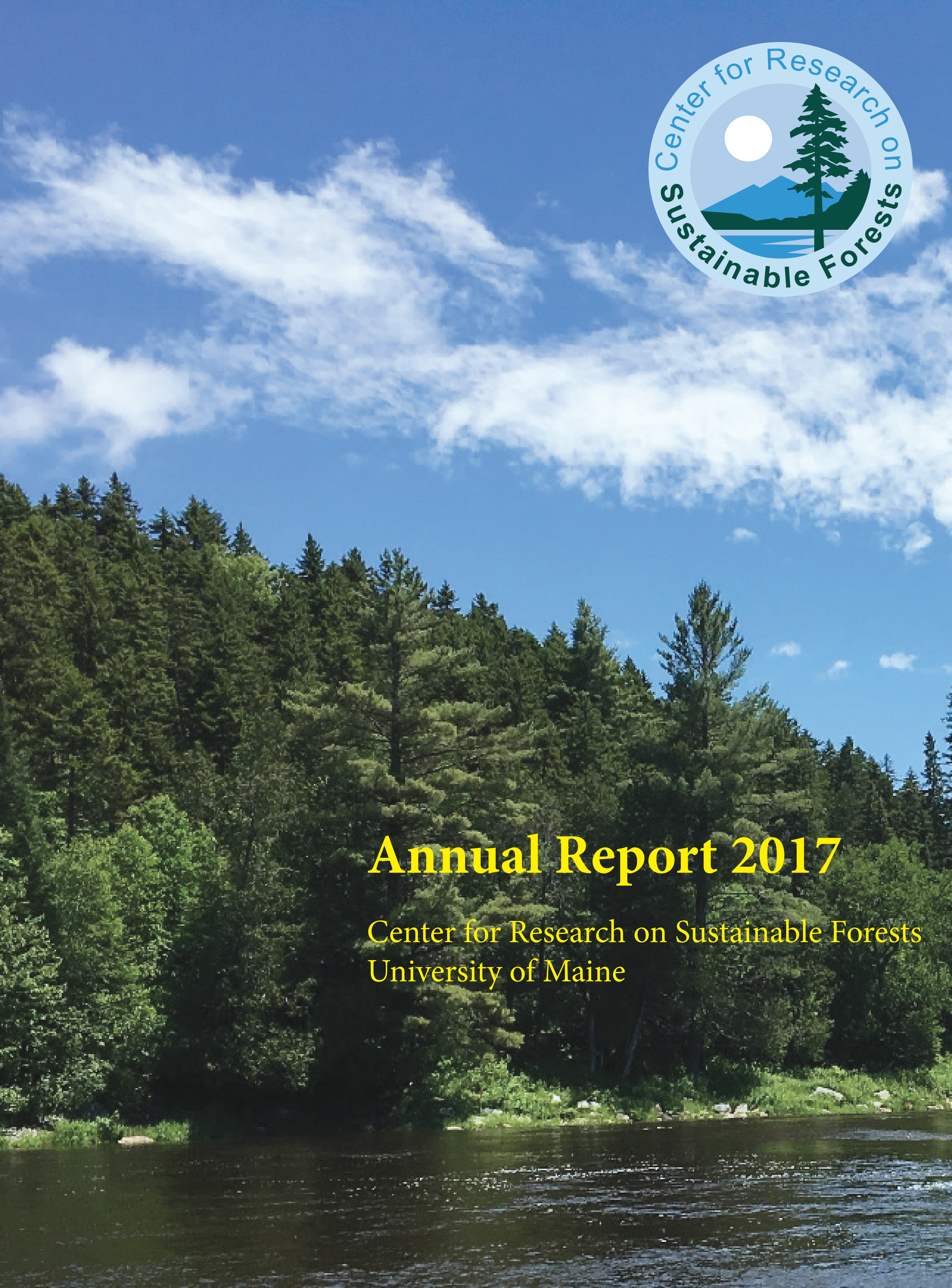

Annual Report 2017

Center for Research on Sustainable Forests
University of Maine

About the Center

The Center for Research on Sustainable Forests (CRSF) was founded in 2006 to build on a rich history of leading forest research and to enhance our understanding of Maine's forest resources in an increasingly complex world. The CRSF houses a variety of initiatives including the Cooperative Forestry Research Unit (CFRU), Northeastern States Research Cooperative (NSRC), and National Science Foundation Center for Advanced Forestry Systems (CAFS). Under the leadership of Dr. Robert Wagner (2010-2016), CRSF focused on four major research programs: Commercial Forests, Family Forests, Conservation Lands, and Nature-Based Tourism. However, forestry is rapidly evolving, due in great part to changing market conditions and the unprecedented availability of data provided by technologies such as LiDAR, high-resolution imagery, and GPS. Going forward, the CRSF will prioritize developing, integrating, and applying these emerging geospatial technologies and informatics methods to address current and future issues to support the sustainable management of the region's natural resources.

Our mission is to conduct and promote leading interdisciplinary research on issues affecting the management and sustainability of northern forest ecosystems and Maine's forest-based economy.

Center for Research on Sustainable Forests
University of Maine
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Cover photo by Meg Fergusson
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Highlights

- Ongoing development within the CRSF to be the region's research data portal and geospatial observatory for forests of the Northeastern US. In addition to updating the CRSF home website, we continue to support three online tools for forest resources professionals and the public:

  Northeast Forest Information System (NEFIS) – an online, open-source, web portal for applied forestry information (http://www.nefismembers.org). More than 1,000 documents were uploaded over the year on a wide range of topics, user numbers have doubled, and monthly page views have reached nearly 5,000.

  Maine Forest Spatial Tool – displays a wide variety of geospatial data on forest resources across the State of Maine for both forest resource professionals and the public (http://mfst.acg.maine.edu).

  Maine Forest Dashboard – The Dashboard was launched in Spring 2017 and can be accessed at http://www.maineforestdashboard.com. The site provides customizable forest statistics and changes using long-term data from the Maine Forest Service and has had nearly 100 page views since its release in early May.

- CRSF scientists **continue to provide a strong return for every dollar provided by the Maine Economic Improvement Fund (MEIF)** to support CRSF research. In the past year, there has been over **$21 in return for every $1** invested in.

- Aaron Weiskittel, along with industry leaders and the Maine Forest Products Council, received nearly $2.5 million in funding from the Economic Development Administration and Maine Technology Institute to support vital work on Maine's economic development team.

- Completion of a CFRU study by Steve Dunham and Dan Harrison focused on the effects of forest management on spruce grouse habitat was well received by key stakeholders.

- CRSF website completely revised, revamped, and updated for new platform to conform with UMaine IT requirements.

- Drs. Brian Roth, Aaron Weiskittel, and Anil Kizha began work on a new CFRU study to examine alternative silvicultural approaches for improving rotation length productivity and value of mid-rotation stands in Maine. The main objective is to establish a network of 18 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. Once established, this network will serve as an operational-scale field laboratory and has received quite a bit of interest from potential collaborators across campus.

- The **Nature-based Tourism Research Program** (led by Dr. Sandra De Urioste-Stone) conducted an undergraduate and graduate student service-learning project to facilitate tourism destination planning in western Maine in collaboration with local stakeholders through a grant provided by the Davis Educational Foundation.

- CRSF affiliated researcher Dr. Shawn Fraver continues to lead several USDA research grants to support national Ameriflux program monitoring efforts on the Howland Forest, which is the second longest running site in the Ameriflux program.

- In addition to the long-term research efforts at Howland Forest, the Holt Research Forest and Penobscot Experimental Forest are now affiliated with CRSF. The three are among the longest running research forests in Maine as well as the Northeast.

- CRSF continues to be the lead on the Maine Spruce Budworm Task Force communications team, maintaining the mainesprucebudworm.org website and Facebook page that are the primary information sources on budworm for the forest industry, state government, researchers and the public.

- CRSF completed a self-study that documented its past accomplishments and outlines a future vision for the research center, which was reviewed by an external committee.

Photo courtesy Pam Wells, Oakleafs Studios.

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Forest research and its application are rapidly evolving today due to unprecedented availability of data provided by a variety of emerging technologies such as LiDAR, high-resolution digital imagery, and GPS. Consequently, a new focus in CRSF will be the integration of technologies and analysis of data to support the sustainable management of the region's natural resources.

Director's Report

The Center for Research on Sustainable Forests (CRSF) continued its transition as a research center in 2016–17 under the leadership of Acting Director Dr. Aaron Weiskittel. As highlighted by this annual report, CRSF remains strong and engaged on a variety of fronts throughout Maine and the larger Northern Forest region. The focus on helping to promote and sustain the region's forest-based economy will remain a key priority in years to come.

In 2016–17, the emphasis was on maintaining current momentum while documenting past successes and outlining a future vision for CRSF. Key priorities were continuing to lead Theme 3 of the Northeastern States Research Cooperative, participate in the National Science Foundation Center for Advanced Forestry Systems, and co-lead the Maine Spruce Budworm Task Force. New focus areas included the Maine Forest Economic Growth Initiative, pursuit of two large-scale, multi-year EPSCoR proposals, and the oversight of research activities at two additional long-term field sites; namely, Holt Research Forest and Penobscot Experimental Forest. All of these are highlighted in detail within this report and showcase the importance of CRSF for coordinating a range of research efforts.

At the request of the Vice-President of Research's Office, CRSF began to compile and assess past accomplishments since its inception in 2006 and to outline a strategic vision, which was primarily formed through the preparation of the two EPSCoR proposals. This information is in the process of being gathered into a formal report that will be reviewed by an external committee. The process has clearly highlighted the many successes that CRSF has had over the years and provides a strong roadmap for future efforts. We hope the review committee will agree.

As in the past, CRSF will continue to evolve and refine its mission to remain relevant. Consequently, the concentration on four research programs (Commercial Forestlands, Family Forests, Conservation Lands, and Nature-based Tourism) under Dr. Robert Wagner's leadership has been revised to increase focus on emerging geospatial technologies and landscape metrics. Efforts to expand these new areas will be a key priority in the years to come, particularly as forest management has shifted from stand-based to more landscape-based.

Overall, I am excited by the CRSF's ongoingl success and bright future, which is only possible by the contributions of a dedicated staff, productive affiliated scientists, and motivated graduate/undergraduate students. I look forward to what the coming years will bring to CRSF given our new focus.

Aaron Weiskittel
Acting Director

People

Leadership & Staff

Aaron Weiskittel, Acting Director

Brian Roth, CFRU Acting Director

John Lee, Research Associate, Howland Research Forest

Holly Hughes, Research Associate, Howland Research Forest

Jack Witham, Associate Scientist, Holt Forest

Arun Kantibose, CFRU Post-Doctoral Research Scientist

Steve Dunham, CFRU Research Scientist

Meg Fergusson, CRSF Administrative Assistant

Cynthia Smith, CFRU Administrative Assistant

CRSF Affiliated Faculty

Sandra de Urioste-Stone, School of Forest Resources, Nature-based Tourism

Shawn Fraver, School of Forest Resources, Howland Research Forest

Dan Harrison, Department of Wildlife, Fisheries, and Conservation Biology, CRSF

Laura Kenefic, Research Forester, Penobscot Experimental Forest, US Forest Service

Neil Thompson, Irving Woodlands Forestry Professor, Univ. of Maine Fort Kent

Project Scientists

Mohammad Bataineh, University of Arkansas (NSRC)

Jeffrey Benjamin, Bangor Christian Schools (NSRC)

Eric Blomberg, Univ. of Maine (CFRU)

John Brissette, USF-NRS (NSRC)

Sophan Chhin, Michigan State University (NSRC)

Stephan Colombo, Ontario Forest Research Institute (NSRC)

Anthony D'Amato, Univ. of Vermont (NSRC)

John Daigle, Univ. of Maine (NSRC)

Michael Day, Univ. of Maine (NSRC)

Mark Ducey, Univ. of New Hampshire (NSRC)

Bob Evans, USDA Forest Service (Howland)

Ivan Fernandez, University of Maine (NSRC)

Shawn Fraver, Univ. of Maine (NSRC, CFRU)

Todd Gabe, Univ. of Maine (Tourism)

Dan Harrison, Univ. of Maine (CFRU)

Chris Hennigar, Univ. of New Brunswick (CFRU, NSRC)

Patrick Hiesl, Clemson University (CFRU)

David Hollinger, USDA Forest Service (NSRC, Howland)

Holly Hughes, Woods Hole Research Center (Howland)

Jennifer Hushaw, INRS, LLC. (NSRC)

Laura Kenefic, USFS-NRS (NSRC, CFRU)

Christian Kuehne, Univ. of Maine (CFRU, NSRC)

Kasey Legaard, Univ. of Maine (CFRU, NSRC)

Robert Lilieholm (NSRC)

Pengxin Lu, Ontario Forest Research Institute (NSRC)

Spencer R. Meyer, Highstead Foundation (NSRC)

Andrew Nelson, Univ. of Arkansas at Monticello (NSRC)

Caroline Noblet, Univ. of Maine (Family Forests, Tourism)

Bill Parker, Ontario Forest Research Institute (NSRC)

Gaetan Pelletier, Northern Hardwoods Research Institute (CFRU)

Parinaz Rahimzadeh, Univ. of Maine (CFRU)

Robert Seymour, University of Maine (NSRC)

Erin Simons-Legaard, Univ. of Maine (CFRU, NSRC)

Ben Rice, LandVest (NSRC)

Susan Stein, USFS-NRS (NSRC)

Brian Sturtevant, USFS-NRS (NSRC)

Michael Ter-Mikaelian, Ontario Ministry of Natural Resources (NSRC)

Jeremy Wilson, Harris Center for Forest Conservation (NSRC)

Ronald Zalesny, U.S. Forest Service (NSRC)

Graduate Students

Xue Bai (NSRC)

Mark Castle (NSRC)

Cen Chen (NSRC, CFRU)

Garth Dixon (NSRC)

Todd Douglass (NSRC)

Erin Fien (NSRC)

Lydia Horne (Tourism)

Cathie-Jo Langley (NSRC)

Margaret Mansfield (NSRC)

Bethany Muñoz (NSRC)

Kaizad Patel (NSRC)

Michael Pounch (NSRC)

Paul Szwedo (NSRC)

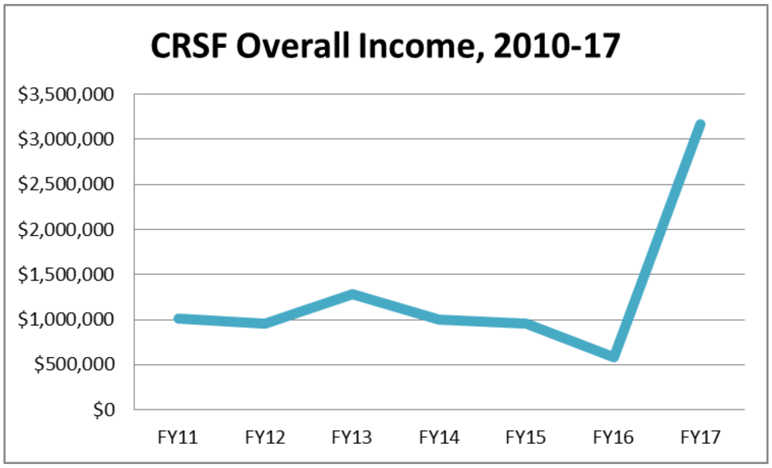
Aaron Teets (Howland)

Bina Thapa (NSRC)

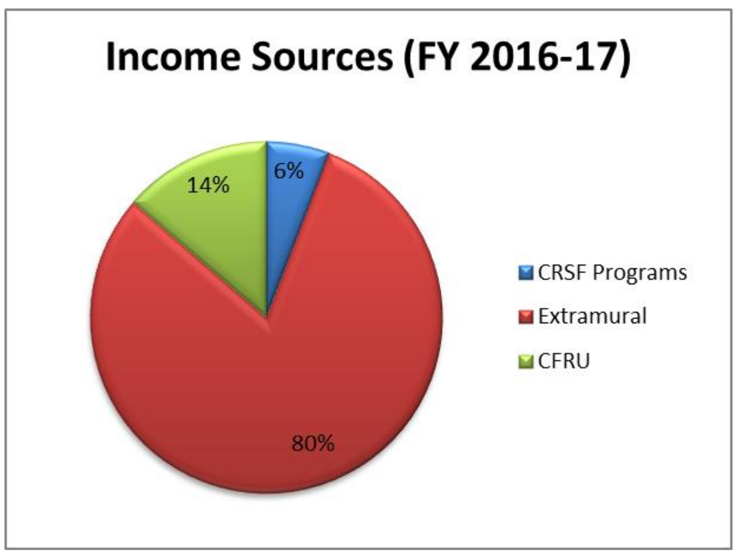
Emily Wilkins (Tourism)

Financial Report

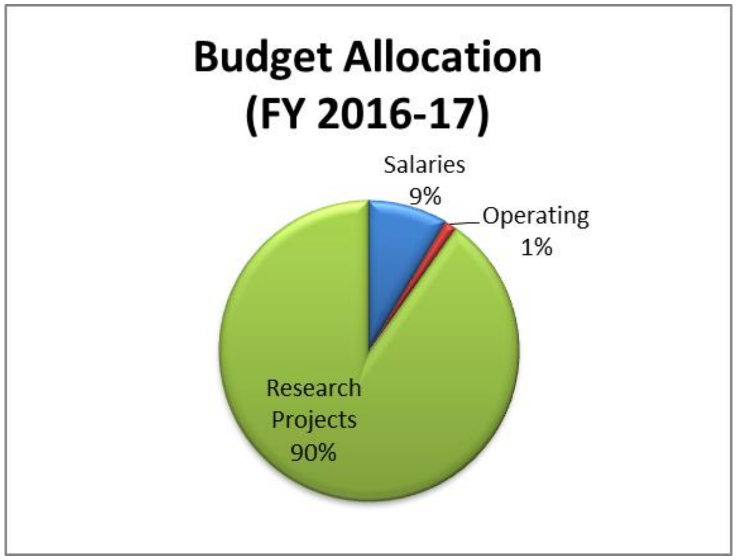
Early in 2017, Center staff began a multi-year review of the CRSF. Over the last five years, the average annual total budget has been $1.86 million. Annual Maine Economic Innovation Funds (MEIF) contributions have averaged $151,420 with the majority of that used to cover Acting Director Weiskittel's salary and fringe (~$120,000). Given that Acting Director Weiskittel has a 20% teaching appointment in SFR, the annual MEIF CRSF staff salary and operating budget has been closer to $32,000. External average annual contributions to CRSF have principally been through NSF CAFS ($70,000), NSRC ($281,500), US Forest Service ($112,727), and other organizations like Small Woodlot Association of Maine and Maine Tree Foundation ($102,599). The recent increase in the CRSF project budget was due to the $2.5 million Economic Development Administration and Maine Technology Institute grants received for the Maine Forest Economy Growth Initiative. CFRU contributions are based on the amount of land managed by the various contributing members and have averaged $540,181 over the last five years, with a general decline over time.



For FY 2016–17, income supporting the center came from programs administered by or that support the general operations of the CRSF ($215,804), extramural grants supporting specific research projects ($3,009,955 [includes aforementioned EDAT grant]) that were received by CRSF scientists from outside agencies, and CFRU cooperators contributed $508,280. Total funding of the CRSF for FY 2016–17 was $3,734,039 million.



The vast majority (90%) of the CRSF budget is allocated directly to the research projects described in this report, supporting nearly two dozen projects under the auspices of the CFRU, Howland and Holt Research Forests, Northeastern States Research Cooperative, Penobscot Experimental Forests, and the CAFS NSF/University cooperative. The remaining funds supported personnel salaries (9%) and center operating expenses (1%).



A key source of financial support for the CRSF is provided by the Maine Economic Improvement Fund (MEIF). The $166,253 investment from MEIF helped leverage $512,833 from other CRSF sources and $2,994,955 in extramural grants for a total leverage of $3,507,788 (or $21.09 for every dollar of MEIF funding) of additional research funding.

Photo courtesy Pam Wells, Oakleafs Studios.

Stakeholders

CRSF researchers strive to conduct not just cutting-edge forest science, but also real-world, applied science about Maine's forests, forest-based businesses, and the public that supports them. We build and foster relationships with a wide variety of organizations and their people to achieve common goals.

Over the past year we have worked with the following partners:

Acadia National Park
American Consulting Foresters
American Tree Farm System
Ameriflux
Appalachian Mountain Club
Baskahegan Corporation
Baxter State Park, Scientific Forest Management Area
BBC Land, LLC
Canopy Timberlands Maine, LLC
Clayton Lake Woodlands Holding, LLC
Cornell University
Downeast Lakes Land Trust
EMC Holdings, LLC
Field Timberlands
Forest Society of Maine
Frontier Forest, LLC
Highstead's Regional Conservation Partnership
Hilton Timberlands, LLC
Huber Engineered Woods, LLC
Irving Woodlands, LLC
Katahdin Forest Management, LLC
LandVest
Maine Bureau of Parks and Lands
Maine Department of Agriculture, Conservation, and Forestry
Maine Department of Environmental Protection
Maine Department of Inland Fisheries and Wildlife
Maine Division of Parks and Public Lands
Maine Forest Service
Maine Forest Products Council
Maine Office of GIS
Maine Office of Tourism
Maine Tree Foundation
Mosquito, LLC
National Science Foundation
Natural Resources Conservation Service
New Brunswick Department of Natural Resources
New England Forestry Foundation
North Woods Maine, LLC
Nova Scotia Department of Natural Resources
PenBay Regional Land Trust
Pennsylvania State University
Penobscot Experimental Forest
Plum Creek Timber Company, Inc.
Prentiss & Carlisle Company, Inc.
Professional Logging Contractors of Maine
ProFOR Consulting
Quebec Ministry of Natural Resources
ReEnergy Holdings, LLC

Robbins Lumber Company
SAPPI Fine Paper
Seven Islands Land Company
Simorg North Forest, LLC
Small Woodland Owners Association of Maine
Snowshoe Timberlands, LLC
St. John Timber, LLC
Sylvan Timberlands, LLC
Social and Economic Sciences Research Center, Washington State University
The Forestland Group, LLC
The Nature Conservancy
Timbervest, LLC
UMaine Cooperative Extension
University of Massachusetts-Amherst
University of New Brunswick
University of New Hampshire
University of Vermont, Rubenstein School of Environment and Natural Resources
UPM Madison Paper
USDA Forest Service, Northern Research Station
USDA Forest Service, Family Forest Research Center
USGS Maine Cooperative Fish & Wildlife Research Unit
USGS West Virginia Cooperative Fish & Wildlife Research Unit
Wagner Forest Management
West Virginia University
Woods Hole Research Center

CRSF Research Programs

Nature-Based Tourism

Tourism plays a vital role in the culture, economy, and future economic development of Maine's rural communities, as well as in the overall economy of the state. Tourism in Maine provides economic and non-economic values to its citizens, including nature conservation, cultural heritage maintenance and pride, and infrastructure and facility improvement. Maine's outstanding tourism assets, along with the diversity of outdoor recreation opportunities, attract millions of visitors annually to and within Maine. Challenges to capturing growth opportunities relate to changes in visitor travel behavior, economic crises, constrained integrated tourism planning and development, and extreme weather events/natural disasters. By regularly gathering, analyzing, and communicating information about the economic impact and trends of tourism in Maine we expect to increase the efficiency of and opportunities for Maine's tourism industry.

Highlights of the program from 2016–17 include an analysis of secondary data and a resident survey to gauge an understanding of Maine residents risk perceptions on metallic mineral mining in the state; a study on the annual economic effects of nature-based tourism visitor spending on the economy of the state of Maine; Assessing stakeholder climate change risk perceptions and likely behavioral responses amongst nature-based tourism stakeholders in Western Maine; and a study to understand the impact of weather on tourism spending.

Sand Beach, Acadia National Park *(Photo courtesy of Pamela Wells, Oakleafs Studios)*

Climate Change Perceptions of Visitors

Emily Wilkins (MS), Lydia Horne (PhD candidate), Dr. Sandra De Urioste-Stone (Principal Investigator)

Final Report

Summary

Tourism is one of the largest industries in Maine. Therefore, any changes to tourism flows or expenditures could have a significant impact on communities in the state. Weather and climate are influential to tourists, impacting when and where people travel and the quality of their experience. Understanding the impact of weather on tourism spending is important because climate change is altering the average weather, so this would provide insight into how spending could change in the future. Additionally, understanding visitors' perceptions on weather and climate change is useful to understand and influence behavior. The study included: (1) analysis of secondary data to investigate the impact of past weather (2004–14) on tourism-related spending at three geographically distinct Maine locations, including Mount Desert Island, Bethel, and Millinocket (Figure 1), and (2) survey of visitors to assess perceptions of risk.

Project Objectives

- Investigate the impacts of weather conditions on spending in three Maine tourism destinations in Maine;
- Predict how climatic changes could impact tourism-related spending in the future;
- Explore perceptions of how weather affects different tourist groups to better understand how behavior might differ under future climate change conditions;
- Examine climate change concern and willingness to take action across tourist groups; and
- Investigate the relationships between visitor place attachment, recreational activities participated in, and intended future visitation under differing weather and environmental conditions resulting from climate change.

Approach

SECONDARY DATA

- A nonparametric method (boosted regression trees) was used to first identify the relative influence of twenty-two weather variables as predictors of tourism spending. Following this, a parametric model was constructed to statistically evaluate tourism spending across different measures and predict potential spending changes due to a warming climate.

VISITOR SURVEY

- A mixed-mode survey was used, with an intercept component (2036 respondents), and a follow-up online-mail survey to collect economic and travel behavior data.
- Visitors were chosen using a two-stage cluster probability sampling design, using simple probability random sampling to select the days/locations to administer surveys, and systematic random sampling of visitors once on-site. We used twenty survey locations throughout the state, including visitor centers, state parks, an international airport, and Acadia National Park.

- The survey instrument included questions on trip characteristics, spending and travel behavior, future visitation intent under varying conditions, activities participated in, attachment to MDI, and demographics.

Key Findings / Accomplishments:

ANALYSIS OF SECONDARY DATA

- Results indicated that warmer temperatures increased tourism spending in the summer and fall, but had more varying results in the winter. Findings suggest tourism businesses in Maine and other relatively colder destinations could capitalize on potential gains in warmer months.
- If temperatures continue to rise as projected, the three locations are predicted to experience on average an 8.1 to 13.5% increase in summer tourism spending by 2050. In contrast, winter spending is forecasted to have a smaller change, decreasing by 0.6-1.4% in Bethel and Millinocket, and increasing by 0.2 to 0.5% in MDI

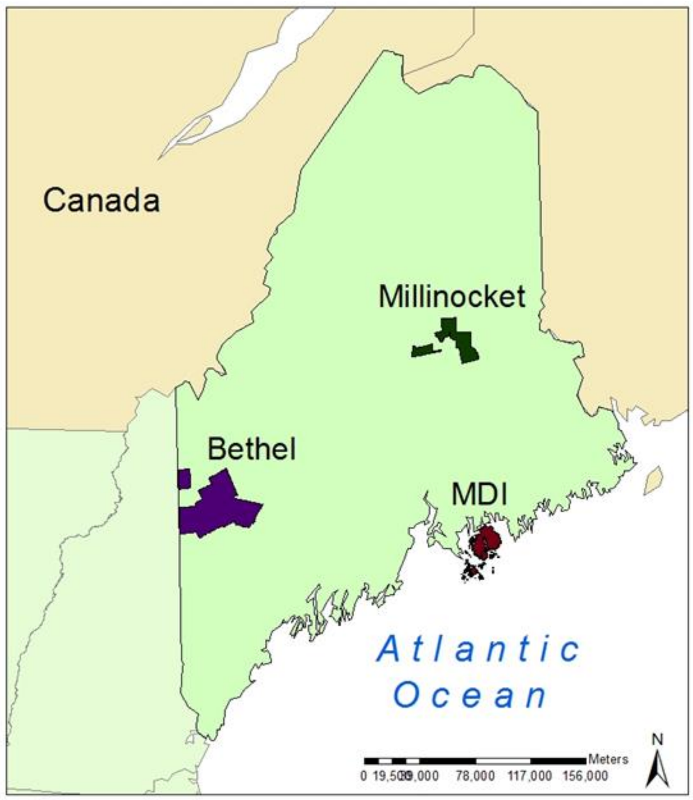


Figure 1. The three economic summary areas studied within Maine. The western is the Bethel region, the northern is the Millinocket region, and the coastal is Mount Desert Island (MDI).

ANALYSIS OF VISITOR SURVEY DATA

- Segmentation analysis on the activities tourists participated in yielded three segments of Maine tourists: non-nature-based tourists (50.6%), nature-based generalists (16.2%), and nature-based specialists (33.2%).
    - Non-nature-based tourists thought that weather variables were less influential during their travels in Maine than the other segments, while nature-based generalists perceived weather to have the highest influence.
    - Nature-based specialists had the highest level of climate change belief, while nature-based generalists had the highest willingness to engage in climate change mitigation behavior.
- Results show that those with high attachment to MDI participated in a greater variety of activities during their travels.
- It was found that those with a high attachment to MDI were less likely to change their future visitation intent under potential negative changing climate conditions.

Economic Impact of the Nature-based Tourism in Maine

Emily Wilkins (MS), Lydia Horne (PhD student), Dr. Sandra De Urioste-Stone (PI)e, Caroline Noblet

Final Report

Summary

The study explored the annual economic effects of nature-based tourism visitor spending on the economy of the state of Maine. Economic impacts were measured as the direct and secondary output, income and jobs in the state resulting from spending by visitors that engaged in nature-based tourism activities. Visitor expenditure estimates were gathered using original data collected from a visitor survey; economic impact attributable to Maine nature-based tourism relates only to new money injected into the Maine economy by out-of-state visitors that participated in nature-based tourism activities as part of their trip.

Project Objectives

- Estimate the economic impact of nature-based tourism in Maine.
- Develop a methodology to estimate economic impact of tourism in the state.
- Estimate the economic impact of Acadia National Park visitation to MDI and Hancock County.

Approach

- Visitor expenditure estimates were gathered using original data collected from a visitor survey.
- A mixed-mode survey was used, with an intercept component (2036 respondents), and a follow-up online-mail survey to collect economic and travel behavior data.
- The economic impact of nature-based tourism was estimated by applying visitor spending to an input-output model (IMPLAN) of the state economy
- Economic impact modelling combined visitor spending, and regional multipliers to compute changes in output, labor income, jobs, and value added in the region.
- An economic impact analysis was also estimated for the Mount Desert Island-Acadia National Park region and Hancock County.

Key Findings / Accomplishments

- Visitors that engaged in nature-based tourism activities spent $8.7 billion in Maine.
- The average visitor group spent $1100 on their trip to Maine.
- On a visitor group trip basis, average spending for visitor groups staying in hotels was $1992.74, while visitor groups that camped spent $626.34. Day Trip visitor groups spent an average of $83.19, while Non-paid Overnight visitor groups spent $310.83. The Local visitor segment spent an average of $230.48 per visitor group trip.
- Visitors on day trips accounted for 1% of the total spending in the state, visitors who stayed in overnight accommodations accounted for 86% of the total spending, visitors who camped accounted for 3% of the total spending, and visitors on non-paid overnight trips accounted for 9% of total spending.
- Spending on hotels (40%), restaurants & bars (20%), and Souvenirs & other expenses (14%) made up the largest proportions of expenditures.

Mining in Maine: Characterization of Public Perceptions

Andrew Morgan (MS), Lydia Horne (MS), Dr. Sandra De Urioste-Stone (PI), Dr. Amanda Olsen (Co-PI), Dr. Jean MacRae (Co-PI), Caroline Noblet, Dr. John Daigle, with help from undergraduate and graduate students in SFR479: Environmental attitudes and behaviors

Final Report

Summary
As new locations for mining activities are sought, some regions with limited recent metallic mineral mining (MMM) history and expertise find themselves grappling with the issues which surround mining activities. Since 2012, Maine found itself in this situation after renewed interest in one of the state's largest metal containing deposits spurred the legislature to revise its MMM laws. In 2017, the debate continues demonstrating the importance of a social license to operate. We conducted an analysis of secondary data and a resident survey to gauge an understanding of Maine residents risk perceptions on MMM in the state.

Project Objectives
- Track the evolution of the mining policy debate since 2012;
- Better understand the perceptions and acceptance levels of Maine residents;
- Determine the barriers that have prevented approval of the rule revisions and the conditions required for approval;
- Provide information to policy makers to aid in their deliberations concerning metallic mineral mining in Maine.

Figure 2. Word cloud showing the most frequently used words in testimonies and news articles from 2012 through 2016.

Approach
- Utilized a mixed methods research approach to collect qualitative and quantitative data.
- Applied an intrinsic case study methodology.
- Conducted a mail survey of Maine residents (501 responses received).
- Performed qualitative content analysis of secondary data (public hearing testimonies and newspaper articles; Figure 2).
- Data was collected between January 2016 and March 2017.

Key Findings / Accomplishments
- Analysis of the secondary data identified several topics that have been prominent concerns for stakeholders. These topics include: water quality, mining on public lands, human and wildlife health, financial assurance, site closure and reclamation, potential impacts to existing industries, mistrust in mining organizations and also the state government.
- Survey participants expressed similar concerns. The majority of survey participants believed that human health (53%), fish and wildlife health (69%), and water quality (67%) would decrease if a

metallic mineral mine were developed near their community. Likewise, the majority of survey participants (64%; Figure 3) agreed that a metallic mineral mine would be harmful to the local natural environment and over half (54%) of participants believed nature-based tourism would decrease as a result of a potential local mine.

- Over three quarters (78%) believed employment opportunities would increase. However, the majority of survey participants (63%; Figure 4) agreed that the negative impacts of MMM outweighed the benefits. These results have recently been reported to the Joint Standing Committee on Environment and Natural Resources to aid in their deliberations on the many mining bills proposed during the current legislative session.
- Undergraduate and graduate students enrolled in SFR 479 participated in a service learning project while conducting a pilot online survey in 2016.

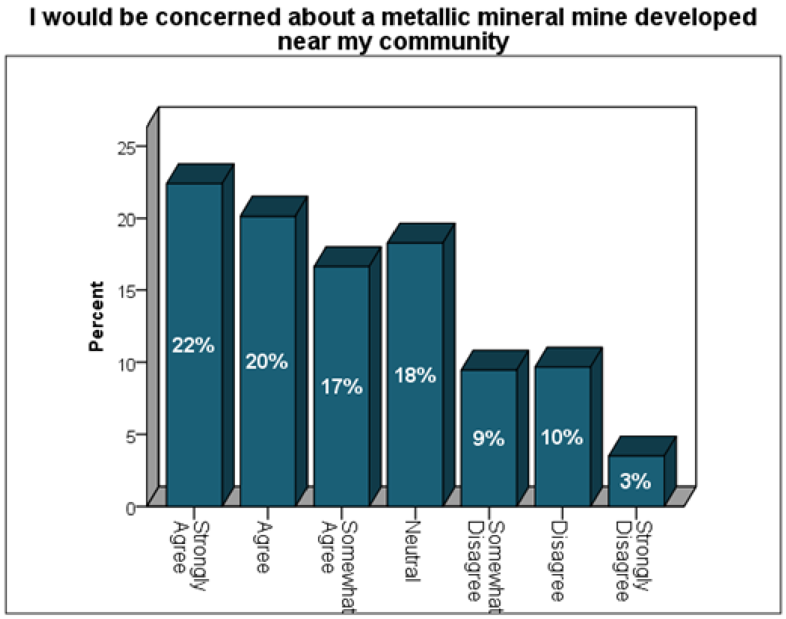


Figure 3. Respondents' level of agreement to the statement: "I would be concerned about a metallic mineral mine developed near my community." *N*=487.

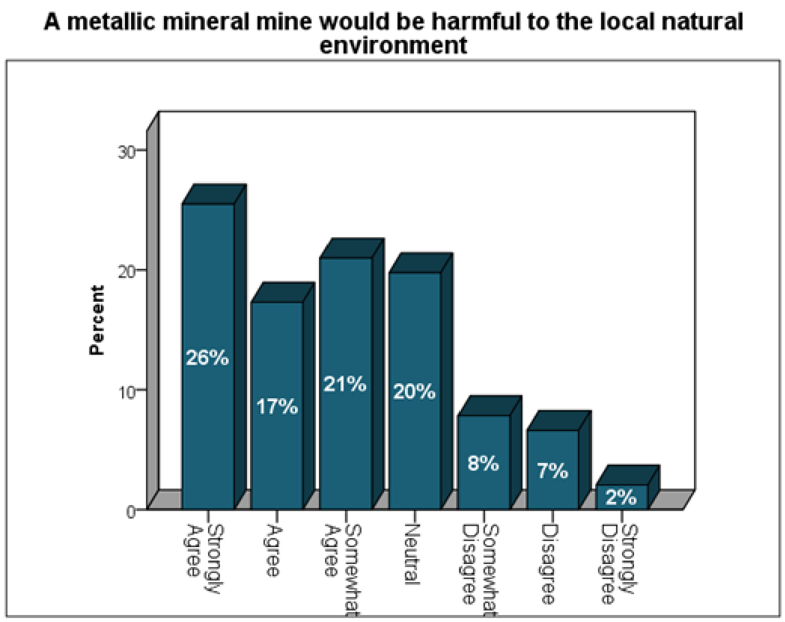


Figure 4. Respondents' level of agreement to the statement: "A metallic mineral mine would be harmful to the local natural environment." *N*=486.

Climate Change Perceptions and Tourism

Lydia Horne (MS), Leah Beck (MS), and Dr. Sandra De Urioste-Stone, University of Maine

Year 1 Progress Report

Summary

Assessing stakeholder climate change risk perceptions is crucial for understanding motivations or barriers to engage in climate change mitigation and adaptation behaviors. Therefore, the goal of this study is to understand climate change risk perceptions and likely behavioral responses amongst nature-based tourism stakeholders in Western Maine using a qualitative approach. The Maine Lakes and Mountains Region has been selected as a study site because of its high dependence on winter outdoor recreation and the importance tourism has in supporting community resilience.

Project Objectives

- Understand climate change risk perceptions of tourism stakeholders in Western Maine.
- Explore group cognition associated with climate change risk among tourism stakeholders.
- Determine facilitators and barriers to the implementation of climate change adaptation and mitigation strategies.

Photo courtesy Meg Fergusson.

Approach

- A phenomenological study was done using semi-structured interviews (20 participants) with key stakeholders in the Maine Lakes and Mountains Region of Maine in 2016.
- A pile sort exercise (33 cards) was conducted with 19 tourism stakeholders in the Maine Lakes and Mountains Region of Maine in 2016
- Interpretative Phenomenological Analysis was used to generate categories and themes.
- Multidimensional scaling was used to analyze data from the pile sorts.

Key Findings / Accomplishments

- A key theme that emerged throughout the study was that of uncertainty of the causes of climate change, impacts to the region, which climate change communication sources to trust, and whether or not experienced environmental changes were related to climate change. Uncertainty hindered participants' abilities to implement adaptation and mitigation behaviors.
- Providing climate change information specific to the study region communicated by scientists or through the local newspaper could help empower participants to adopt more mitigation and adaptation strategies, thus bolstering the resilience of the tourism destination.
- Stakeholders believed climate change to be a psychologically distant phenomenon and perceptions of uncertainty hindered participants' abilities to devise and implement adaptation actions to increase destination resilience.

Commercial Forests (CFRU)

Maine's commercial forests cover the northern half of the state and provide the backbone of the state's annual $8 billion forest products economy. These private landowners manage large tracts of land that involve complex decisions about a wide variety of forest resource issues over long periods of time. To help meet this challenge, these landowners recognized the need long ago for a strong applied research program to provide new information about how to best manage their lands. As a result, they partnered with the University of Maine in 1975 to form the Cooperative Forestry Research Unit (CFRU).

The year 2016 marked the 40th year that the CFRU has been carrying on its mission to *"conduct applied scientific research that contributes to the sustainable management of Maine's forests for desired products, services, and conditions."* Currently composed of 34 private and public forestland management organizations, wood processors, conservation organizations, and other members, the CFRU guides and supports research on key issues facing Maine's forest landowners and managers. These members represent nearly 8.3 million acres, or half of Maine's forestland. The CFRU is one of the oldest industry/university forest research cooperatives in the United States, and serves as a model for stakeholder-driven research at the University of Maine.

This year, the CFRU raised $508,280 in member contributions and leveraged an additional $376,155 in extramural grants and in-kind support. An additional $1,740,646 in leveraged funding for LiDAR acquisition from federal and local sources and $60,000 from the National Science Foundation as part of CFRU's membership in the national Center for Advanced Forestry Systems (CAFS) has helped to support the Commercial Thinning Research Network and Growth & Yield modeling projects

Project highlights include the findings from revisiting a 10-year-old study of **beech control in partially harvested stands** using ground-based herbicides that indicates a lasting benefit on understory sugar maple abundance but not height; a new study using **Landsat satellite imagery to detect and estimate SBW defoliation severity** on the landscape that is similar to the aerial sketch mapping of the past; The **opportunity costs of managing Deer Wintering Areas** (DWAs) was quantified by modeling common silvicultural scenarios from two representative timberland properties; the **effects of moose density on forest regeneration, composition and damage** was investigated over two years in hardwood, mixedwood and conifer stands of varying age and harvest histories; a **20 meter resolution map of predicted site quality** was made for the entire Acadian Forest Region as a function of climate, lithology, soils and topographic features (http://www.forusresearch.com/bgi.php); the **influence of tree stem form and defects** on potential product recovery, diameter increment, probability of survival, and occurrence of decay in northern hardwood species was modeled; and findings from a study examining the **effects of mechanized harvesting operations on residual stand conditions** demonstrated that despite severe rutting and soil disturbance at the time of Whole Tree clearcut harvesting at the Weymouth Point Study, there was no negative impact observed on forest composition, structure, or crop tree growth after 32 years.

2016 CFRU Fall Field Tour to Seven Islands Land Company operational understory beech control.

Photo courtesy Brian Roth.

CFRU PROJECT SUMMARIES

Silviculture & Productivity

Strategies for Rehabilitating Beech-Dominated Stands

Dr. Robert Wagner, Purdue University; Dr. Aaron Weiskittel, University of Maine; Dr. Arun Bose, University of Maine; Dr. Brian Roth, University of Maine; and Dr. Gaetan Pelletier, University of Moncton, New Brunswick

Year 1 Progress Report Summary

In Maine, beech is present in 36% of the total forest area and it is dominant in 9%, which has remained stable over the past 16-years. We examined regeneration characteristics nine-years after application of glyphosate (0.56, 1.12, and 1.68 kg ha_{-1}) and surfactant (0.0, 0.25, 0.5, and 1.0% v v_{-1}) in three shelterwood-harvested stands in central Maine. Successful sugar maple release was sustained through year nine. The herbicide treatment had increased the abundances of sugar maple regeneration, but had no effect on total height of the saplings and seedlings. In contrast, the abundance and height of beech regeneration was decreased with increasing glyphosate rate. It appears that post-release browsing and combined with increasing overstory basal area has suppressed the height of the sugar maple. Our results indicate that glyphosate can increase the abundance of sugar maple regeneration, however, subsequent browsing combined with the negative influence of the residual overstory can reduce the overall benefits from these treatments.

Identifying Old-Growth Characteristics in Northern White-Cedar Stands for Forest Management and Planning

Dr. Laura Kenefic, US Forest Service, Northern Research Station; Dr. Shawn Fraver, University of Maine; and Dr. Aaron Weiskittel, University of Maine

Final Report Summary

Forestry practitioners are confronted with challenges when managing northern white-cedar, including the recognition of old-growth characteristics and the differentiation between old-growth and partially harvested stands, particularly in the context of Forest Stewardship Council (FSC-US) certification. To identify the structural characteristics potentially unique to old-growth northern white-cedar stands, we compared detailed

Old-growth northern white-cedar swamp at Big Reed Forest Preserve, Maine. *Photo courtesy Nathan Wesely.*

forest inventories from 16 old-growth stands and 17 partially harvested stands in Maine and New Brunswick. Using a generalized linear mixed-model approach, two significant predictors were identified that differentiate old-growth from partially harvested stands: the volume of advanced-decay coarse woody material (logs in decay classes 4 and 5 using a 5-decay-class system) and live tree quadratic mean diameter. Our research shows that these two measures can be used, in combination, to identify old-growth northern white-cedar stands, and it improves our understanding of old-growth characteristics in this forest type, aiding in its successful management.

The Effects of Mechanized Harvesting Operations on Residual Stand Conditions

Cody Lachance, University of Maine; Dr. Robert G. Wagner, Purdue University; and Dr. Brian E. Roth, University of Maine

Final Report Summary

We examined the effects of whole-tree (WT) and cut-to-length (CTL) harvesting systems on residual stand and soil disturbance in Maine spruce-fir stands using two long-term CFRU study sites. The first (Austin Pond Study), quantified stem, root, and crown damage following commercial thinning (CT). The treatments were three levels of relative density reduction (33, 50, and 66%) in stands that had pre-commercial thinning (PCT) and no-PCT. Greater tree densities (i.e. no-PCT) combined with WT harvesting increased the probability of residual stem damage (86%). Stem and root damage increased with removals above 33% while trees closer to harvest trails were more likely to have stem and root damage in addition to the severity of such wounds.

The second study (Weymouth Point), quantified current stand composition and growth 32 years following WT clearcut harvesting using soil disturbance transects established at the time of harvest. Despite severe soil rutting and mineral soil exposure at the time of harvest, we were unable to detect any differences in subsequent forest composition, structure, or crop tree growth. Soil disturbance had no influence on tree- and stand-level variables, including basal area, density, percent hardwood, volume, DBH, and height. Historic annual radial growth rates between two contrasting subsets of balsam-fir crop trees that had grown on the most and least disturbed soil conditions did not differ.

Precommercial thinning stand with cut-to-length harvest system (left); no precommercial thinning stand with whole tree harvest system (right). *Photos courtesy Patrick Hiesl and Brian Roth.*

GROWTH & YIELD MODELING

Assessing the Influence of Stem Form and Damage on Commercial Hardwood's Growth, Volume, and Biomass in Maine

Dr. Aaron Weiskittel, University of Maine; Jereme Frank, University of Maine; and Mark Castle, University of Maine;

Final Report Summary

The influence of stem form and defects remain unaccounted for in most volume/biomass equations or even growth and yield models. To account for this deficit, standing tree measurements incorporating form and risk protocols were taken on merchantable trees (DBH > 4.5") in 175 PSPs across 7 sites in Maine and New Hampshire. In addition, selected trees were destructively sampled to examine the implication of internal stem decay on biomass and merchantable volume.

Using the collected data, quantitative models were developed to evaluate the influence of stem form and risk on potential product recovery, diameter increment, probability of survival, and occurrence of decay. Potential product recovery was significantly lower for trees with multiple sweeps or stems, severe lean, significant forks or those considered to be high risk. Annual diameter growth was 6% lower for high risk trees and the probability of survival was lower for trees demonstrating severe lean, and multiple stems or sweeps. The inclusion of risk classifications in model frameworks used to predict the occurrence of decay improved classification rates by 5%. In addition, stem taper, crown ratio, and species were found to be influential factors for predicting the occurrence of internal stem decay.

Maine Statewide Light Detection and Ranging (LiDAR) Data Acquisition

Joseph Young, Maine Office of Geographic Information Systems; Dr. Brian Roth, University of Maine; and Dan Walters, US Geology Survey

Year 4 Progress Report Summary

LiDAR data and Geographic Information Systems (GIS) have brought the capability for making large scale accurate assessments of forest resources. Software options are increasing and it is becoming easier for forestry professionals to take advantage of the power of this 3D GIS technology. GIS analysis has proven to be a reliable method for analyzing, quantifying and graphically illustrating forest resources. These resources include; biomasses, canopy height, stem diameter, basal area, gross merchantable volume, gross total volume and stem density. Now prior to walking any particular forest plot a forester can have a working knowledge of the topography and forest biometrics, thus improving overall efficiency of professional time spent in the field. The goal of this project is to assemble a complete statewide base LiDAR data set. This would provide a historic benchmark for comparing future acquisitions of LiDAR data.

Identifying Relationships between Spruce Budworm Moth Abundance, Larval Density, and Mapped Forest Conditions for Risk Assessment during Outbreak Development

Dr. Erin M. Simons-Legaard, University of Maine; Kasey R. Legaard, University of Maine; and Dr. Brian E. Roth, University of Maine

Year 1 Progress Report Summary

Risk of defoliation and damage due to spruce budworm varies in space and time as an outbreak develops. Effective planning to limit losses requires early detection of local population change and sound predictions of outbreak progression. Our approach to providing the information needed for understanding changing budworm population conditions is based on repeat sampling of pheromone traps and larval density using a network of locations established across northern Maine in Year 1. Trap locations will provide a representative sample of forest conditions, terrain elements, and environmental gradients that are known or hypothesized to influence establishment and growth of local populations, and which will provide the basis for developing predictive models of moth or larval abundance in Year 2.

Development of a Novel Model for the Early Detection and Monitoring of Spruce Budworm (SBW) Forest Defoliation over Maine using Fine Resolution Remote Sensing Imagery

Dr. Parinaz Rahimzadeh, University of Maine; Dr. Aaron Weiskittel, University of Maine; Dr. Daniel Kneeshaw, University of Quebec at Montral; and Dr. David MacLean, University of New Brunswick

Spruce budworm pheromone traps. *Photo courtesy Meg Fergusson.*

Year 1 Progress Report Summary

Remote sensing (RS) studies of Spruce Budworm (SBW) annual defoliation detection have received little attention because of data scarcity during the short time window when the foliage turns a reddish-brown color. Landsat satellite imagery has advanced to a stage where it can be applied to develop a tool for the rapid, cost-effective detection and quantification of current and annual SBW defoliation on landscape scale. Using a study site on the North Shore of the St. Lawrence River in Quebec, seven Landsat-derived vegetation indices (VIs) were estimated over four years to detect and quantify SBW defoliation using non-parametric statistical methods. The results indicated that the VIs are effective at detecting and classifying areas of defoliation (around 95%). This model could be used to detect and estimate SBW defoliation severity for the future SBW outbreaks in Maine similar to the aerial sketch mapping (ASM) products of the past with the advantage of greater accuracy, near real-time availability, increased cost effectiveness and non-subjective methodology over traditional methods.

Acadian Forest Site Productivity Model

Dr. Chris Hennigar, FORUS Research; Dr. Aaron Weiskittel, University of Maine; and Dr. Lee Allen, ProFOR Consulting

Final Report Summary

A detailed report on development and evaluation of a biomass growth index (BGI) for the Acadian forest region was presented in the 2015 CFRU annual report in year one of this project. In addition, pdf wall maps and raster files containing biomass growth index predictions for Maine (Figure 5), Nova Scotia, New Brunswick, and PEI were made available for download from www.forusresearch.com/bgi.php. BGI explained 0-30% of spruce-fir site index variability depending on dataset, and showed similar predictive performance (± 5%) when compared to existing land productivity classifications.

During 2016, Dr. Parinaz Rahimzadeh prepared three sets of satellite imagery for the region, which were applied to be used for site productivity modeling at three different scales alone or in combination with site variables. MODIS 1 km Gross Primary Productivity (GPP) annual data were retrieved for eleven years (2000-2010) and the relationship between MODIS 1 km Average GPP and BGI was studied. A weak but significant relationship was observed between satellite-derived GPP and BGI. The weak relationship between GPP and BGI, can be attributed to errors in both products. However, the relationship was further improved as described below.

In addition to MODIS GPP, MODIS 500 m and 1 km enhanced vegetation index (EVI) data for eight years (total of 112 images) during growing season (Day of the year 145 to 241) were applied to estimate max vegetation cover during growing season over different forest cover types and to be used as an remote sensing variable in BGI model. EVI can enhance the vegetation signal in regions with dense vegetation cover and does not get saturated like normalized difference vegetation index (NDVI). The relationships between MODIS max EVI and BG and BGI at both 500 m and 1 km were evaluated. Results showed that EVI could be used as a sound variable for site productivity modeling, but data on stand age, time since harvest, and forest composition are likely required for further improvements.

At fine scale, 24 scenes of Landsat imagery for years 2000 to 2007 were used to map max EVI at 30 m resolution for Maine and New Brunswick. Landsat-derived max EVI were explored as additional site predictors. There was visual evidence of good site detection when comparing Landsat-derived site variable values to known poor and good sites across the Acadian region, however, due to the confounding effects of variable hardwood content and management (e.g. recent harvesting) it was found that difference between metric values between stand types was more influential on these metrics than topographical position, climate, and soils. This suggests that all above these remotely sensed metrics retrieved at different scales can be useful if normalized for stand type (percent hardwood, age, and management) and would require additional research.

The 2015 CFRU report was improved in 2016 and published (Hennigar *et al.* 2017). The maps and raster files made available in 2015 were not updated in 2016, as no significant model improvements were possible. In 2016, BGI was identified as a significant predictor of tree height in New Brunswick for planted, PCT, and extensively managed forest types by the New Brunswick Department of Energy and Resource Development (NB ERD). BGI was also identified as a significant predictor of tree DBH growth across the larger Acadian region (NB, NS, Maine, and PEI) for planted, PCT, and extensively managed forest types by NB ERD. New BGI-enhanced NB tree height models and Acadian regional tree DBH growth models have been introduced into the Open Stand Model version 1.0.3.2 by FORUS Research. Future site mapping work should explore the possible use of LiDAR-derived metrics and satellite-derived metrics as higher resolution site response variables and as independent site predictor variables.

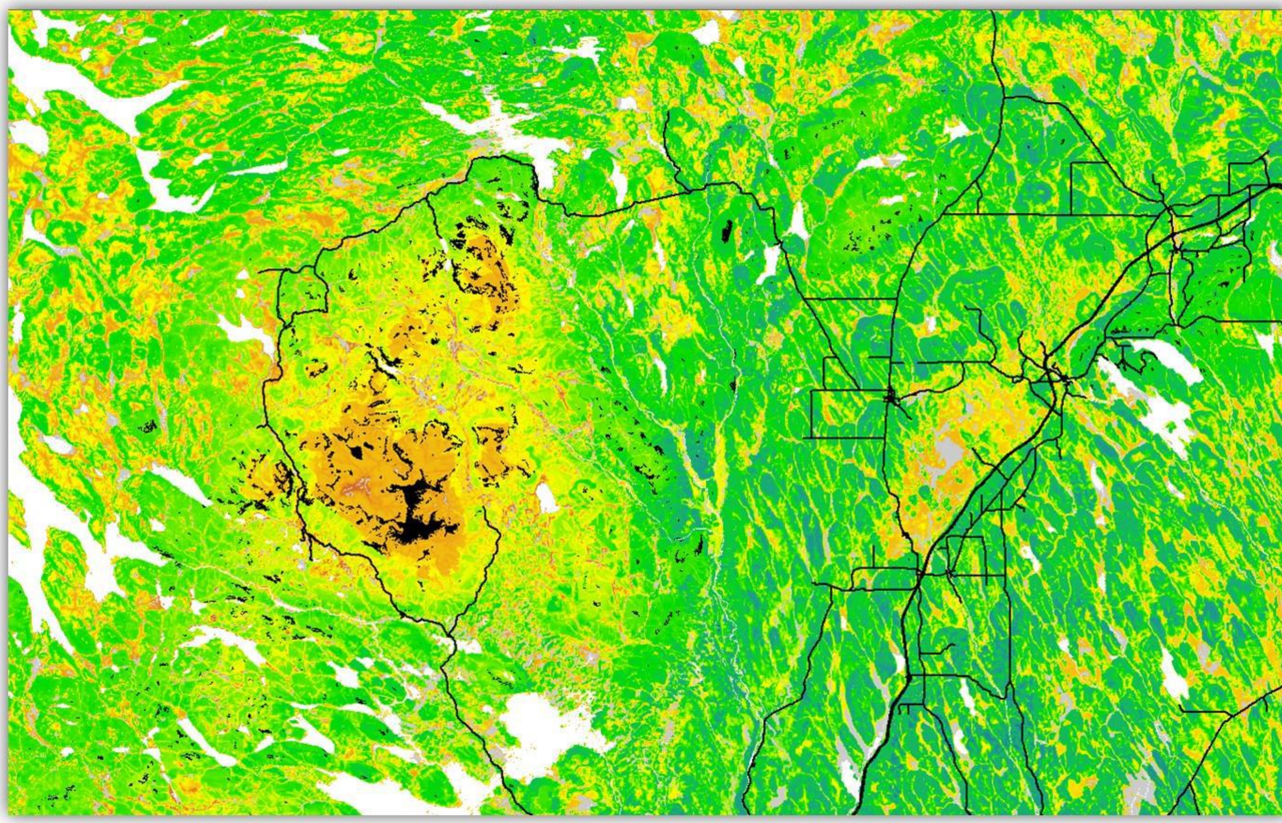


Figure 5. Biomass Growth Index Map of Mount Katahdin and surroundings in Maine.

WILDLIFE HABITAT

Population Dynamics of Spruce Grouse in the Managed Forest Landscapes of Northern Maine

Joel M. Tebbenkamp, University of Maine; Dr. Erik J. Blomberg, University of Maine; and Dr. Daniel J. Harrison, University of Maine

Progress Report, Year 2

During the 2016 field season, we monitored 57 radio-marked spruce grouse, including 30 females and 27 males. We obtained approximately 650 locations from these birds to locate nests, track brood success, monitor survival, and evaluate habitat use. All females radio-marked prior to the breeding season initiated nests, and apparent nest success was 86% (6/7). We monitored 13 broods, and apparent brood success was 62% (8/13). We conducted vegetation sampling at all 7 nests and 3 random locations associated with each nest, totaling 28 vegetation plots. During June and July, 2016 we located adults (males and females) approximately once per week and conducted vegetation sampling at the location of use and at one random location, which resulted in a total of 200 (100 use and 100 random) vegetation plots being measured for the 14 female and 8 male spruce grouse monitored during this time period. Thus far, we have captured and monitored a total of 88 spruce grouse and will continue these efforts in 2017.

Bat Ecology in Maine Commercial Forests: Information Synthesis, Future Research Needs, and Pilot Data Collection

Dr. Erik Blomberg, University of Maine; Dr. Shawn Fraver, University of Maine; Dr. Sabrina Morano, University of Maine; Michael Thompson, Penobscot Environmental Consulting, Inc.; and Trevor Peterson, Stantec Consulting Services, Inc.

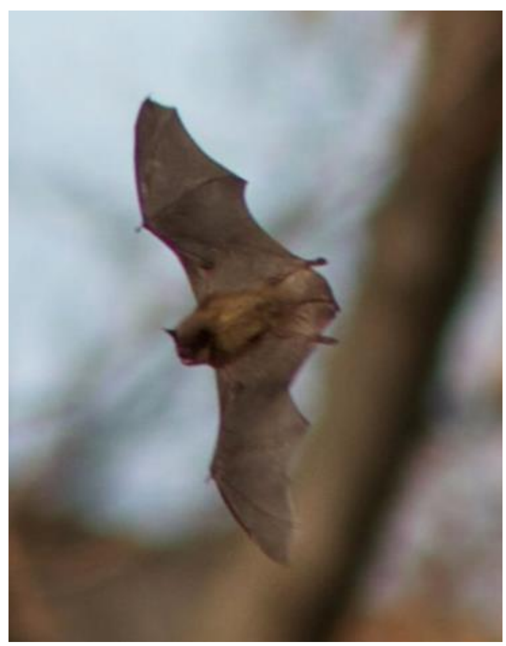


Photo courtesy Maine Audubon.

Final Report Summary

The conservation challenges facing cave-hibernating bats in North America are unprecedented, after a fungal disease commonly known as White Nose Syndrome has decimated populations. This has led to regulatory policies at state and federal levels with potential to affect forest management. Of particular concern are Northern Long-Eared Bats, which were listed as ESA Threatened in 2015. We reviewed literature on bats in forest ecosystems and focused on issues germane to bats in the northeast. We also sampled bat occupancy to evaluate several detection methods and assess acoustic survey efficacy in Maine forests. We found that Northern

Long-Eared Bats have generalist habitat preferences, some of which may differ in the northeast relative to other portions of the species range. In Maine, Northern Long-Eared bats are now uncommon but remain widely dispersed. Acoustic surveys may fail to detect the species if detectors are not deployed for a sufficient number of sampling nights

Economic Impacts of Wildlife Regulations on Forest Management and Industry: The Opportunity Cost of Managing Deer Wintering Areas

Karen N. Bothwell, University of Maine; Dr. Mindy S. Crandall, University of Maine; and Dr. Amber M. Roth, University of Maine

Final Report Summary

Abundance of white-tailed deer (Odocoileus virginianus) in northern Maine has been consistently below desired levels since the 1970s, due in part to the heavy toll of severe winter weather. To mitigate winter-related mortality, the Maine Department of Inland Fisheries and Wildlife (MDIFW) implemented a system of winter habitat conservation through timber harvest restrictions. While there are benefits to supporting the deer population, there are also drawbacks to managing for winter habitat on land used primarily for timber production. Through computer simulations of six silvicultural management scenarios, we evaluated the economic implications of this policy by quantifying the opportunity cost to landowners of managing part of their land as deer wintering areas, or DWAs. Results were specific to site and the influence of landowner objectives on past management, and ranged from lower revenues inside deeryards because of less stand tending, to higher revenues because of commercially favorable species composition. With adaptive implementation of currently used and novel silvicultural systems modeled here, there is opportunity for positive habitat-level outcomes with commercially viable timber management. Clearer habitat management guidelines based on standard forest inventory metrics may facilitate the harvest approval process and help foresters realize the potential of silvicultural management within deeryards.

Photo courtesy Pam Wells, Oakleafs Studios.

Moose Density and Forest Regeneration Relationships in Maine

Peter Pekins, University of New Hampshire; Dr. Sabrina Morano, University of Maine; and Dr. Fred Servello, University of Maine

Final Report Summary

High moose density can influence forest composition, growth, and regeneration and is a management concern in Maine. This study was designed to assess composition, regeneration, and damage in 5-10, 10-15, 15-20, and >30 year old cuts in 2 harvest regimes (clear-cut, partial harvest) within 3 forest types (softwood, hardwood, mixed wood). In summers 2015 and 2016, 145 younger-aged (5-20 years) stands were measured with a milacre plot protocol; 19 stands >30 years old were measured via standard forestry inventory. The dominant stem in the majority of plots regardless of forest type, age class, or harvest type was a commercial species without severe damage; relative damage (light crook) was consistently higher in hardwood plots, declined with age, yet was still <20% occurrence at 15-20 years. An acceptable stocking rate of 40-60% of stems without severe damage was documented in each forest and harvest type at 16-20 years. The majority (~80%) of trees in the >30 year old plots were commercial species, undamaged, and of Form 1 or 2 (single stem) and of vigor R1 or R2 (96%) indicating that trees were commercially valuable.

Photo courtesy Pam Wells, Oakleafs Studios.

Partnerships and Initiatives

An important dimension of the CRSF's mission is collaboration with other programs that can help advance research on various aspects of forest resources. These initiatives and partnerships strengthen our overall mission by leveraging funds, facilities, and talent, as well as fostering interdisciplinary cooperation on key issues facing forest resources.

For example, CRSF continues to provide leadership as part of the Spruce Budworm Task Force, maintaining its website and related social media focus on all aspects of budworm-related research efforts related to the coming spruce budworm outbreak in northern Maine. The CRSF also leads Theme 3 of the **Northeastern States Research Cooperative (NSRC)**, which has provided competitive research funding since 2006 for projects that advance understanding about forest productivity. CRSF researchers are active participants in the National Science Foundation's **Center for Advanced Forestry Systems (CAFS)**, which provides funding with nine other industry/university forest research cooperatives across the country. CRSF is also home to long-term research forests, including **Howland Research Forest**, which is part of the national Ameriflux network measuring the atmospheric flux of carbon dioxide; **Holt Research Forest**, site of ecosystem research; and the **Penobscot Experimental Forest**, a USFS-UMaine research partnership. The CRSF is a proud partner in **Forests for Maine's Future**, which provides a social media and website connection on important forest resource issues to the general public, and collaborates on a number of relevant issues with the **Maine Tree Foundation** and the **Maine Forest Service**.

In addition to the aforementioned stakeholders, this year CRSF participated in the following strategic partnership and initiatives:

FBRI Forest Bioproducts Research Institute

CAFS Center for Advanced Forestry Systems

NSF

SSI maine's sustainability solutions initiative

Maine EPSCoR

Forests for Maine's Future

NSRC Northeastern States Research Cooperative

Center for Advanced Forestry Systems

This year saw the completion of the third year of Phase II for the UMaine site under the Center for Advanced Forestry Systems (CAFS). CAFS is funded by the National Science Foundation (NSF) Industry/University Cooperative Research Centers Program (I/UCRC) in partnership with CFRU members. CAFS is a partnership between CFRU members and I/UCRC to support a University of Maine research site for CAFS. CAFS unites ten university forest research programs with forest industry members across the United States to collaborate on solving complex, industry-wide problems at multiple scales. The mission of CAFS is *to optimize genetic and cultural systems to produce high quality raw forest materials for new and existing products by conducting collaborative research that transcends species, regions, and disciplinary boundaries*. CAFS is a multi-university center that works to solve forestry problems using multi-faceted approaches and questions at multiple scales, including molecular, cellular, individual tree, stand, and ecosystem levels. Collaboration among scientists with expertise in biological sciences (biotechnology, genomics, ecology, physiology, and soils) and management (silviculture, bioinformatics, modeling, remote sensing, and spatial analysis) is at the core of CAFS research.

Phase II of CAFS contributes $60,000 per year for 5 years to the center as long as CFRU members contribute a minimum of $350,000 per year to support the work of the site. This past year of CAFS funding supported Dr. Arun Bose's efforts to better understand regional regeneration patterns and most influential factors, particularly with respect to American beech.

The Northeastern States Research

Since its inception in 2001, the Northeastern States Research Cooperative (NSRC) has been a critically important source of funding for applied forest research and outreach efforts throughout the Northern Forest. The program is jointly directed through the USDA Forest Service, Northern Research Station, and a designated institution in each of the four Northern Forest states: The Rubenstein School of Environment and Natural Resources at the University of Vermont, the University of New Hampshire in cooperation with the Hubbard Brook Research Foundation in New Hampshire, the Center for Research on Sustainable Forests at the University of Maine, and the State University of New York College of Environmental Science and Forestry.

Over the course of its 16-year history, the U.S. Forest Service Northern Research Station (USFS-NRS) has awarded the NSRC nearly $24 million in support of more than 335 individual projects from 50 organizations across diverse topics and issues relevant to the Northern Forest.

In early 2017, after years of declining congressional funding for the program, project funding was suspended. The NSRC leadership and the USDA Forest Service Northern Research Station are currently working together to determine the future of NSRC. As part of that effort, in May 2017 a survey of researchers, stakeholders, and students was conducted to track impacts and outcomes of past NSRC-funded projects. The information gathered from that survey, along with planned workshops with those groups, will help NSRC leadership address the impact that the withdrawal of support will have on the region, and chart a potential course for its future mission and direction. A comprehensive business report covering key accomplishments and contributions to the region's unique working landscape is expected to be released in 2018.

The structure and organization of the NSRC has evolved over the years, with a shift in 2008 toward greater integration of the four research themes managed by each state. Projects are currently organized into 14 core research interest areas across four broad themes: (1) sustaining productive forest communities, (2) sustaining ecosystem health in northern forests, (3) forest productivity and forest products, and (4) biodiversity and protected area management.

Theme 3 at CRSF

NSRC Theme 3 is managed by the CRSF and supports research that will quantify, improve, and sustain productivity of the products-based economy of the Northern Forest. Aspects of primary interest include underlying biological processes, management practices, and methods of prediction that will influence future wood supplies and forest conditions. Dr. Aaron Weiskittel and Meg Fergusson manage the NSRC within CRSF.

During FY 2016–17, CRSF continued to support over a dozen ongoing NSRC projects granted in past years. Summaries of the final reports from projects completed this year and progress reports from current Theme 3 projects follow (full reports available on the NSRC web site at nsrcforest.org).

NSRC Project Summaries

Forest Productivity & Forest Products: Improving Regional Growth and Yield Simulators and Decision-Support Systems for Large-Scale Pest Outbreaks

Mohammad Bataineh (Principal Investigator), School of Forestry & Natural Resources, University of Arkansas at Monticello; Aaron Weiskittel, School of Forest Resources, University of Maine; Robert Seymour, School of Forest Resources, University of Maine; David MacLean, Faculty of Forestry and Environmental Management, University of New Brunswick; Brian Roth, Cooperative Forestry Research Unit, University of Maine; Laura Kenefic, Northern Research Station, U.S. Forest Service; Cen Chen, School of Forest Resources, University of Maine

Year 3 Progress Report

Summary

Following our previous investigation on the influence of spruce budworm (SBW) defoliation on stand and individual-tree growth and mortality, the variation and temporal development of individual-tree defoliation caused by SBW were evaluated and modeled using data of over 47,000 individual-tree observations of defoliation collected in Maine and New Brunswick. Our results demonstrated that the majority of explained variation in individual tree defoliation was attributed to host species, while considering a variety of tree and stand characteristics. Meanwhile, defoliation of both balsam fir and red/black spruce was found to develop towards converged trajectories over time despite differences in initial defoliation, stand and site conditions, and geographical locations. These findings were consistent between Maine and New Brunswick despite their differences in past forest management and SBW outbreak histories. Overall, the developed modeling framework should be extendable to other forms of defoliation.

Table 1. Akaike Information Criterion (AIC) and changes in AIC (ΔAIC) of models predicting individual tree defoliation with various covariates by region, where DEF_P is plot defoliation (%); *SPP* is species (balsam fir, red/black spruce, and white spruce); *BA* and BA_{SW} are basal area and that of softwood trees in a plot (m^2 ha^{-1}), respectively; *ABD* is relative species abundance in a plot; *DBH* is diameter at breast height (cm); *HT* is height (m); MHT_{SW} is mean height of softwood trees in a plot (m); *BAL* is basal area of trees larger than the subject tree in DBH in a plot(m^2 ha^{-1}); and *CR* is crown ratio. The results indicate that species is the single most important predictor of individual tree defoliation at given plot defoliation level, while all the other potential covariates do not have as much influence individually or in combination.

	Maine (n = 42 349)		New Brunswick (n = 5 519)	
Model	AIC	ΔAIC	AIC	ΔAIC
Null	14904	--	241	--
DEF_P	-10614	-25518	-4151	-4392
DEF_P, SPP	-18711	-8097	-4868	-717
DEF_P, SPP, BA_{HW}*/BA*	-20191	-1480	-5086	-218
DEF_P, SPP, BA_{HW}*/BA, ABD, DBH, HT, HT/*MHT_{SW}*, BAL, CR**	-21320	-1129	-5418	-332

* For New Brunswick, *HT* and MHT_{SW} were initial values measured at the beginning of the study, and *CR* was not available.

Project Objectives

- Assess spruce budworm impact on individual-tree growth, mortality, and ingrowth and develop modifiers to adjust the current FVS-ACD equations
- Develop a relationship between stand-level mean defoliation to within-stand variation in defoliation
- Compare the newly developed modifiers to those currently used in the spruce budworm decision support system for New Brunswick (Table 1)
- Incorporate the newly developed modifiers into FVS-ACD and project growth and yield of various compositional and structural archetypes under various defoliation and forest protection scenarios

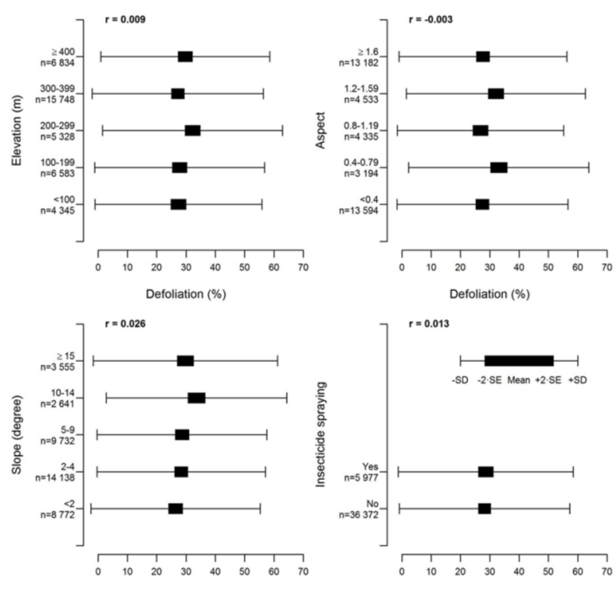


Figure 6. Relationships between individual-tree defoliation and topographic as well as insecticide spraying attributes, where aspect is computed as cos(45º – aspect in degree) + 1. As indicated by the correlation coefficients (r), these relationships are only nominal.

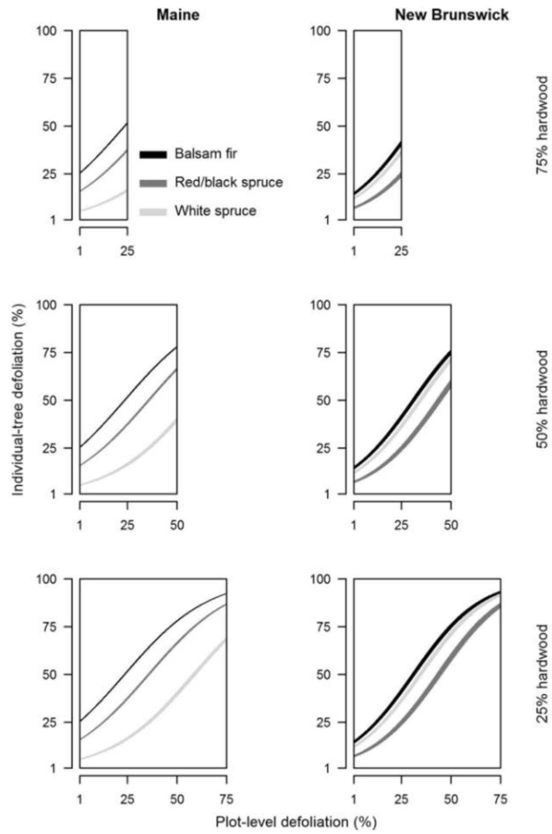


Figure 7. Predictions of individual tree defoliation (%) with 95% credible intervals as a function of plot defoliation (%; with all the other covariates at their means) by percentages of hardwoods in a plot and region.

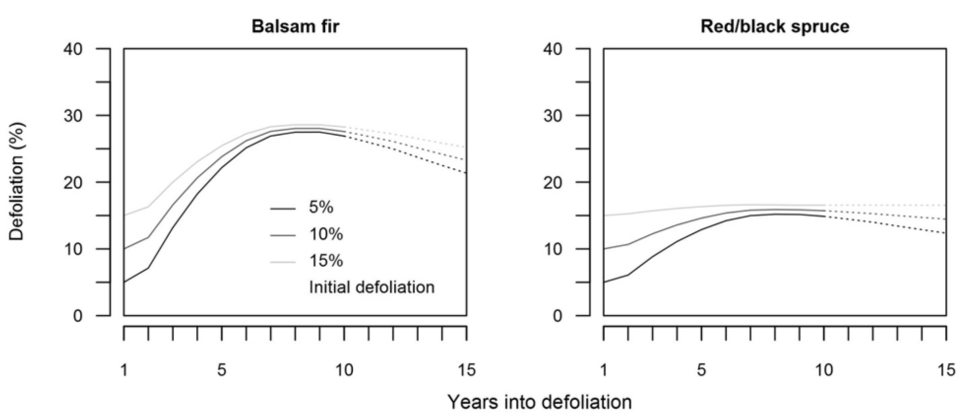


Figure 8. Predictions of the temporal development of individual tree defoliation (%) as a function of time (year) at various levels of initial (first year) defoliation (%) by species. Dotted lines are extrapolations of these predictions.

Approach

- Derived information on individual-tree and plot defoliation, host species and plot species composition, tree dimension, stand structure, site topography, and insecticide spraying status from data containing over 47,000 individual-tree observations collected at 560 permanent sample plots in the 1970s-1980s in Maine, USA and New Brunswick, Canada (Figure 6, Figure 7, Figure 8).
- Bayesian models based on Markov chain Monte Carlo technique were developed to model individual-tree defoliation in relation to plot defoliation and temporal development of individual-tree defoliation based on its initial observation using the most important variables selected from the above attributes.
- Perform the above modeling and evaluation in Maine and New Brunswick, which differ in forest management and spruce budworm outbreak histories, to better verify the robustness and consistency of our findings.

Key Findings / Accomplishments

- The majority of explained variation in individual tree defoliation was attributed to host species, while considering a variety of tree and stand characteristics.
- Defoliation was lower in pure stands than in mixed stands of the host species.
- Defoliation of both balsam fir and red/black spruce was found to develop towards converged trajectories over time despite differences in initial defoliation, stand and site conditions, and geographical locations

Future Plans

- Evaluating the influence of spruce budworm defoliation on forest dynamics at landscape level, while assessing how the dynamics of defoliation itself are affected by the connectivity and patchiness of forest landscapes.
- Design a sampling procedure better capturing the influences of stand structure and composition, management history, and site quality on growth responses to defoliation, while taking into consideration the population dynamics of spruce budworm.
- Design and conduct an experimental study to investigate the effectiveness of insecticide spraying on reducing the influence of spruce budworm defoliation on forest growth and mortality.

Understanding Landscape Level Factors Influencing Spruce Budworm (SBW) Outbreak Patterns in Maine and Forecasting Future Risk at High Spatial Resolution

Parinaz Rahimzadeh (Principal Investigator), School of Forest Resources, UMaine; Aaron Weiskittel, School of Forest Resources, UMaine; Daniel Kneeshaw, Department of Biological Sciences, UQAM, Quebec; David MacLean, Forestry and Environmental Management, University of New Brunswick, Canada

Year 1 Progress Report

Summary

Accurate spruce budworm (SBW) defoliation data are essential for effective forest management and planning and understanding factors influencing SBW outbreaks. Landscape mapping of SBW defoliation is based on aerial sketch mapping (ASM). Here we are developing a comprehensive method to detect and quantify SBW annual defoliation applying remote sensing techniques to add accuracy to ASMs. Also we use the method to improve historical SBW defoliation maps of Maine to understand factors influencing SBW outbreak. Several data including annual egg mass, SBW ASM, defoliation field data, forest cover type, Landsat-MSS imagery for 1970s and 1980s were collected and their accuracy is being evaluated. Landsat-MSS imagery with combination of ancillary data have shown to have the potential to map SBW defoliation extent at finer resolution with more accuracy than ASMs. Also three remotely sensed indices have been identified to detect and separate two major common forest disturbances including intensive harvest activities and SBW defoliation in 1970s and 1980s in Maine.

Project Objectives

- To develop and suggest a practical and comprehensive method to add accuracy to aerial sketch maps using satellite remote sensing and ancillary data.
- Apply suggested method to refine historical ASM of Maine (the current version is too coarse and inaccurate) and to identify landscape factors affecting SBW outbreak patterns.

Approach

- Data collection: (1) annual egg mass data from 1973 to 1985 and annual aerial SBW defoliation sketch maps for 1972 to 1989 for Maine in GIS format were provided through Hennigar et al., (2013) project. (2) Landsat-MSS cloud free imagery (WRS-1 path 13, row 28) having four spectral bands and 60 m (197 ft) spatial resolution for years 1973, 1975, 1978, 1982 and forest cover type map of 1975 derived from Landsat-MSS for scene 13/28 were provided through Legaard et al., (2015) project, (3) Landsat-MSS of 1972 for the same scene was collected through USGS-EarthExplorer website. (4) Field data on SBW annual defoliation were provided through Chen et al., (2017) project and (5) Historical aerial imagery (NASA-U2) for year 1973 for Northern of Maine obtained through other colleagues.

- Data evaluation and processing: 1) all satellite imagery had already been radiometrically normalized. Only 1972 image was radiometrically corrected using 1973 image as the base image. 2) quality of all available field data is being checked manually as both egg mass data and field data coordinates have some geolocation errors that are being checked using historical aerial imagery. 3) three remotely sensed indices were calculated in this research to detect forest disturbances from Landsat-MSS imagery: i) Normalized Difference Vegetation Index (NDVI) and ii) and iii) Tasseled Cap brightness (TCB) and greenness (TCG) vegetation indices. It should be mentioned that Landsat-MSS sensor has limited spectral bands and vegetation indices like Normalized Difference Moisture Index (NDMI) suited for pest-induced defoliation detection cannot be estimated. Using NDVI moderate to severe defoliation can be detected. Before defoliation mapping harvested pixels were removed using TCB and TCG indices (Rahimzadeh-Bajgiran et al., in preparation; Baumann et al., 2014).

Key Findings / Accomplishments

- The study area represents a unique situation where three forms of disturbances had occurred at the landscape scale simultaneously and intensively. To separate other disturbances from those related to SBW, several remote sensing techniques were tried. The results indicated that TCB and TCG vegetation indices are suitable indices to detect and classify disturbance types when several disturbances including defoliation, partial harvest and clear-cuts have intensively changed the landscape of the region. SBW defoliation maps can be produced for years 1973, 1975, 1978, 1982 for entire Landsat-MSS 13/28 scene using NDVI. Light defoliation is difficult to detect due to both sensor quality and NDVI limitations (Rahimzadeh-Bajgiran et al., in preparation) (Figure 9), however we are attempting to classify the maps into two classes of severity similar to historical SBW ASM data (low-moderate and moderate-severe) using the relationship between field data and NDVI and Random Forest statistical tool.
- Fine resolution forest cover maps (e.g Landsat derived maps) can be a very essential source of information to map SBW defoliation for both remote sensing-derived and ASMs. Using remotely sensed derived forest cover change maps and forest cover data we are able to refine historical aerial sketch maps. However the data is currently only available for scene 13/ 28.

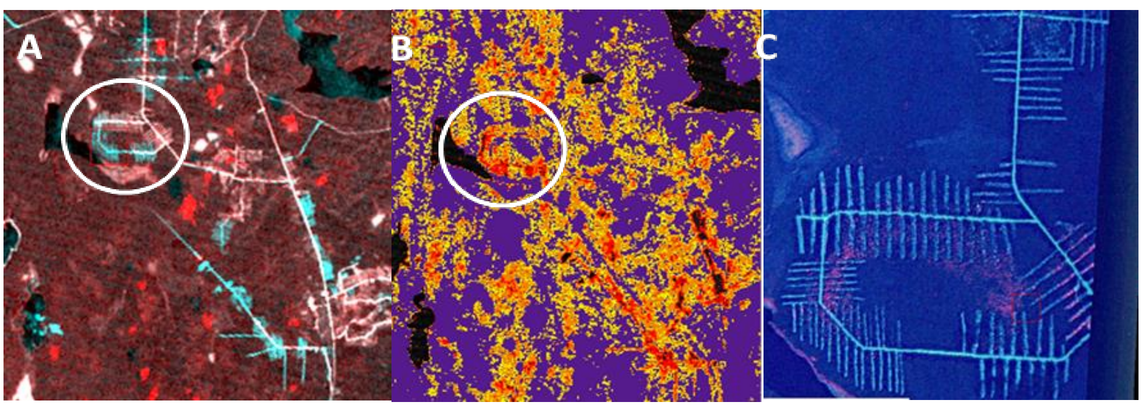


Figure 9. (A) Landsat-MSS 60m RGB Delta-TCB/TCG image of 1973 to detect only forest disturbances due to harvest. White and cyan colors are harvest activities, black and clear red spots are water bodies and clouds respectively, background reddish colors are areas with no change or change related to other disturbance (B) Landsat-MSS 60m Delta-NDVI image of 1973, showing all disturbances regardless of their type in yellow, orange and red (light to severe) and purple are the areas with no change (C) NASA-U2 aerial image for 1973 having 5m spatial resolution used as ground truth data to evaluate the performance of TCG and TCB indices to detect harvest disturbances, the extent of the area is marked in Figure 9A and 9B.

Future Plans

- Classifying NDVI maps to produce SBW severity of three classes (Nil, Low-moderate, Moderate to high).

- Refining SBW ASMs for 1970s and 1980s for Landsat scene 13/28 to study effect of site factors on SBW defoliation patterns.
- Apply and evaluate the approach used for Landsat-MSS imagery to detect and separate SBW defoliated forest from harvested areas for recent multi-spectral satellite imagery as these data have more spectral bands and finer radiometric and spatial resolutions to separate partial harvest from light to moderate SBW defoliation.

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Nitrogen Controls on Detrital Organic Matter Dynamics in the Northern Forest: Evidence from a 26-year Nitrogen Addition Experiment at the Bear Brook Watershed in Maine

Coarse and find woody debris inventory at the BBWM in October-November 2016 using line intercept method. *Photo courtesy M-C Gruselle.*

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Year 1 Progress Report

Summary

The project goal is to better understand the influence of elevated N input on downed wood debris dynamics. Between July 1, 2016 and June 30, 2017, the personnel implemented downed dead wood inventory and sampling as well as a standard wood 'decay stake' experiment at the Bear Brook Watershed in Maine (BBWM). Since 1989, the BBWM is a manipulative whole-ecosystem and paired-watershed experiment with one watershed receiving N fertilizer and another one remaining untreated. Calculation of woody debris biomass was performed based on the inventory data. This is the first time the abundance and characteristics of woody detritus

were determined in both watersheds. Whole ecosystem carbon (C) and nitrogen (N) budgets are being established based on long-term ecosystem C and N stock data from the site. Former ^{15}N tracer additions at the site will also allow us to determine the fate of N in decomposing wood stakes and woody debris.

Project Objectives

- Determine the biomass, C and N concentrations, and ^{15}N composition, of downed woody detritus in the treated and the reference watersheds at the BBWM by species and decay class.
- Compare C and N dynamics and ^{15}N recoveries in standard 'decay stakes' of sugar maple and red spruce between watersheds in a field decomposition experiment.
- Test the influence of watershed N status, decay stake characteristics (tree species, initial wood density and chemistry), and local drivers of decomposition on C and N dynamics and ^{15}N recoveries of sugar maple and red spruce wood 'decay stakes' in a field decomposition experiment.

Approach

- This study combines a descriptive and an experimental approach and capitalizes on the well-established infrastructure and existing long-term ecosystem data from the BBWM.
- In the ***descriptive approach***, downed coarse and fine woody debris (CWD and FWD, respectively) were inventoried using the standard line-intercept method applied at 19 systematically selected positions in the fall of 2016. Stumps and standing dead trees as well as the living overstory trees are being inventoried in summer 2017 in 400 m2 circular plots centered at each inventory position used in 2016 for CWD and FWD. The inventories allow us to estimate the volume of CWD and FWD by species and decay class. Based on published literature of wood density these volumes were transformed into biomasses.
- Also in the scope of the ***descriptive approach***, CWD, FWD, snags and stump materials are being sampled (June-August 2017) for chemical analysis (C, N, ^{15}N). The chemical analysis for C, N and tracer N (^{15}N) coupled with biomass data will allow us to calculate C, N and ^{15}N recoveries in CWD and FWD components that ultimately will be compared between watersheds (i.e. eco-system N status).
- In the ***experimental approach***, standard red spruce and sugar maple wood 'decay stakes' were fabricated and installed in July 2016 in both watersheds. The decay-stake method allows us to follow wood decomposition and the fate of N in woody debris in the field by making use of pre-existing whole watershed ^{15}N pulse-chase labeling experiments at the BBWM.

Coarse woody debris sampling in June-July 2017 using a Japanese saw to cut one cross-sectional disk per CWD piece. *Photo courtesy M-C Gruselle.*

Key Findings / Accomplishments

- The activities of the first year of the project went smoothly.

- An inventory of 265 CWD logs and 4,367 FWD pieces was successfully completed in fall 2016 for to determine biomass of these two ecosystem components. The inventory of 2016 was the first to date to record CWD and FWD abundance and biomass at the BBWM.
- Two posters including results from the 2016 woody debris inventory were presented in March 2017 (see Section Products Delivered - Conference Papers).
- Red spruce and sugar maple standard wood 'decay stakes' were installed in the field in July 2016 (320 stakes in total), with plans to collect them after close to two years of decay.
- CWD cross-sectional disks were sampled in the field (179 disks collected to date). These disks are being processed for chemical analyses by 2 summer student workers (Michaela Kuhn and Elyse Daub).
- Suitable archived FWD samples from litterfall were identified for background wood ^{15}N data from both watersheds. These samples date from 1999-2000. These archived samples are being processed for chemical analyses by 2 summer student workers (Michaela Kuhn and Elyse Daub).
- Suitable locations were found outside (but nearby) the boundaries of the research site in order to collect reference samples of woody detritus for ^{15}N background levels by watershed. The reference CWD and FWD samples will be taken from the Y and A plots of Eckhoff and Wiersma (2002), which are situated outside of the boundaries of the treated and the reference watersheds. This extra sampling effort was detailed in the proposal and is necessary to calculate ^{15}N recoveries in woody detritus.

Future Plans

- Completing the sampling of reference CWD and FWD samples.
- Processing all CWD and FWD samples in the laboratory in Deering Hall and their subsequent preparation and submission to UC Davis Stable Isotope Facility for C, N, and ^{15}N analyses. The data turn-around is usually 4 to 8 weeks (http://stableisotopefacility.ucdavis.edu /13cand15 npricing.html). Thus, this aspect of the project will occupy a large part of the second year of the project.
- Performing a stump, snags and overstory inventory in order to relate stand characteristics to the abundance of downed woody debris (planned early on in the second year of the project).
- Writing a publication on C budgets at the BBWM including downed CWD and FWD.
- Collecting the first half of the red spruce and sugar maple 'decay stakes' (160 in total) from the field and determine the mass loss and chemistry (C, N, ^{15}N) of the 'decay stakes'. This will be performed at the end of the second year of the project to allow sufficient decomposition of the wooden stakes in the field.
- Submitting the processed decomposed decay stakes to UC Davis Stable Isotope Facility for C, N, and ^{15}N analyses.
- Writing a publication on the influence of ecosystem N status and local drivers of decomposition on mass loss, chemistry, and ^{15}N recoveries of sugar maple and red spruce wood 'decay stakes'.

References

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A Long-Term Perspective on Biomass Harvesting: Northern Conifer Forest Productivity 50 Years after Whole-Tree and Stem-Only Harvesting

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Year 3 Progress Report

Summary
Beginning summer 2014, 23 permanent sample plots (PSPs) were installed in Compartment 33, located within the Penobscot Experimental Forest (Figure 10). Established in 1964-65, three treatments were conducted on C33: whole-tree harvesting (WTH), stem-only harvesting (SOH), and post-harvest prescribed burning (SOHB) (Table 2**Error! Reference source not found.**). For treated areas, we measured growing stock, composition, and site conditions (drainage and parent material). Using mixed-effects models to compare productivity across treatments, we found that neither WTH nor SOHB appear to reduce site productivity in comparison to SOH. Though we were unable to test for differences in species composition before and after harvest, there may be productivity implications with species shifts (i.e., shade-tolerant conifer to intolerant hardwood) associated with the utilization of WTH methods with intensive silvicultural treatments in northern mixedwood stands. We are currently conducting soil and foliar nutrient analyses to further inform our findings. To address concerns over repeated WTH, C33 will be re-harvested this winter.

Table 2. Summary Statistics by Treatment

	Stem-Only Harvest		Stem-Only Harvest with Burn		Whole-Tree Harvest		Overall	
Number of Plots	6		6		7		19	
Variable	Mean(SD)	Range	Mean(SD)	Range	Mean(SD)	Range	Mean(SD)	Range
Trees Per Hectare (trees ha^{-1})	6149(1663)	3175-7561	6491(1868)	3534-8154	6312(2095)	3509-9452	6317(1795)	3175-9452
Total Basal Area (m^2 ha^{-1})	39.4(9.3)	23.4-49.6	41(3.9)	34.2-45	43(4.8)	36.2-49	41.3(6.2)	23.4-49.6
Average Height (m)	12(1.9)	9.4-15.2	12.2(1.3)	11.2-14.6	11.6(1.1)	9.9-12.9	11.9(1.4)	9.4-15.2
Mean Dominant Height (m)	18.6(3.2)	15.3-24.2	19.4(0.9)	18.2-20.8	19(2.4)	16-22.5	19(2.2)	15.3-24.2
Quadratic Mean Diameter (cm)	9.1(1)	7.9-10.6	9.2(1.1)	8.2-11.1	9.7(1.9)	8.1-13.3	9.3(1.4)	7.9-13.3
% Hardwood Basal Area	55.9(11.9)	43.1-74.9	70.7(14)	54.2-87.3	58.3(20.8)	36.6-98.1	61.5(16.8)	36.6-98.1
% Softwood Basal Area	44.1(11.9)	25.1-56.9	29.3(14)	12.7-45.8	41.7(20.8)	1.9-63.4	38.5(16.8)	1.9-63.4
Total Live-Tree Carbon Stock (Mg ha^{-1})	73.7(21.3)	40.1-100.5	82.1(5)	74.9-87.3	83.6(19)	66.9-122.7	80(16.5)	40.1-122.7
Total Snag Carbon Stock (Mg ha^{-1})	1.2(0.7)	0.1-2.4	1.9(0.9)	1-3.5	0.9(1.2)	0-2.9	1.3(1)	0-3.5
Total Down Woody Material Carbon Stock (Mg ha^{-1})	0.9(0.7)	0-1.7	2.3(2.4)	0.4-7	1(1.1)	0-2.6	1.4(1.6)	0-7
Total Aboveground Carbon Stock (Mg ha^{-1})	75.8(21.7)	41.9-103.1	86.3(7.4)	76.5-97.8	85.5(19.4)	67.8-123.7	82.7(17.2)	41.9-123.7
O Horizon Thickness (cm)	4.8(2.4)	1.9-8.9	10.8(6.4)	2.1-19.5	5.4(5)	0-12.6	6.9(5.3)	0-19.5
Cartographic Depth-to-Water (m)	2.3(1.7)	0.3-4.4	2.8(1.7)	0.8-5.7	2.7(1.9)	0.4-4.9	2.6(1.7)	0.3-5.7

Project Objectives

- Quantify site productivity (stand structure, composition, and carbon stock) 50 years after treatment in a designed experiment of clearcutting with WTH, SOH, and SOHB
- Determine the effect, if any, of incremental (SOH, SOHB, WTH) biomass removal on productivity
- Determine soil and foliar nutrient status 50 years after treatment with WTH and SOH
- Synthesize our findings with those from other studies of WTH in the Northern Forest to provide insight for future sustainable biomass harvesting guidelines
- Address concerns over repeated WTH on sites with low to moderate production potential

Approach

- At each PSP, height, diameter at breast height (dbh, 1.37 m), and species of living and standing dead trees were measured for stand structure and composition analysis
- For plant-available nutrient measurements, we installed ion exchange resin membranes (IERMs) at the bases of two red maple (*Acer rubrum*) and two balsam fir (*Abies balsamea*) trees demonstrating dominant characteristics within each unit (i.e., each tree had one cation and one anion IERM strip placed side by side, at a distance ~10x the dbh of the tree, azimuth of 180°)
- Foliage samples were then obtained on the upper 1/3 canopy from each of those trees, targeting the current year's growth
- Down woody debris ≥ 10 cm in diameter was measured using modified Brown's transects on all PSPs (van Wagner 1968, Brown 1971, Brown 1974)
- Regeneration up to < 1.37 m in height was inventoried on all PSPs
- Depth of the 'O' horizon within the soil was measured, as well as both parent material and soil drainage type confirmed in field, for use as potential explanatory variables on all PSPs

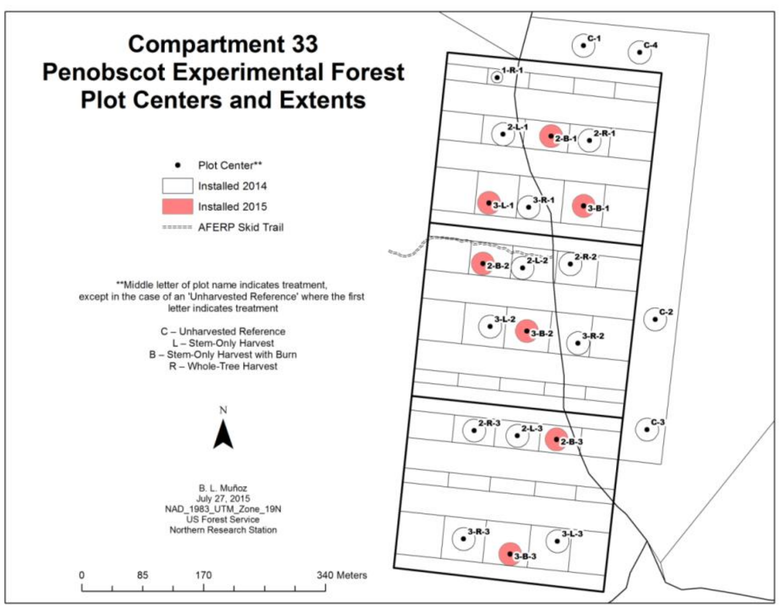

Figure 10. Map of compartment 33 plot centers and extents.

Key Findings / Accomplishments

- Treatment, site condition, or an interaction of the two did not have an effect on live-tree density, mean dominant height, overall percent hardwood composition, coarse wood carbon stock, total basal area, or live and total aboveground carbon stock at either plot-level or species-level
- Neither WTH nor SOHB reduced northern mixedwood site productivity 50 years after harvest, as reflected by stand structure or composition

Future Plans

- December 2016 – October 2017: Muñoz will complete data analysis, producing two chapters in her dissertation dedicated to this project
- Chapters will be submitted for publication, targeting Forest Ecology and Management and other natural resource journals
- November 2017: Presentation of all results at Muñoz dissertation defense
- December 2017-Februrary(?) 2018: Re-harvest C33

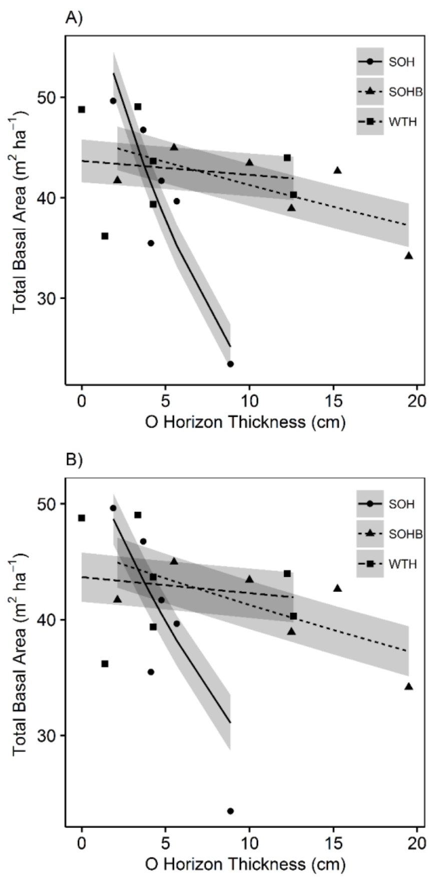

Figure 11. Predicted (line) and observed (point) total basal area with O horizon thickness, for trees ≥ 1.3 cm dbh. Plot a) displays the predicted line for SOH with the influential point and b) displays the predicted line for SOH without the influential point. Gray shading around predicted lines represent 95% confidence bands.

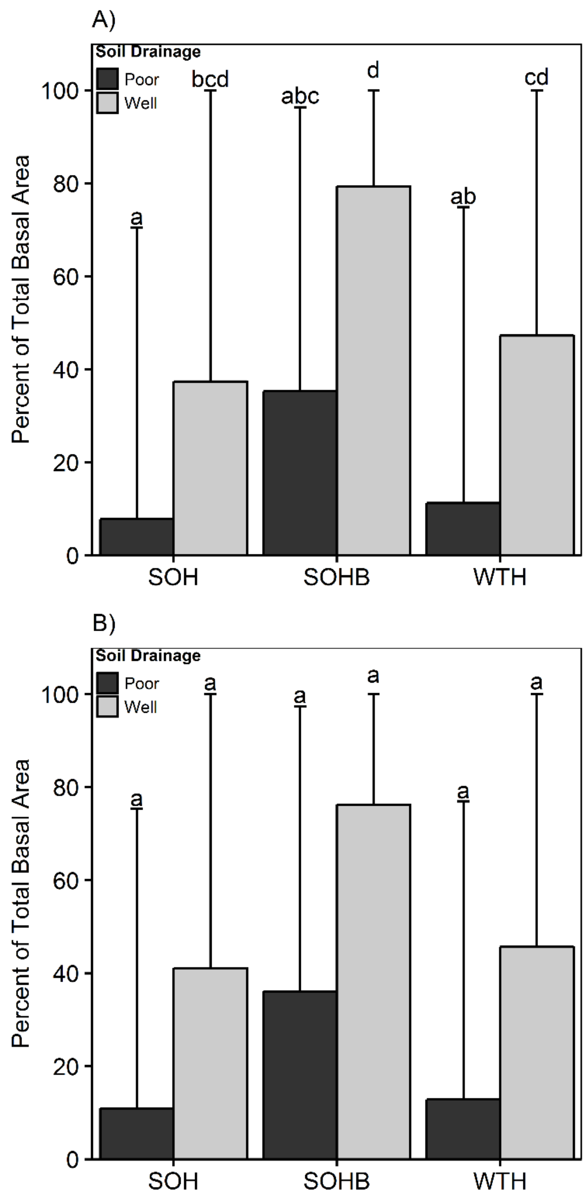

Figure 12. Aspen basal area (% of total basal area) least-squares means by treatment and drainage type, for trees ≥ 1.3 cm dbh. Plot a) displays least-squares means for SOH with the influential plot and b) displays least-squares means for SOH without the influential plot. Treatments are as follows: SOH = stem-only harvest; SOHB = stem-only harvest with burn; WTH = whole-tree harvest. Different lower-case letters indicate significant differences.

Table 3. Preliminary relationships (Pearson's r) between mineral soil nutrient concentrations and foliar nutrient content, before applying dilution factor

	Soil NO_3^-	Soil NH_4^+	Soil Ca^{2+}	Soil K^+	Soil Mg^{2+}	Soil P	Soil S	Foliar N	Foliar Ca	Foliar K	Foliar Mg	Foliar P
Soil NO_3^-	1											
Soil NH_4^+	-0.05	1										
Soil Ca^{2+}	0.31	-0.14	1									
Soil K^+	-0.07	0.07	-0.4	1								
Soil Mg^{2+}	0.36	-0.15	0.93	-0.37	1							
Soil P	-0.08	0.02	0.18	-0.03	0.07	1						
Soil S	0.06	-0.08	0.45	-0.23	0.4	-0.04	1					
Foliar N	-0.11	-0.01	-0.21	0.02	-0.15	-0.04	-0.24	1				
Foliar Ca	-0.08	-0.21	0.1	0.11	0.06	0.23	-0.07	0.28	1			
Foliar K	-0.09	-0.13	-0.2	0.11	-0.2	-0.3	-0.05	-0.23	-0.03	1		
Foliar Mg	-0.14	-0.09	-0.14	0.28	-0.11	0.02	-0.15	0.54	0.61	-0.13	1	
Foliar P	-0.03	-0.13	-0.44	0.21	-0.48	-0.23	-0.16	0.12	0.16	0.41	0.31	1

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Assessing the Influence of Tree Form and Damage on Commercial Hardwoods Growth, Volume and Biomass in Maine

Aaron Weiskittel (Principal Investigator), School of Forest Resources, UMaine; Gaetian Pelletier, Northern Hardwoods Research Institute; Jereme Frank, School of Forest Resources, UMaine; Mark Castle, School of Forest Resources, UMaine

Year 2 Progress Report

Summary

We are currently in the process of analyzing data and finalizing a couple of manuscripts using the data collected during the 2015 and 2016 field seasons. To date we have taken intensive tree measurements incorporating form and risk protocols for 7016 hardwood species across PSPs in the following locations: (1) Austin Pond Research Forest, (2) Demerit University Forest, (3) Dixmont Community Forest, (4) The Holt Research Forest, (5) Kingman Farms Research Forest, (6) The Penobscot Experimental Forest, (7) and The Scientific Forest Management Area (SFMA). Further data collection has been carried out on the Harvard Forest to verify terrestrial LiDAR scanning (TLS) as a tool for assessing tree volume and form. Current results indicate that stem form and risk have important implications on potential sawlog recov-ery (Figure 13), annual diameter growth (Figure), and probability of survival (Figure 15) for several northern commercial hardwood species. Analysis using destructively sampled trees suggest that riskclassifica-tions can also be used to improve predictions of the occurrence of internal stem decay (Figure 146).

Project Objectives

- Assess variation in stem form and risk across several prominent northern commercial hardwood species.

- Quantify the influence of stem form and damage on potential sawlog volume, diameter increment, and probability of survival.
- Use destructively sampled trees to (1) examine the influence of commonly measured tree metrics such as size, taper, risk class and crown ratio on a tree's susceptibility to decay, and (2) assess whether decay varies between species.
- Develop a revised framework for classification system that could be used for hardwood management in the Northeast.

Approach

- Standing measurements were taken on hardwoods of varying tree form and vigor across PSPs in Maine and New Hampshire. These data were used to analyze the influence of stem form and risk on product potential, diameter growth and survival.

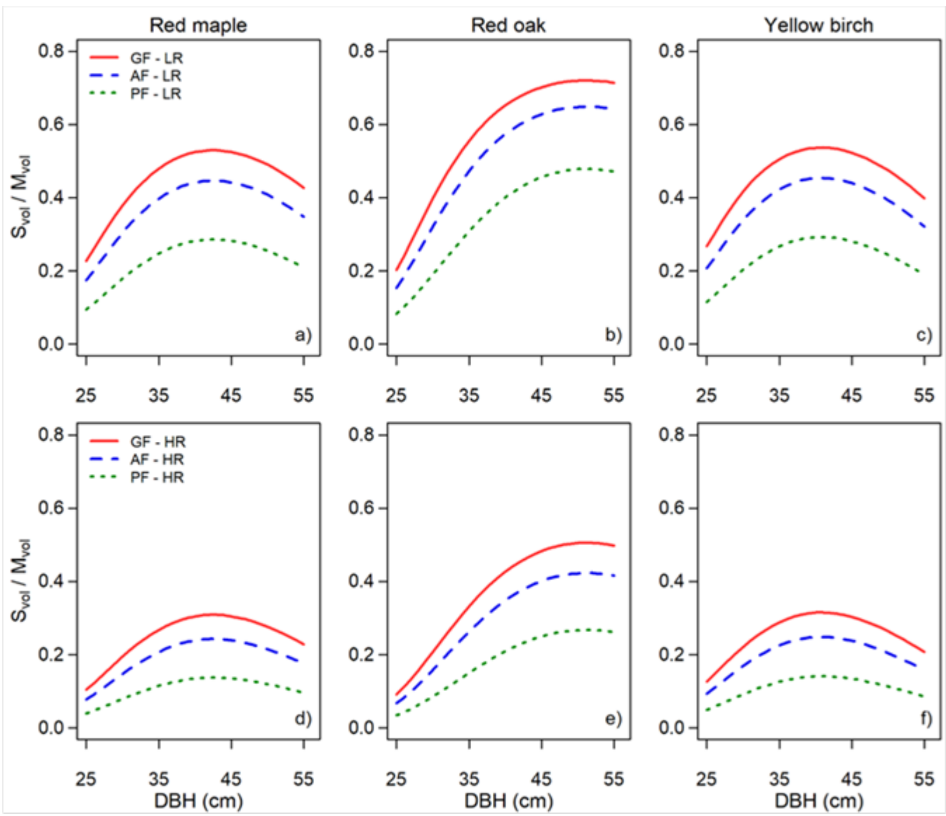

Figure 13. Predictions of the proportion of sawlog volume to merchantable volume (S_{vol}/M_{vol}) in an individual tree stem across DBH, stem form (AF, GF, PF), and risk classes (LR and HR) for red maple (a and d), red oak (b and e), and yellow birch (c and f). AF, GF and PF correspond to acceptable form (tree with multiple stems, sweep or significant lean), good form (tree with single straight stem) and poor form (tree with at least 1 significant fork on first 5 m of stem) respectively. LR and HR correspond to low risk (trees with little or no damage) and high risk trees (trees with extensive or severe damage), respectively.

On adjacent sites, destructively sampled trees with poor form/ high damage were collected to assess decay proportion, volume and biomass deductions.

- Generalized linear mixed effects models were used to predict the occurrence of stem form and risk across species. Subsequent beta regression models were used to predict sawlog recovery as a function of a tree's size, stem form and risk.

- Nonlinear mixed effects models were developed to quantify annualized diameter increment and survival using stem form and risk as covariates.
- Evaluated several different kinds of modelling frameworks and explanatory variables for predicting the probability and proportion of internal stem decay.
- Incorporate resultant equations and modifiers into FVS – ACD.

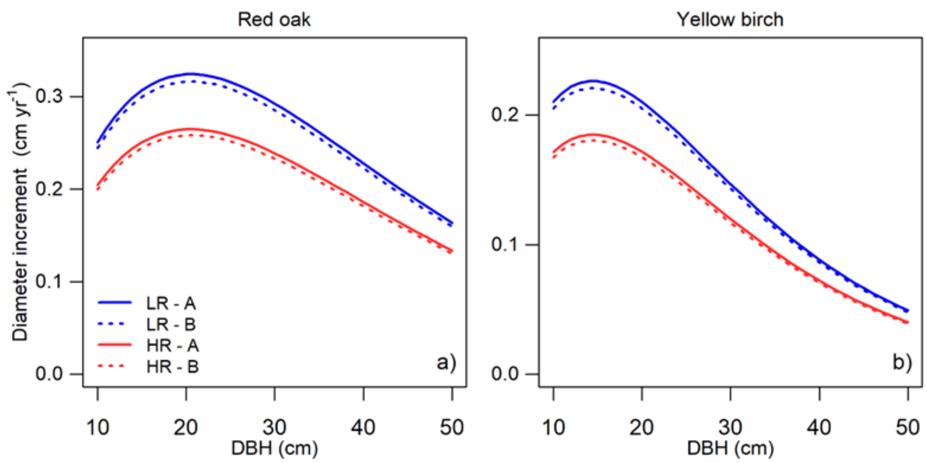

Figure 14. Predictions of annual diameter increment across DBH, stem form (A, B), risk class (LR, HR) for red oak (a) and yellow birch (b). Form class A corresponds to trees with single straight stems or those with significant forks on the lower portion of their bole and form class B corresponds to trees with either multiple stems, multiple sweeps, or significant lean. LR and HR correspond to low risk (trees with little or no damage) and high risk trees (trees with extensive or severe damage).

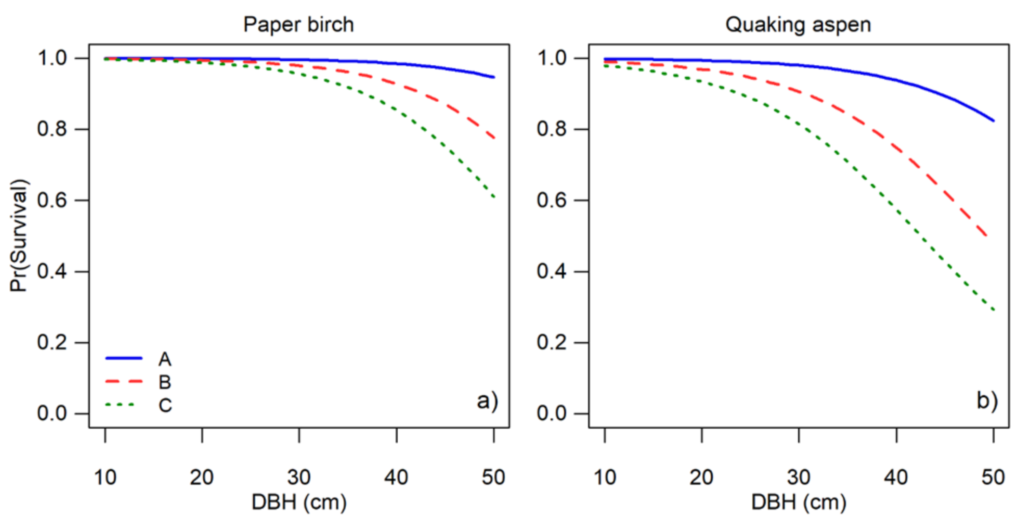

Figure 15. Predictions of annual probability of survival (Pr(Surivival)) across DBH, stem form (A, B, C) for paper birch (a) and quaking aspen (b). Form class A corresponds to trees with single straight stems or those with significant forks on the lower portion of their bole, form class B corresponds to trees with multiple sweeps or significant lean, and form class C corresponds to trees with multiple stems.

Key Findings / Accomplishments:

- Potential sawlog recovery was significantly lower for trees that demonstrated excessive sweep or lean, multiple stems, significant forks, or severe/extensive damage.
- Annual diameter increment was about 8% lower for trees considered to be high risk.
- Probability of survival was lower for trees demonstrating significant lean or sweep and multiple stems.
- Key predictors of decay occurrence included risk class, taper (DBH/Height), crown ratio, and species.
- Trees considered to be high risk were 1.8 times more likely to demonstrate decay than low risk trees.

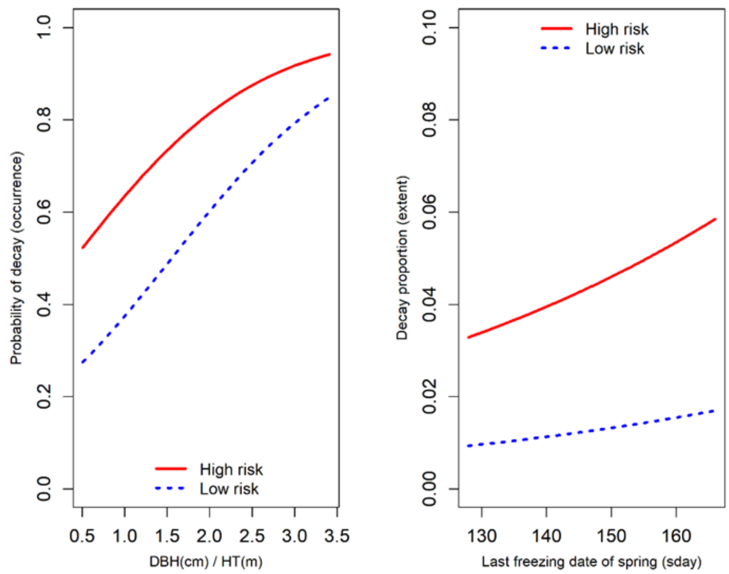

Figure 16. Probability of decay occurrence as a function of diameter to height ratio (DBH/HT), risk classification (high/low) based on external symptoms which may lead to loss in value or increase in mortality; and decay proportion based on risk class and the Julian date of the last freezing day in spring.

Future Plans

- Further analysis and continued preparation of manuscripts.
- Work with FIA to incorporate form and risk classification protocols into statewide inventory in Maine.
- Data collected by FIA will be used to further validate models.
- We have just completed a field campaign on the Harvard Forest where trees were scanned using terrestrial LiDAR scanners (TLS) and then destructively sampled. Over the next year, TLS will be evaluated as a tool for measuring stem volume and form.

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Classifying and Evaluating Partial Harvests and Their Effect on Stand Dynamics in Northern Maine

Christian Kuehne (Principal Investigator), School of Forest Resources, UMaine; Kasey Legaard, School of Forest Resources, UMaine; Aaron Weiskittel, School of Forest Resources, UMaine

Year 2 Progress Report

Summary

Two years into this project, we have made significant progress in the preparation and analysis of both field measurements and remote sensing data sources, needed for quantitative characterization of harvesting trends across northern Maine. Initial analyses were completed, and substantial methodological improvements were made. Remaining stand development projections and their classification into development trajectories were postponed as the forest growth and yield model to be used for the projections is currently revised to improve prediction accuracy. Additional funding could be secured to accomplish the model revision and extension efforts. Once finalized, a new set of stand development trajectories and silvicultural pathways that better reflect predominant harvesting practices will be derived. As a result of the ongoing growth and yield model improvements and the resulting postponement of the stand development projections, a 1-year no-cost extension was requested. An extension will also enable a statewide expansion of remote sensing and spatial analyses based on new, more efficient software implementations of our algorithms. Work planned for year 3 will complete project objectives, with multiple important improvements over the work originally proposed.

- Refine and evaluate the distribution of partial harvest conditions in northern Maine.
- Map incremental changes in partial harvest conditions across a ~10 million acre study area and a ~30 year time period.
- Project the development and quantify the shift in species composition and structure of residual stands created following the most commonly used types of partial harvest identified in objective #1.
- Group these projections into a new set of average stand development trajectories based on past harvest actions which will serve as the basis for an updated classification scheme.

Approach

- Apply a forest harvest classification system based on basal area removed, residual basal area, and pre-harvest species composition to USFS Forest Inventory and Analysis (FIA) plot measurements to evaluate the distribution of partial harvest conditions across a ~15 year time period.
- Map partial harvest conditions across a ~30 year time period using spatial models of basal area removed, residual basal area, and pre-harvest species composition based on a time series of Landsat satellite imagery linked to FIA field measurements.
- Extend and update the Acadian Variant of the Forest Vegetation Simulator (FSV-ACD) by incorporating new submodels (so called thinning modifiers) projecting individual tree growth and mortality after various types of partial harvest
- Project the development of residual stands created from common classes of partial harvest using the updated Acadian Variant of the Forest Vegetation Simulator.

- Evaluate short- and long-term projected shifts if species composition and forest structure induced by common classes of partial harvesting
- Develop a new set of stand development pathways representing current harvest practices and anticipated silvicultural outcomes by grouping projected stand conditions.

Key Findings / Accomplishments

- We have compiled FIA data statewide (2000-2015) and classified apparent harvest events across three separate measurement cycles at each plot. After compiling results into rolling 5-year measurement periods, we have analyzed outcomes for trends in harvest conditions and found little evidence of contemporary shifts in partial harvest practices as characterized by the proposed harvest classification system.
- Regional differences in factors that influence harvest regimes (e.g., ownership, forest management legacy, bioclimatic conditions) may cause apparent regional differences in harvest conditions. These differences are of potential importance to spatial wood supply analyses, reinforcing the need to extend analyses by linking FIA to Landsat.
- We have refined methods for mapping harvest events, harvest intensity, and pre-harvest composition, through significant improvements in data handling and prediction algorithms. These should result in tangible improvements to maps.
- By extending this project into a third year, we will capitalize on outcomes of other projects to expand spatial data statewide. Under other funding, we have partnered with software and cyberinfrastructure engineers in the UMaine Advanced Computing Group to develop a much more parallelized implementation of our prediction algorithms coupled with more efficient and more flexible workflows. This new software implementation will overcome computation and data management barriers that have thus far limited work to a northern Maine study area. A statewide expansion of mapping objectives will provide a comprehensive accounting of harvest trends needed for a statewide spatial wood supply analysis.
- We developed individual tree-level forest treatment response functions for the two most important conifer species of the study area (red spruce and balsam fir) and incorporated these treatment modifiers into FVS-ACD.
- We have partially leveraged this project and obtained additional funding for the upcoming fiscal year that will further support refinement of predictions of stand dynamics after forest management interventions (funding agency: Cooperative Forest Research Unit, funding amount: $34,102, project title: Development of individual-tree and stand-level approaches for predicting hardwood mortality and growth response to forest management treatments in mixed-species forests of northeastern North America).

Future Plans

- We are well positioned to complete proposed objectives during the next year. In a number of cases, this will include significant improvement over the work we originally planned.
- Information derived from plot-level analyses and mapped partial harvest conditions will be used to define common classes of partial harvest and the resulting residual stand conditions.
- Using the Acadian Variant of the Forest Vegetation Simulator we will project the development of residual stands created from common classes of partial harvest to quantify short- and long-term shifts in species composition and structure.

Productivity, Regeneration Patterns, and Pre-Commercial Treatment Options of Two Ecologically Based Silvicultural Systems: 20-Year results from the AFERP Study

Robert S. Seymour (Principal Investigator, University of Maine; Shawn Fraver (Co-PI), University of Maine; Paul Szwedo (MF/MS candidate), Micahael Pounch (MF), Margaret Mansfield (MS)

Year 2 Progress Report

Summary

The Acadian Forest Ecosystem Research Project (AFERP, established on the Penobscot Experimental Forest, Maine) represents a 20-year ongoing effort to test an ecologically based silvicultural system in a mixed-species forest type representative of much of the Northern Forest. We have been working to evaluate the silvicultural performance (regeneration, growth, mortality) of two variants of natural disturbance-based expanding gap silviculture installed in the AFERP study. Throughout the time period of *July 1, 2015 to June 30, 2016* we completed overstory and sapling permanent plot measurements of research areas 1, 2, 3, 5, 6, 7, and 9. All overstory trees and saplings within the nested plot design were stem mapped, given new tags, and trees were re-marked with a bark scribe and tree paint at breast height. In February 2016, the second replicate (research areas 5/6) were marked for harvest with operations concluding in March 2016.

Project Objectives

- Extend the short-term (10-year) results from earlier work (NSRC 2007; Arsenault and Saunders 2011) by quantifying 20-year stand development patterns (regeneration, growth, and mortality) in terms of conventional stemwood volumes and carbon stocks, focusing on the productivity tradeoffs among matrix forests, regeneration, and permanent reserve trees
- Examine within-gap regeneration patterns to isolate the effects of harvest timing, location within gap, and proximity to reserve trees
- Compare regeneration patterns and stemwood productivity by silvicultural treatment (large gap, small gap, unharvested matrix, unharvested control) and quantify statistically significant differences
- Install a new study of stand-tending intermediate treatment options for the regenerating gaps.

Approach

- To characterize general long-term growth and composition trends and provide baseline comparisons between treatment types and control areas, a permanent plot network of nested, fixed-area overstory, sapling, and regeneration plots have been measured every five years since 1995 (Saunders et al. 2012). Trees >9.5 cm dbh are stem-mapped on 20 0.05-ha plots per research area; saplings are measured on nested 0.01-ha plots. We have been working to remeasure these plots prior to harvest entries, and again after completion, to complete a 20-year record. Data include species, dbh, status, height (total and crown base), crown stratum, and Bechtold's (2003) light exposure class.
- We will establish an intensive sample of regeneration plots within harvest gaps, and use these data to (1) document 20-year regeneration patterns, and (2) inform the prescription of precommerical composition and density control treatments (Objective 4).

- We will use the data from objectives (1) and (2) to further stratify results by silvicultural treatment to determine the effect of harvest prescription on stand dynamics and development. This will be accomplished by assessing the significance of gap size, position within gap, time since harvest, and proximity to retention trees.
- We will use the results of the vegetation clustering from Objective (2) to create specific crop-tree release and precommercial thinning prescriptions. Treatments will focus on shifting species composition to higher-value, longer-lived, and locally uncommon species where possible. Each managed research area will be split in half, such that the permanent plots and areas in harvest gaps are represented as equally as possible. Treatments will be applied by trained workers to the sapling regeneration in a randomly chosen half of each research area, using a combination of herbicide basal sprays (for hardwood sprout clumps) and motor-manual cutting. The treatments will be applied during the first growing season following the third harvest entry (2017).

Key Findings / Accomplishments

- Harvest layout, implementation RA 7/9 completed
- Post-harvest inventory RA 7/9 completed (Photo 3)
- Preliminary stand development analysis all Research Areas
- Comprehensive analysis of reserve-tree growth and mortality (David Carter MS Thesis); Second paper on growth published.
- We established (July 2017 – October 2017) an intensive sample of regeneration plots within harvest gaps, and use these data to (1) document 20-year regeneration patterns, and (2) inform the prescription of precommerical composition and density control treatments (Objective 4).
- We converted stem mapping data from permanent the plot inventory (azimuth and distance from established plot center) to X Y coordinates in R 3.2.1 (R Project, 2015) and import into ArcGIS 10.4.1 to create a geodatabase for spatially explicit analysis (winter 2017)
- We used the results of the vegetation clustering from Objective (2) to create specific crop-tree release and precommercial thinning prescriptions. Treatments focus on shifting species composition to higher-value, longer-lived, and locally uncommon species where possible. RA 1 was so treated during winter/spring of 2017.

Learning from the Past to Predict the Future: Validation of the Spruce Budworm Disturbance Model in Northwestern Maine

Brian R. Sturtevant (Principal Investigator), USFS, Northern Research Station; Eric J. Gustafson, USFS, Northern Research Station; Kasey Legaard, University of Maine

Year 2 Progress Report

Summary

The goal of our research is to validate a new LANDIS-II disturbance extension (Budworm Population Disturbance) against observed budworm damage for a historic outbreak in northwestern Maine as documented by aerial surveys and state impact reports. To date we have mapped forest conditions *circa* 1985 using machine-learning techniques applied to Landsat TM imagery and historic plot data, with

relatively high accuracy. Budworm model parameters implemented within the LANDIS-II environment have produced the range of anticipated budworm behaviors and consequent impacts under simplified (i.e., homogenous) scenarios. While dispersal behaviors complicated the synchronization process more than anticipated, the modelled behaviors are consistent with empirical observations from the Border Lakes Landscape (Minnesota & Ontario). Future work will focus on backcasting of 1985 Maine forests to pre-outbreak conditions *circa* 1973, final calibration of the extension to the Border Lakes Landscape, and finally Maine applications necessary for model validation by comparison with a historic outbreak.

Project Objectives

1. *Map forest conditions ca. 1973* using previously developed maps, historic plot data, and new remote sensing analyses
2. *Retrospective modeling of the last outbreak in Maine* to validate modeled budworm outbreaks against documented outbreak behavior.

Approach

Objective 1

- Utilize Landsat Thematic Mapper imagery acquired in 1985, and then backdate pre-outbreak spruce-fir distributions to 1973 using a previously developed time series of forest disturbance maps.
- Digitize the locations of a large set of plots measured by private companies in 1985, from hand-written records maintained by the U. Maine Cooperative Forestry Research Unit.
- Develop a new predictive modeling algorithm capable of (1) using either occurrence-only data or occurrence data mixed with unlabeled data, and (2) providing alternative mapped distributions differing in spruce-fir acreage.

Objective 2

- Develop parameters for the Spruce Budworm Population disturbance extension for LANDIS-II that reproduce observed outbreak behaviors for the Border Lakes Landscape (BLL) of NE Minnesota and adjacent Ontario.
- Apply the above parameters to simulations of budworm outbreak dynamics in space and time using the forest conditions of northwestern Maine in 1973 as the initial conditions for the outbreak.
- Replicated simulations will produce statistical distributions of landscape-scale outbreak features in terms of dynamics (extent, duration) and impacts (growth reduction, mortality) that will be compared (via confidence intervals) to documented features of budworm outbreak of the 70s and 80s

Key Findings / Accomplishments

Objective 1

Year One

- 178 historic spruce-fir plot locations were digitized from hand-written records provided by the U. Maine CFRU.
- Topo-climatic attributes and Landsat images were compiled and pre-processed for predictive modeling and mapping.
- We developed a new machine learning approach to the problem of predicting class distributions from incomplete reference data by combining a 1-class support vector machine prediction algorithm (SVM; Liu et al. 2002) with a multi-objective genetic algorithm (Deb et al. 2002). This is a new approach to prediction from presence-only reference data that simultaneously generates multiple maps with varying levels of class prevalence.

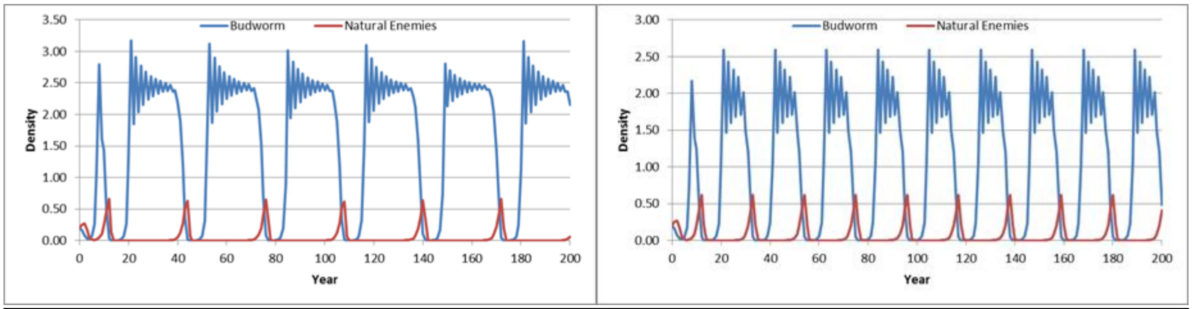

Figure 17. Simulated spruce budworm population dynamics within A. pure host forest, versus B. mixed forest (0.6 host conifers and 0.4 nonhost hardwoods). Critical features include both high frequency (i.e., "sawtooth" at high density) and low frequency (i.e., broad oscillation between endemic and outbreak densities) populations; lower frequency outbreak cycles under pure host conditions, due to comparatively slower response of natural enemies (see Sturtevant et al. 2015). In this case, a non-host effect was controlled by an input parameter.

- An initial comparison of our 1-class multi-objective SVM algorithm with an analogous 2-class SVM algorithm demonstrated that both could predict contemporary spruce-fir distributions at approximately 85% accuracy with mapped acreage matching that obtained from USFS FIA field plots.

Year Two

- We performed a more thorough verification of the 1-class multi-objective SVM algorithm developed in Year One, including execution on a larger set of test problems.
- With the assistance of the Maine Forest Service, we obtained plot coordinates for a large set of historic plot measurements made by the FIA program.
- We used historic FIA measurements to predict spruce-fir distributions using a 2-class SVM algorithm, and compared outcomes to those generated by our 1-class approach based on CFRU plot data.
- Direct comparisons were made complicated by multiple factors, including differences in sample size, plot placement relative to stand conditions, and plot location accuracy, and more work is needed to refine outcomes before selecting a single best approach.
- We made significant progress in developing spatial algorithms and code needed to back-date predicted spruce-fir distributions to 1973.

Objective 2

Year One

- We developed population parameters to produce the range of temporal outbreak behaviors observed within the Border Lakes region (Robert et al. 2012):
- Critical outbreak behaviors have been reproduced according to hypothesized relationships with hardwood content of the forest.
- Demonstrated realistic responses in terms of damage experienced by forests, and the consequent response of the forest via succession in LANDIS-II.
- While some critical outbreak behaviors were reproduced under spatialized modeling environments (i.e., explicit dispersal), the spatial feedbacks generally overwhelmed the temporal effects, such that the system was dominated by fine-scaled spatial waves spirals that did not allow the outbreak to synchronize over long time periods.

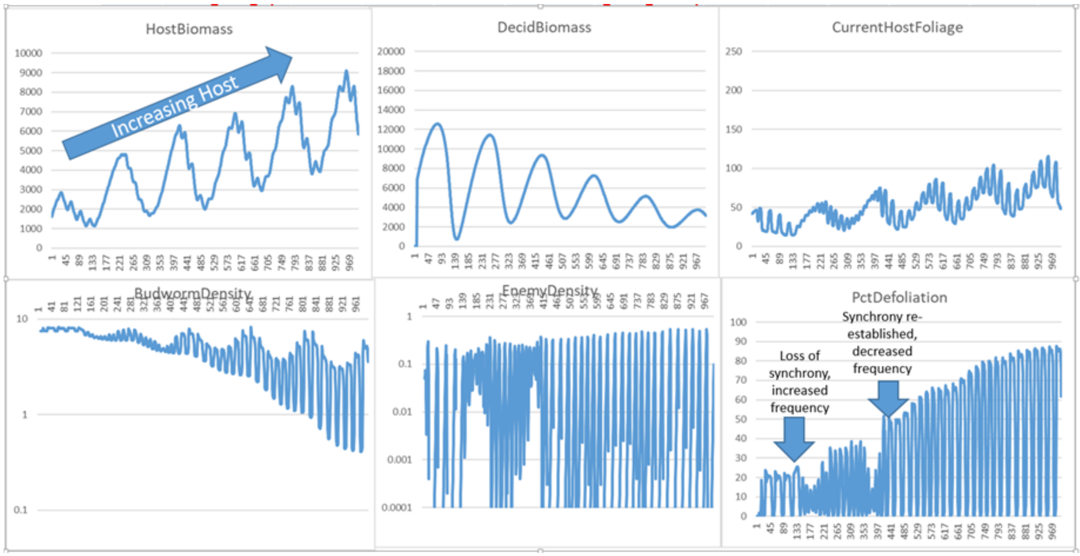

Figure 18. Forest landscape dynamics of budworm host (white spruce), nonhost (trembling aspen), spruce budworm populations and natural enemy "populations." Outbreak dynamics are an emergent property of spatiotemporal feedbacks between budworm and landscape forest conditions.

Year Two

- We constructed a system for systematic evaluation of parameter assumptions and parameter space – enabling more rapid calibration of the model
- We had a breakthrough in dispersal parameters that enabled system synchronization across small test landscapes
- The latest parameterization remains sensitive to landscape conditions in a way that is consistent with observed spatiotemporal outbreak behavior in the Border Lakes Landscape. In essence, outbreak frequency increases as synchrony breaks down, as observed in natural systems. Further, the simultaneous increase in frequency and decrease in synchrony is a nonlinear function of the amount and configuration of budworm host (Figure 18). Hence, outbreak dynamics are an emergent property of the feedback between the insects and the forest.

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Potential Impacts of Alternative Future Land Uses on Forest Management and Wood Supply across Maine

Spencer R. Meyer (Principal Investigator), Senior Conservationist, Highstead Foundation; Associate, Harvard Forest

Final Report

Summary

Maine is the most heavily forested state in the United States and has the highest percentage of its forests in private ownership (95%). These forests support rural economies across the state through forest-based manufacturing as well as outdoor recreation and tourism. However, much of Maine has a rural character, attractive quality-of-place, and relatively low land cost that continues to encourage development, which in turn puts pressure on private forest resources. The likely prospect of future development poses a risk to the wood supply upon which Maine's forest products economy relies.

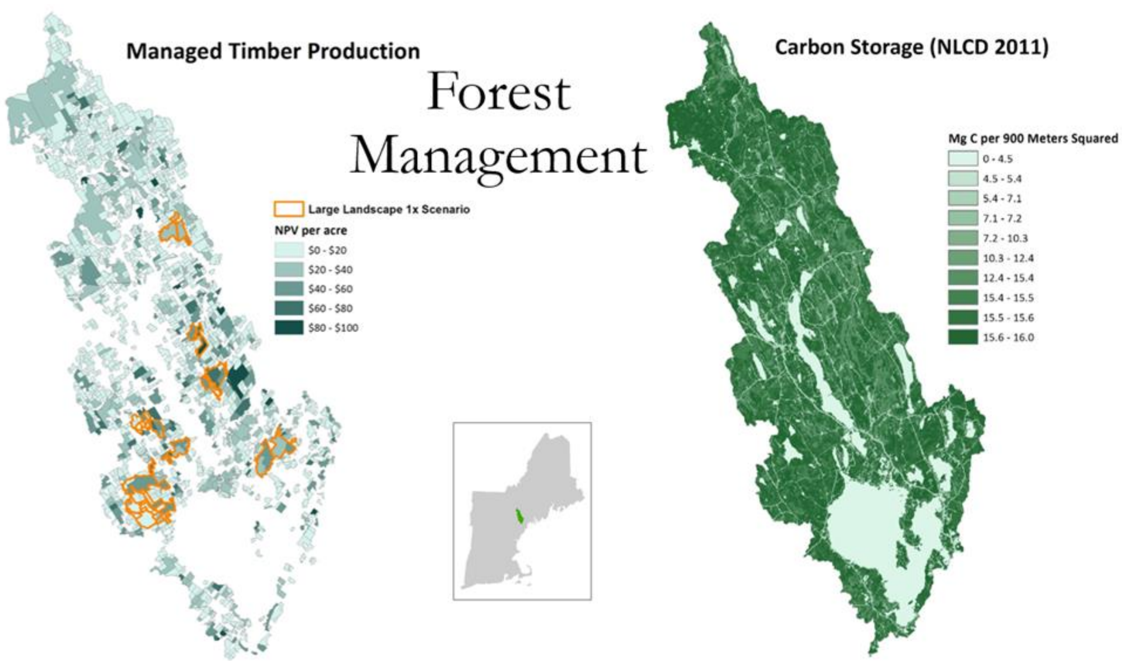


Figure 19. Combing parcel information and simulated Forest Inventory and Analysis data reveals areas of particular value for timber and carbon management.

In this project, we combined land use planning with forestry suitability modeling to evaluate the potential impact of development on the forest products sector across 4.5-million acres of Maine in the Penobscot and Casco Bay/Lower Androscoggin watersheds (Figure 19). Through focus groups with expert stakeholders, we created land use suitability computer models for development (i.e., residential, commercial, and amenity) and forest management. We also applied multiple scenarios of future development patterns to assess the portion of the landscape that could be affected by development. The modeling and stakeholder engagement work in this project led to the development of the award-winning Maine Futures Community Mapper (www.MaineLandUseFutures.org), which is a web-based spatial planning and scenario analysis tool geared for land use planners, communities, conservationists and natural resource managers. The tool has been used by at least two towns during develop of their comprehensive plans, and has been used in multiple conservation planning projects. Notably, the tool is now being used to develop a conservation action plan for the Sebago Clean Waters initiative, which is a new partnership between a water utility and several local, regional and national conservation NGOs (Figure 20).

The data generated in this project were also used in an ecosystem services study that quantified the values of forest management, carbon sequestration, biodiversity, and water quality in the Sebago Lake

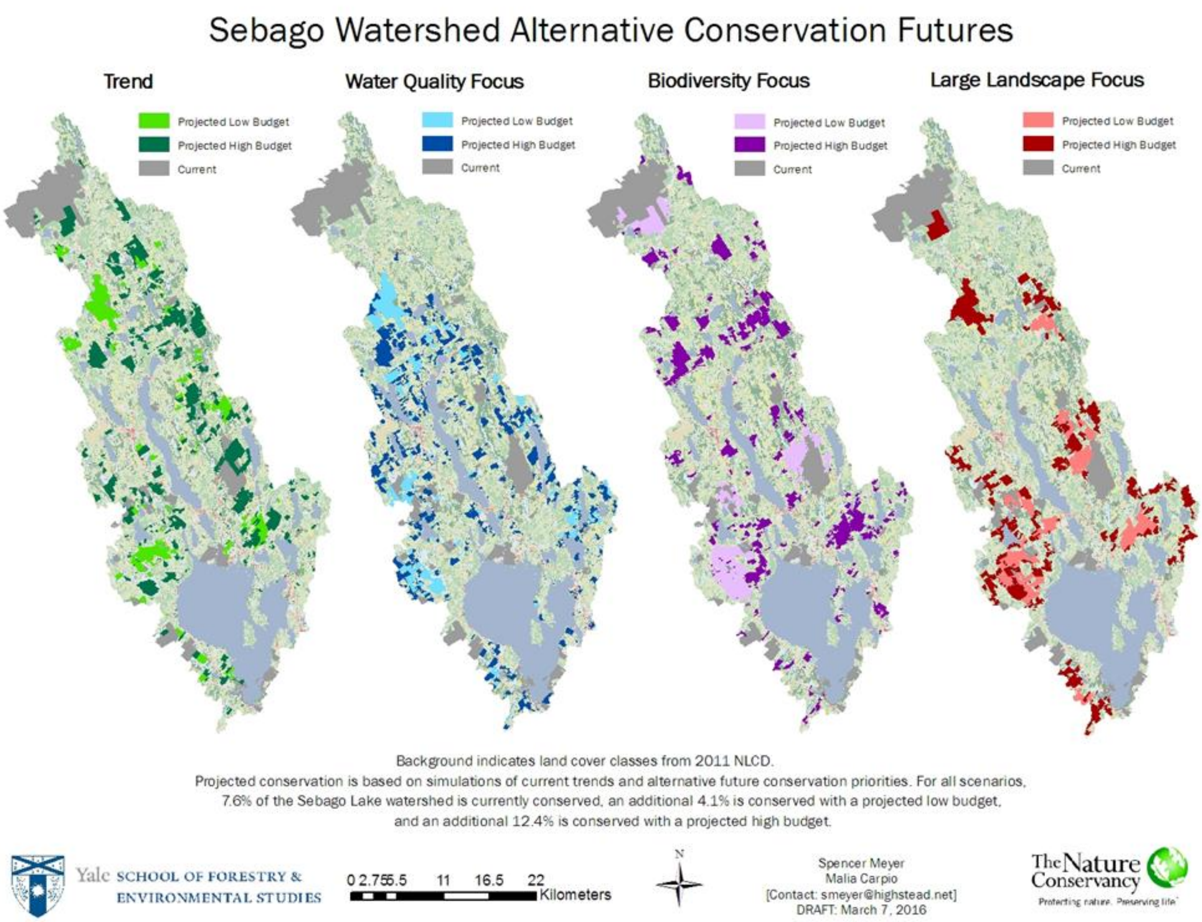


Figure 20 Results of a 30-year alternative scenarios conservation analysis comparing outcomes of conserving forestland with an emphasis on water quality, biodiversity, or working forests compared with the trend. Lighter shades indicate a projection of the recent trends level of land protection and darker shaed indicate a 1.5x amount of land protection compared with current trends. Note several areas where the simulation chooses the same land to protect, suggesting significant overlap between ecosystem service conservation priorities.

region. Those results are currently being used to evaluate the economic impact and develop a business case for additional investment in forest conservation for water quality and associated co-benefits as part of the Sebago Clean Waters initiative.

In addition to contributing to the online mapping tool (Figure 21), the results from this project contributed to three academic papers.

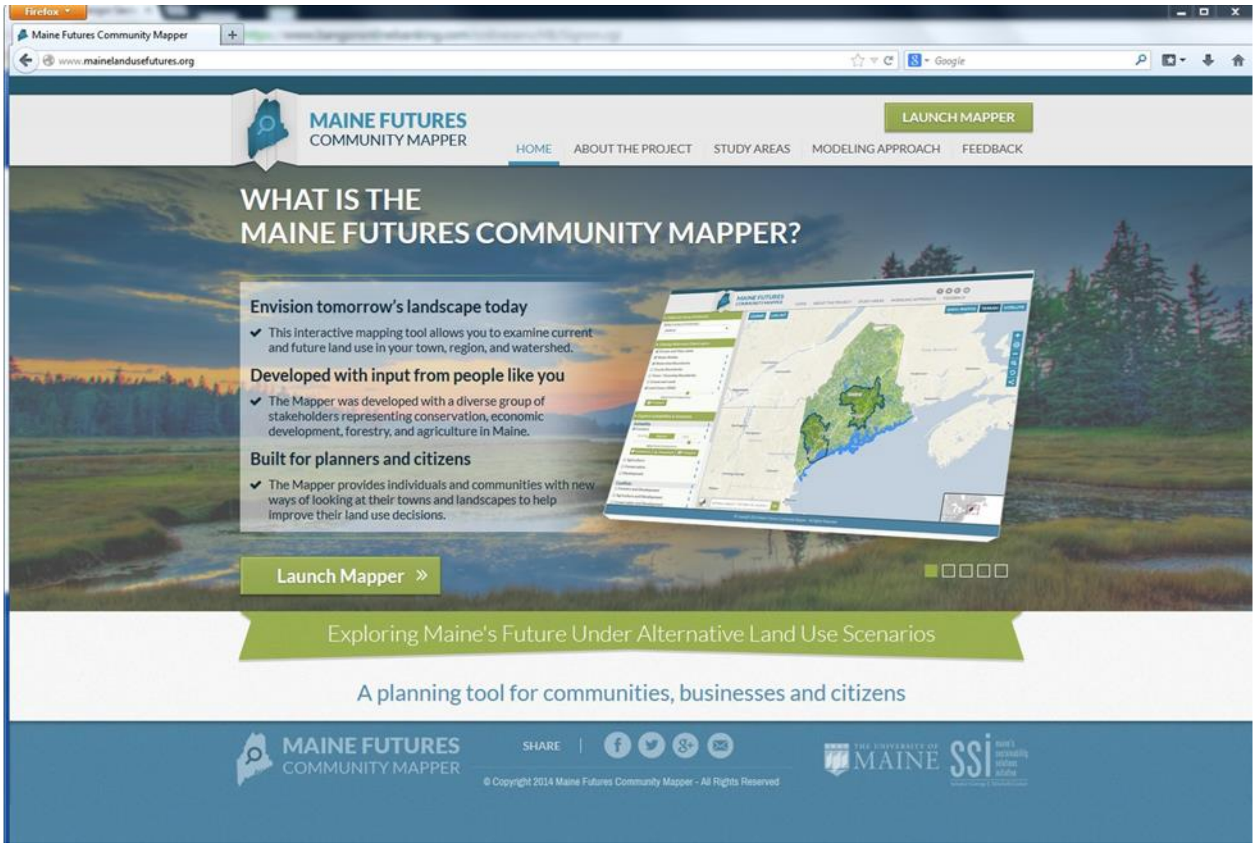


Figure 21. *The Maine Futures Community Mapper (www.MaineLandUseFutures.org) is a community-based spatial planning tool for natural resource management and conservation.*

Howland Research Forest

The CRSF is home to the Howland Research Forest. The Howland Forest is a continuously operating forest ecosystem research site estab-lished in 1986 by University of Maine researchers with the cooperation of International Paper. It is located approximately 30 miles north of Orono, Maine, and situated within an expansive low elevation conifer/northern hardwood transitional forest.

Initially funded to conduct biogeochemical cycling and acid rain research, Howland Forest has since been host to various model and sensor development efforts as well as numerous studies focusing on nutrient cycling, forest ecology, ecosystem modeling, acid deposition, remote sensing, climate change, and carbon sequestration. Howland Forest, with its long fetch and low surface roughness, is an ideally situated tower research site for micro-meteorological measurements. With infrastructure in place and a comprehensive data train of ecological monitoring from below the soil to above the tree canopy, the site continues to attract scientists from around the globe associated with numerous universities, independent research organizations, and federal agencies (such as the USDA Forest Service, NOAA, NASA, EPA, DOE, and DOD).

Already a member of several research networks, Howland Forest became the first base site for the Ameriflux network in 1996. The current research focus is based around our ability to measure the flux of carbon dioxide (i.e. the forest-atmosphere exchange). This, along with the many ancillary ecological and atmospheric data measurement systems, provides valuable information about how the landscape breathes and grows, and is the foundation for related research to further our understanding of how the environment works. Howland Forest is managed by the Environmental Physics group of the University of Maine, and is currently funded by the Department of Energy through its Ameriflux program and the USDA Forest Service through its Global Change Program.

Research Scientist Holly Hughes atop the Howland Tower.
Photo courtesy Dave Hollinger, USDA Forest Service.

US Forest Service Joint Venture Agreement to Support AmeriFlux Research at the Howland Forest

Dr. Shawn Fraver, Assistant Professor, University of Maine; John Lee, Research Associate, University of Maine; Holly Hughes, Research Associate, University of Maine; Aaron Teets, Scientific Research Specialist, University of Maine

Collaborators: Dave Hollinger, US Forest Service, Northern Research Station, Durham, NH; Andrew Richardson, Harvard University, Cambridge, MA; Kathleen Savage, Woods Hole Research Center, MA; Eric Davidson, Appalachian Laboratory, Frostburg, MD; Northeast Wilderness Trust, Montpelier, VT.

Summary

The AmeriFlux network is a nation-wide set of research sites measuring fluxes of CO_2, water, energy, as well as other terrestrial processes, to quantify and understand carbon sources and sinks and the response of terrestrial ecosystems to climate and disturbance. The Howland Research Forest, Maine, is one of the Core Sites of the AmeriFlux program. The general expectations for Core Sites include providing high quality data with long-term duration, participating cooperatively in the network, and being responsive to Department of Energy requests.

Project Objectives

The primary objective of this project is to support ongoing research activities at the Howland Research Forest, Maine. These activities include (1) providing overall technical support for the CO_2 flux, meteorological, soil flux, and ecological activities associated with the Howland Forest AmeriFlux site, (2) assisting with sensor calibration, telecommunications, flux calculations, data processing, and ecological measurements, (3) Ensure adequate communication between the University of Maine and Forest Service personnel regarding project status, (4) sharing data freely with the AmeriFlux Management Project, and various AmeriFlux data reposi-tories, and (5) providing general upkeep and safety of the Howland Forest site, including liaising with the Howland Forest landowner.

Approach

The project objectives are met through the work of two full-time Research Associates, John Lee and Holly Hughes. In addition, the infrastructure and continuous, long-term data at Howland Forest provide an ideal framework for graduate student research, which is conducted through the School of Forest Resources. Such research allows us to address additional questions complementary to the core Ameriflux mission, thereby expanding the project’s reach and scope. Recent graduate students on this project include Aaron Teets (M.S. completed December, 2016) and Erin Fien (M.S., current).

Key Findings / Accomplishments

The Howland Forest site has had continuous atmosphere-forest canopy CO_2 flux data since 1996, making it the second longest running flux site in North America.

Future Plans

Ensure continuous data streams from the Howland Forest site.

Awards

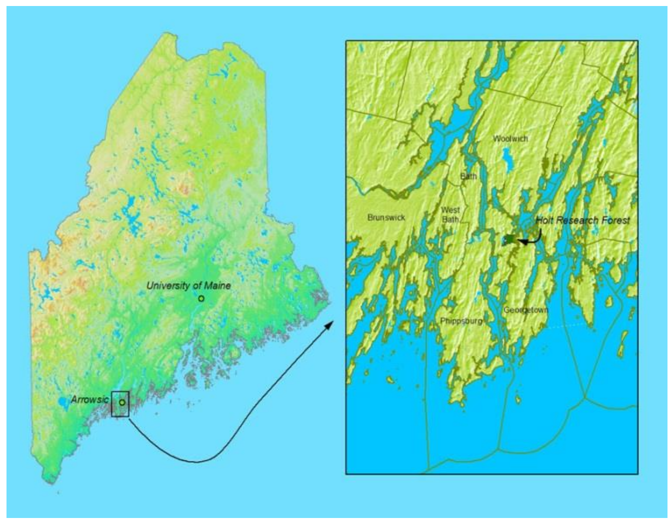
Dwight B. Demeritt Award for undergraduate excellence, awarded to Hunter Manley (Field Assistant at the Howland Research Forest), 2017.

Howland Research Forest 2016 field crew. *Photo courtesy Aaron Teets.*

Holt Research Forest

The CRSF welcomed Holt Research Forest (HRF) into its fold in 2016. HRF has been the site of a long-term pine-oak forest ecosystem study continuously since 1983, collecting data on trees and regeneration, small mammals, and a variety of avian species. Research has been conducted at the site by a number of multi-disciplinary teams of scientists from the University of Maine's College of Natural Sciences, Forestry, and Agriculture since its inception. The Holt Woodland Research Foundation, established specifically to support this project, provided the vast majority of the funding until 2014 when the foundation was merged into the Maine TREE Foundation, which continues to support the site.

Located in Arrowsic, an island town in the Kennebec Estuary, HRF is approximately 100 miles southwest of Orono. The site is situated between a fresh water pond and an estuarine river and includes approximately 300 acres of forest and 50 acres of wetlands, mostly salt marsh. This region has the greatest woody plant species richness in the state in part because it falls within the transition between the Northeastern coastal forest to the west and south and the New England/Acadian forest to the east and north.



Research and Management

The HRF research plan has two goals: (1) to monitor long-term changes in animal and plant populations and (2) to document the effects of forest management on these species. In concert with these goals, the HRF endeavors to provide a continued economic return from the sale of forest products; maintain and improve the diversity and abundance of wildlife; and maintain and improve the aesthetic appeal of the forest.

Continuous, long-term data sets in ecology such as the one at HRF are rare and unusually valuable. Most ecological research operates in time scales of 2-5 years, driven by cycles of funding and graduate projects, while ecological processes often occur over decades. The HRF is the only operating oak-pine research forest in Maine and it is one of only two forests (with the Harvard Forest) dedicated to oak-pine research in the Northeast. Though the oak and pine forest types represent only 10% of Maine's forestland, over 80% of the forest cover in Maine's southern counties is oak pine types and it is responsible for a significant portion of Maine's total forest economy.

Furthermore, the HRF is located in the part of the state that has the greatest human population density and fastest growth. Land management in this region requires a balance between human habitat needs and ecological values. HRF is well situated for public outreach and to convey the importance of sustainable forest management to a large audience.

Photo courtesy Jack Witham.

The primary study area is 40ha overlaid with a well-marked grid system. The 25 x 25 m resolution study grid has allowed for the development of an extensive spatial database of many components including oak-pine ecosystem types, 20ha of stemmed mapped trees, high intensity soils maps, forest canopy gaps, bird territories, and more. Areas of study include these components as well as yearly seed and seedling data, sapling counts and mapping, plant species distribution and coverage, salamander and small mammal abundance, 100% tree tallies, and other ecologically important components.

Working with several graduate students through the Barbara Wheatland Geospatial Lab at the University of Maine, new high resolution imagery and HRF stemmed map data is being utilized to help ground truth the data. In addition, NASA has tested its new Goddard's LiDAR, Hyperspectral & Thermal Imager (G-LiHT) portable imaging system for the second time at the Holt Research Forest, with the most recent flight being in the early summer of 2015.

The Holt Research Forest has hosted numerous cooperating researchers, a variety of training opportunities for graduate and undergraduate students, and several public service and outreach activities to the community. Graduate and undergraduate students have made up a significant portion of the work force, carrying out much of the field work that forms the 35 year database. To date, more than 20 research scientists have studied here or used Holt Research Forest data, over 100 students have had career building work experience, and some 1,000 people including natural resource professionals, small woodlot owners, and the interested public have attended workshops and other educational programs here.

Holt Research Forest holds promise as a site to examine many relevant current and emerging issues in Maine's forest community. Recent accomplishments include an NSF - Field Station and Marine Lab planning grant which is being used to develop a strategic plan to layout research, management, and outreach and education goals for the second 35 years.

From forest dynamics as it relates to climate change, public health issues with vector-borne diseases, forest and landscape fragmentation, as well as the continuing issue of integrating commodity production with maintaining ecological integrity which has always motivated research activities at the HRF, and will continue to do so.

Photo courtesy Jack Witham.

Penobscot Experimental Forest

The Penobscot Experimental Forest (PEF) is one of 80 experimental forests and ranges nationwide designated by the Chief of the U.S. Forest Service for long-term ecology and management research. Land for the PEF was purchased in 1950 by nine pulp, paper, and land-holding companies and leased to the Northeastern Forest Experiment Station (now the Northern Research Station) of the U.S. Forest Service as a site for long-term forest management research in the northeastern spruce-fir forest. In 1994, the industrial owners of the PEF donated the land to the University of Maine Foundation. When the PEF was donated, the industrial owners stated that the mission of the forest is: to afford a setting for long-term research conducted cooperatively among Forest Service scientists, university researchers, and professional forest managers in Maine; to enhance forestry education of students and the public; and to demonstrate how the timber needs of society are met from a working forest. Today, the University of Maine and Northern Research Station manage the PEF under a Joint Venture Agreement.

Forest Characteristics

About 10 miles north of Bangor, Maine, the PEF is in the Acadian Forest, a region covering much of Maine and Atlantic Canada. This is an ecotone between boreal and broadleaf biomes dominated by northern conifers. Red spruce is the signature species. Balsam fir, a boreal species, is at its southern limit, while eastern hemlock and eastern white pine are at their northern limits. Stand-replacing fires are less frequent than in the boreal or other temperate forests. Insect epidemics (e.g., spruce budworm) and windstorms cause sporadic mortality. Most of the forest in the region has been periodically cut since the 18th century; a water-powered sawmill was located on the land that became PEF in the late 1700s.

The Acadian Forest is more compositionally diverse than commercial spruce-fir forests farther north. The canopy is dominated by conifers, including hemlock, spruce (mostly red but some white and black), balsam fir, northern white-cedar, white pine, and an occasional tamarack or red pine. These species often occur as mixedwoods (i.e., in softwood-hardwood mixtures in which neither component contributes more than 75% of basal area). Common hardwoods include red maple, paper and gray birch, and trembling and bigtooth aspen.

Research

The PEF is home to long-term silviculture and ecology research by the Forest Service (1950s to present) and the University of Maine (1990s to present), contributing to sustainable management of working forests in Maine and elsewhere. The Center for Research on Sustainable Forests has partnered with the Forest Service to maintain their large-scale silviculture experiments across 1,000 acres of the PEF. This work includes the Management Intensity Demonstration (1950-present), Compartment Management Study (1952 to present), Biomass (Whole-Tree and Stem-Only) Harvesting Study (1964 to present), Precommercial Thinning x Fertilization Study (1976 to present), and Silvicultural Rehabilitation Study (2008 to present). Treatments are applied at the stand level and include single-tree selection cutting on 5-, 10-, 15-, and 20-year cutting cycles, modified (guiding) and fixed diameter limit cutting, uniform and irregular shelterwood, precommercial and commercial thinning, and commercial and silvicultural clearcutting. Harvesting operations have evolved over time from hand crews with horse or cable skidding to mechanized harvesting with processors, forwarders, or grapple skidding. As such, treatment application and outcomes are relevant to contemporary forest management, and measured response variables include a suite of commodity production and ecological variables.

In addition to collaborating on data collection, analysis, and presentation or publication of the results of PEF research, the Center has supported Forest Service research data and archive management leading to publication of permanent sample plot data from many studies. As a result, the PEF is a national leader in experimental forest data publication and a valuable resource for researchers worldwide interested in using longitudinal forest data in their studies. The PEF is also the location of a Smart Forest network installation, linking wireless sensor data collection across sites.

Education and Demonstration

In addition to a number of demonstration areas, the PEF provides opportunities for training and education of University students and others through field tours, workshops, and summer and school-year employment. Numerous graduate student and faculty research projects have been overlain on the Forest Service experiments, making the PEF a key part of both research and academics at the University.

Publications and Presentations

Refereed Journals

Bothwell, K.N., M.S. Crandall, and A.M. Roth. *In Prep.* The opportunity cost to landowners of managing deer wintering areas in Maine.

Castle, M., Weiskittel A., Wagner, R., Ducey, M., Pelletier, G., and J. Frank. *In Prep.* Variation in hardwood stem form and risk across four commercially important species in the Acadian Forest: Implications for potential sawlog volume and classification systems. Can. J. For. Res.

Castle, M., Weiskittel A., Wagner, R., Ducey, M., Pelletier, G., and J. Frank. *In Prep.* Incorporation of stem form and risk into predictions of tree growth and survival for several northern commercial hardwood species. For. Chron.

Chen, C., Weiskittel, A., Bataineh, M., and MacLean, D.A. 2017. Evaluating the influence of varying levels of spruce budworm defoliation on annualized individual tree growth and mortality in Maine, USA and New Brunswick, Canada. Forest Ecology and Management 396: 184-194.

Eckardt, R., and J.G. Benjamin. 2015. Human-Centric Approaches to the Study of Forest Operations: A Review and Integration of Organizational Science Research Areas. Journal of Forestry 113(2): 248-256.

Frank, J., Castle, M., Westfall, J., Weiskittel A., MacFarlane, D., Baral, S., Radtke, P., and G. Pelletier. *In review.* Variation in occurrence and extent of internal stem decay in standing trees across the eastern US and Canada: Evaluation of statistical approaches and influential factors. Forestry.

Hayashi, R., Weiskittel, A.R., and J.A. Kershaw. 2016. Influence of Prediction Cell Size on LiDAR-Derived Area-Based Estimates of Total Volume in Mixed-Species and Multicohort Forests in Northeastern North America. Canadian Journal of Remote Sensing. 42(5):473-488.

Hiesl, P., Benjamin, J.G. 2015. Estimating Processing Times of Harvesters in Thinning Operations in Maine. Forest Products Journal 65(3-4): 180-186.

Hiesl, P., Benjamin, J.G., and B.E. Roth. 2015. Evaluating harvest costs and profit of commercial thinnings in softwood stands in west-central Maine: A case study. Forestry Chronicle 91(2): 150-160.

Hiesl, P., Waring, T.M., and J.G. Benjamin. 2015. The effect of hardwood component on grapple skidder and stroke delimber idle time and productivity - An agent based model. Computers and Electronics in Agriculture. 118: 270-280.

Kuehne C., Weiskittel A.R., Wagner R.G., and B.E. Roth. 2016. Development and evaluation of individual tree- and stand-level approaches for predicting spruce-fir response to commercial thinning in Maine, USA. Forest Ecology and Management 376: 84-95.

Lilieholm, R.J., C.S. Cronan, M.L. Johnson, S.R. Meyer, and D. Owen. 2014. Alternative Futures Modeling in Maine's Penobscot River Watershed: Forging a Regional Identity for River Restoration. Pg 171-204 in: Levitt, J.N. (ed) Conservation Catalysts: The Academy as Nature's Agent. Lincoln Institute of Land Policy. ISBN 978-1-55844-301-3. 350 p.

Mallampalli, V.R., G. Mavrommati, J. Thompson, M. Duveneck, S.R. Meyer, A. Ligmann-Zielinska, C. Gottschealk Druschke, K. Hychka, M.A. Kenney, K. Kok, M.E. Borsuk. 2016. Methods for Translating Narrative Scenarios into Quantitative Assessments of Land Use Change. Environmental Modelling & Software 82, 7-20. DOI: 10.1016/j.envsoft.2016.04.011

Meyer, S.R., M.L. Johnson, R.J. Lilieholm, and C.S. Cronan. 2014. *Development of a stakeholder-driven spatial modeling framework for strategic landscape planning using Bayesian networks across two urban-rural*

gradients in Maine, USA. Ecological Modelling 291:42-57. DOI: 10.1016/j.ecolmodel.2014.06.023.

Morano, S., E.J. Blomberg, M. Thompson, and S. Fraver. *In Prep*. Bats in Maine Forests: A Review of Ecology, Policy, and Priorities. Maine Policy Review 00:000-000.

Nelson, A.S., Wagner, R.G., Day, M.E., Fernandez, I.J., Weiskittel, A.R., and M.R. Saunders. 2016. Light absorption and light-use efficiency of juvenile white spruce trees in natural stands and plantations. Forest Ecology and Management. 376: 158-165.

Ogawa, R., A. Mortelliti, J. W. Witham, and M. L. Hunter Jr. 2017. Demographic mechanisms linking tree seeds and rodent population fluctuations: insights from a 33-year study. Journal of Mammalogy. Volume 98, 419–427

Simons-Legaard, E.M., Harrison, D.J., and K.R. Legaard. 2016. Habitat monitoring and projections for Canada lynx: linking the Landsat archive with carnivore occurrence and prey density. Journal of Applied Ecology. 53(4): 1260-1269. Castle, M., *Weiskittel, A.*, Wagner, R., Ducey, M., Frank, J., and Pelletier, G. 2017. Variation in stem form and risk of four commercially important hardwood species in the Acadian Forest: Implications for potential sawlog volume and tree classification systems. Canadian Journal of Forest Research, In press.

Teets, A., S. Fraver, D. Hollinger, A. Weiskittel, R.S. Seymour, and A. Richardson. *In Press.* Linking annual tree growth with eddy-flux measures of net ecosystem productivity across twenty years of observation in a mixed conifer forest. *Agricultural and Forest Meteorology*.

Wood, C. M., J. W. Witham, and M. L. Hunter Jr. 2016. Climate-driven range shifts are stochastic processes at a local level: two flying squirrel species in Maine. Ecosphere 7(2):e01240. 10.1002/ecs2.1240

Research Reports

Kuehne C., Weiskittel A., Wagner R., Roth B. 2016. Development and evaluation of stand and individual tree-level growth and mortality modifiers for thinned spruce-fir (*Picea-Abies*) forests of the Acadian Region. In: Roth B.E. (ed.) Cooperative Forestry Research Unit: 2015 Annual Report. University of Maine. Orono, ME. 21-23.

Theses

Anderson, E. K. 2016. Environmental features influencing *Myotis* bat presence in the Penobscot Experimental Forest. Honors Thesis, University of Maine Honors College.

Castle, M.E. 2017. Evaluating the Influence of Stem Form and Vigor on Product Potential, Growth, and Survival for Several Northern Commercial Hardwood Species, Master's thesis, University of Maine

Dunham, S. 2016. Spruce Grouse habitat ecology in Maine's commercially managed Acadian forest. MS Thesis, University of Maine, Orono. 104 p.

Lachance, C. 2016. Influence of logging disturbance on tree growth, species composition, and residual stand damage following harvesting in two Maine spruce-fir stands. M.S. thesis, University of Maine, Orono. 109 p.

Teets, Aaron. 2016. Linking Forest Carbon Sequestration, CO_2 Flux, and Climate: 20 Years of Eddy Covariance Data from the Howland Forest, Maine. M.S. Thesis, School of Forest Resources, University of Maine.

Wesely N.J. 2016. Old-growth Characteristics of Northern White-cedar Stands. M.S. thesis, University of Maine, Orono.

Research Reports, Conference Papers, Presentations/Workshops/Field Tours

Blomberg, E. J. Occupancy Analysis and its Application to Bat Population Monitoring. International Bat Research Symposium., April 2016. Winter Harbor, ME. Oral Presentation.

Blomberg, E. J., S. Morano, and C. Mosby. Monitoring bat populations in Maine: new strategies for citizen science data collection. Northeast Bat Working Group Symposium, January 2016. Baltimore, MD. Conference Paper.

Blomberg, E.J. 2015. Update on current state and federal regulatory decisions related to northern long-eared bats (*Myotis septentionalis*). Cooperative Forestry Research Unit Spring Meeting. 22 April 2015. Orono, ME.

Blomberg, E.J. 2016. Update on current state and federal regulatory decisions related to northern long-eared bats (*Myotis septentionalis*). Cooperative Forestry Research Unit Winter Meeting. 20 January 2016. Orono, ME.

Bose, A. K., Wagner, R.G., Weiskittel, A., and C. Kuehne. 2016. Classification, projection, and financial impact of beech-dominated understories in mid-rotation stands in Maine. Centre for Advanced Forestry Systems meeting. April 26-28, 2015. Pensacola, Florida.

Bose, A. K., Weiskittel, A. and R.G. Wagner. 2016. Beech dynamics, stand archetypes, and management in the Northeast. Presentation, Cooperative Forestry Research Unit Advisory Committee Meeting, April 20, 2016. Bangor, ME.

Bose, A.K., Weiskittel, A.R. and R.G. Wagner. 2016. Climate driven landscape-level changes in key hardwood species occurrence and abundance over the last three decades in forests of Northeastern USA. Presentation at the 8th Eastern ECANUSA Forest Science Conference. September 30th, 2016. Burlington, VT.

Bothwell, K.N. 2016. An Economic Evaluation of Alternative Silvicultural Systems for Managing Deer Wintering Areas in Northern Maine. Maine Cooperative Fish and Wildlife Research Unit Annual Coordinating Committee Meeting, March 23, 2016, Buchanan Alumni Hall, Orono, ME. Poster.

Bothwell, K.N. 2016. An Economic Evaluation of Alternative Silvicultural Systems for Managing Deer Wintering Areas in Northern Maine. New England Chapter Society of American Foresters Annual Winter Meeting, March 2016. Sturbridge, MA. Poster.

Bothwell, K.N. 2016. An Economic Evaluation of Alternative Silvicultural Systems for Managing Deer Wintering Areas in Northern Maine. University of Maine Undergraduate and Graduate Student Research Symposium, April 27, 2016. Cross Insurance Center, Bangor, ME. Poster.

Bothwell, K.N. 2016. An Economic Evaluation of Alternative Silvicultural Systems for Managing Deer Wintering Areas in Northern Maine. Maine Economics Conference, April 30, 2016. Bates College, Lewiston, ME. Poster.

Bothwell, K.N. 2016. Evaluating the Opportunity Cost of Deer Wintering Areas. J.D. Irving Woodlands Representative Visit to the University of Maine, March 1, 2016. Nutting Hall, Orono, ME.

Bothwell, K.N. 2016. White-tailed deer: Biology, Behavior, Economics and Policy. SWIFT: Supporting Women in Forestry Today Field Tour, October 14, 2016. Penobscot Experimental Forest, Bradley, ME.

Castle, M. 2016. Influence of stem form and damage on product potential, growth, and mortality for northern commercial hardwood species. Presentation at the Cooperative Forestry Research Unit Winter Meeting. 20 January 2016. Orono, ME.

Castle, M. and A.R. Weiskittel. 2015. Influence of stem form and damage on product potential, growth, and mortality for northern commercial hardwood species. Presentation on November 16, 2015. Northeastern Mensuration Meeting. Stowe, VT.

Castle, M. and A.R. Weiskittel. 2016. Evaluating the influence of stem form and vigor on volume, product potential and growth for northern commercial hardwood species. Wood QC 2016: Modelling wood quality, supply, and value chain networks, June 16, 2016. Quebec City, Quebec, Canada. Anderson, E., E. J. Blomberg, and S. Fraver. Environmental features influencing Myotis bat presence in the Penobscot Experimental Forest, Central Maine. International Bat Research Symposium, Winter Harbor, ME, April 2016. Poster.

Castle, M. and Weiskittel A.R. 2016. Evaluating the Influence of Stem Form and Vigor on Product Potential, Growth, and Survival for Northern Commercial Hardwood Species. Presentation on November 14, 2016. Northeastern Mensuration Meeting. Concord, Massachusetts.

Castle, M. and Weiskittel A.R. 2016. Evaluating the Influence of Stem Form and Vigor on Product Potential, Growth, and Survival for Northern Commercial Hardwood Species. Presentation on September 30, 2016. ECANUSA meeting. Burlington Vermont.

Castle, M., Weiskittel, A.R., Wagner, R.G. and M. Ducey. 2016. Evaluating the influence of stem form and vigor on product potential, growth, and survival for several northern commercial hardwood species. Presentation at the 8th Eastern ECANUSA Forest Science Conference. September 30th, 2016. Burlington, VT.

Chen, C. 2016. Modeling variation in individual tree defoliation caused by spruce budworm in Maine, USA and New Brunswick, Canada. Northeastern Mensurationist Organization and Southern Mensurationists Group joint annual meeting, Nov. 14, 2016, Concord, MA.

Fien, E, S Fraver, A Teets, D Hollinger. Factors influencing tree mortality risk in a late-successional conifer forest in central Maine, USA. 11th North American Forest Ecology Workshop. Edmonton, Alberta. 20 June, 2017.

Frank, J. and A.R. Weiskittel. 2015. Advancing individual tree biomass prediction: assessment and alternatives to the component ratio method. Presentation on November 16, 2015. Northeastern Mensuration Meeting. Stowe, VT.

Frank, J. and A.R. Weiskittel. 2016. Combining measures of standing hardwood tree form with existing data to improve estimates of internal wood properties across the Acadian Region. Presentation on June 16, 2016. Wood QC 2016: Modelling wood quality, supply, and value chain networks. Quebec City, Quebec, Canada.

Frank, J. and Weiskittel, A.R. An exploration of methods and factors influencing the prediction of occurrence and proportion of rot in trees of the Northeastern United States. Presentation on November 15, 2016. Northeastern Mensuration Meeting. Concord, Massachusetts.

Harrison, D. 2015. Wildlife Projects Update: Snowshoe Hare, Spruce Grouse, and Forest Birds. Presentation, Cooperative Forestry Research Unit Advisory Committee Meeting, October 28, 2015. Houlton, ME.

Harrison, D. 2016. Effects of Management on Relative Densities of Spruce Grouse. Presentation, Cooperative Forestry Research Unit Advisory Committee Meeting, April 20, 2016. Bangor, ME.

Hennigar, C. 2016. Design and performance of an Acadian forest site productivity index. CFRU Technology Workshop. Presentation on Apr 21st. Bangor, ME.

Kenefic, L. Presentation of Chapter 1 findings, "*Northern mixedwood productivity 50 years after biomass harvesting and post-harvest prescribed burning*" at New England Society of American Foresters (NESAF) Meeting (March 9, 2017)

Kenefic, L. Presentation of Chapter 1 findings, "*Stand structure, composition, and carbon stock 50 years after whole-tree and stem-only harvesting in a northern mixedwood forest*" Field tour for SWIFT "A Penobscot Experimental Forest tour and dinner for women in forest resources", Penobscot Experimental Forest (October 14, 2016)

Kenefic, L. Presentation of Chapter 2 findings, "*Quantifying northern mixedwood soil nutrient availability 50 years following biomass harvesting"* at North American Forest Ecology Workshop (NAFEW; June 19, 2017)

Kenefic, L. Presentation, "*Aboveground live-tree biomass and carbon storage 50 years after whole-tree and stem-only harvesting in a northern mixedwood forest*" at Ecological Society of America (ESA) Meeting (August 9, 2016)

Kenefic, L. Presentation, "*Northern mixedwood site productivity 50 years after whole-tree and stem-only harvesting, with and without prescribed burning*" at ECANUSA Meeting (September 30, 2016)

Kenefic, L.S., Wesely, N., Fraver, S., and A.R. Weiskittel. 2016. Northern White-Cedar Research Update. Presentation, Cooperative Forestry Research Unit Advisory Committee Meeting, April 20, 2016. Bangor, ME.

Kenefic, L.S., Wesely, N.J., Fraver S.F. 2016. Structural Characteristics of Old-growth Northern White-cedar Stands. Presentation at the 8th Eastern ECANUSA Forest Science Conference. September 30th, 2016. Burlington, VT.

Kuehne C., Weiskittel A.R., Wagner R.G. 2015. Growth and mortality modifiers for thinned spruce-fir stands of the Acadian Forest. 2015 Northeastern Mensurationists Organization (NEMO) Annual Meeting. Stowe, VT.

Morano, S., E. J. Blomberg, and C. Mosby. Monitoring bat populations in Maine: new strategies for citizen science data collection. The Wildlife Society Annual Conference, October 2016. Raleigh, NC. Poster.

Morano, S., E. J. Blomberg, and C. Mosby. Monitoring bat populations in Maine: new strategies for citizen science data collection. International Bat Research Symposium, April 2016. Winter Harbor, ME. Poster.

Muñoz, B. 2016. Stand structure, composition, and carbon stock 50 years after whole-tree and stem-only harvesting in a northern mixedwood forest. Field tour for SWIFT "*A Penobscot Experimental Forest tour and dinner for women in forest resources*", October 14, 2016, Penobscot Experimental Forest, Bradley, ME.

Muñoz, B., L. Kenefic, A. Weiskittel, I. Fernandez, J. Benjamin, and S. Fraver. 2016. Aboveground live-tree biomass and carbon storage 50 years after whole-tree and stem-only harvesting in a northern mixedwood forest. Ecological Society of America (ESA) Meeting, August 9, 2016, Ft. Lauderdale Convention Center, Fort Lauderdale, FL.

Muñoz, B., L. Kenefic, A. Weiskittel, I. Fernandez. 2016. Northern mixedwood site productivity 50 years after whole-tree and stem-only harvesting, with and without prescribed burning. Eastern CANUSA Meeting, September 30, 2016, University of Vermont, Burlington, VT.

Muñoz, B., L. Kenefic, A. Weiskittel, I. Fernandez. 2017. Northern mixedwood productivity 50 years after biomass harvesting and post-harvest prescribed burning. New England Society of American Foresters (NESAF) Meeting, March 9, 2017, Cross Insurance Center, Bangor, ME.

Muñoz, B., L. Kenefic, A. Weiskittel, I. Fernandez. 2017. Quantifying northern mixedwood soil nutrient availability 50 years following biomass harvesting. North American Forest Ecology Workshop (NAFEW), June 19, 2017, University of Alberta, Edmonton, AB, CAN.

Rahimzadeh-Bajgiran, P., Weiskittel, A. R., Kneeshaw D., and D. MacLean. 2016. A model for spruce budworm defoliation detection and quantification using Landsat imagery. SFR-UMaine/MSG/NASA planning workshop, November 2016. Portland, ME.

Roth, B.E. and D.J. Hayes. 2016. LiDAR and remote sensing research at the CFRU and the University of Maine. Presentation at the LiDAR USGS 3DEP QL2 Kickoff Meeting. May 19th, 2016. Old Town, ME.

Roth, B.E. and E. Sypitkowski. 2015. Statewide LiDAR acquisition Campaign & Single Photon LiDAR Pilot Trial. Presentation, Cooperative Forestry Research Unit Advisory Committee Meeting, October 28, 2015. Houlton, ME.

Roth, B.E., Lachance, C, Wagner, R.G. , and J.G. Benjamin. 2016. Influence of logging disturbance on tree growth, species composition, and residual stand damage following harvesting in two Maine Spruce-fir stands. Presentation at the 8th Eastern ECANUSA Forest Science Conference. September 30th, 2016. Burlington, VT.

Tebbenkamp, J. M., E. Blomberg, D. Harrison, B. Allen, and K. Sullivan. 2016. Spruce Grouse Demography and Population Status in Commercially-Harvested Forests of Northern Maine. Maine Cooperative Fish and Wildlife Research Unit Annual Coordinating Committee Meeting, March 23, 2016. Buchanan Alumni Hall, Orono, ME. Poster.

Teets, A, S Fraver, D Hollinger, R Seymour, A Weiskittel, A Richardson. Linking forest carbon sequestration with annual CO2 flux. 11th North American Forest Ecology Workshop. Edmonton, Alberta. 19 June, 2017. (Fraver presented in place of Teets)

Teets, A, S Fraver, DY Hollinger, RS Seymour, AR Weiskittel. Testing the link between tree-biomass increment and CO_2 flux: 20 years of eddy covariance data from the Howland Forest, Maine. Presentation, Association of American Geographers, San Francisco, CA. 29 March, 2016.

Wagner, R.G. and D. Struble. 2015. Spruce Budworm Task Team Report and Maine L2 Survey. Presentation, Cooperative Forestry Research Unit Advisory Committee Meeting, October 28, 2015. Houlton, ME.

Wagner, R.G., Bose, A. K., and A.R. Weiskittel. 2016. American beech / sugar maple dynamics, stand archetypes, and management in northern hardwood stands of the NE. Optimizing the Hardwood Value Chain: From Seedling to End Product, Northern Hardwood Research Institute, February 17-18, 2016. Edmundston, New Brunswick, Canada.

Weiskittel, A.R. 2016. Modeling the impacts of Spruce Budworm on growth and yield of spruce-fir stands. Presentation at the Cooperative Forestry Research Unit Winter Meeting. 20 January 2016. Orono, ME.

Wesely, N., Cutko, A., and L.S. Kenefic. 2016. Cedar Training.: Presentation and Field Tour for Irving Woodlands, LLC, August 16, 2016. Fort Kent, ME.

Wesely, N., Kenefic, L.S., and S. Fraver. 2016. Cedar Club Meeting: Old-growth northern white-cedar stands. Presentation, Research Meeting, February 17, 2016, Quebec City, Quebec.

Wesely, N., Kenefic, L.S., and S. Fraver. 2016. Old-growth northern white-cedar stands. Presentation, US Forest Service, Northern Research Station, University of Maine Visit, May 17, 2016. Orono, ME.

Posters

Gruselle, M.-C., Fraver, S., Kuehne, C., Fernandez, I.J. 2017. Nitrogen controls on detrital organic matter dynamics in the Northern Forest: Evidence from a 26-year nitrogen addition experiment at the Bear Brook Watershed in Maine. Northeastern Ecosystem Research Cooperative Conference. Saratoga Springs, New York, USA, March 28-29. (Poster).

Gruselle, M.-C., Fraver, S., Puhlick, J.J., Fernandez, I.J., Woodall, C.W. 2017. Buried dead wood: An often overlooked detrital pool in the Acadian Forest? New England SAF - 97th Winter Meeting, Northeastern Forest Pest Council - 79th Annual Meeting, Maine Chapter of The Wildlife Society – 41st Annual Meeting. Adapt, Adopt, Advance: Resiliency in Natural Resource Management. Bangor, Maine, March 8–10. (Poster).

Teets, A, S Fraver, D Hollinger. Linking forest carbon mass increment and CO_2 flux: 20 years of eddy covariance data from the Howland forest, Maine (poster). Poster, Ameriflux Annual Meeting, Golden, CO. 21-23 September, 2016.