand the scope of the project by focusing on wood turtle microhabitat and macrohabitat selection within forestry lands.

PROJECT OBJECTIVES

Our CFRU-funded project is continuing and expanding on work initiated in 2023. Broadly, the goals of this ongoing project are to examine population and movement ecology of wood turtles on Maine's forested lands. The specific objectives of the CFRU project are to:

- Estimate population demographic characteristics (e.g., population size, age class structure, and sex ratio) and conduct site-specific population viability analyses using data from time constrained surveys of fixed transects and capture-mark-recapture (CMR) methods. As many years of CMR data are typically required to accurately assess population dynamics, we plan to construct models and estimate confidence intervals for key demographic parameters at the close of the 2026 field season before submitting results for publication.

Photo 1. (Below) Wood turtle (Glyptemys insculpta). Photo by Sequoia Dixson.

- Investigate movement ecology (e.g., habitat selection, home ranges, and movement patterns) by tracking turtles using long-life VHF and GPS tags.
- Funds awarded through the CFRU are being used to expand the initial objectives by including microhabitat selection (in addition to macrohabitat selection), thereby providing a greater understanding of wood turtle habitat needs in Maine's working forests.

APPROACH

- In 2023, we selected three study sites in western Maine; each site was chosen because of the presence of wood turtles and its proximity to forestry lands including those owned by Wagner Forest Management (WFM), American Forestry Management, and Weyerhaeuser Company.
- From 2023–2025, we conducted standardized population surveys along 2 km of river at two of the three study sites. We plan to continue surveys until the completion of the project in 2026. These surveys are used to determine fundamental population demographic characteristics, as well as capture turtles for the habitat selection study. During surveys, we locate turtles visually, either on foot or by boat. In addition, we regularly employ the use of conservation scent detection dogs that have been trained to locate wood turtles.
- In 2023 and 2024, a subset of 41 healthy adult turtles received VHF and GPS tags. After processing, all turtles were released at the site of capture.
- In 2024 and 2025, we used VHF radio telemetry to locate wood turtles 5–10 times each during the active season and record micro- and macrohabitat characteristics. Data collection also included a general health assessment and any interesting behaviors (e.g., feeding, courtship, agonistic interactions). We then classified the habitat around the turtles using variable radius plot sampling methods and characterized the amount of coarse woody debris and other important microhabitat features.
- In 2024 and 2025, we ground-truthed stand maps provided by WFM using variable radius plots in every stand or mapped polygon that contained turtle locations (as determined through GPS tag data collected in 2024). This ground-truthing will allow us to determine which stand types turtles may be selecting or avoiding.

KEY FINDINGS/ACCOMPLISHMENTS

As of the close of Year 2 of the CFRU-funded project, we have:

- Captured 192 unique turtles across the three study sites in western Maine.
- Deployed 41 VHF tags on a subset of healthy adult turtles, with a balance of males and females.
- Deployed 41 GPS tags concurrently with the VHF tags. As the GPS tags we are using in this project do not contain VHF capability, turtles receiving GPS tags also require VHF tags.
- Downloaded data from all the GPS tags deployed in 2024. This spatial data is currently being analyzed using a GIS framework.
- Completed 69 forestry plots for ground-truthing stand maps provided by WFM.

FUTURE PLANS

- During our final field season in 2026, we will continue to conduct standardized stream surveys to collect population demographic data.
- Graduate student Sequoia Dixson plans to graduate in the spring of 2026; her MS thesis will be provided to CFRU members upon request.
- Pending significant results, we plan to submit findings from the habitat selection and movement pattern analyses for peer-reviewed publication in 2026.
- In the spring of 2027, we will submit a final report with results and management suggestions to the CFRU.
- Pending significant results, we plan to submit findings from the population demography and viability analyses for peer-reviewed publication in 2027.

GEOGRAPHIC LOCATION OF PROJECT

We work within managed forests in western Maine. Due to the risk of collection for the illegal wildlife trade, precise locality information is not being provided.

Photo 2. (Above) Study turtle 8332 with a VHF transmitter (left) and GPS tag with 3D-printed housing (right). Photo by Sequoia Dixson.

ACKNOWLEDGEMENTS

We thank our undergraduate field assistants Tyler Locke, Courtney White, and Astrid Niles. We additionally thank Abigail Slater, Trina Wantman, Henning Stabins, Michael Jones, Bradley Compton, Erin Simons-Legaard, Derek Yorks, Lindsay Ware, Cheryl Frederick, Regina Smith, Darren Miller, Mike Jurgiewich, and all of our forestry company partners for their input on study design, assistance with fieldwork, and willingness to answer our many forestry-related questions.

PARTNERS/STAKEHOLDERS/COLLABORATORS

National Council for Air and Stream Improvement, Inc. (NCASI)
Wagner Forest Management
Weyerhaeuser Company
American Forest Management
Cooperative Forestry Research Unit

EXTERNAL/MATCHED FUNDING SOURCES

Source:	Amount:	Direct/Indirect:
NCASI	$20,000	$16,667 - Direct $3,333 - Indirect

Table 1.Manly - Chesson selection preferences for differing wetland types for male and female wood turtles. The gray indicates no GPS records of the wood turtled in those areas

Male	Wetland Code	Female
Preference (+)	NW	Preference (+)
Avoidance (-)	PEM1/SS1E	Avoidance (-)
Avoidance (-)	PEM1E	Avoidance (-)
-	PEM1Eh	Avoidance (-)
Preference (+)	PFO1/4C	Preference (+)
Preference (+)	PFO1C	-
-	PFO4/1E	Avoidance (-)
Preference (+)	PFO4/SS1E	Preference (+)
Preference (+)	PFO4E	Avoidance (-)
-	PFO4Eb	Avoidance (-)
-	PFO5Fh	Avoidance (-)
Avoidance (-)	PSS1/EM1E	-
Preference (+)	PSS1/FO4E	Avoidance (-)
Preference (+)	PSS1C	Avoidance (-)
Preference (+)	PSS1E	Preference (+)
Avoidance (-)	PSS1Eh	Avoidance (-)
Preference (+)	PSS1F	Preference (+)
Avoidance (-)	PSS1Fb	-
Avoidance (-)	PSS1Fh	-
Avoidance (-)	PSS4E	Avoidance (-)
Avoidance (-)	PSS4Eh	-
Avoidance (-)	PSS7E	Avoidance (-)
Avoidance (-)	PUBF	-
Avoidance (-)	PUBH	-
-	PUBHh	Avoidance (-)
Preference (+)	R2UBH	Preference (+)

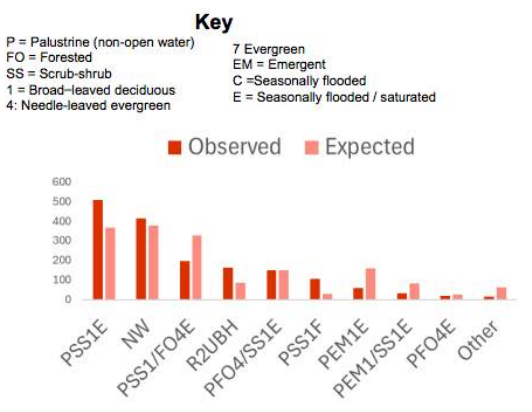


Figure 4. Female observed vs expected habitat distribution results

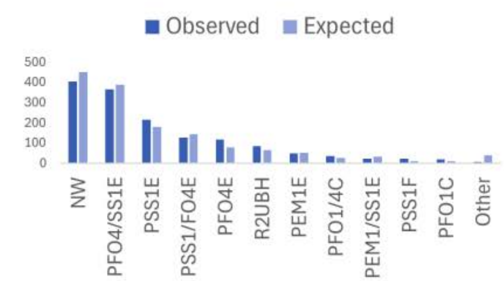


Figure 5. Male observed vs expected habitat distribution results

A table and figures from undergraduate field assistant Tyler Locke's presentation at the University of Maine Student Symposium. Tyler analyzed habitat selection of wood turtles based on the national wetland inventory maps and found that they selected palustrine forested wetlands with both deciduous and coniferous composition.

RESEARCH PRODUCTS DELIVERED IN 2025

COMMUNITY ENGAGEMENT

Mech, Angela. 2025. Town Hall, sponsored by Keeping Maine's Forests, Maine Forest Service, Cooperative Forestry Research Unit, and the Spruce Budworm Taskforce. Spruce Budworm Information Session. Presenter and Panelist: Spruce Budworm Biology and Monitoring. May 2025.

Mech, Angela, 2025. Legislative Breakfast, sponsored by the Maine Forest Products Council. Maine State Legislature. Return of the Spruce Budworm. Presenter and Panelist: Early Intervention Strategy & Spruce Budworm Monitoring. January 2025.

Mech, Angela, 2025. Spruce Budworm Lab tours in 2025: Senator Susan Collin's Staff, University of Maine Board of Trustee member, Tree Pests and Diseases (SFR 458) class

CONFERENCE PAPERS

Goldspiel, HB, Kubel, JE, Grey, EK, Charney, ND. 2025. "Detection and Succession Properties of Vernal Pool Communities with eDNA Metabarcoding." Poster at Northeast Partners in Amphibian and Reptile Conservation, 10–12 August 2025, Dingmans Ferry, PA, USA.

Goldspiel, HB, Kubel, JE, Grey, EK, Charney, ND. 2025. "Detection and Succession Properties of Vernal Pool Communities with eDNA Metabarcoding." Poster at Northeast Natural History Conservation, 4 – 6 April 2025, Springfield, MA, USA.

FIELD TOURS/MEETINGS/PRESENTATIONS/WORKSHOPS

Carter, A., Premer, M.I., Weiskittel, A., Kenefic, L., and R. Seymour. Developing. High resolution modeling of spruce habitat suitability in Maine. Northeastern/Southern Mensurationists meeting in Stowe, VT. November 5, 2024.

Carter, A., Premer, M.I., Weiskittel, A., Kenefic, L., and R. Seymour. Developing digital site suitability systems for adaptive management of Maine's spruce forests. North American Forest Ecology Workshop in Asheville, NC. June 25, 2024

Carter, A., Premer, M.I., Weiskittel, A., Kenefic, L., and R. Seymour. Developing digital site suitability systems for adaptive management of Maine's spruce forests. New England Society of American Foresters. Burlington, VT. March 28, 2024

Goldspiel, HB. 2025. Cryptic species and biodiversity in vernal pools: a view from Maine and Frog Pond. Orono Land Trust, Annual Members Meeting.

Goldspiel, HB. 2025. Exploring the capacity of eDNA for studying cryptic salamanders and vernal pool biodiversity in Maine. Maine Association of Wetland Scientists, Spring 2025 Meeting.

Kenefic, Laura S. 2024. Penobscot Experimental Forest. Presented at the U.S. Forest Service, Northern Research Station and Hubbard Brook Foundation, Experimental Forests of the Northeast Partner Engagement Session, 17 September 2024, Woodstock, NH. Virtual.

Kenefic, Laura S. 2025. Northern conifer and mixedwood management in the Northeast.
Presented to University of Missouri, Advanced Silviculture, 8 April 2025, Columbia, MO. Virtual.

Kenefic, Laura S. 2025. Northern conifer forest management: ecological and economic context.
Presented to Oregon State University, International Programs, Exploring the Pine Tree State: Evolving Forests and Communities in Maine, 25 March 2025, Orono, ME.

Locke, Tyler. 2025. Presented at the University of Maine Student Symposium using data collected from Movement Ecology of Wood Turtles (Glyptemys insculpta) in Maine's Working Forests, including his work on wood turtle use of wetland types. 30 April 2025, Orono, ME.

Mech, A. Spruce budworm sampling and analysis. 87th Northeastern Forest Pest Council Annual Meeting. March 2025. [Invited Speaker]

McCloskey, Dustin; Kenefic, Laura S.; Simons-Legaard, Erin; Rogers, Nicole; Sachdeva, Sonya; Roach, Skylar. 2025. Climate adaptivity outcomes of conventional silviculture in northern conifer forests. Presented at the New England Society of American Foresters Annual Winter Meeting, 26 March 2025, Devens, MA.

Noone-Prive, Maeve, William H. Livingston, Josh Sherrill, Mike Premer, and Justin G.A. Whitehill. 2025 Developing Strategies to Reduce Damage Caused by the White Pine Weevil (Pissodes strobi)[Peck]. Northeast Forest Pest Council, Middlebury, VT. March 11, 2025. (Presentation)

Noone-Price, Maeve , William Livingston, Mike Premer, Justin Whitehill. Eastern White Pine: How Do We Reduce White Pine Weevil Damage? New England Society of American Foresters Annual Meeting, Burlington, VT. March 28, 2024. (Poster)

Rahimzadeh-Bajgiran P., Progress in remote sensing technology and products for spruce budworm monitoring: a 10-year overview, 2025 Northeast Forest Pest Council Annual Meeting, Middlebury, VT, March 10-11, 2025.

Rahimzadeh-Bajgiran P. Innovations in remote sensing of forest health, Maine Division of Society of American Foresters Annual Meeting, Brewer, Maine, October 10, 2024.

Ulsamer, P.G. 2024. Forest Bird Response to Forest Silviculture. Maine Chapter of the Wildlife Society, Fall Meeting and Wildlife Research Symposium. December 6, 2024. Buchanan Alumni House, University of Maine, Orono, ME.

PRODUCTS DELIVERED

NOAA C-CAP 1-meter land cover, available on the NOAA Digital Coast. https://coast.noaa.gov/digitalcoast/data/

Ulsamer, P.G. 2025. CFRU MASN ARU Protocol 2025 Season. University of Maine, Orono. 19p.

REFEREED JOURNAL PUBLICATIONS

Bhattarai, R., & Rahimzadeh-Bajgiran, P. 2025. Optimizing forest defoliation detection using remote sensing data: a multi–resolution approach using machine learning algorithms. Trees, Forests and People, 101009. https://doi.org/10.1016/j.tfp.2025.101009.

Foster, A., Rahimzadeh-Bajgiran, P., Daigneault, A., & Weiskittel, A. 2024. Cost-effectiveness of remote sensing technology for spruce budworm monitoring in Maine, USA. Forests Monitor, 1 (1): 66-98. https://doi.org/10.62320/fm.v1.i1.14.

Goldspiel, HB, Davis, S, Winiarski, E, Kubel, J, Grey, E, Charney, N. In review. Detection and succession properties of forested vernal pools with eDNA metabarcoding.

Goldspiel, HB, Charney, ND. In review. Ambystoma laterale-jeffersonianum complex (Unisexual Ambystoma). Polydactyly.

Goldspiel, HB, Hoffmann, KE, Charney, ND. 2025. Light at the end of the funnel: Taxonomic biases of trapping methods for studying wetland-breeding amphibians at variable depths. Journal of Herpetology 59.1: 1–10. https://doi.org/10.1670/2460810

RESEARCH NOTES

Carter, A. and Premer, M. 2025. Spruce-site suitability for Maine's forestlands. figshare. Journal contribution. https://doi.org/10.6084/m9.figshare.28557176.v1

Dumais, Daniel; Kenefic, Laura S.; Thomas-Van Gundy, Melissa; McNulty, Steven; Perron, Martin. In review. Picea rubens Sarg. (Red spruce). In: Silvics of North America. U.S. Department of Agriculture, Forest Service.

Premer, M.I., Carter, A., Beck, L., Curry, S., and T. Locke. The spruce is loose: Juvenile performance of improved planted spruce forests. Maine Forest Management Lab Research Note. 2 p.

Simons-Legaard, Erin; Kenefic, Laura; Rogers, Nicole; Seymour, Robert; Kanoti, Keith. 2025. A new silvicultural guide for northern conifers in the Northeast. Final Report. Northeastern States Research Cooperative. 6 p.

RESEARCHER & PROJECT AWARDS

Mech, Angela. 2025. Abby Holman Public Service Award, Awarded by the Maine Forest Products Council for recognition of her leadership and research at the University of Maine Spruce Budworm Lab

Goldspeil, HB. 2025. Northeast Partners in Amphibian and Reptile Conservation: Best Graduate Student Poster.

THESES

Carter, Ashley, "Enhancing Spruce Forest Management in Maine: Digital Habitat Suitability Modeling and Structural-Productivity Dynamics of Species Mixtures" (2025). Electronic Theses and Dissertations. 4221. https://digitalcommons.library.umaine.edu/etd/4221

Noone-Price, Maeve. 2025. How white pine weevil (Pissodes strobi [peck]) damage to eastern white pine (Pinus strobus [l.]) varies with site, climate and mechanical resistance factors. MS Thesis, University of Maine. 92 p. https://digitalcommons.library.umaine.edu/etd/4255/
Presentation at the New England Society of American Foresters Annual Winter Meeting. 15 March 2023.

Legaard, K., Guay, A., Kiedrowski, C., Simons-Legaard, E., and Bundy, K. 2022. State of Maine high resolution forest type and biomass mapping using multi-source remote sensing and FIA plot data. 2022 Forest Inventory and Analysis Science Stakeholder Meeting, November 17, 2022, Minneapolis/St. Paul, MN.

NEWS, SOCIALS, & WEB

Goldspiel, HB. 2025. Edna and Al. Spire: The Maine Journal of Conservation and Sustainability Vol. 9. https://umaine.edu/spire/2025/04/19/goldspiel/

Mech, Angela, 2025. Understanding the impact of a Spruce Budworm outbreak. By Jackie Mundry. 2/24/25 WMTW 8 ABC https://www.wmtw.com/article/understanding-the-impact-of-a-spruce-budworm-outbreak/63906552

Mech, Angela. 2025. Webinar. Spruce Budworm and the Early Intervention Strategy being Implemented in Maine. Sponsored by the Vermont Department of Forests, Parks and Recreation. May 2025. 110 participants.

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Bhattarai, R., Rahimzadeh-Bajgiran, P., Weiskittel, A., 2022. Multi-source mapping of forest susceptibility to spruce budworm defoliation based on stand age and composition across a complex landscape in Maine, USA. Canadian Journal of Remote Sensing, 48 (6), 873-893.

Center for Biological Diversity. 2012. Petition to list 53 amphibians and reptiles in the United States as Threatened or Endangered species under the Endangered Species Act. Petition submitted to the U.S. Secretary of the Interior. 454 pp.

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Jones, M.T., Willey, L.L., Mays, J.D., Akre, T.S.B., Tamplin, J.W., Gipe, K.D., Burne, M.R., Kleopfer, J.D., and Badje, A. 2021. Habitat. In Jones, M.T. and Willey, L.L. (Eds.). Biology and Conservation of the Wood Turtle. Petersburgh, NY: Northeast Association of Fish and Wildlife Agencies, Inc., pp. 81–112.

Kaufmann, J. H. 1992. Habitat use by wood turtles in central Pennsylvania. Journal of Herpetology 26:315–321.

Kenefic, Laura S.; Rogers, Nicole S.; Roach, Skylar K.; Zukswert, Jenna; Horan, Sean, eds. In review. Northern Conifer Silviculture Guide. Gen. Tech. Rep. NRS. Madison, WI: U.S. Department of Agriculture, Forest Service, Northern Research Station.

Legaard, K. 2018. New approaches to mapping forest conditions and landscape change from moderate resolution remote sensing data across the species-rich and structurally diverse Atlantic Northern Forest of northeastern North America, Ph.D. Dissertation, The University of Maine.

Legaard, K., Simons-Legaard E., Weiskittel, A. 2020. Multi-objective support vector regression reduces systematic error in moderate resolution maps of tree species abundance. Remote Sensing, 12, 1739. doi 10.3390/rs12111739.

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