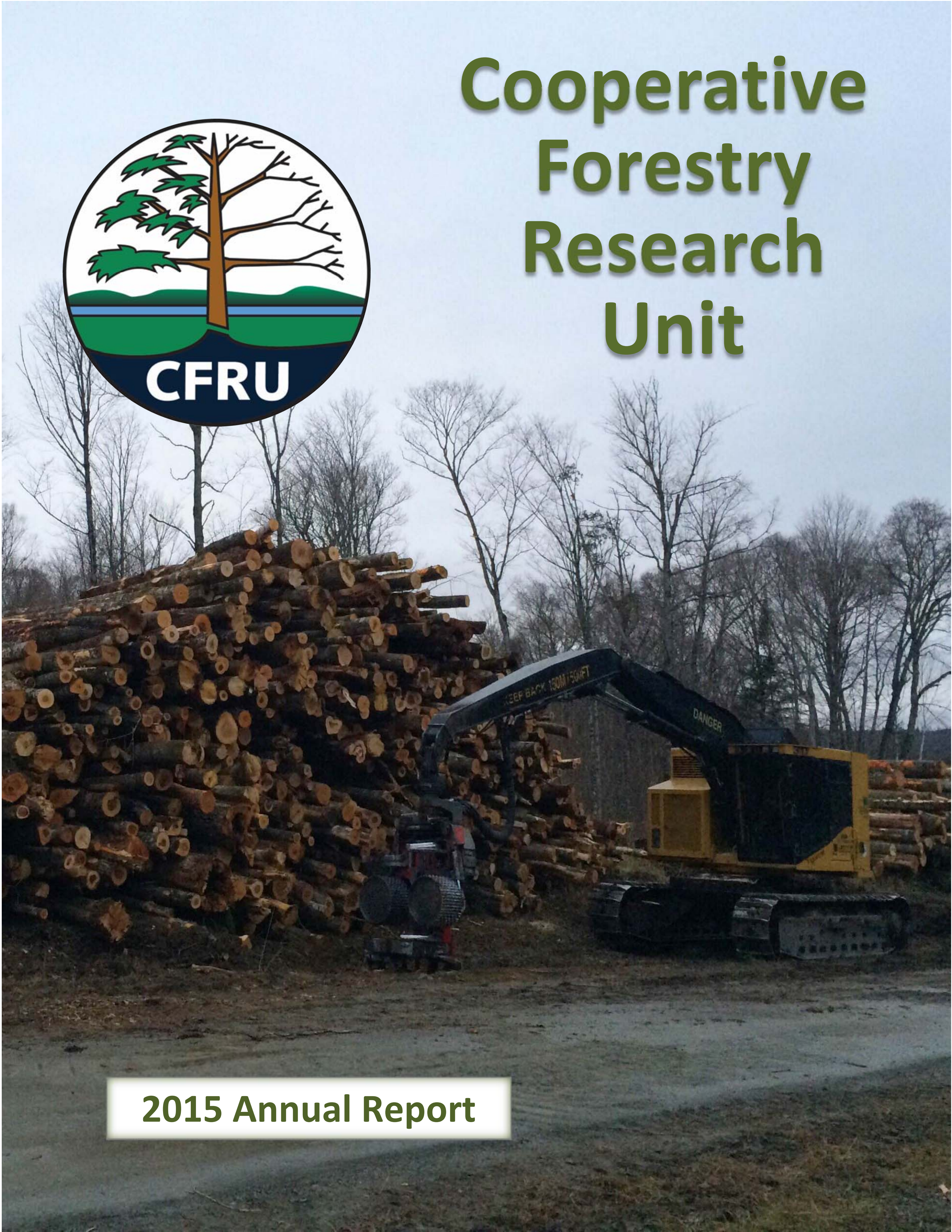
Cooperative Forestry Research Unit

CFRU



2015 Annual Report

Cooperative Forestry Research Unit
2015 Annual Report

Brian E. Roth, Editor

About the CFRU

Founded in 1975, the CFRU is one of the oldest industry/university forest research cooperatives in the United States. We are composed of 36 member organizations including private and public forest landowners, wood processors, conservation organizations, and other private contributors. Research by the CFRU seeks to solve the most important problems facing the managers of Maine's forests.

Cooperative Forestry Research Unit
5755 Nutting Hall
Orono, Maine 04469-5755
http://www.umaine.edu/cfru/

Citation

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Front Page Photo

Tigercat processor (JG Logging of Fort Kent) working on a hardwood crop tree release/overstory removal on the Blanchet Road in T11 R11 WELS in the late autumn of 2015 – photo courtesy of, Emma Schultz (LandVest).

Credits

Design work is done by Pamela Wells of Oakleafs Studio, Old Town, Maine. Individual sections were written by authors as indicated. Photography compliments of CFRU archives, Pamela Wells or as indicated.

A Note About Units

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

2015 CFRU Highlights

- CFRU membership and funding remained relatively stable this year, with 35 member organizations representing half (8.3 million acres) of Maine's commercial forests (See page 11).
- CFRU continued to leverage a wide variety of funding sources to support member research priorities. For every $1 contributed by CFRU's largest members, an additional $18.74 was leveraged from other sources (See page 10).
- CFRU has lead a statewide spruce budworm assessment and preparation plan along with the Maine Forest Service and Maine Forest Products Council (See page 16).
- CFRU in coordination with the Maine office of GIS has leveraged almost $1.5 million for the first phase of LiDAR acquisition to be completed in western Maine in the spring of 2016 (See page 48).

Silviculture & Productivity Research

- Data from the **Commercial Thinning Research Network** was used to develop tree-level thinning treatment response functions for spruce-fir stands, which significantly improve predictions of annual stand-level basal area growth and mortality (See page 21).
- A new research project was initiated to quantify the compositional and structural characteristics of **old-growth Northern White-Cedar** dominated stands and to identify which attributes best differentiate old- from second-growth stands (See page 24).
- A one year project to **revisit Maine's historic tree improvement trials** identified and measured over a dozen field trials that were still intact and useful for growth & yield, climate change and forest productivity research (See page 28).
- Preliminary findings from a study examining the **effects of mechanized harvesting operations on residual stand conditions** demonstrated that the probability of stem wounding was the highest in stands with low removal intensities that had not previously received a PCT treatment (See page 32).

Growth & Yield Modeling Research

- **The influence of tree stem form and defects** on biomass, merchantable volume, diameter increment and survival was evaluated in northern commercial hardwood species; growing stock acceptability (AGS vs. UGS) and diameter were the best predictor of the proportion of rot in a tree while species alone is the best predictor or rot occurrence (See page 38).
- **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; the products are available on the CFRU website for download (See page 43).
- A three year plan **to acquire Statewide LiDAR data** has been implemented with the first year's data to be completed in 2016 (See page 48).

Wildlife Habitat Research

- A multi-year project examining the **relationships among forest harvesting, snowshoe hares, and Canada lynx in Maine** has been completed, and it is apparent that the extent and distribution of high quality hare habitat will drive the long-term dynamics of hares and lynx across the broader landscape (See page 52).
- Results from the first year of a three year project examining **the link between commercial forest management, forest habitat characteristics and population performance of spruce grouse** indicates that selection by adult females at the sub-stand includes lower tree densities, taller trees, greater QMD and higher densities of saplings during the brooding season (See page 57).
- **Forest bird communities** have been found to be most abundant in forests with mature structure (large diameter trees), however, preliminary analysis suggest that both Bay-breasted and Cape May Warblers were associated with regenerating and pre-commercially thinned stands, along with dense canopy cover, high spruce-fir composition and mid-successional stand structure (See page 62) .
- The **effects of moose density on forest regeneration** was investigated by examining the presence and stocking rate of commercial species in softwood, mixed wood and hardwood stands in Maine; relative damage was highest in hardwood stands and declined with age and by age 30 the majority of trees were non-damaged commercial species (See page 72).

Crop Tree Release - Wells Forest – photo Pamela Wells

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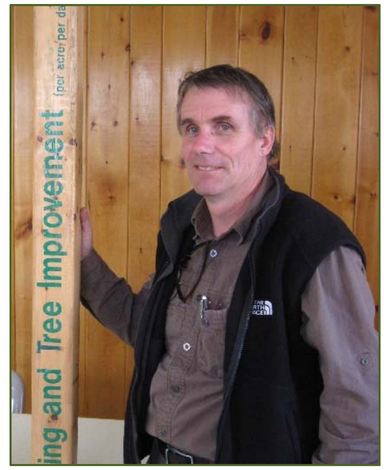
Chair's Report



Greg Adams - CFRU Chair

It is my pleasure to report on another highly productive year in the CFRU which has been distilled down into an excellent overview by **Dr. Brian Roth**, the CFRU team and scientists participating in the wide range of projects. Readers may not want to open the report if there is something that you need to do right away because likely the content will catch your attention for some time. The breadth of projects mirror the complexity of forest management, everything from high-tech (Site Productivity Mapping and LiDAR) through to deep wildlife ecology (Snowshoe Hares and Lynx, Spruce Grouse and Songbird Communities).

The CFRU membership has been made aware that **Dr. Bob Wagner** is leaving the helm of CFRU in August after 18 years at UMaine to assume a leadership role at **Purdue University**. What can I say? Our loss is certainly their gain. Bob has done such an excellent job of directing the CFRU to address the needs and interests of all of our members. He has maneuvered the CFRU through significant challenges including restructuring the Unit, the major land divestitures and ever changing forest management issues. He leaves the CFRU with a much expanded membership and dues base. The organization is well recognized by funding bodies and researchers as being the conduit into real world research needs as demonstrated by the 1:18.74 leveraged funding ratio of CFRU dollars to outside sources reported this year.

Like any good leader, Bob has also been instrumental in bringing highly qualified and engaged people into the University of Maine system. Two examples are Drs. Aaron Weiskittel and Brian Roth, both of whom will be key to carrying on the great work that is done by the CFRU. I wish Bob the very best in his new position and I am sure he will excel. I won't go into any detail on the projects summarized in this year's report, but see for yourself – the CFRU continues to work on important ongoing topics in forest management as well as addressing new issues. Many thanks and congratulations to the whole team.

Greg Adams (JD Irving)
CFRU Chair

Brian Roth, Greg Adams, Aaron Weiskittel, Bob Wagner, David Young and Blake Brunsdon

Robert Wagner, CFRU Director

Director's Report

This is my final annual report as Director of CFRU. After more than 18 years, nearly half of CFRU's 40 years of operation, I bid farewell to all of my friends and colleagues as I move onto lead the **Forestry & Natural Resources Department** at **Purdue University**. It has been an incredible privilege and honor to serve Maine's forestry community as CFRU Director.

I believe that the CFRU is the best invention of **UMaine's** forestry program since it was founded over a century ago. The CFRU is a national model of stakeholder-driven research that has provided critical information to improve forest management and policy across the state and region. The CFRU also has made **UMaine** more relevant by helping create students and faculty with expertise on the most important forest resource issues and challenges of the day. For these reasons, it is vital that **UMaine** and Maine's forestry community continue to keep CFRU strong.

The list of people that I wish to thank over the past 18 years is far too long for this introduction, but I cannot thank the many CFRU members, scientists, staff, and students enough for the pleasure of working with them over the years. We celebrated some important victories together as well as weathered a number of storms together, both of which have made the program what it is today. I am especially proud of the many research, education, and service contributions that we have made in silviculture, forest productivity, forest modeling, forest operations, biodiversity, and wildlife habitat management.

Thank you again for the wonderful opportunity! I will always look back at my years with CFRU and **UMaine** with great pride and fondness.

Robert G. Wagner

Robert G. Wagner
CFRU Director

Robert Wagner – Photo by Maxwell McCormack

Membership

FOREST LANDOWNERS / MANAGERS:

Irving Woodlands, LLC
Wagner Forest Management
BBC Land, LLC
Plum Creek Timber Company, Inc.
Prentiss and Carlisle Company, Inc.
Seven Islands Land Company
Clayton Lake Woodlands Holding, LLC
Maine Bureau of Parks & Public Lands
Katahdin Forest Management, LLC
Canopy Timberlands Maine, LLC
The Nature Conservancy
Snowshoe Timberlands, LLC
The Forestland Group, LLC
Baskahegan Corporation
Sylvan Timberlands, LLC
North Woods Maine, LLC
Appalachian Mountain Club
Simorg North Forest LLC
Frontier Forest, LLC
Downeast Lakes Land Trust
Baxter State Park, SFMA
Robbins Lumber Company
Timbervest, LLC
St. John Timber, LLC
EMC Holdings, LLC
Mosquito, LLC
New England Forestry Foundation

WOOD PROCESSORS:

SAPPI Fine Paper
UPM Madison Paper

CORPORATE / INDIVIDUAL MEMBERS:

ReEnergy Holdings, LLC
James W. Sewall Company
Huber Engineered Woods, LLC
Forest Society of Maine
LandVest
Field Timberlands

ADVISORY COMMITTEE:

Chair
Greg Adams
Irving Woodlands, LLC

Vice Chair
Eric Dumond
ReEnergy Holdings, LLC

Financial Officer
Bill Patterson
The Nature Conservancy, LLC

Member-at-Large
Kenny Fergusson
Huber Resources Corp.
Snowshoe Timberlands, LLC; Sylvan Timberlands, LLC; North Woods ME Timberlands, LLC; St. John Timber, LLC

Members:

Kyle Burdick – *Downeast Lakes Land Trust*
John Bryant – *American Forest Management*
Jason Desjardins – *Canopy Timberlands Maine, Inc. (Orion Timberlands, LLC)*
Tom Charles – *Maine Division of Parks and Public Lands*
Brian Condon – *The Forestland Group, LLC*
Dave Daut – *Timbervest, LLC*
Frank Cuff – *Plum Creek Timber Company, Inc.*
Dave Dow – *Prentiss and Carlisle Company, Inc.*
Gordon Gamble – *Wagner Forest Management*
Alec Giffen – *New England Forestry Foundation*
Brian Higgs – *Baskahegan Corporation*
Eugene Maher – *Frontier Forest, LLC; Clayton Lake Woodlands Holding, LLC; Simorg North Forests, LLC; EMC Holdings, LLC (LandVest)*
Kevin McCarthy – *SAPPI Fine Papers*
Marcia McKeague – *Katahdin Forest Management, LLC*
Wil Mercier – *J.W. Sewall Company*
Jacob Metzler – *Forest Society of Maine*
Eben Sypitkowski – *Baxter State Park*
Ian Prior – *Seven Islands Land Company*
David Publicover – *Appalachian Mountain Club*
Butch Barberi – *Madison Paper Industries*

Research Team

Ring-necked Ducks

Staff

Robert Wagner, PhD, CFRU Director
Brian Roth, PhD, Associate Director
Cynthia Smith, Administrative Specialist

Cooperating Scientists

Jeffrey Benjamin, PhD, Assistant Professor of Forest Operations
Daniel Harrison, PhD, Professor of Wildlife Ecology
Aaron Weiskittel, PhD, Assistant Professor of Forest Biometrics and Modeling

Project Scientists

Lee Allen, PhD, ProFOR Consulting
Erik Blomberg, PhD, University of Maine
Shawn Fraver, PhD, University of Maine
Laura Kenefic, PhD, USDA U.S. Forest Service, Northern Research Station
Christian Kuehne, PhD, University of Maine
Chris Hennigar, PhD, University of New Brunswick
Laura Leites, PhD, Pennsylvania State University
Cynthia Loftin, PhD, USGS Maine Cooperative Fish and Wildlife Research Unit
Sabrina Morano, MS, University of Maine
Peter Pekins, PhD, University of New Hampshire
Fred Servello, PhD, University of Maine
Daniel Walters, US Geological Survey
Petra Wood, PhD, USGS West Virginia Cooperative Fish and Wildlife Research Unit
Joseph Young, Maine Office of GIS

Graduate Students

Mark Castle (MS student – Weiskittel) – Hardwood stem form & vigor
Steven Dunham (MS student - Harrison) - Spruce grouse habitat
Cody Lachance (MS student – Wagner/Roth) – Mechanized harvesting conditions
Brian Rolek (PhD student - Harrison) - Bird communities
Joel Tebbenkamp (PhD student – Harrison) – Spruce grouse habitat
Nathan Wesley (MS student – Kenefic/Fraver) – Old growth cedar

Photo Pamela Wells

Financial Report

Robert Wagner,
CFRU Director

Photo - Pamela Wells

Thirty-five members representing 8.26 million acres of Maine's forestland contributed $508,239 to support the CFRU this year (**Table 1**). These member contributions will be used to support research activities during FY 2015-16. The amount of acreage by our Landowner/Manager members decreased by 34,746 acres (0.4%) following land sales and purchases this year. A significant addition this year was welcoming **James W. Sewall Company** as a new Corporate member of the CFRU. We look forward to working with **Sewall** in the coming years. Tons of wood products produced by Wood Processor members decreased (6,000 tons or 0.3%) relative to last year, despite the loss of **Old Town Fuel & Fiber**. With all of these changes, overall CFRU member contributions remained stable (a $3,214 or 0.6% increase) relative to FY 2013-14. We thank all of our members for their continued financial and in-kind contributions, as well as the trust in the CFRU and UMaine that these contributions represent.

In addition to member financial contribution, CFRU Cooperating and Project Scientists were successful at leveraging an additional $371,913 in extramural grants to support CFRU research projects. This amount does not include $1,423,153 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)**, which is supporting the Commercial Thinning Research Network and Growth & Yield modeling projects. These external grants made up 32% of CFRU total income this year (Fig. 1). In addition to extramural sources, UMaine provided $157,777 in direct support to CFRU projects in the form of graduate research assistantships and summer student salaries. Reduced indirect charges by the university on CFRU research projects contributed another $116,358. Therefore, UMaine provided an additional $274,135 or 24% of total funding. In total, about 66% ($646,048) of all CFRU funding came from external sources or from direct and indirect support from UMaine.

As a result, for every $1 contributed on average by CFRU's five largest members (**Irving Woodlands, Wagner Forest Management, BBC Land, Plum Creek Timber Company, and Prentiss & Carlisle**) this year, $7.13 was received from other CFRU member contributions, $6.68 was contributed by external grants through CFRU scientists, and $4.92 was received from UMaine in direct and indirect contributions; for a ***total leveraging of $18.74 for every $1 contributed by CFRU's largest members***.

Continued sound fiscal management by CFRU scientists and staff resulted in spending $33,220 (6.6%) less than the $502,989 that was approved by the Advisory Committee for this fiscal year (**Table 2**). Most projects came in at or near budget. About one third of the CTRN budget was not spent, since the installation of mixedwood installations in the original proposal was not carried out. The PI's felt that an entirely new project would be necessary for mixedwood studies (a comprehensive proposal will be presented to the Advisory committee in the spring of 2016 for consideration). The 'Effects of Mechanized Harvesting Operations on Residual Stand Conditions' project of **Dr. Jeff Benjamin's** was reduced following his departure**. Drs. Bob Wagner** and **Brian Roth** presented a revised proposal at the

January 2015 Advisory Committee which was approved. **Dr. Bob Wagner** requested that the $33,220 surplus in the research projects budget be directed towards the purchase of replacement vehicles in the CFRU Fleet. This request was approved at the October 2015 Advisory Committee meeting in Houlton, ME.

CFRU research expenses by category this year included 32% on four silviculture & productivity projects, 26% on three growth & yield modeling projects, and 42% on four wildlife habitat projects (**Figure**).

Table 1. CFRU member contributions received FY 2014-15 (for allocation during FY 2015-16).

CFRU Member	FY14-15		FY15-16		Changes Acres/tons	Assessed Amount	Received as of 11/17/2015	% Receieved
FOREST LANDOWNERS / MANAGERS:								
Irving Woodlands, LLC	1,255,000	acres	1,255,000	acres	0	$68,804	$68,804	100.0%
Wagner Forest Management	1,121,515	acres	1,129,024	acres	7,509	$62,404	$62,404	100.0%
BBC Land, LLC	971,178	acres	973,230	acres	2,052	$54,423	$54,423	100.0%
Plum Creek Timber Company, Inc.	884,000	acres	865,000	acres	-19,000	$48,655	$48,655	100.0%
Prentiss and Carlisle Company, Inc.	810,722	acres	778,166	acres	-32,556	$44,026	$44,026	100.0%
Seven Islands Land Company	746,791	acres	746,791	acres	0	$42,354	$42,354	100.0%
Clayton Lake Woodlands Holding, LLC	451,160	acres	464,178	acres	13,018	$27,108	$27,180	100.3%
Maine Bureau of Parks & Public Lands	407,000	acres	407,000	acres	0	$23,769	$23,769	100.0%
Katahdin Forest Management, LLC	301,000	acres	299,000	acres	-2,000	$17,462	$17,462	100.0%
Canopy Timberlands Maine, LLC	294,179	acres	294,179	acres	0	$17,180	$17,180	100.0%
The Nature Conservancy	170,985	acres	158,723	acres	-12,262	$9,269	$9,269	100.0%
Snowshoe Timberlands, LLC	137,720	acres	137,720	acres	0	$8,043	$8,043	100.0%
Baskahegan Corporation	117,738	acres	117,953	acres	215	$6,888	$6,888	100.0%
Sylvan Timberlands, LLC	105,510	acres	105,510	acres	0	$6,162	$6,162	100.0%
North Woods Maine, LLC	83,409	acres	83,409	acres	0	$4,871	$4,871	100.0%
The Forestland Group, LLC	70,525	acres	70,525	acres	0	$4,119	$4,119	100.0%
Appalachian Mountain Club	65,489	acres	65,489	acres	0	$3,825	$3,825	100.0%
Simorg North Forests, LLC	61,643	acres	61,643	acres	0	$3,600	$3,600	100.0%
Frontier Forest, LLC	53,338	acres	53,338	acres	0	$3,115	$3,115	100.0%
Downeast Lakes Land Trust	33,708	acres	33,808	acres	100	$1,974	$1,974	100.0%
EMC Holdings, LLC	23,526	acres	31,689	acres	8,163	$1,851	$1,851	100.0%
Baxter State Park, SFMA	29,537	acres	29,537	acres	0	$1,725	$1,725	100.0%
Robbins Lumber Company	26,771	acres	26,786	acres	15	$1,564	$1,564	100.0%
Timbervest, LLC	25,191	acres	25,191	acres	0	$1,471	$1,471	100.0%
St. John Timber, LLC	24,617	acres	24,617	acres	0	$1,438	$1,438	100.0%
Mosquito, LLC	16,222	acres	16,222	acres	0	$947	$1,000	105.6%
New England Forestry Foundation	2,852	acres	2,852	acres	0	$1,000	$1,000	100.0%
TOTAL	8,291,326	acres	8,256,580	acres	-34,746	$468,047	$468,172	100.0%
WOOD PROCESSORS:								
SAPPI Fine Paper	1,850,400	tons	1,850,400	tons	0	$23,500	$23,500	100.0%
UPM Madison Paper	342,000	tons	336,000	tons	-6,000	$4,267	$4,267	100.0%
TOTAL	2,192,400	tons	2,186,400	tons	-6,000	$27,767	$27,767	100.0%
CORPORATE and INDIVIDUAL MEMBERS:								
ReEnergy Holdings, LLC	1	static	1	static		$5,000	$5,000	100.0%
James W. Sewall Company	1	static	1	static		$5,000	$5,000	100.0%
Huber Engineered Woods, LLC	1	static	1	static		$1,000	$1,000	100.0%
Forest Society of Maine	1	static	1	static		$1,000	$1,000	100.0%
LandVest	1	static	1	static		$200	$200	100.0%
Field Timberlands	1	static	1	static		$100	$100	100.0%
TOTAL						$12,300	$12,300	100.0%
GRAND TOTAL (35 members):						$508,114	$508,239	100.0%

Table 2. CFRU expenses incurred during FY 2014-15.

Expense	Principal Investigator	Approved Amount	Amount Spent To-Date	Balance Remaining		% Balance Remaining
Administration:		**$212,609**	**$209,737**	**$2,872**		**1%**
Administration		$196,131	$193,259	$2,872		1%
Update and Overhaul of the CFRU Website		$16,478	$16,478	$0		0%
Research Projects						
Silviculture & Productivity:		**$113,208**	**$84,323**	**$28,885**		**26%**
CFRU Commercial Thinning Research Network: Continued Measurements and New Opportunities	Wagner	$43,742	$31,855	$11,887		27%
1) The Effects of Mechanized Harvesting Operations on Residual Stand Condition	Benjamin	$48,754	$33,947	$14,807		30%
Identifying Attributes that Distinguish Old-and Second-Growth Northern White-Cedar Stands for Forest Management and Planning	Kenefic / Weiskittel	$12,000	$11,783	$217		2%
Revisiting Maine's Tree Improvement and Plantation Trials	Roth	$8,712	$6,737	$1,975		23%
Growth & Yield Modeling:		**$66,587**	**$66,521**	**$66**		**0%**
Assessing the Influence of Tree Form and Damage on Commercial Hardwoods	Weiskittel	$28,828	$28,762	$66		0%
Linking Site Quality to Tree Growth and Survival in the Acadian Forest	Weiskittel	$27,759	$27,759	$0		0%
Maine Statewide Light Detection and Ranging (LiDAR)	Young	$10,000	$10,000	$0		0%
Wildlife Habitat:		**$110,585**	**$109,188**	**$1,397**		**1%**
Long-Term Studies of Snowshoe Hares, Canada Lynx and Forest Structure *	Harrison	$29,207	$29,273	-$66		0%
Population Dynamics of Spruce Grouse in the Managed Forest Landscapes of Northern Maine	Blomberg	$29,456	$29,378	$78		0%
Effects of forest management practices in the Acadian conifer forests of Maine on forest bird communities, with emphasis on species of federal conservation priority	Harrison	$30,032	$29,978	$54		0%
Moose Density and Forest Regeneration Relationships in Maine	Pekins	$21,890	$20,559	$1,331		6%
TOTAL		**$502,989**	**$469,768**	**$33,220**	2)	**7%**

1) Revised downward from $67,676 with proposal modification at the January 2015 Advisory Committee Meeting

2) Director requesting this year's budget surplus to be dedicated to the purchase of a new truck as part of a plan to replace the three oldest CFRU Trucks

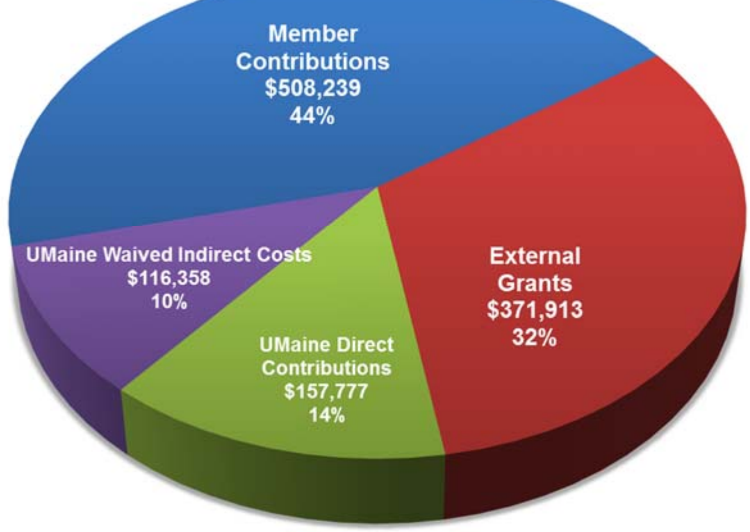


Figure 1. CFRU income sources FY 2014-15.

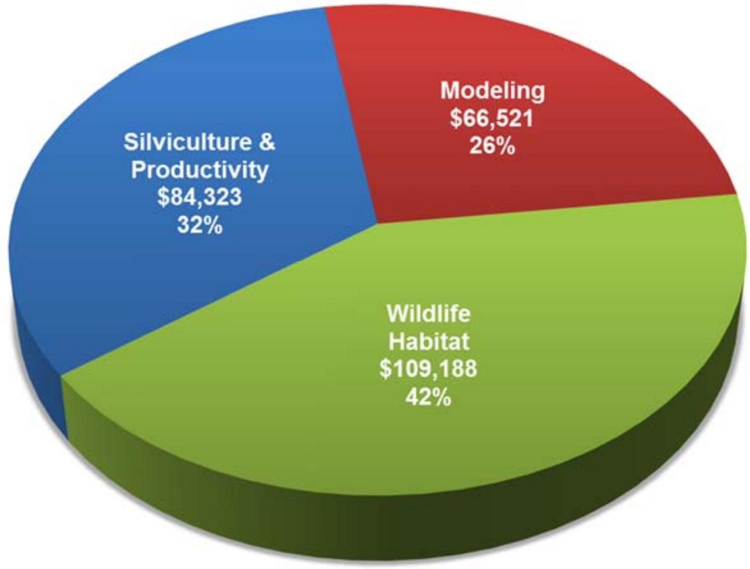


Figure 2. CFRU research expenses FY 2014-15.

Activities

Sundews - photo Pamela Wells

Advisory Committee

The CFRU is guided by our member organizations through an Advisory Committee. The CFRU Advisory Committee elects officers for the Executive Committee for two-year terms in the positions of Chairperson, Vice Chairperson, Member-at-Large, and Financial Officer. The Vice Chairperson serves as Chairperson after one term, and the past Chairperson moves to the position of Financial Officer for one term. 2015 marks the mid-point of the current 2-year term with executive officers as follows: **Greg Adams (JD Irving)** in the position of Chairperson, **Eric Dumond (ReEnergy Holdings, LLC)** as Vice Chairperson, **Bill Patterson (The Nature Conservancy)** Financial Officer, and **Kenny Fergusson (Huber Resources)** as Member-at-Large.

The Advisory Committee meets three times a year for business meetings. The first business meeting of FY 2014-15 was held on October 29, 2014 at the **University of Maine (UMaine)** where there was a discussion on member contribution rate adjustments for inflation. At the second meeting, held on January 21, 2015 at UMaine, five pre-proposals were presented to the Advisory Committee. Of these, all five were approved to advance to the full proposal stage and were presented at the April 22nd, 2015 business meeting. Five projects were approved for funding beginning on October 1, 2015. Look for updates on these projects in future CFRU publications and annual reports. In addition to the business meetings, a special Strategic Planning retreat for CFRU Advisory Committee members was held on February 24th, 2015 where Maine's future forest research priorities were brainstormed and defined. Outcomes will be incorporated into the next CFRU Operating Prospectus.

Cooperators

CFRU membership was remarkably stable in 2014-15 with one new member and only a slight loss in acres managed due to land sales (Table 1). **James W. Sewall Company** joined as a corporate member. Welcome to the CFRU!

Personnel

Drs. Arun Bose and **Christian Kuehne** are working on CFRU projects as Post-Doc's with the support of CAFS. Arun is working on forest regeneration patterns while Christian is using the CTRN dataset to develop thinning modifiers for existing growth and yield models. **Dr. Jeff Benjamin** left UMaine and the CFRU in 2015 to become the headmaster at Bangor Christian Schools. We thank Jeff for his years of service with the CFRU as a Cooperating Scientist and wish him the best in his new academic role. **Cindy Smith** is doing a fantastic job with CFRU administration, while **Dr. Brian Roth** continues to serve as CFRU Associate Director. CFRU Director **Dr. Bob Wagner** is on a one-year sabbatical following his 5-year term as Director of the UMaine's School of Forest Resources and has been focusing on the Spruce Budworm Task Force as well as other projects within the CRSF and CFRU.

2015 Fall Workshop

The CFRU followed up on last year's very popular SBW Fall Workshop with a SBW themed field tour in Northern Maine on October 29th, 2015. The tour was hosted on **Irving Woodlands** property and focused on SBW: and Deer Wintering Areas, commercial thinning and PCT, Early Intervention Strategy, protection strategies and current population updates. Presenters were leading SBW experts from **Quebec, New Brunswick and Maine.** This field tour was attended by nearly 100 CFRU members, stakeholders, State and Federal policy makers.

Students

The CFRU continued to contribute to the development of students, with six graduate students working on CFRU projects this year. **Brian Rolek** completed his PhD on the forest birds project under the direction of **Dr. Dan Harrison**. **Patrick Hiesl**, under the direction of **Dr. Jeff Benjamin,** has completed his PhD on forest harvest productivity and costs. There are currently five graduate students working on CFRU funded projects**: Dr. Harrison** is supervising **Steve Dunham** (MS, Spruce Grouse) and **Joel Tebbenkamp** (Ph.D, Spruce Grouse). **Drs. Bob Wagner and Brian Roth** are co-supervising **Cody Lachance** (MS, stand conditions following mechanized harvesting). **Drs. Laura Kenefic** (USFS) and **Shawn Fraver** are supervising **Nathan Wesely** (MS, characteristics of old-growth cedar). **Dr. Aaron Weiskittel** is supervising **Mark Castle** (MS, Hardwood Stem form Growth & Yield). In addition, almost two dozen undergraduate students were hired as research technicians for CFRU projects during the summer of 2015.

Sundews - Wells Forest

Spruce Budworm Assessment & Preparation Plan

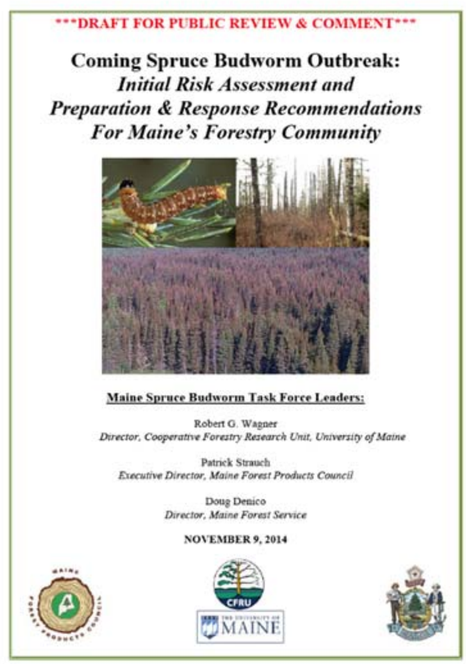
About 40 years ago, the spruce budworm (SBW) was devastating spruce-fir forests across northern Maine. This outbreak was a regional event covering more than 130 million acres across Quebec, Northern New England, and the Maritime Provinces of Canada. That outbreak lasted about 15 years (1970-85) and shaped the forest, forestry politics, and careers of most foresters during this period. It was during this period that the CFRU also was formed to help forest landowners work together with the University of Maine to meet the challenges associated with the SBW.

Returning on a natural 30-60 year cycle, the next outbreak is now at Maine's doorstep. The current outbreak began in Quebec in around 2008 and has spread to cause severe defoliation on over 10 million acres of spruce-fir forest. Insect traps in northern Maine and New Brunswick have captured steadily increasing SBW moth counts over the past several years, and defoliation of spruce-fir stands is within a few miles of Maine's northern border. Therefore, Maine is likely only 2 to 3 years away from seeing the first defoliated trees.

To help Maine prepare for the coming outbreak, the CFRU, Maine Forest Service, and Maine Forest Products Council formed a joint SBW Task Force in 2013. More than 65 experts contributed to task teams this year to address:

- Monitoring strategies,
- Forest management strategies,
- Protection options,
- Policy, regulatory & funding issues,
- Wildlife habitat issues,
- Public communications & outreach, and
- Research priorities.

The findings of the Task Force were compiled into a report that was unveiled at the State House after undergoing a public review. The report includes a detailed risk assessment and nearly 70 recommendations for how Maine's forestry community can begin preparing for and responding to the coming outbreak. The final report is available at: http://www.sprucebudwormmaine.org/



DRAFT FOR PUBLIC REVIEW & COMMENT

Coming Spruce Budworm Outbreak:
Initial Risk Assessment and Preparation & Response Recommendations For Maine's Forestry Community

Maine Spruce Budworm Task Force Leaders:

Robert G. Wagner
Director, Cooperative Forestry Research Unit, University of Maine

Patrick Strauch
Executive Director, Maine Forest Products Council

Doug Denico
Director, Maine Forest Service

NOVEMBER 9, 2014

Center for Advanced Forestry Systems (CAFS)

Bob Wagner and Aaron Weiskittel

The **Center for Advanced Forestry Systems (CAFS)** is funded by the **National Science Foundation (NSF)** Industry/University Cooperative Research Centers Program (I/UCRC) in partnership with CFRU members. This year, **Bob Wagner** and **Aaron Weiskittel** submitted a successful proposal to NSF for the Maine CAFS site to enter Phase II of the I/UCRC. In Phase II, NSF will provide $60,000 per year for 5 years if CFRU members contribute a minimum of $350,000 per year. Phase 1 of CAFS contributed $70,000 per year to the **University of Maine** since CFRU members contributed a minimum of $300,000 per year to support the work of the site.

CAFS unites nine university forest research programs with forest industry members across the US 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.

Two new CAFS projects were funded this year (15.59 & 15.64). Project 15.59 supports Post-Doc, Dr. Arun Bose's research on the classification, projection, and financial impact of beech-dominated understories in mid-rotation stands in the northeast. Project 15.64 supports Post-Doc, Dr. Christian Kuehne's research on the impact of commercial thinning on the growth response and upper diameter distribution potential of commercial forest stands.

CFRU staff and several Advisory Committee members represented the Maine CAFS site at the Eighth Annual CAFS Industrial Advisory Board (IAB) Meeting held May 19-21, 2015 in **Asheville, North Carolina**. The meeting was well attended by scientists, graduate students, and forest industry representatives who met to review and approve all CAFS projects nationwide. CFRU looks forward to another 5-years of collaboration with the NSF I/UCRC through CAFS.

NC STATE UNIVERSITY

Oregon State University OSU

PURDUE UNIVERSITY

AUBURN UNIVERSITY

The University of Georgia

University of Idaho

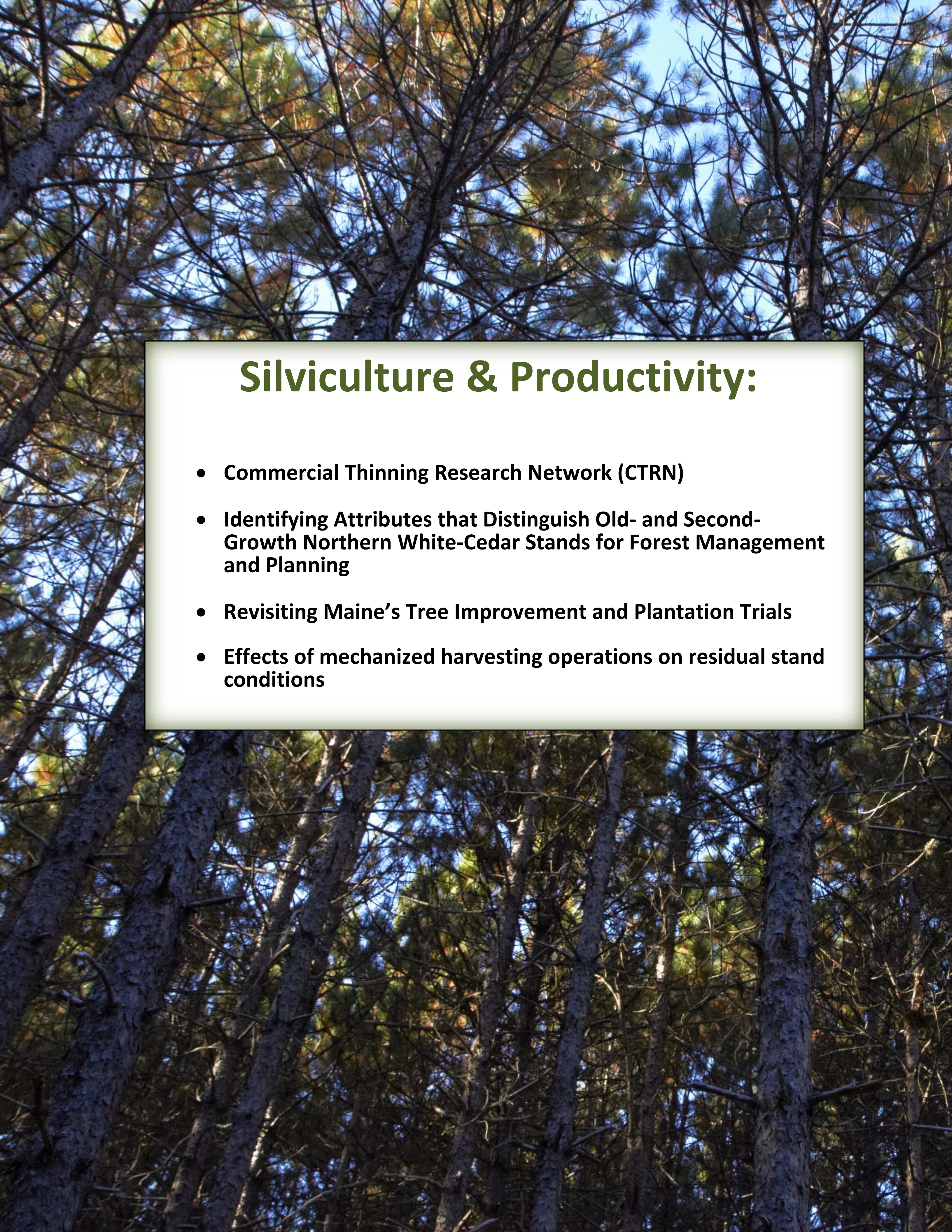
1865 THE UNIVERSITY OF MAINE

UNIVERSITY of WASHINGTON

VirginiaTech

Common Yellow-throated Warbler - Photo Pamela Wells

Research Project Reports



Silviculture & Productivity:

- Commercial Thinning Research Network (CTRN)
- Identifying Attributes that Distinguish Old- and Second-Growth Northern White-Cedar Stands for Forest Management and Planning
- Revisiting Maine's Tree Improvement and Plantation Trials
- Effects of mechanized harvesting operations on residual stand conditions

Commercial Thinning Research Network (CTRN)

Christian Kuehne, Aaron Weiskittel, Robert Wagner, Brian Roth

University of Maine

Status: Progress Report, Year 3 of 4

Crop Tree Release

Summary:

The Commercial Thinning Research Network (CTRN) examines commercial thinning (CT) responses in Maine spruce-fir stands. There were two experiments established in 2000 with additional ones beginning in 2011. The initial experiments consisted of 12 study sites across Maine examining response in pre-commercially thinned (PCT) balsam fir stands (6 sites) and mature spruce-fir stands not receiving PCT (6 sites). The PCT study quantified the growth and yield responses from the timing of first CT (i.e., now, delay five years, and delay 10 years) and level of residual relative density (i.e., 33% and 50% relative density reduction). The no-PCT study is designed to quantify the growth and yield response from commercial thinning methods (i.e., low, crown, and dominant) and level of residual relative density (i.e., 33% and 50% relative density reduction). Beginning in 2011, the CTRN was expanded to include previously established thinning studies, such as the Early Commercial Thinning (ECT) and Austin Pond Third Wave projects. These experiments also have the advantage of unit area replication within locations, which is absent in the first three experiments.

Key findings this year: Individual tree-level thinning treatment response functions for spruce-fir stands were developed and evaluated and were shown to significantly improve predictions of annual stand-level basal area growth and mortality. When the developed thinning modifiers were included in stand- and individual-tree growth models, a significant improvement in prediction over baseline models was achieved, yet the individual-tree approach was superior for predicting long-term response to various thinning treatments (Fig 3.).

Project Objectives:

Develop and evaluate stand and individual tree-level growth and mortality modifiers for thinned spruce-fir (*Picea-Abies*) forests of the Acadian Region using a series of regional, comprehensive, multi-year, and replicated thinning studies. Specifically:

- develop annual thinning response modifiers for stand-level basal area growth, dominant height increment, and mortality

- establish annual and species-specific thinning response modifiers for individual-tree diameter, height, and height to crown base increment as well as mortality

- evaluate predictions of thinning response across a range of treatments using both the stand- and individual tree-level modifiers

Approach:

Measurements from 16 study locations across northern Maine, which are part of the University of Maine's Cooperative Forestry Research Unit's Commercial Thinning Research Network (CTRN) were used for this investigation. Individual tree response to treatments were modeled as modifiers of baseline equations.

Key Findings / Accomplishments:

- Individual tree-level thinning treatment response functions for spruce-fir stands were developed and evaluated and were shown to significantly improve predictions of annual stand-level basal area growth and mortality.

- Additional improvement was demonstrated for species-specific, individual tree-level annual diameter increment, height to crown base increment, and mortality functions.

- The duration and magnitude of these response functions were significantly influenced by thinning intensity and to a lesser extent by thinning method.

- In contrast, modifiers for stand-level dominant height increment and tree-level height increment did not show significant improvement when compared to the baseline model.

- When the developed thinning modifiers were included in stand- and individual-tree growth models, a significant improvement in prediction over baseline models was achieved, yet the individual-tree approach was superior for predicting long-term response to various thinning treatments.

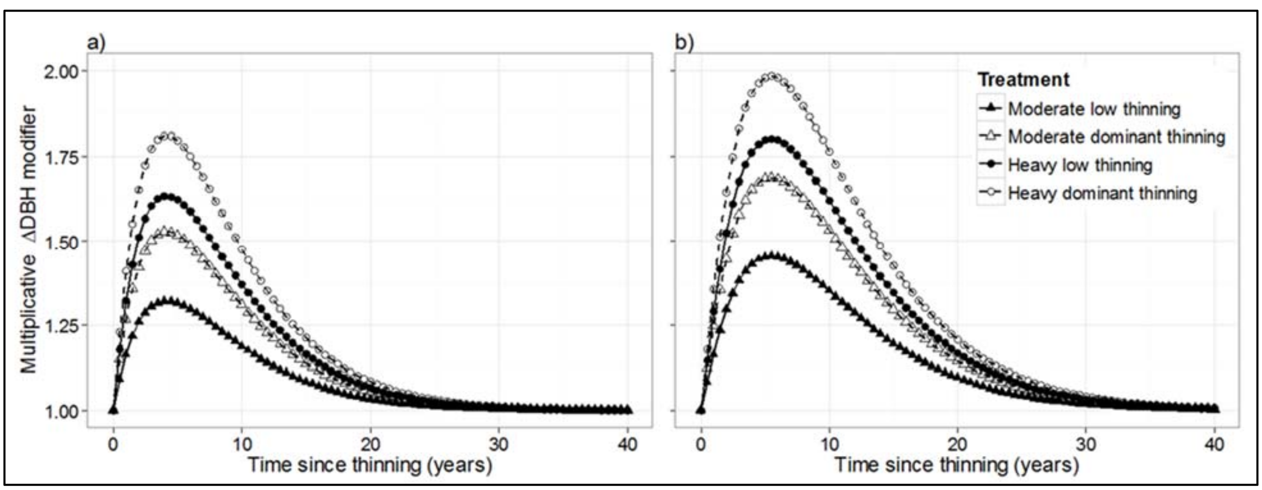


Figure 3. *Individual tree-level annual DBH increment (ΔDBH) thinning-response functions for exemplary moderate and heavy (25% or 50% basal area removal, respectively) low or dominant thinnings (QMD ratio = 0.7 or 1.1, respectively) for a) balsam fir and b) red spruce.*

Future Plans:

Future work will focus on better quantifying individual-tree responses using distance-dependent competition indices that can effectively capture the spatial and compositional variability created by thinning. Spatial data from remote sensing imagery and LiDAR will be used in this analysis.

Products Delivered:

Journal Publications:

Kuehne, C., A.R. Weiskittel, R.G. Wagner, 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. Accepted in Forest Ecology and Management.

Conferences:

Roth, B.E.. 2015. Herbicide, PCT and Commercial Thinning in the CTRN & Austin Pond Studies. NERCOFE Workshop, March 10^{th}, Wells Conference Center, University of Maine. Orono, ME.

Hiesl, P., J.G. Benjamin, and B.E. Roth. 2015. PCT/non-PCT Study: Austin Pond – a Case Study. NERCOFE Workshop, March 10^{th}, Wells Conference Center, University of Maine. Orono, ME.

Theses:

Hiesl, P. 2015. Forest Harvesting Productivity and Cost in Maine: New Tools and Processes. Ph.D. Dissertation, University of Maine, Orono. 142 p.

Partners / Stakeholders / Collaborators:

- Appalachian Mountain Club
- Baskahegan Corporation
- BBC Land, LLC
- Irving Woodlands, LLC
- Maine Division of Parks and Public Lands
- Plum Creek Timber Company, Inc.
- Prentiss & Carlisle Company, Inc.
- Seven Islands Land Company
- Simorg North Forests, LLC
- Sylvan Timberlands, LLC
- Wagner Forest Management

Identifying Attributes that Distinguish Old- and Second-Growth Northern White-Cedar Stands for Forest Management and Planning

Laura Kenefic[1], Shawn Fraver[2] and Aaron Weiskittel[2]

[1] U.S. Forest Service, Northern Research Station

[2] University of Maine

Status: Progress Report, Year 1 of 2

From L to R: Chuck Hulsey (MDIFW), Charles Tardif (Maibec), Nathan Wesely (UMaine), Laura Kenefic (USFS), Erick Lariviere (Wagner), Jean-Claude Ruel (Laval), Jean-Martin Lussier (CFS), and Catherine Larouche (QMFFP) led a tour about NWC ecology and management in the Lower Enchanted Township in Fall 2015. Photo: U.S. Forest Service.

Summary:

Northern white-cedar (NWC) has received limited research attention and land managers are confronted with challenges in the management of this species. This includes the recognition of old-growth (OG) characteristics and the differentiation between OG and second-growth (SG) stands. The goal of this project is to quantify the compositional and structural characteristics of OG NWC-dominated stands and identify which attributes best differentiate OG from SG stands. To accomplish this, known OG stands were located and sampled along with SG stands that have experienced a range of intensities of partial harvesting. Thirty-one plots were installed in five locations across Maine and New Brunswick. With 8 additional plots at Big Reed Forest Reserve collected as part of an earlier study (Fraver et al. 2009), we now have 39 plots in the dataset. Roughly half of the plots were considered old-growth and half were considered second-growth. Data summary and analysis are underway (Tables 1 & 2).

Project Objectives:

- Quantify the compositional and structural attributes of old- and second-growth northern white-cedar dominated stands.
- Identify which attributes best differentiate old- from second-growth stands.
- Develop management guidelines for ecologically based forestry in cedar stands, building upon the recently published “Silvicultural Guide for Northern White-Cedar” (Boulfroy et al. 2012).

Approach:

- Identified stands of known OG and associated SG by communicating with collaborators, exploring geodatabases, and visiting sites.
- Established randomly located fixed-area plots (0.1 ha) to measure and map all live and dead trees ≥ 10 cm dbh. (Fig. 4)
- Downed woody materials were measured using three 40-m transects radiating outward from plot center, recording diameter and decay class at point of intersection (Fig 5.).
- Subplots were established to record sapling and seedling data.

Key Findings / Accomplishments:

- In addition to Big Reed, three OG northern white-cedar stands were identified at the following locations: Deboullie Ecoreserve and the Baker Branch of the St. John in Maine, and MacFarlane Brook in New Brunswick.
- Sampling of 31 plots in five locations, making a total of 39 plots in the dataset including 8 collected at Big Reed Forest Reserve from previous OG research (Fraver et al. 2009).

Table 3. Total number of plots represented in the dataset by forest type.

Forest Type	Status	Number of plots
NWC Swamp	Old-growth	11
NWC Swamp	Second-growth	10
NWC Seep	Old-growth	11
NWC Seep	Second-growth	7

Table 4. Mean (Standard Deviation) of structural measures for all plots (Fig. 6). Live trees ≥4 inches (10 cm) DBH. BA=Basal Area (ft²/ac). TPA=Trees per acre

Measure	Old-growth	Second-growth
Live tree BA	258 (81)	237 (48)
TPA	342 (85)	426 (120)
NWC BA (%)	77 (20)	81 (11)
BA, trees ≥16 in DBH	119 (63)	77 (56)
TPA,trees ≥16 in DBH	62 (32)	39 (27)
Snag BA	50 (39)	83 (44)
Snag TPA	75 (41)	131 (63)
DWD Vol. (ft³/ac)	2244 (829)	1786 (1143)

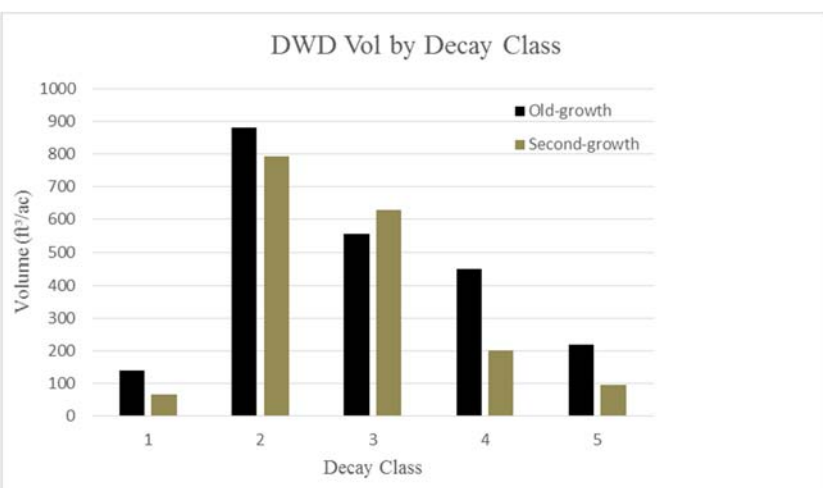


Figure 4. *Average volume of down woody debris by decay class for all old- and second-growth plots.*

Figure 5. *Measuring the diameter of dead wood at point of intersection with transect. Photo: Nathan Wesely.*

Figure 6. *Measuring diameter at breast height of overstory trees. Photo: Nathan Wesely.*

Future Plans:

- Perform data analysis to identify best differentiating features between old- and second-growth; present and publish findings.
- Develop management guidelines for ecologically based forestry in cedar stands, building upon the recently published "Silvicultural Guide for Northern White-Cedar" (Boulfroy et al. 2012).

Products Delivered:

Presentations / Workshops / Meetings / Field Tours:

Kenefic, L.S., Larouche, C., Lussier, J.M., Ruel, J.C., Tardif, C., Wesely, N. 2015. Northern White-Cedar Management in the Acadian Forest: New Findings. Maine SAF Field Tour, September 23, 2015, Solon, ME.

Kenefic, L.S., Larouche, C., Lessard, G., Ruel, J.C., Tardif, C., Tremblay, S., Wesely, N. 2014. New Northern White-Cedar Research and Opportunities for Collaboration. Cedar Club Research Meeting, October 16, 2014, Rimouski, Quebec.

Kenefic, L.S., Fraver, S., Wesely, N. 2014. Identifying Attributes that Distinguish Old- and Second-Growth Northern White-Cedar Stands for Forest Management and Planning: Progress Report. Presentation, CFRU Advisory Committee Meeting, January 21, 2014, Wells Center, Orono, ME.

References:

Boulfroy, E., Forget, E., Hofmeyer, P. V., Kenefic, L. S., Larouche, C., Lessard, G., Weiskittel, A. (2012). Silviculture guide for northern white-cedar (eastern white-cedar). Newton Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.

Fraver, S., White, A. S., & Seymour, R. S. (2009). Patterns of natural disturbance in an old-growth landscape of northern Maine, USA. Ecology, 97, 289-298.

Acknowledgements:

We thank the Maine chapter of The Nature Conservancy and the Maine Natural Areas Program for their collaboration, and the New Brunswick Department of Natural Resources for permission to sample on their reserves. We would also like to give a special thanks to the many individuals who participated in the process of identifying study sites.

Sunset on Pushaw Lake in January - Photo Brian Roth

Revisiting Maine's Tree Improvement and Plantation Trials

Brian Roth[1], Aaron Weiskittel[1], and Laura Leites[2]

[1] University of Maine

[2] Pennsylvania State University

Status: Final Report

White Spruce Progeny Test - Photo Brian Roth

Summary:

In the 1980's there was a concerted effort to increase the productivity of Maine's forested land base in response to a predicted shortfall of merchantable spruce-fir due to an unbalanced age structure as a result of the spruce budworm outbreak in the 1970's (Greenwood et al. 1988). To gain information on which species and seed sources were best suited for planting in Maine, a variety of species, provenances and genotypes were established in field tests across the state using optimum silvicultural treatments. These tests were measured periodically up until the late 1990's, but measurements stopped abruptly during a period of drastic change in land ownership and management objectives. While interest in establishing plantations in Maine has waned, a subset of these tests continue to hold immeasurable value as a source of data for the improvement of growth & yield models as well as predicting forest response to a changing climate (Carter 1996). This project revisited over 3 dozen historic tree improvement and plantation trials in Maine of which around one third were still intact and useful (Table 5.). Plot boundaries were monumented in the field and GIS shapefiles were sent to landowners/managers to protect these stands through rotation.

Project Objectives:

Our goal was to revisit existing tree improvement trials in Maine and capture data before these stands are compromised from partial or final harvests. Data will be used in improving Growth & Yield models and predicting the productivity potential of Maine's forests in a changing climate.

Approach:

- This was a two stage process: assessment followed by inventory/analysis. The assessment phase identified tests with the most promise while the inventory/assessment phase focus is on re-measurement and analysis.
- The assessment phase was completed ahead of schedule and the measurement phase was completed as part of this project.
- Analysis will be part of a future project.

Key Findings / Accomplishments:

- Field visits and evaluation of nearly four dozen historic research sites in Maine (Fig.6).
- Identified 20 trials intact and useful.
- Placed aluminum research signs around high value locations.
- Surveyed GPS polygons and forwarded to landowners/managers to include in GIS layers.
- One location was thinned to the best two trees out of each original four tree row plot.
- Digitized paper data sheets with historical datasets.
- Completed field measurements on a dozen trials.

Table 5. Research installations intact and of interest in preserving and re-measuring in the state of Maine.

Year-study	Species	Type	Township	Lat	Long
1960-1	White Pine	Provenance Trial	Bradley(PEF)	44.879240	-68.654051
1962	White Spruce	Provenance Trial	Bradley(PEF)	44.878251	-68.653675
1976-2	Balsam Fir	Half-sib progeny (22 parents)	Dover-Foxcroft	45.141863	-69.147850
1977-1	Japanese Larch	Provenance test (16 provenances)	Dover-Foxcroft	45.142818	-69.146678
1977-7	Larch	3 Species (JL,EL,SL)	Orneville	45.177985	-68.997276
1977-11	White Birch	Provenance Test	Orneville	45.178498	-68.997501
1978-1	Green Ash	Provenance Test	Augusta	44.290344	-69.768405
1978-4	Scots Pine	Provenance Test (54 provenances)	West Forks	45.392440	-70.011597
1979-8	Norway Spruce	Provenance Test (56 provenances)	Bingham	45.022880	-69.781758
1979-12	Scots Pine	Provenance test (~44 Soviet)	T1R13	45.691081	-69.358419
1979-13	Scots Pine	Provenance test (~50 Soviet)	T4R14	46.028711	-69.482560
1981-2	White Spruce	Progeny Test	T6R14	46.125134	-69.591347
1981-3	Black Spruce	Progeny Test	T6R14	46.125134	-69.591347
1981-4	Black Spruce	Progeny test (63 OP families)	Brassua	45.701378	-69.977907
1981-5	Black Spruce	Progeny test (55 OP families)	Howland	45.226478	-68.743181
1982-2	Balsam Fir	Provenance 113 sources (progeny?) Test	Orneville	45.171293	-68.988996
1985-2	Tamarack Larch	Clonal Test	Westmanland	46.958381	-68.236988
1986-2	Black Spruce	Family Test	Beddington	44.810194	-68.065727
1986-3	Black Spruce	Seedling Seed Orchard	Howland	45.218559	-68.710972
SR8701	Multiple	Species Comp. (HL,WS,JP,RP)	Bradstreet	45.505470	-70.236429

Figure 6. *Drs. Robert Weir (left) and Michael Greenwood (right) in a 26 year-old hybrid larch plantation near Fairfield, ME. The stand has already been thinned once several years earlier. Photo, October 2014.*

Future Plans:

- Utilize data from these genetic tests to evaluate adaptability of species to changing climate and improve growth and yield models.
- Use stem maps of plots to assist with development of enhanced forest inventory generalized equations from LiDAR.

Products Delivered:

Journal Publications:

Greenwood, M.S., B. E. Roth, D. Maass and L. C. Irland. 2015. Near rotation-length performance of selected hybrid larch in Central Maine. Silvae Genetica 64(1-2):73-80.

Presentations / Workshops / Meetings / Field Tours:

Roth, B.E. 2015. Update at CFRU Advisory Committee meeting. October 28th. Houlton, ME.

References:

Carter, C. 1996. Provenance tests as indicators of growth response to climate change in 10 north temperate tree species. Can. J. For. Res. 26: 1089-1095.

Greenwood, M.S., Seymour, R.S. and M.W. Blumenstock. 1988. Productivity of Maine's forest underestimated: More intensive approaches are needed. Maine Agricultural Experiment Station Miscellaneous Report no. 328. Orono, ME 04469. 8 p.

Acknowledgements:

We thank the landowners and land managers for permission to visit, measure and protect these trials. The assistance of Drs. Michael Greenwood and Robert Weir with field evaluation was invaluable. We recognize the efforts of the student summer crew with remeasurements and installation maintenance (Kyle Arvisais, Aiden Ruel, Ben Aldrich, Icaro Neary, garth Dixon, Andrew Kennedy, and Ben Greenwood). Financial support for Icaro Neary was provided through the Brazil Scientific Mobility Program. Special thanks to Pete Caron for assistance in locating many sites that he had planted decades earlier. Drs. Cathy Carter, David Canavera and many others for the considerable effort and expense in installing these field trials over the years.

Effects of mechanized harvesting operations on residual stand conditions

Robert Wagner[1], Brian Roth[1], Cody Lachance[1] and Jeffery Benjamin[2]

[1] University of Maine

[2] Bangor Christian Schools

Status: Progress Report, Year 2 of 3

Note: This ongoing study has been modified following the departures of Drs. Jeff Benjamin from the University of Maine and Eric Labelle, from the Northern Hardwood Research Institute.

Summary:

The spruce-fir forest type is one of Maine's most abundant forest types and has immense ecological and economic value to the state. Mechanized harvesting operations can lead to detrimental residual stand conditions including soil disturbance and residual stem damage. The goal of this study is to investigate the impacts of mechanized harvesting at two long-term experimental sites. The Austin Pond study site will be used to test whether commercial thinning operations have an impact on residual stem damage. The Weymouth Point study site will be used to assess how soil disturbance following whole-tree harvesting influenced long-term tree growth and species composition (Martin 1988). Results from this study will help forest managers better understand the relation between logging disturbance and the long-term impact on future stand growth, quality, and value.

Project Objectives:

- Investigate the effects of stand density and level of removal on residual stem damage following commercial thinning operations in spruce-fir stands in northern Maine.
- Investigate the long-term influence of soil disturbance following whole-tree harvesting on the subsequent growth and composition of naturally regenerated spruce-fir stands

Approach:

- Measured all residual trees on 21 plots at the Austin Pond study site. Recorded tree DBH, species, distance from the center of the closest trail, and wounding characteristics if tree was wounded (size, height, and severity).
- Analyzed data to investigate potential influences of PCT and CT treatments along with distance from the center of the closest trail on probability of stem wounding, stem wound area, and wound area index.

- Revisited balsam fir crop trees located on high and low disturbance areas and took tree cores at 30 cm from the ground along with depth to seasonal high water table and organic horizon measurements.
- Analyzed data to investigate potential influences of soil disturbance, depth to seasonal high water table, and organic horizon on species composition, basal area, and trees per acre.

Key Findings / Accomplishments:

Probability of Stem Wounding (Fig. 7):

- The probability of a tree experiencing stem wounding was influenced by the treatment effects of PCT and CT, along with the distance the tree was from the center of the closest trail.
- Trees on plots that did not receive a PCT treatment had a higher probability than trees on plots that received a PCT treatment.
- Trees on plots that received CT standing softwood removal intensities of 66% and 50% had a higher probability of stem wounding compared to trees on 33% removal intensity treatment plots.
- Trees located relatively closer to the center of the closest trail were at a higher risk of stem wounding compared to those farther away.
- Managers aiming to reduce probability of stem wounding in spruce-fir stands should consider employing PCT treatments that are followed up with CT treatments that have relatively low removal intensities, along with wide trail spacing.

Total Wound Area Observed per Tree (Fig. 8):

- Total wound area observed on an individual tree was influenced by the treatment effects of PCT and CT.
- Individual trees on plots that did not receive a PCT treatment were found to have a higher total wound area compared to those that did receive a PCT treatment.
- Individual trees on plots that received CT standing softwood removal intensities of 66% and 50% had higher total wound areas compared to trees on 33% removal intensity treatment plots.
- To help reduce total wound area per tree, managers should consider using PCT treatments before a CT treatment to help reduce the density at the beginning of the CT harvest.

Wound Area Index per Plot (Fig. 9):

- Wound area index was calculated by dividing the total wound surface area per plot after the CT harvest by the basal area of the plot before the harvest. This ratio explains the proportion of damage done after the harvest compared to the initial stand conditions before the CT treatment.
- Plots that received a PCT treatment had a significantly lower wound area index than plots that did not receive a PCT treatment. The relatively lower density at the beginning of the CT harvest resulted in a lesser total wound area on a per plot basis.

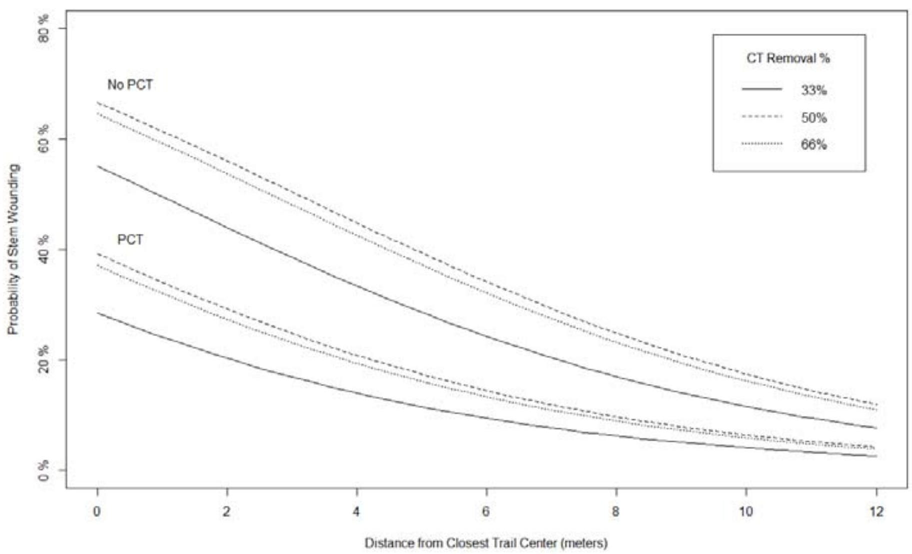


Figure 7. *Probability of an individual tree experiencing stem wounding in relation to distance from the center of the closest trail. Each line represents a different treatment combination of PCT and CT. Predictor variables of PCT, CT, and distance from trail center all were statistically significant.*

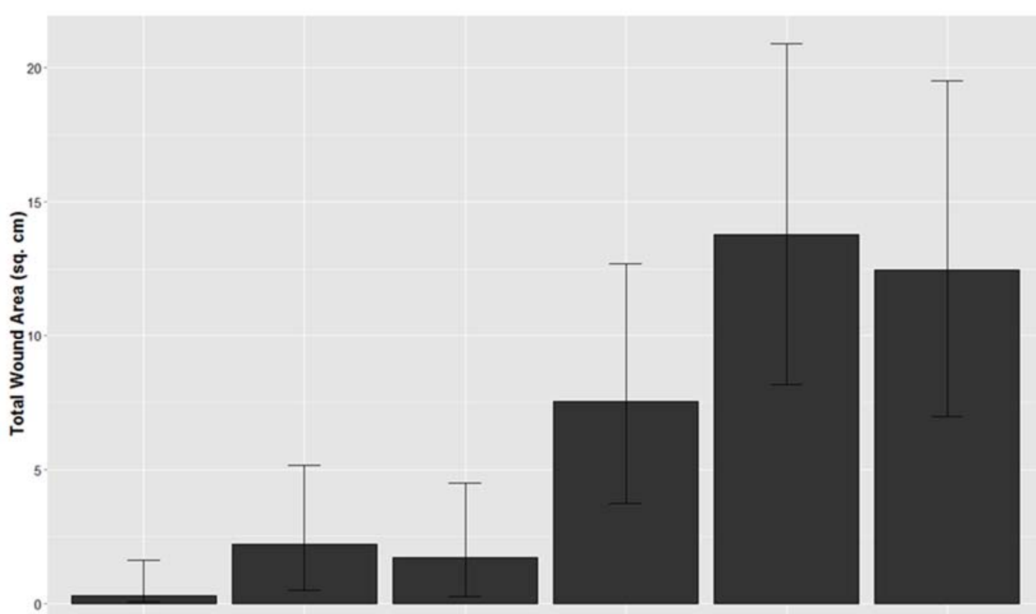


Figure 8. *Least square mean total wound area with 95% confidence intervals for an individual tree. Each bar represents a different treatment combination of PCT and CT. Predictor variables of PCT and CT were statistically significant (p<0.05).*

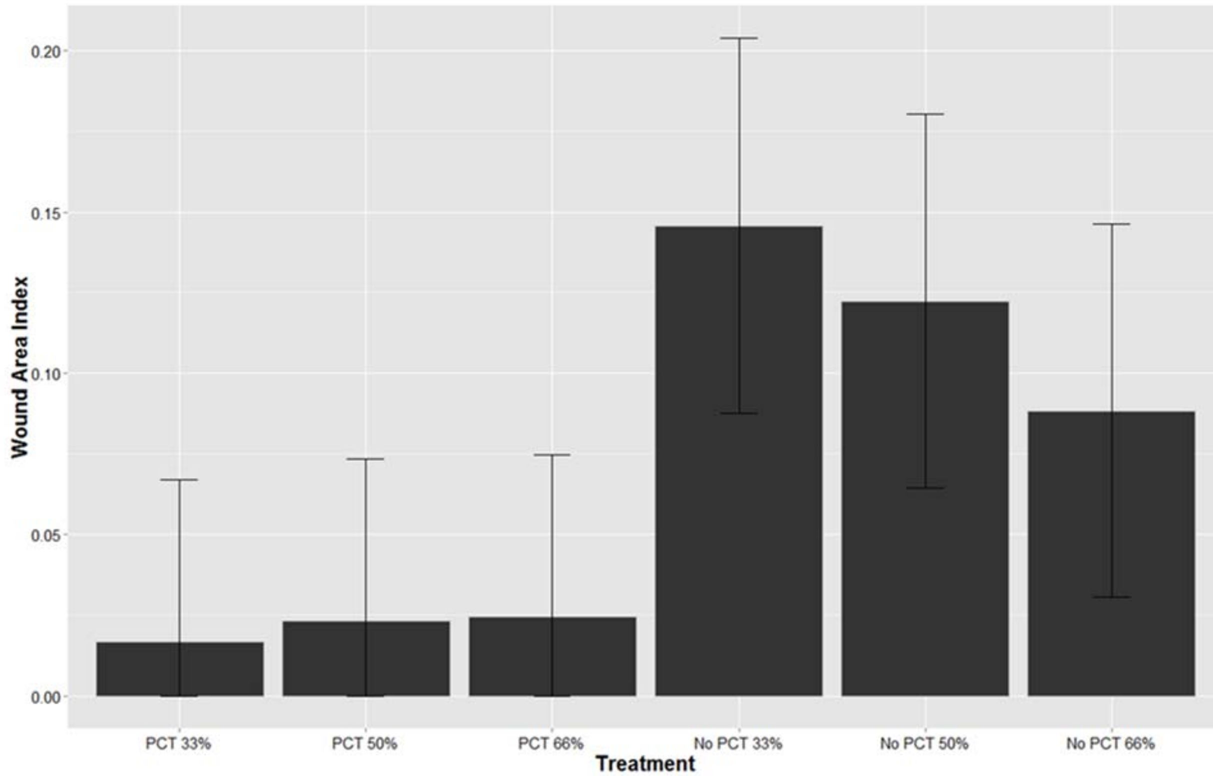


Figure 9. *Least square means wound area index per plot with 95% confidence intervals. Wound area index was calculated by dividing the total wound surface area per plot after the CT harvest by the basal area of the plot before the harvest Each bar represents a different treatment combination of PCT and CT. The predictor variable PCT was statistically significant ($p<0.05$).*

Future Plans:

- Measure balsam fir tree cores taken from Weymouth Point study site to find average annual growth per tree.
- Explore the long-term influence of soil disturbance following whole-tree harvesting on the subsequent growth and composition of naturally regenerated spruce-fir stands.

References:

Martin, C.W. 1988. Soil disturbance by logging in New England – Review and management recommendations. Northern Journal of Applied Forestry Research 5: 30-34.

Acknowledgements:

We would like to thank Plum Creek and Katahdin Forest Management for their commitment to continuing research efforts at the Austin Pond and Weymouth Point Study sites, respectively.

Dr. Brian Roth next to a major rut at the Weymouth Point Study Area

Growth & Yield Modeling

- **Evaluating the Influence of Stem Form and Vigor on Product Potential, Growth, and Mortality for Northern Commercial Hardwood Species**
- **Linking Site Quality to Tree Growth and Survival in the Acadian Forest**
- **Maine Statewide Light Detection and Ranging (LiDAR) Data Acquisition**

Evaluating the Influence of Stem Form and Vigor on Product Potential, Growth, and Mortality for Northern Commercial Hardwood Species

Photo by Pamela Wells

Aaron Weiskittel, Jereme Frank, and Mark Castle

University of Maine

Status: Progress Report, Year 1 of 2

Summary:

Compared to softwood species, northern hardwoods display a wide variety of stem forms and defects whose presence are not accounted for in most volume/biomass equations or even growth and yield models. To account for these deficits, the primary goals of this project were to quantify the influence of form and defects on biomass, merchantable volume, diameter increment, and survival of northern commercial hardwood species. To accomplish these goals, intensive tree measurements incorporating form and damage protocols were taken on standing and felled trees across several sites in Maine and New Hampshire.

Preliminary work suggests that the probability that rot occurs varies between species, while growing stock acceptability and diameter are significant factors when predicting the proportion of tree rot. Further analyses will: 1) predict occurrence of stem defects and their impacts on biomass/merchantable volume and 2) evaluate the influence of stem form and damage on individual tree growth and mortality.

Project Objectives:

- Identify a hardwood tree classification system that can effectively assess both stem form and tree vigor.
- Quantify the occurrence of specific defects and percentage of potential saw log volume across tree size, species, and stand conditions.
- Incorporate stem form and damage attributes into growth and mortality predictions.
- Develop models to predict the probability that rot occurs and the proportion of rot in a tree.

Approach:

- Measurements on standing hardwood and softwood trees were taken from permanent plots across the following locations: Austin Pond, Holt Research Forest, Kingman Farms, Penobscot Experimental Forest, and Scientific Forest Management Area.
- Model the occurrence of defects and percentage of potential saw log volume as a function of tree size, form, risk and stand conditions (Figs. 10 – 12).
- Quantify the influence of stem form, risk, and stand conditions on individual tree diameter increment and mortality predictions.
- Selection of a tree classification system that adequately assesses stem form and vigor based on results of aforementioned quantitative analyses.
- Destructive sampling trees of varying risk and form classes for key species to assess rot.

Key Findings / Accomplishments:

- 4919 hardwoods and 4665 softwoods standing tree measurements were taken on 157 permanent plots across a range of conditions in Maine and New Hampshire (Table 6).
- Preliminary boosted regression tree analysis suggested that species, DBH, crown class, and basal area per hectare were influential variables in determining if a tree was either acceptable or unacceptable growing stock.
- A preliminary analysis of the 131 destructively sampled trees suggests that growing stock (Acceptable: AGS or Unacceptable: UGS) and diameter best predict the proportion of rot in a tree, while species alone may help determine the probability of occurrence.

Table 6. Summary of standing hardwood tree measurements (commercial species of interest with DBH 11.4 cm and greater) by plots.

Species	Count	Occurrence by plot	Mean DBH (cm)	St.dev DBH (cm)	Min DBH (cm)	Max DBH (cm)	AGS (%)	UGS (%)
Aspen	370	44	21.3	8.7	11.4	49.5	65.7	34.3
Paper Birch	435	79	18.2	6.3	11.4	45	53	47
Red Maple	1514	131	19.2	7.1	11.4	57.1	19.8	80.2
Red Oak	978	70	31.1	11.5	11.4	76.7	68.8	31.2
Sugar Maple	220	54	22.5	11.8	11.4	64.3	63.8	36.2
Yellow Birch	266	32	20	7.9	11.4	53.8	77.8	22.2
Total	3783	157	22.6	10.2	11.4	76.7	47.1	52.9

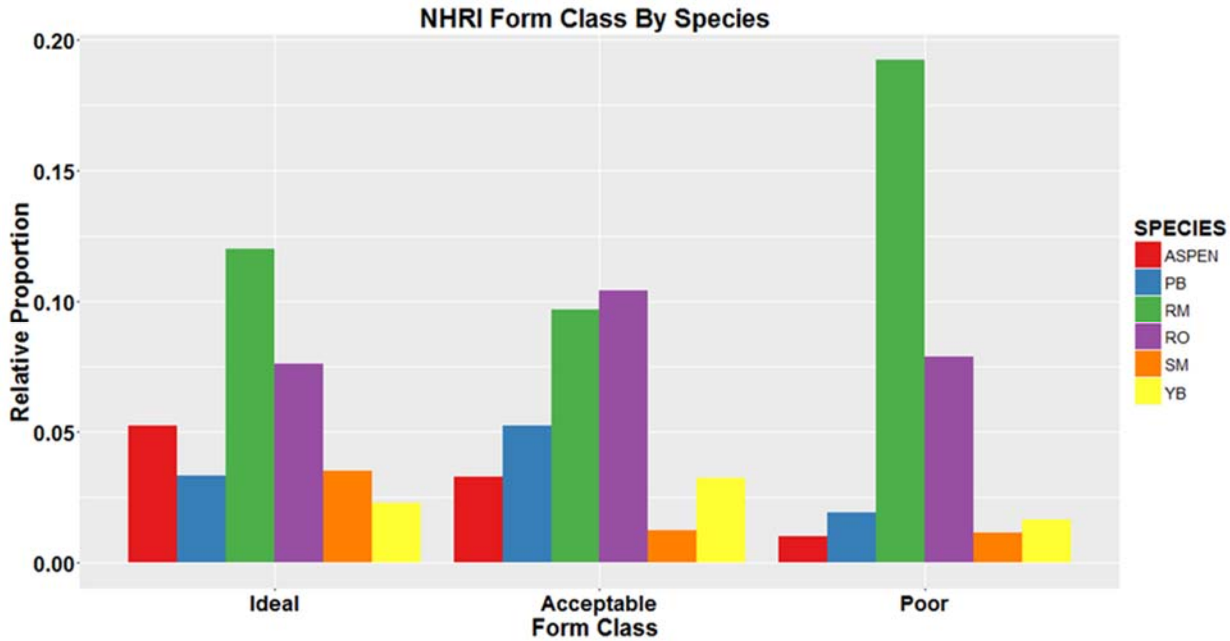


Figure 10. *Relative proportion of sampled trees by species across Northern Hardwood Research Institute (NHRI) form classes.*

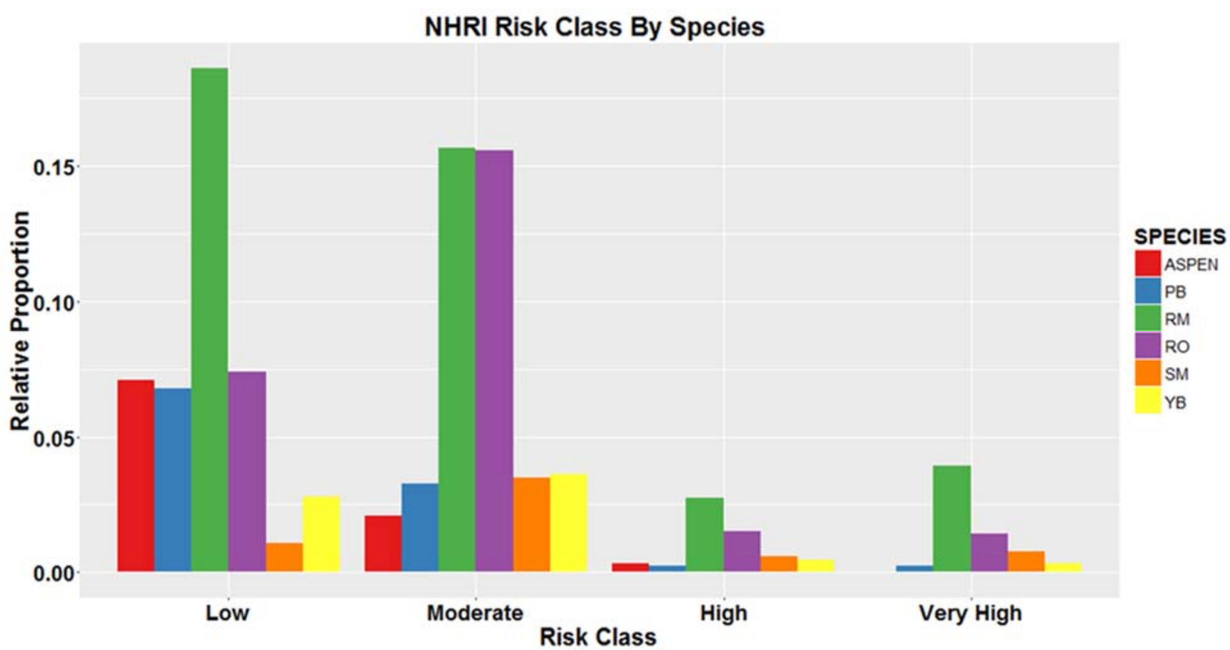


Figure 11. *Relative proportion of sampled trees by species across NHRI risk classes.*

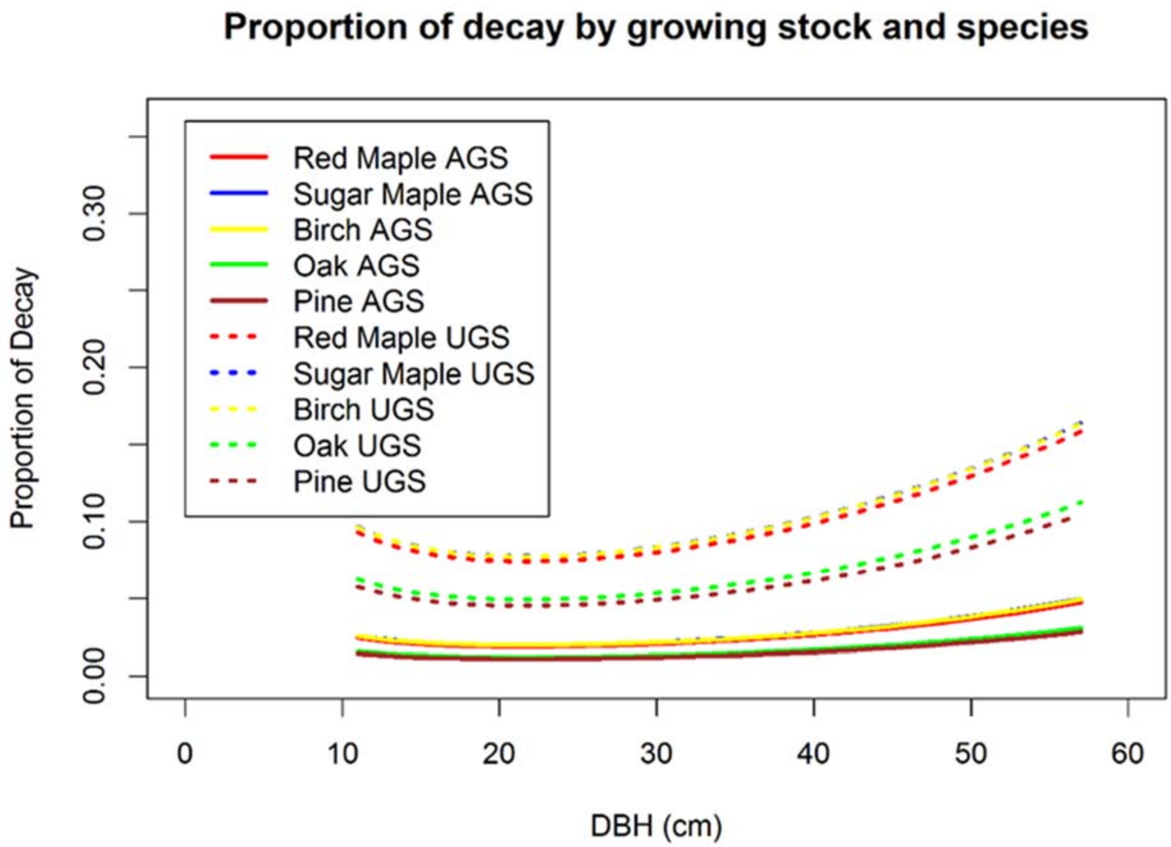


Figure 12. *The proportion of decay modeled as a function of DBH, species and growing stock coupled with the proportion of AGS (as opposed to UGS) sampled here for a given species or species group. Note: the trend line for red maple AGS and yellow birch AGS obscure the trend line for sugar maple AGS indicating that while sugar maples have a much higher proportion of AGS than red maple (see table insert for these data and table 1 for a more representative sample of standing trees), AGS of both species have similar proportions of decay. A similar corollary can be made for UGS.*

Future Plans:

- Develop models to predict the occurrence of stem defects and percentage of potential saw log volume for individual hardwood trees.
- Quantify the influence of stem form, risk, and stand conditions on individual tree growth and mortality.
- Select a tree classification system that can adequately assess form and vigor based on the findings of quantitative analyses.
- Acquire additional datasets and/or destructively sample more trees to improve our assessment of rot.

Products Delivered:

Workshops:

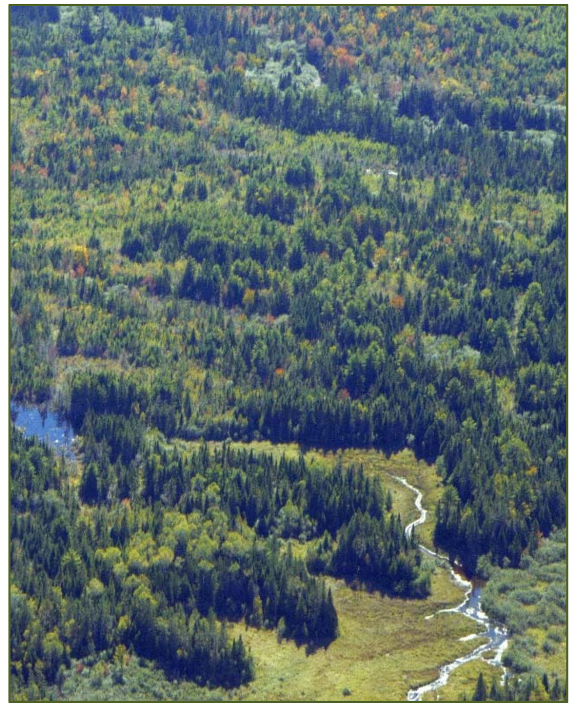
Castle, M. 2015. Influence of stem form and damage on product potential, growth, and mortality for northern commercial hardwood species. Presentation on November 16, 2015. Northeastern Mensuration Meeting. Stowe, Vermont.

Acknowledgements:

We thank the CFRU, United States Forest Service, Holt Research Forest, Baxter State Park and the University of New Hampshire for providing access to managed lands and data.

Select hardwood logs in northern Maine. Photo: Rich Carbonetti

Linking Site Quality to Tree Growth and Survival in the Acadian Forest: Acadian Forest Site Productivity Model



Bog in Wells Forest

Chris Hennigar[1], Aaron Weiskittel[2], and Lee Allen[3]

[1] University of New Brunswick

[2] University of Maine

[3] ProFOR Consulting

Status: Final Report

Summary:

Stand growth and dominant tree height-age (i.e., site tree) measurements from ~10,900 plot locations were compiled from Maine, Nova Scotia (NS), New Brunswick, and Prince Edward Island to predict and map forest productivity for the Acadian forest region as a function of climate, lithology, soils, and topographic metrics. Forest productivity was defined here as the theoretical maximum above-ground biomass survivor growth rate (BGI; kg/ha/yr). Regionally, 65% of the variation in biomass survivor growth was explained as a function of mean growing season temperature, frost free days, bedrock type, soil depth to root restriction, soil % course fragments, slope, and depth to water in combination with stand structure and species predictors. BGI was mapped on a 20m grid holding stand structure and species constant (Fig. 13).

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 (LC) in each province. Lack of a responsive site index dataset in Maine limited validation for this state. When the NS LC was combined with BGI to predict site index, error explained increased relatively by ~40% for NS compared to LC or BGI used independently. Limitations and future improvements to soils and topographic metrics are discussed.

Project Objectives:

- Provide a quantitative, species-independent, and unified site productivity model for the Acadian forest region (Maine, New Brunswick [NB], Nova Scotia [NS], and Prince Edward Island [PEI]).

- Consider a full suite of potential site factors including climate, bedrock, soils, drainage, and topography.
- Match or exceed precision of existing site classification systems used in each jurisdiction for explaining spatial differences in tree height growth rate.
- Predict potential productivity at high precision (20 m) for forest operations and stand yield prediction.

Approach:

- Data were compiled from inventory plots where individual tree growth overtime and/or site trees (co-dominant & dominant tree height vs. age samples) had been measured by government and industrial forestry organizations across Maine, New Brunswick (NB), Nova Scotia (NS), and Prince Edward Island (PEI).
- In total, 8,460 plot locations had at least one fir or spruce site tree, and 6,804 locations had at least one 3-10 year plot growth measurement period.
- Plot above-ground biomass growth between 5-year measurement periods was calculated from diameter and height growth of surviving trees ≥3.5” DBH using Lambert et al. (2005) tree biomass equations.
- Spruce or fir site index (height at breast-height age 50) for each plot was based on the average spruce or fir index calculated for each site tree as a function of breast-height age and total tree height using Ker and Bowling (1990).
- Influential predictors identified with Random Forests™ were carried forward into development of a generalized non-linear equation to predict BG as a combination of site and stand structural and compositional metrics.
- When mapping site productivity estimates for the region, stand and species variables were held constant.

Key Findings / Accomplishments:

Climate:

- Most climate variables were moderately to weakly correlated with observed BG, but as expected, were also strongly correlated to one another.
- The only climate variables retained in the final model were average growing season temperature and frost free days; however, May-Sept average temperature was a close alternative and performed nearly as well on its own.

Lithology:

- Rock type was important for all jurisdictions; excluding PEI, which was assumed to have with same rock type throughout.
- Rock type classification was limited to eight broad groups, partly due to difficulty interpreting lithological descriptions in each jurisdiction, and also to avoid cases where the rock type was restricted to a limited range of climatic or geographic zones.

- As expected, the granite type (e.g., quartz, rhyolite, granite) was consistently observed, on average, to result in the worst site productivity of all rock types.
- Calcareous origins lead to the highest bedrock productivity.

Soils:

- Mineral soil root restriction depth (RRD; e.g., depth to hardpan, bedrock, up to 100 cm) and to a lesser extent % course fragments (CF) showed consistent moderate to weak correlation with site productivity measures.
- Soil influence on site was moderate-weak in NS and PEI, and weak-poor in Maine and NB, which suggest that more effort is needed to accurately and more precisely map soil attributes that drive productivity in the Acadian forest region.
- In Maine, soil polygon profiles sometimes vary more across township borders than within townships.

Topography:

- Site was negatively correlated with elevation, but elevation was highly correlated with temperature. Elevation resulted in almost no model improvement when temperature was included, and therefore was dropped from the final model.
- Degree of slope was the strongest and most consistent site predictor across all jurisdictions of all topographical variables tested including elevation, depth to water (DTW; Murphy *et al.* 2009) and SAGA terrain indexes (Böhner *et al.* 2006): topographic wetness, roughness, positive openness, and slope position class.
- Site generally increased logarithmically with slope, peaked at 5-10 degrees, and then declined linearly thereafter.
- Depth to water (DTW) outperformed topographic wetness index, but only slightly, and both drainage measures only weakly improved overall site variance explained. DTW, while important, was the least significant variable retained in the final model.
- Future DEM improvements via LIDAR, and perhaps through new algorithms that can measure the stagnancy of the water table are likely to improve the prediction importance of topographic measures explored here.

Stand species and structure:

- Above-ground dry-biomass (BM) of surviving trees in the plot and plot quadratic mean diameter (QMD) ≥ 3.5” DBH explained more variability in BG than all other site factors combined.
- Plot growth was increasingly under predicted as proportions of poplar (*Populus* spp.) or pine (*Pinus* spp.) increased in the plot; so, these species were incorporated into the final site model.

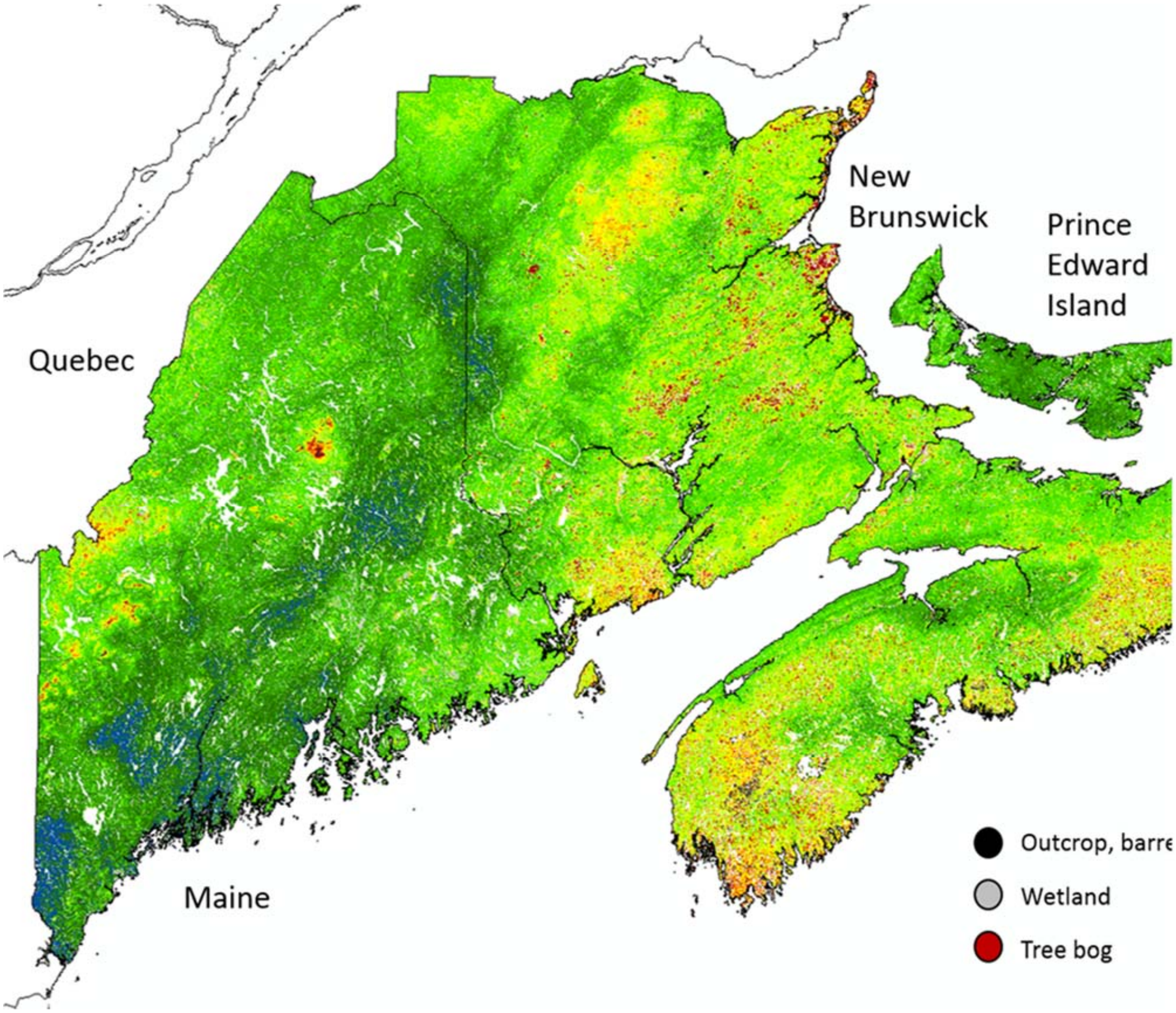


Figure 13. *Biomass growth index (BGI; kg/ha/yr) estimated at 20 m resolution. Available rock outcrop, wetlands, and tree bogs from forest or soils inventory layers superimposed.*

References:

Böhner, J., McCloy, K.R., Strobl, J. [eds.] 2006: SAGA - Analysis and Modelling Applications. Göttinger Geographische Abhandlungen, Vol.115, 130pp.

Ker, M.F., Bowling, C. 1991. Polymorphic site index equations for four New Brunswick softwood species. Can. J. For. Res. 21: 728-732.

Murphy, P.N.C., Ogilvie, J., Arp, P.A. 2009. Topographic modelling of soil moisture conditions: a comparison and verification of two models. European J. of Soil Sci. 60:94-109.

Future Plans:

This site model is expected to replace the climate-only site model currently used in the Open Stand Model for Acadian region tree-level equations for height, diameter and height growth, and mortality.

Consideration of individual jurisdictions as a term in these tree models would help to correct jurisdiction BGI bias (-7% in Maine, 5% NB). Leveraging classifications of site in NS and PEI in combination with BGI may result in better tree models compared to using BGI alone. Future efforts will focus on incorporating remote sensing information, refining of the topographic indices assessed, and additional evaluation of model performance and assumptions.

Products Delivered:

GIS Layers:

Site predictions for Acadian Region as a 20 X 20 m raster grid; available on CFRU Website.

Presentations:

Hennigar, C. 2015. Design and performance of an Acadian forest site productivity index: Prince Edward Island results. Presentation on Dec 4th, 2015. Charlottetown, PEI.

Hennigar, C. 2015. Design and performance of an Acadian forest site productivity index. Presentation on Oct 6th, 2015. Canadian Woodlands Forum, Fredericton, New Brunswick.

Weiskittel, A. and Hennigar, C. 2014. Acadian site model: Maine draft results. Presentation on April 22nd, 2015. Coop. For. Res. Unit, U. Of Maine, Orono, Maine.

Hennigar, C. 2014. Acadian site model: New Brunswick results. Presentation on Feb 11th, 2015. New Brunswick Growth and Yield Unit, Fredericton, New Brunswick.

Hennigar, C. 2014. Acadian site model: Nova Scotia results. Presentation on Jan, 22nd 2015. Nova Scotia Department of Natural Resources, Truro, Nova Scotia.

Hennigar, C. 2014. Acadian site model: preliminary results. Presentation on Sept 10th, 2014. New Brunswick Growth and Yield Unit, Fredericton, New Brunswick.

Acknowledgements:

Funding was supported by the Coop. For. Research Unit, NB Dept. of Nat. Res. (NBDNR), and PEI For., Fish and Wildlife (PEIFFW). Special thanks to: Sean Lamb, Evan Dracup, and David MacLean (UNB) for data compilation and management; Paul Arp (UNB), Mark Colpitts (NBDNR), and Kevin Keys (NS Dept. Nat. Res.; NSDNR) for helpful discussions. Individuals assisting with substantial information sharing and interpretation (Table 1 and 2): Adam Dick and Dale Wilson (NBDNR); Mike Montigny (PEIFFW); Chris Bailey, James Bruce, Peter Neily, and Kevin Keys (NSDNR); Jody Jenkins (Acadian Timber Inc.); Shona Millican, David Young, and Greg Adams (J.D. Irving, Limited); Dan McKenney and Pia Papadopol (Nat. Res. Can.); and Shane Furze and Mark Castonguay (Forest Watershed Research Centre, UNB).

White Pine Stand – Demeritt Forest

Maine Statewide Light Detection and Ranging (LiDAR) Data Acquisition

Joseph Young[1], Brian Roth[2], and Daniel Walters[3]

[1] *Maine Office of GIS*

[2] *University of Maine*

[3] *U.S. Geological Survey*

Sunkhaze Stream - Wells Forest

Status: progress report, year 3 of 5

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.

Project Objectives:

- The overall objective of this project is to acquire a statewide LiDAR data set that will provide the greatest benefit to the greatest number of potential users at the best price.

Approach:

- Solicit large landowners, communities and other stakeholders in the unorganized territories to partner on LiDAR acquisition projects.
- The Maine GeoLibrary Board is actively pursuing legislation to establish a Geospatial Data Reserve Fund which will match outside funding sources with State funds on a one to one basis.
- Partner with the USGS, NRCS, FEMA and other agencies to cost share LiDAR acquisition projects.

Key Accomplishments:

- A Geospatial Data Reserve Fund has been authorized which will match outside funding sources with State funds on a one to one basis.
- Agreement negotiated whereby landowners can participate at a cost of $0.14/acre.
- A three year acquisition plan has been drafted with the first acquisition to be completed in the spring of 2016 (Figs. 14 & 15).
- A pilot trial using new technology (Single Photon LiDAR) will be flown in the Spring of 2016 across the Baxter State Park SFMA.
- Higher resolution versions of the base elevation and WAM have also been produced (where available) in the northeastern and southern coastal portions of the state.

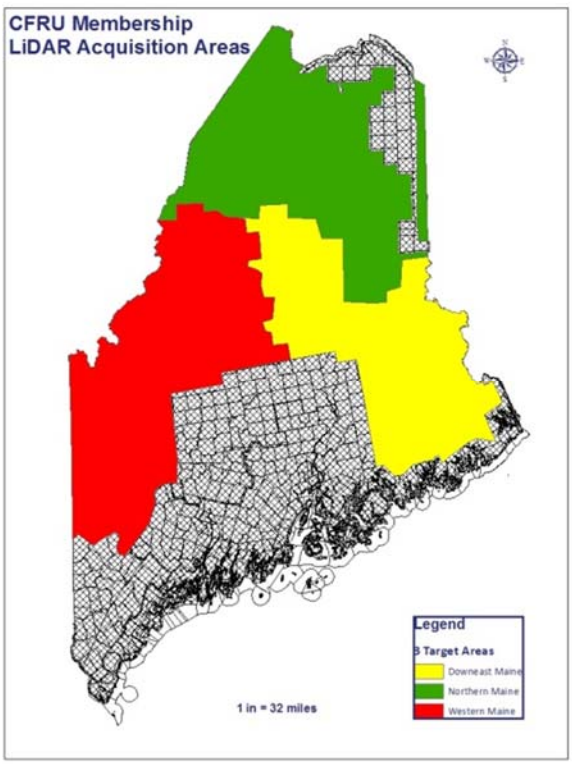


Figure 14. *Proposed LiDAR acquisition schedule for Maine (2016- 2018).*

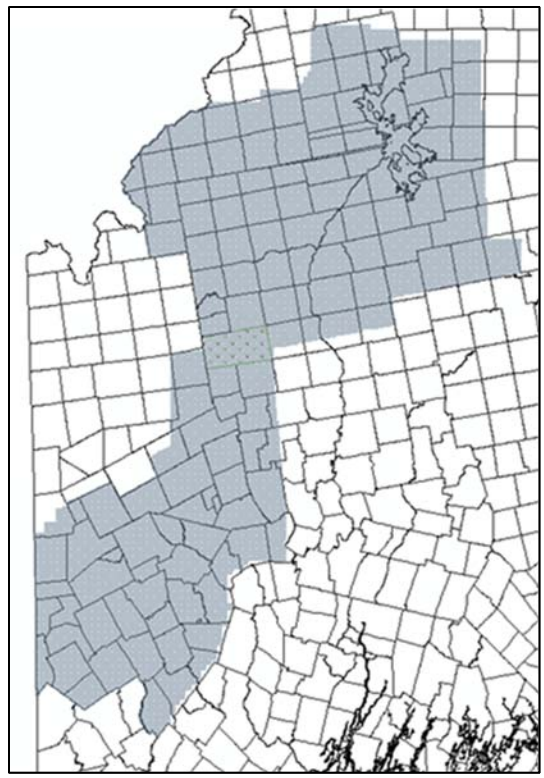


Figure 15. *Area of interest in 2015 includes 5053 sq. mi. in Oxford, Franklin, Piscataquis and Somerset Counties.*

Future Plans:

- Develop models to predict Enhanced Forest Inventory (EFI) metrics from LiDAR data.
- Update statewide Depth to Water Table maps at high resolution.
- Demonstration and training of easy to use tools for managing EFI products.
- Use the data for landscape level wildlife habitat and forest productivity analyses.

Products Delivered:

Contracts:

Maine Office of GIS approved LiDAR data acquisition master contract to provide LAS files, 1 meter digital elevation models, 2’ contour lines, hillshade and slope models.

Acknowledgements:

We thank the Maine Office of GIS and the GeoLibrary Board for contract administration, quality control and coordination amongst the stakeholders.

UMaine forestry undergraduates ready for field laboratory at Nutting Hall. Photo: Brian Roth

Wildlife Habitat:

- **Relationships among forest harvesting, snowshoe hares, and Canada lynx in Maine**
- **Population Dynamics of Spruce Grouse in the Managed Forest Landscapes of Northern Maine**
- **Bird communities of coniferous forests in the Acadian region: Habitat associations and responses to forest management**
- **Moose Density and Forest Regeneration Relationships in Maine**

Relationships among forest harvesting, snowshoe hares, and Canada lynx in Maine

Daniel Harrison, Sabrina Morano, and Sheryn Olson

University of Maine

Snowshoe Hare - Photo Pamela Wells

Status: Final Report (one year extension)

Summary:

This year we completed fieldwork on a 15-year study of temporal dynamics in snowshoe hare populations across regenerating conifer stands, as well as comparing over-winter hare densities across a range of forests harvesting treatments. This was part of a larger study of the inter-relationships between forest harvesting, Canada lynx, snowshoe hares, habitat structure, forest succession, and natural population cycles conducted from 2001-2015. Results on lynx food habits, resource selection by lynx across multiple spatial scales, and on effects of forest structure and seasons on habitat selection by hares have been presented each year in CFRU Annual Reports from 2008 - 2014. As such, this report focuses on the 15-year trends in over-winter hare populations across our 38 stands located within our 2,516 km^2 study area in Piscataquis and Aroostook counties, northern Maine.

Hare densities were highest in regenerating conifer stands (REGEN) with a previous history of clearcut harvesting, followed by herbicide application to suppress competing deciduous hardwoods. These stands provided superior habitat for a period from 15 - 40 years post-harvest due to dense conifer regeneration ranging from 2,200 - 13,000 stems ha^{-1} (stems defined as >1.0 m height), which suppressed stand growth rate and maintained high cover value for hares. Hare densities ranged from 2.3 times higher in REGEN than in uncut mature stands (MAT) during 2014, to 4.3 times higher in REGEN compared to MAT in 2008. Across the period 2008 to 2015, MAT stands averaged 0.25 hares ha^{-1} (range 0.20 - 0.33), partial harvest stands averaged 0.43 hares ha^{-1} (range 0.31 - 0.59), and REGEN stands averaged 0.86 hares ha^{-1} (range 0.77 - 0.99).

Our REGEN stands were monitored over a longer period to assess evidence for natural cyclic dynamics in hare populations, as has been reported for northern boreal study sites in Alberta, Northwest Territories, Yukon Territories, and Alaska. It has been speculated that hares do not cycle near the southern portion of their geographic range, but longitudinal empirical studies are absent for this region. We documented that hares maintained relatively high and stable densities in REGEN stands across a consecutive 6-year period from 2001 - 2006 when annual densities averaged 1.98 hares ha^{-1} (range 1.79 - 2.22). Hares transitioned to intermediate densities of 1.19 ha^{-1} during a decline year in 2007 and then stabilized at a relatively lower annual density averaging 0.86 ha^{-1} (range 0.77 - 0.99) across the final 8 years of our study spanning 2008 - 2015. Our data do not suggest the presence of 10-year cycles typical of northern hare populations, but suggest long-term stable equilibria where densities vary approximately 2.3-fold and where density transitions from a stable high period to a lower density phase across only a single

year. Although we cannot rule out a cycle of longer periodicity (i.e. >20 years) based on our data, it is apparent that hares in Maine do not cycle with the frequency and at the magnitude (e.g., 5- to 25-fold) observed in northern boreal populations. This has significant implications for management of Canada lynx, which exhibit greatly decreased reproduction, declining survival, expanded home ranges, and decaying spatial structuring at the nadir of hare cycles in the north. Changes in home range area, habitat selection, and spatial behavior by lynx were not observed during the range of hare densities that we observed.

Across our various studies, the extent and distribution of high quality hare habitat (i.e., conifer-dominated stands 15 -4 0 years post stand-replacing disturbance) will drive the long-term dynamics of hares and lynx across the broader landscape. In the future, these processes will be most influenced by forest harvesting and silvicultural practices (e.g., clearcut versus partial harvesting, herbicide application versus natural regeneration, plantations) and by natural processes (e.g., spruce-budworm) that influence forest successional patterns across the Acadian forest landscapes occupied by hares and lynx. In the longer term, climate change may also affect the southern range limit for some conifer tree species, snowshoe hares, and Canada lynx and may influence snow characteristics affecting competitive interactions between lynx and other mesopredators (e.g., fishers, bobcats, coyotes, red foxes) that also consume hares.

Project Objectives (Final Study Phase):

- To assess the extent that hare densities changed between seasons across regenerating conifer (15 - 42 years post-harvest), selection harvest, and mature conifer/mixed forest stands.

- To assess evidence to support or refute the hypothesis that snowshoe hares at the southeastern extent of their range do not cycle and exhibit unpredictable fluctuations in density across space and time.

Approach:

- We conducted semi-annual (May and September) pellet surveys within 53 different regenerating-conifer, selection harvest, and mature conifer/mixed stands monitored during 2001 - 2015 (range 4 - 41 stands monitored in each year).

- We measured a range of structural and vegetation characteristics in monitored stands during 2001, 2005, 2008, and 2012.

Key Findings / Accomplishments:

- A final report on the seasonal effects of habitat change on hare densities across forest treatments, as well as our final results from the lynx food habits studies were completed as a graduate thesis (Sheryn Olson, May 2015; avail. on CFRU website).

- We cleared pellets in our 18 REGEN stands in autumn 2014 and counted in May - June 2015 to derive our final estimates of over-winter hare densities in our benchmark REGEN stands.

- We completed analyses of temporal trends in hare densities across stand types and across harvest treatment through time.

- We completed a meta-analysis to evaluate evidence for cyclicity in Maine's population of snowshoe hare by analyzing pellet surveys conducted across stands surveyed during 2001-2015. Hare densities were highest in regenerating conifer stands (REGEN) with a previous history of clearcut harvesting, followed by herbicide application to suppress competing deciduous hardwoods. These stands provided superior habitat for a period from 15 - 40 years post-harvest due to dense conifer regeneration ranging from 2,200 - 13,000 stems ha^{-1} (stems defined as >1.0 m).

- Hare densities ranged from 2.3 times higher in REGEN than in uncut mature stands (MAT) during 2014, to 4.3 times higher in REGEN compared to MAT in 2008 (Figure 1). Across the period 2008 to 2015, MAT stands averaged 0.25 hares/ha (range 0.20-0.33), partial harvest stands averaged 0.43 hares/ha (range 0.31-0.59), and REGEN stands averaged 0.86 hares ha^{-1} (range 0.77-0.99; (Fig. 16).

- We documented that hares maintained relatively high and stable densities in REGEN stands across a consecutive 6-year period from 2001-2006 when annual densities averaged 1.98 hares ha^{-1} (range 1.79 - 2.22). Hares transitioned to intermediate densities of 1.19 ha^{-1} during a decline year in 2007 and then stabilized at a relatively lower annual density averaging 0.86 ha^{-1} (range 0.77 - 0.99) across the final 8 years of our study spanning 2008 - 2015 (Fig. 17).

- Our data do not indicate that the presence of a 10-year cycle typical of northern hare populations, but suggest long-term stable equilibria where densities vary approximately 2.3-fold, and where densities transition from a stable high period to a lower density phase across only a single year.

- Our results have significant implications for management of Canada lynx, which exhibit greatly decreased reproduction, declining survival, expanded home ranges, and decaying spatial structuring at the nadir of hare cycles in the north. Changes in home range area, habitat selection, and spatial behavior by lynx were not observed during the range of hare densities that we observed (see CFRU Annual Report for 2012: pages 79 - 84).

- Across our various studies, the extent and distribution of high quality hare habitat (i.e., conifer-dominated stands 15 - 40 years post stand-replacing disturbance) will drive the long-term dynamics of hares and lynx across the broader landscape. In the future, these processes will be most influenced by forest harvesting and silvicultural practices (e.g., clearcut versus partial harvesting, herbicide application versus natural regeneration, plantations) and by natural processes (e.g., spruce-budworm) that influence forest successional patterns across the Acadian forest landscapes occupied by hares and lynx.

- In the longer term, climate change may also affect the southern range limit for some conifer trees, snowshoe hares, and Canada lynx and may influence snow characteristics affecting competitive interactions between lynx and other mesopredators (e.g., fishers, bobcats, coyotes, red foxes) that also consume hares.

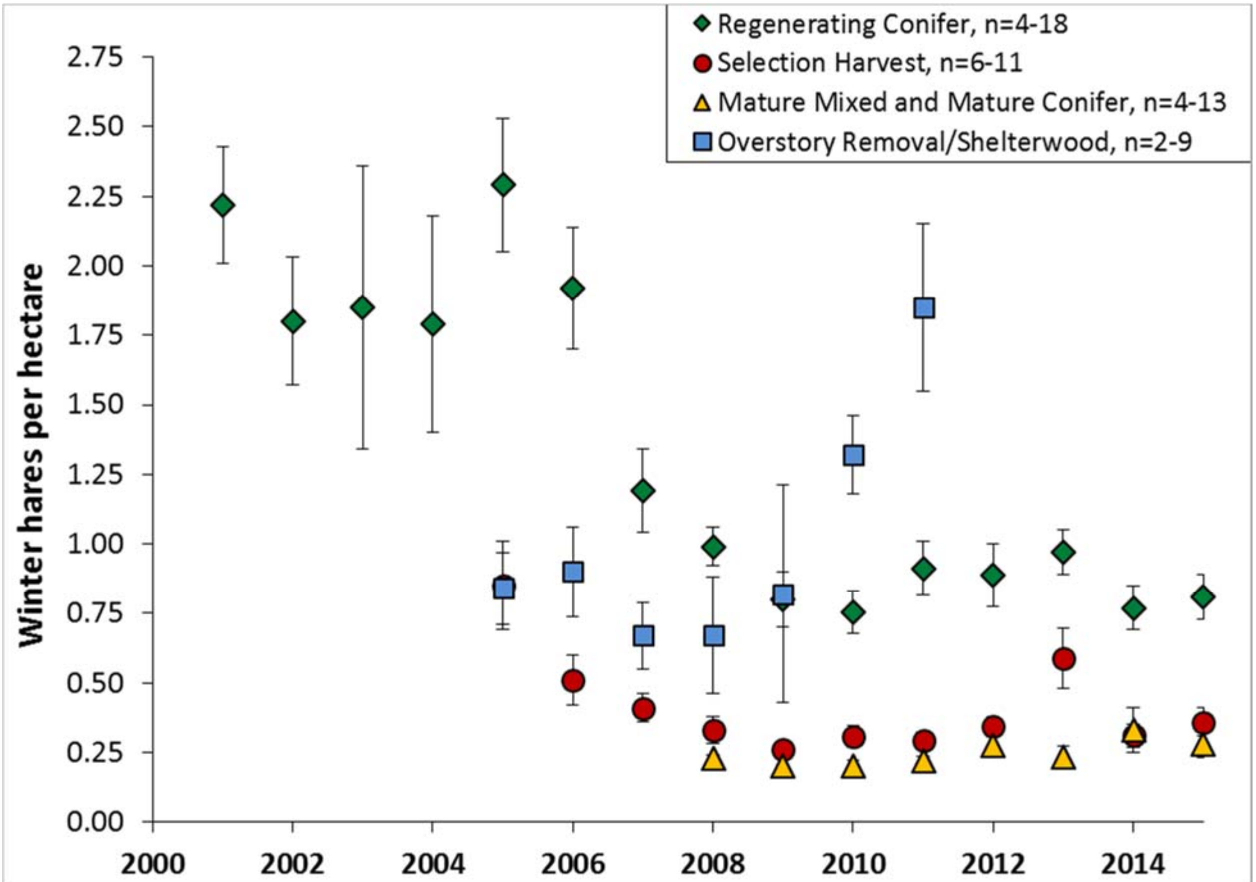


Figure 16. *Winter snowshoe hare densities (+/-SE) from 2001-2015 in four forest stand types: regenerated conifer stands 19 to 40 years post-clearcut, and herbicide treated three to five years post-harvest, overstory removal and shelterwood retention harvest, selection harvest, and a mature category that combines mature softwood and mature mixed wood. Whiskers represent one standard error. Sample sizes vary each year and are shown in the legend.*

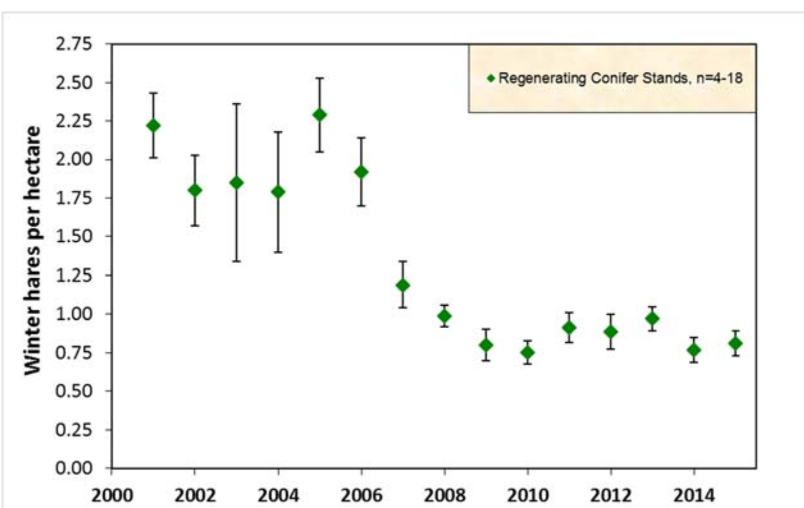


Figure 17. *Winter snowshoe hare density (+/-SE) from 2001-2015 in regenerated conifer stands 19 to 40 years post-clearcut as of 2014, and treated with herbicide three to five years post-harvest. Whiskers represent +/- one standard error. Sample sizes are: year 2001, n=13; 2002, n=17; 2003 – 2004, n=4; 2005 – 2011, n=15; 2012 – 2014, n=18.*

Future Plans:

We completed the study and expended all remaining CFRU funds. With support from the Maine Agricultural and Forest Experiment Station and the U.S. Fish and Wildlife Service we will continue to work to publish several papers summarizing project results in refereed journals during 2016.

Products Delivered:

Research Reports:

Harrison, D., and S. Olson. 2015. Relationships among forest harvesting, snowshoe hares, and Canada lynx in Maine. Pages 68-74 *in* R.G. Wagner, editor, Cooperative Forestry Research Unit: 2014 Annual Report, University of Maine, Orono.

Theses:

Olson, S. 2015. Seasonal influences on habitat use by snowshoe hares: implications for Canada lynx in northern Maine. M.S. Thesis, University of Maine, Orono, 153pp.

Acknowledgements:

We acknowledge the participation of Katahdin Forest Management LLC and Clayton Lake Woodlands LLC for providing unrestricted use of their lands during this ongoing study and to Katahdin Forest Management LLC for altering their harvesting schedules to accommodate our study design. We acknowledge the many undergraduate and post-graduate technicians who assisted with hare pellets and vegetation surveys across the many years of this study. Funding was provided by the CFRU, U.S. Fish and Wildlife Service, Maine Agricultural and Forest Experiment Station, Department of Wildlife Ecology at The University of Maine, and by the Maine Department of Inland Fisheries and Wildlife.

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

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University of Maine

Status: Progress Report, Year 1 of 3

Joel Tebbenkamp - Photo Rebecca Fontes

Summary:

During the 2015 field season we monitored 44 radio-marked spruce grouse, including 30 females and 14 males in northern Maine (Figs. 18 & 19). We obtained approximately 225 locations from these birds to locate nests, track brood success, and evaluate habitat use. All females radio-marked prior to the breeding season initiated nests, and apparent nest success was 50% (4/8). We monitored 11 broods, and apparent brood success was 73% (8/11). We conducted vegetation sampling at nests and areas used by females post-nesting (both brooded and non-brooded), and also collected similar data at random locations. Additionally, we completed measurement at sites of use by 28 female spruce grouse monitored by telemetry during 2012 - 2014 and compared to random sites within the stands where the birds were captured. During June and July 2015 we located females approximately once per week and conducted vegetation sampling at the use and 1 dependent random location resulting in a total of 116 (58 use and 58 random) vegetation plots from the 15 females monitored during this time period. In future years we will focus on increasing our sample sizes and expanding analyses of demographic responses and habitat selection in relation to various forms of forest management.

Project Objectives:

Our overall goal for this work is to provide a comprehensive assessment of the link between commercial forest management, forest habitat characteristics, and population performance of spruce grouse in Northern Maine. Our specific objectives are:

Objective 1: Estimate demographic rates (adult survival for males and females, nest success, chick survival) of spruce grouse using a combination of radio-telemetry and capture-mark-recapture methods. Compare demographic rates among 1) regenerating clearcuts (25-30 years post-cutting); 2) stands that have been clearcut (25-35 years previous), treated with herbicide, and pre-commercially thinned; and 3) "classic" stands of mid- and late-successional black spruce and tamarack.

Objective 2: Evaluate substand-scale characteristics such as understory composition, canopy cover, or tree basal area, at locations used by spruce grouse during important life phases (e.g. brood rearing or nesting) and determine the influence of these habitat characteristics on demographic rates. Contrast these relationships between stand types to understand the mechanisms responsible for any stand-level differences in survival or reproduction.

Objective 3: Relate objectives 1 and 2 to population performance using predictive age-structured population models. Use these models to evaluate the overall contributions of the three stand types to spruce grouse population growth and overall population performance.

Objective 4: Develop management guidelines and produce recommendations related to spruce grouse conservation in managed conifer forests.

Approach:

- Capture and radio-mark female and male spruce grouse
- Monitor survival and reproductive activities (nesting, brood rearing) of radio-marked birds.
- Measure characteristics of forest structure and composition (e.g. basal area, visual obstruction) at use and random locations.
- Use appropriate data analysis methods to link forest characteristics to spruce grouse habitat use (resource selection functions), demographics (mark-recapture analyses) and population dynamics (stage-based population models).

Key Findings / Accomplishments:

- Monitored 28 adult female spruce grouse during summers of 2012-2014.
- Monitored 44 spruce grouse in 2015, including 34 (23 female, 11 male) that were captured and radio-marked during 2015.
- Collected 225 locations from the 15 radio-marked females monitored during the reproductive season.
- Measured forest structure and composition at 148 plot locations.
- Documented significantly greater shrub cover ($p = 0.025$; Fig. 20) and forb cover ($p = 0.031$; Fig. 21) at locations used by female spruce grouse monitored in 2015 compared to random locations.
- Conducted analyses for resource selection by 28 adult female spruce grouse during summers of 2012-2014.
- Observed selection by adult female grouse for sub-stand features including lower tree densities, taller trees, greater quadratic mean diameter of trees, and higher densities of saplings during the brooding season (Fig. 22).

- Located 8 spruce grouse nests and monitored 11 broods during 2015.

- Documented 50% apparent nest success (hatched 1 or more eggs) and 73% apparent brood success (fledged 1 or more chicks).

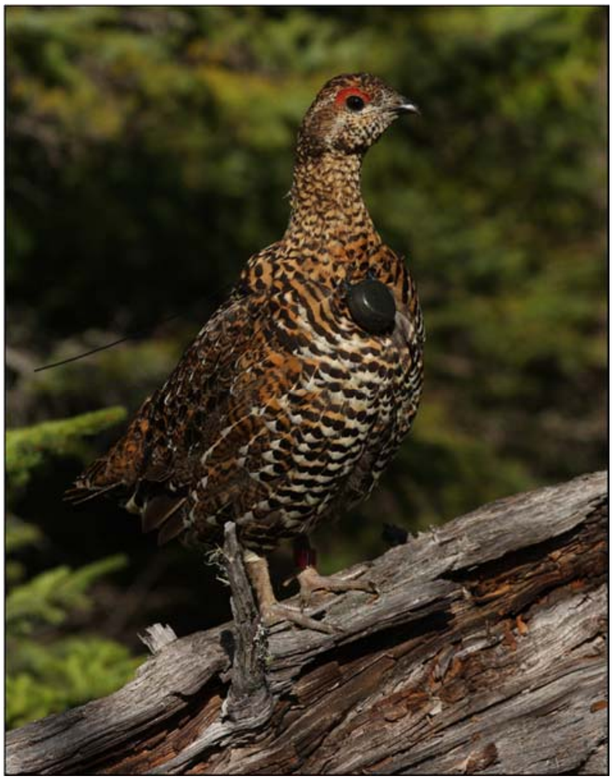

Figure 18. *Radio-marked female spruce grouse standing guard over her chicks. Photo by Erik Blomberg.*

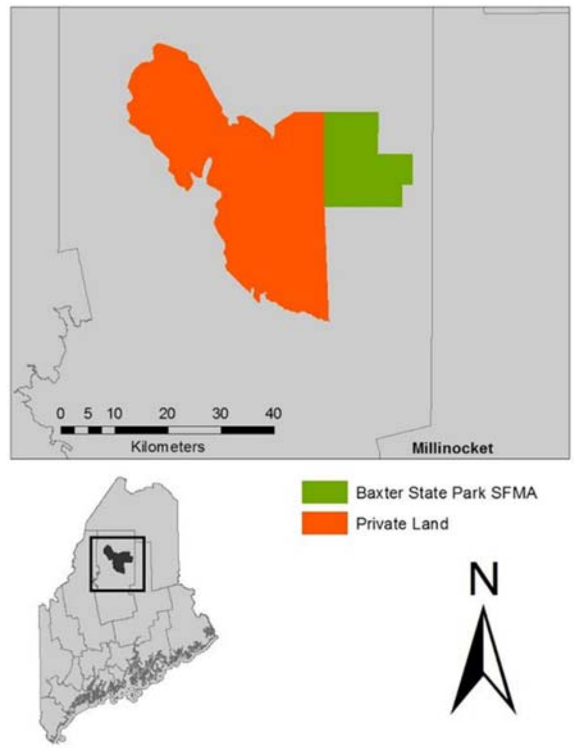

Figure 19. *Location and extent of the study area in Piscataquis County, Maine.*

Future Plans:

- Continue to capture and radio-mark grouse to increase sample size.

- Collect two additional seasons of reproductive and habitat use data.

- Conduct habitat selection and demographic analyses.

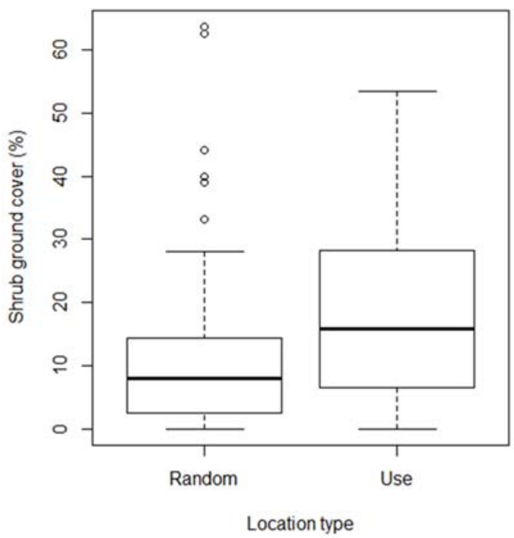

Figure 20. Comparison of shrub cover between areas used by adult female spruce grouse (n = 58) and random locations (n = 58) during summer 2015. Shrub cover was significantly greater (t-test, p = 0.025) at sites used by adult females.

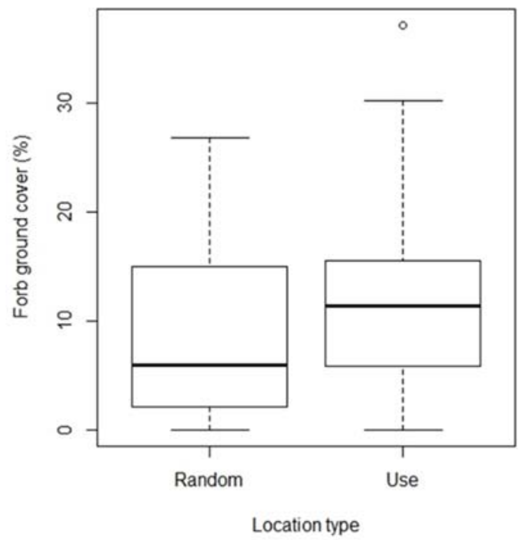

Figure 21. Comparison of forb groundcover between areas used by adult female spruce grouse (n = 58) and random locations (n = 58) during summer 2015. Forb groundcover was significantly greater (t-test, p = 0.031) at locations used by adult females.

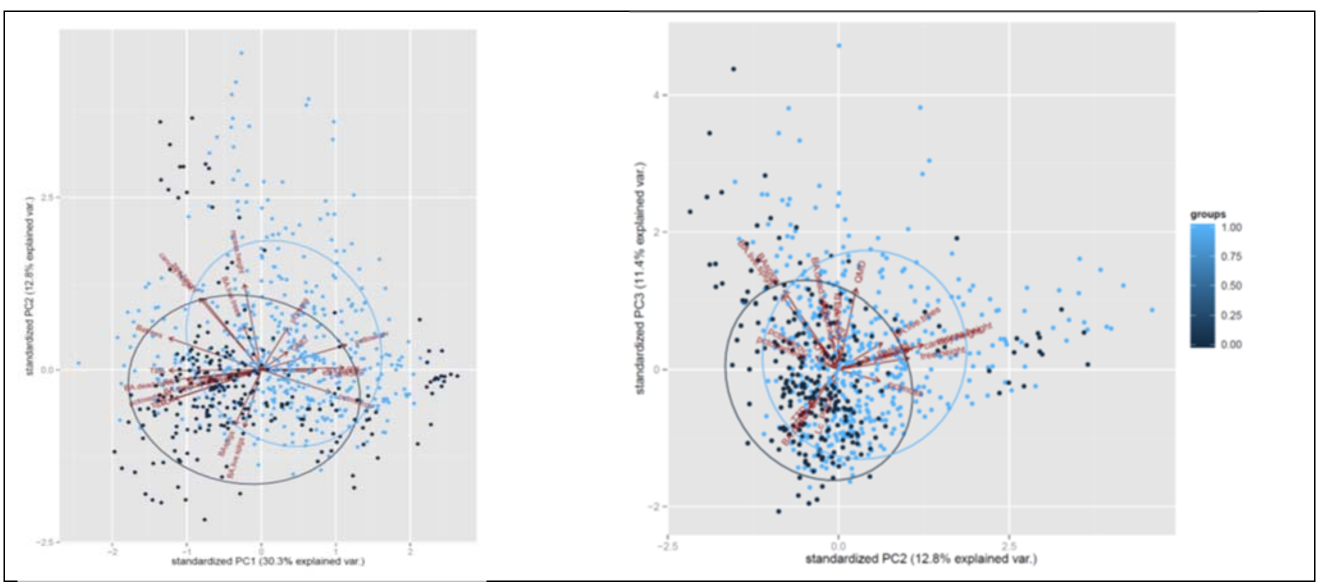

Figure 22. *Ordination diagrams for the three dominant (explain 55% of variation) principle components describing the difference in forest age & structure between points used by 28 adult female spruce grouse (telemetry locations) and those available within the stand where the grouse was captured (2012-14breeding season). Gaussian confidence ellipses are shown centered around the sample means. Female grouse selected for within-stand attributes including lower tree densities, taller trees, greater quadratic mean diameter of trees, and higher densities of saplings during the brooding season.*

Products Delivered:

Research Reports:

Dunham, S., and D. Harrison. 2014. Patch occupancy, habitat use, and population performance of spruce grouse in commercially managed conifer stands. Pages 75-79 *in* R.G. Wagner, editor, Cooperative Forestry Research Unit: 2014 Annual Report, University of Maine, Orono.

Presentations/Workshops/Meetings/Field Tours:

Dunham, S. W., D. J. Harrison, and E. J. Blomberg. 2015. Spruce grouse (*Falcipennis canadensis)* patch occupancy and abundance estimates in the commercially managed forests of Maine. *Presentation at the 13th International Grouse Symposium, Reykjavik, Iceland,* September 8.

Dunham, S. W., and D. J. Harrison. 2014. Spruce grouse breeding season patch occupancy and female home range use across forest management treatments in Maine. *Poster presented at the Annual Conference of The Wildlife Society, Pittsburgh, Pennsylvania,* October 27-28.

Tebbenkamp, J. M., E. Blomberg, D. Harrison, B. Allen, K. Sullivan. 2015. Spruce Grouse Demography and Population Status in Commercially-Harvested Forests of Northern Maine. Poster Presentation, Maine Cooperative Fish and Wildlife Research Unit Annual Meeting.

Dunham, S. W., and D. J. Harrison. 2015. Spruce Grouse Breeding Season Patch Occupancy and Female Home Range Use Across Forest Management Treatments in Maine. Poster presented at the Annual USGS Maine Cooperative Fish and Wildlife Research Unit Coordinating Committee Meeting, Orono, Maine.

Acknowledgements:

We acknowledge the participation of Katahdin Forest Management LLC for providing unrestricted use of their lands during this ongoing study and to Katahdin Forest Management LLC for altering their harvesting schedules to accommodate our study design. Additionally, personnel associated with Baxter State Park, particularly Jensen Bissell and Jean Hoekwater were helpful with logistics and accommodating to our study. This project received additional financial support from the Maine Outdoor Heritage Fund. Finally, Larry Pelletier of Gerald Pelletier Inc. has been very accommodating to our field crews at the CFRU's Telos Camp.

Bird communities of coniferous forests in the Acadian region: Habitat associations and responses to forest management

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Blackburnian Warbler

Status: Final Report

Summary:

Several bird species of concern are found in the coniferous forests of Northern New England. Cape May (*Setophaga tigrina*) and Bay-Breasted Warbler (*Setophaga castanea*) have been declining within the Acadian Region since region-wide monitoring began with the USGS Breeding Bird Survey in 1966, whereas, species such as Blackburnian Warbler (*Setophaga fusca*) are increasing (Sauer *et al.* 2012, Fig. 23). The United States Federal government has the authority to manage these species under the U.S. Migratory Bird Treaty Act. Maine contributes up to 96% of breeding habitat (e.g., Bay-Breasted Warbler, M. Hartley, USFWS, unpublished data) for some of these spruce-fir associated species in the United States, and the apparent population declines of some species are not well understood. The coniferous forests where these species reside are heavily managed by the timber industry with a variety of silvicultural and industrial prescriptions. Habitat requirements for these species are not well-defined, nor are the species' responses to forest management.

We sampled birds across sites located within the Acadian Forest Region (Fig. 24), which coincides roughly with Bird Conservation Region 14 in the United States (Fig. 25). In 2013, we established survey points in the North Maine Woods (Clayton Lake and Telos), Baxter State Park, and four National Wildlife Refuges (Nulhegan Basin Division of Silvio Conte, Umbagog, Moosehorn, and Aroostook). We tested for bird community response to management with non-metric multidimensional scaling to group bird species within forest management types and across common vegetation measurements representing the structure and composition of stands (Fig. 26). Preliminary analyses suggest that both Bay-breasted and Cape May Warblers were associated with regenerating and pre-commercially thinned treatments, along with dense canopy cover, high proportion of spruce-fir composition, and mid-successional stand structure.

Project Objectives:

Our goals are to investigate factors influencing the distribution and abundance of species that represent the Acadian coniferous forests and to assess the influence of prevalent forest management practices on the Acadian forest bird community. Our objectives are to:

- Quantify the composition and forest associations of coniferous bird communities in five silvicultural treatments representing a gradient in mature canopy residuals including conifer regenerating, overstory removal, pre-commercially thinned, selection, and shelterwood harvest compared to mature softwood reference sites.

- Model the influences of silvicultural practices on coniferous forest bird communities while accounting for detection error.

- Use data at both landscape and local scales to determine important habitat and beneficial forest management practices.

- Provide accessible and interpretable results for forest managers that can be used to manage for avian species of concern in managed forest landscapes and stands.

Approach:

- Bird community surveys and vegetation measurements were conducted within 117 forest stands located in Maine, New Hampshire, and Vermont (Table 7, Fig. 24). We surveyed birds using standard point count survey methods at 657 point locations within our 117 focal stands. We adapted methods from the Forest Inventory Analysis and Breeding Bird Research and Monitoring Database (Martin *et al.* 1997) to measure vegetation at each point count location. Data collected included 22 structural and compositional measurements.

- We deployed 234 multipher (pheromone) spruce budworm traps consistent with Maine Forest Service protocols and conducted reproductive surveys for Bay-breasted Warbler in 2015 to test for the influence of spruce budworm on warbler reproduction.

- We used point count data for 56 species (Table 8) and nonmetric multidimensional scaling (NMDS) to fit generalized additive models to visualize relationships between avian communities, harvest treatments, and habitat characteristics with data that are not corrected for detection probability (Sheehan *et al.* 2014, Oksanen *et al.* 2012).

Key Findings / Accomplishments:

- In 2013, we surveyed 110 forest stands (Fig. 25, Table 7) with approximately 3 to 8 survey points per stand for a total of 609 sampled points. In 2014 and 2015, we added 48 points in 7 stands to increase sample size in shelterwood harvests, increasing total samples to 657 points in 117 stands. Across all study areas, we recorded 19,431 detections of 123 bird species in 2013; 22,784 detections of 106 bird species in 2014; and 23,608 of 118 bird species in 2015 totaling 65,435 detections and 137 species. We adapted methods from the Forest Inventory Analysis and

Breeding Bird Research and Monitoring Database (Martin *et al.* 1997) to measure vegetation at the location of each point count. Data collected included an array of structural and compositional measurements. We completed 1,320 vegetation plots and measured 15,024 trees during those surveys.

- Abundances of declining spruce-fir species such as Bay-breasted Warbler and Cape May Warbler, *Setophaga tigrina*, were associated with mid-successional regenerating and pre-commercially thinned treatments with tree species composition dominated by spruces and balsam fir.

- Harvest treatment (R^2=29%, Fig. 26) was an important predictor for bird abundance.

- Forest attributes that were important predictors of bird abundance included mature forest structure (measured by quadratic mean diameter - QMD) which was the strongest predictor of community bird abundance (R^2=63%), followed by canopy cover (R^2=50%), proportion spruce-fir (R^2=41%, Figure 5), ground cover (R^2=30%), midstory (R^2=28%), then shrubs (R^2=26%). Variation between year of survey, a potentially confounding factor, explained little of the variance in bird communities (R^2=2%).

- Results suggest that mature forest structure may be an important determinant for bird communities, which is ultimately influenced by forest management.

Future Plans

- We will correct for the probability of detection to obtain abundance estimates in a Bayesian framework.

- We will test whether adult spruce budworm captures in pheromone traps is correlated with Bay-breasted warbler reproductive success.

- We will conduct more in-depth analyses on the abundance of focal species such as Bay-breasted and Cape May Warbler.

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Sheehan, J., P. B. Wood, D. A. Buehler, P. D. Keyser, J. L. Larkin, A. D. Rodewald, T. B. Wigley, T. J. Boves, G. A. George, M. H. Bakermans, T. A. Beachy, A. Evans, M. E. McDermott, F. L. Newell, K. A. Perkins, and M. White. 2014. Avian response to timber harvesting applied experimentally to manage Cerulean Warbler breeding populations. Forest Ecology and Management 321:5–18.

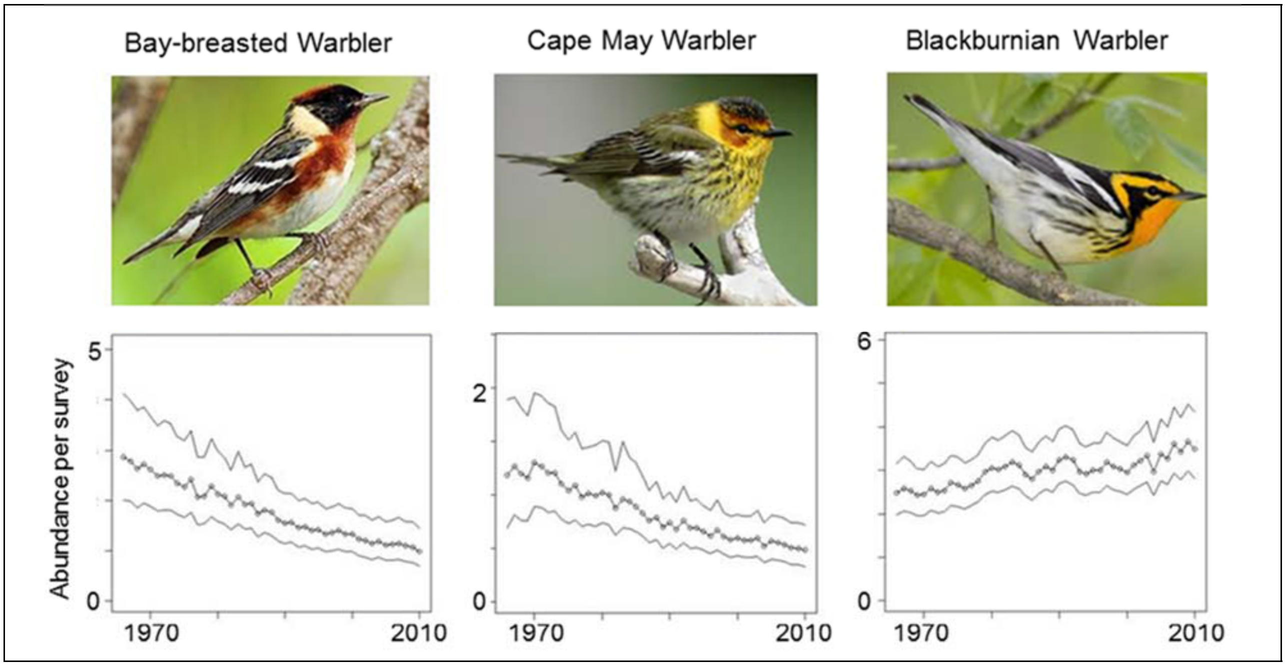

Figure 23. *Three species of conservation concern and their estimated population trends in Bird Conservation Region 14 from USGS Breeding Bird Survey data. Photo credits: Bay-breasted Warbler by Bill Majoros, Cape May Warbler and Blackburnian Warbler were used from USGS Breeding Bird Survey data.*

Figure 24. *James (Mack) McGraw, an undergraduate student at The University of Maine, conducting bird surveys at Moosehorn National Wildlife Refuge during 2015.*

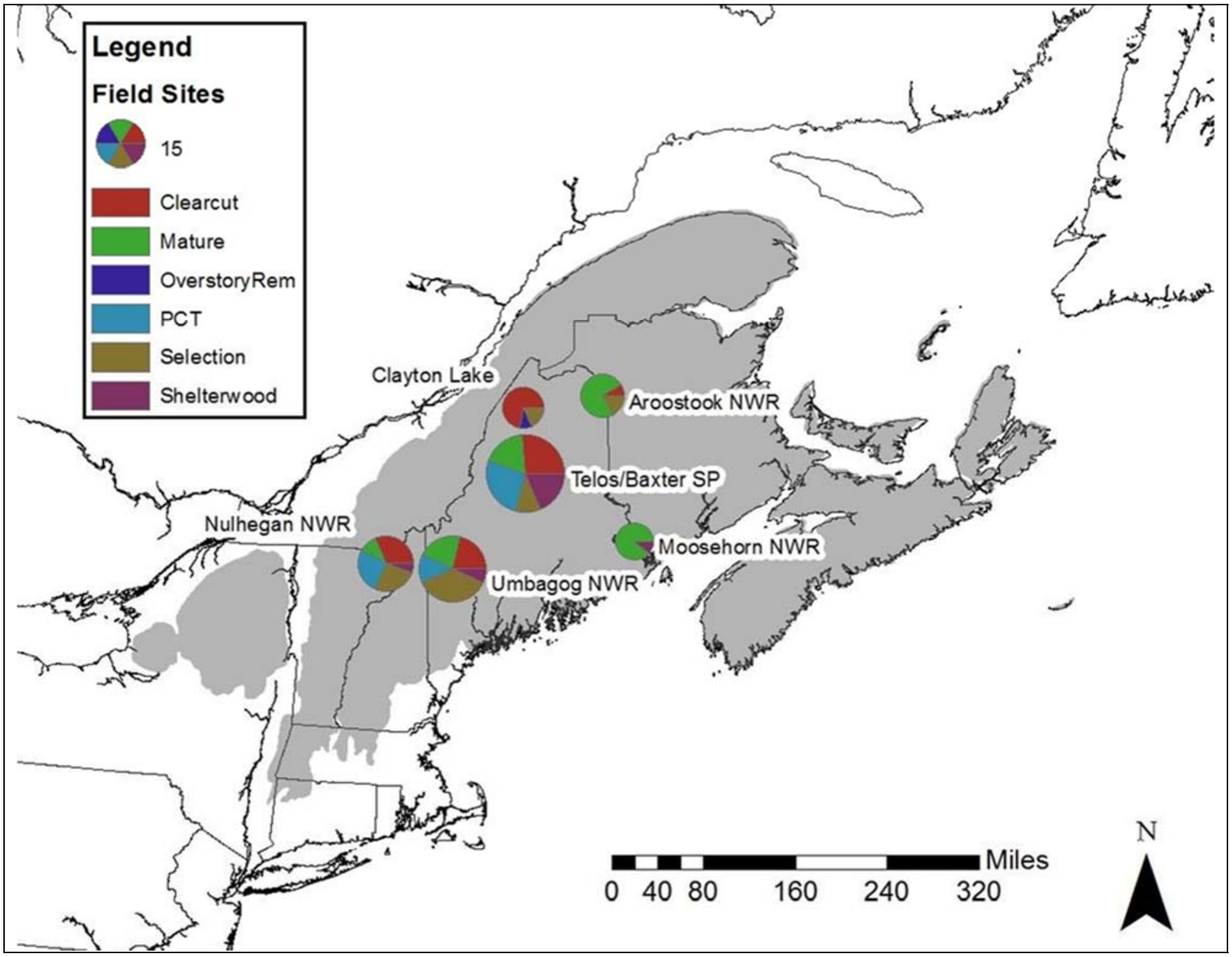

Figure 25. *Survey areas in Northern New England. The size of each pie chart is proportional to the number of stands surveyed in each area; pie charts show the proportion of stands in each treatment category; and the shaded gray area is Bird Conservation Region 14. We detected 65,435 birds during 6,129 surveys.*

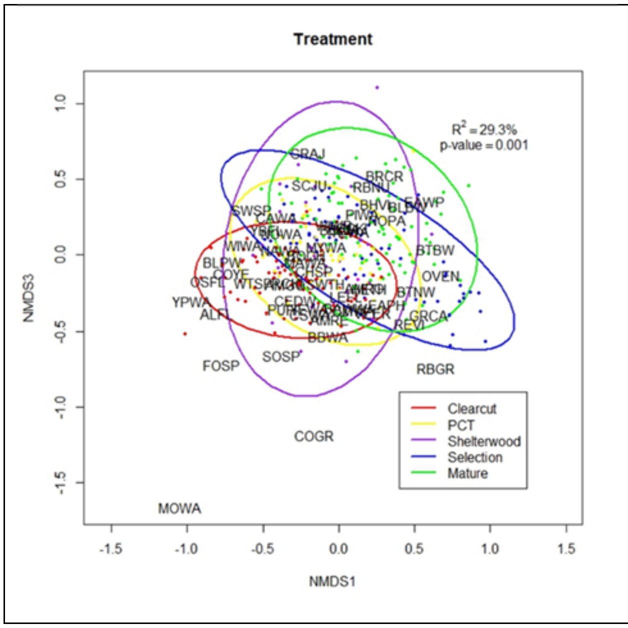

Figure 26. *NMDS ordinations of bird species abundance fit to generalized additive models of harvest treatment.*

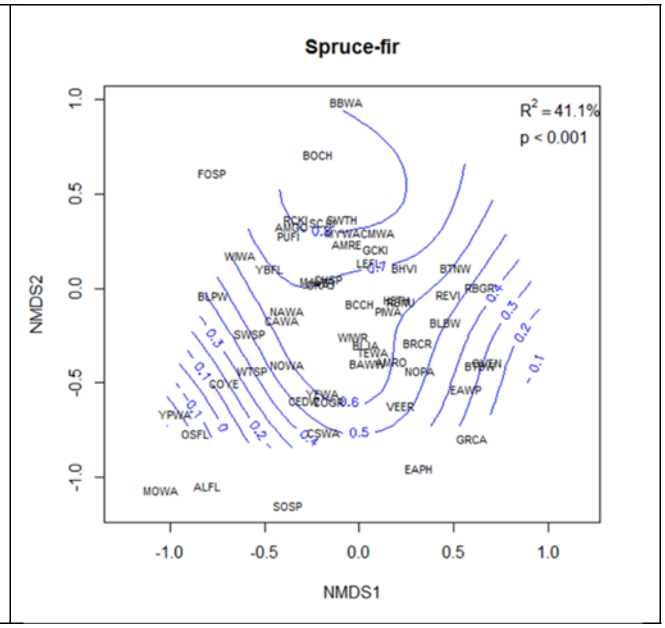

Figure 27. *NMDS ordinations of bird species abundance fit to generalized additive models of spruce-fir composition.*

Table 7. The number of stands in each treatment class at each property that were surveyed in 2013 2014, and/or 2015 and the total at all sites combined. PCT=pre-commercially thinned.

Property	Number of stands in each treatment						
	Conifer Regen	Mature	Overstory Removal	PCT	Selection	Shelterwood	Total
Aroostook NWR	1	9	0	0	2	0	12
Baxter State Park	0	2	0	0	0	7	9
Clayton Lake	8	0	1	0	2	0	11
Moosehorn NWR	0	8	0	0	0	1	9
Nulhegan NWR	6	2	0	5	5	1	19
Telos	10	5	0	10	4	0	29
Umbagog NWR	6	6	0	4	10	2	28
Total	31	32	1	19	23	11	117

Table 8. Passerine birds at all study areas detected > 10 times within 50m of survey locations during point count surveys conducted in 2013, 2014 and 2015 (data pooled). Codes were used in figure 3. Column A) is the total number detected, B) is the number of locations detected, C) is mean abundance per point and standard deviation, and D) is the proportion of locations where a bird was detected.

Code	Common name	Genus species	A	B	C	D
ALFL	ALDER FLYCATCHER	*Empidonax alnorum*	84	68	0.13 (0.4)	0.1
AMGO	AMERICAN GOLDFINCH	*Spinus tristis*	24	22	0.04 (0.2)	0.03
AMRE	AMERICAN REDSTART	*Setophaga ruticilla*	256	222	0.39 (0.59)	0.34
AMRO	AMERICAN ROBIN	*Turdus migratorius*	345	273	0.53 (0.72)	0.42
BAWW	BLACK-AND-WHITE WARBLER	*Mniotilta varia*	314	270	0.48 (0.63)	0.41
BBWA	BAY-BREASTED WARBLER	*Setophaga castanea*	162	140	0.25 (0.51)	0.21
BCCH	BLACK-CAPPED CHICKADEE	*Parus atricapillus*	766	483	1.17 (1.05)	0.74
BHVI	BLUE-HEADED VIREO	*Vireo solitarius*	402	355	0.61 (0.62)	0.54
BLBW	BLACKBURNIAN WARBLER	*Setophaga fusca*	354	288	0.54 (0.68)	0.44
BLJA	BLUE JAY	*Cyanocitta cristata*	347	284	0.53 (0.7)	0.43
BLPW	BLACKPOLL WARBLER	*Setophaga striata*	70	54	0.11 (0.4)	0.08
BOCH	BOREAL CHICKADEE	*Poecile hudsonicus*	385	272	0.59 (0.86)	0.41
BRCR	BROWN CREEPER	*Certhia americana*	188	174	0.29 (0.5)	0.26
BTBW	BLACK-THROATED BLUE WARBLER	*Setophaga caerulescens*	319	264	0.49 (0.65)	0.4
BTNW	BLACK-THROATED GREEN WARBLER	*Setophaga virens*	537	396	0.82 (0.82)	0.6
CAWA	CANADA WARBLER	*Cardellina canadensis*	339	259	0.52 (0.73)	0.39
CEDW	CEDAR WAXWING	*Bombycilla cedrorum*	343	247	0.52 (0.85)	0.38
CHSP	CHIPPING SPARROW	*Spizella passerina*	57	49	0.09 (0.33)	0.07
CMWA	CAPE MAY WARBLER	*Setophaga tigrina*	29	27	0.04 (0.22)	0.04
COGR	COMMON GRACKLE	*Quiscalus quiscula*	17	15	0.03 (0.18)	0.02
COYE	COMMON YELLOWTHROAT	*Geothlypis trichas*	370	277	0.56 (0.76)	0.42
CSWA	CHESTNUT-SIDED WARBLER	*Setophaga pensylvanica*	123	104	0.19 (0.47)	0.16

EAPH	EASTERN PHOEBE	*Sayornis phoebe*	15	14	0.02 (0.16)	0.02
EAWP	EASTERN WOOD-PEWEE	*Contopus virens*	33	31	0.05 (0.23)	0.05
FOSP	FOX SPARROW	*Passerella iliaca*	58	49	0.09 (0.33)	0.07
GCKI	GOLDEN-CROWNED KINGLET	*Regulus satrapa*	799	581	1.22 (0.71)	0.88
GRAJ	GRAY JAY	*Perisoreus*	150	102	0.23 (0.65)	0.16
GRCA	GRAY CATBIRD	*Dumetella carolinensis*	22	21	0.03 (0.19)	0.03
HETH	HERMIT THRUSH	*Catharus guttatus*	839	537	1.28 (0.87)	0.82
LEFL	LEAST FLYCATCHER	*Empidonax minimus*	183	156	0.28 (0.55)	0.24
MAWA	MAGNOLIA WARBLER	*Setophaga magnolia*	1084	596	1.65 (0.93)	0.91
MOWA	MOURNING WARBLER	*Geothlypis philadelphia*	14	14	0.02 (0.14)	0.02
MYWA	MYRTLE WARBLER	*Setophaga coronata*	659	485	1 (0.8)	0.74
NAWA	NASHVILLE WARBLER	*Vermivora ruficapilla*	710	469	1.08 (0.88)	0.71
NOPA	NORTHERN PARULA	*Setophaga americana*	465	370	0.71 (0.72)	0.56
NOWA	NORTHERN WATERTHRUSH	*Parkesia noveboracensis*	222	177	0.34 (0.62)	0.27
OSFL	OLIVE-SIDED FLYCATCHER	*Contopus cooperi*	58	49	0.09 (0.33)	0.07
OVEN	OVENBIRD	*Seiurus aurocapilla*	498	336	0.76 (0.89)	0.51
PIWA	PINE WARBLER	*Sylvia cantillans*	204	171	0.31 (0.57)	0.26
PUFI	PURPLE FINCH	*Carpodacus purpureus*	171	164	0.26 (0.46)	0.25
RBGR	ROSE-BREASTED GROSBEAK	*Pheucticus ludovicianus*	33	31	0.05 (0.23)	0.05
RBNU	RED-BREASTED NUTHATCH	*Sitta canadensis*	609	459	0.93 (0.76)	0.7
RCKI	RUBY-CROWNED KINGLET	*Regulus calendula*	253	212	0.39 (0.61)	0.32
REVI	RED-EYED VIREO	*Vireo olivaceus*	503	408	0.77 (0.7)	0.62
SCJU	DARK-EYED JUNCO	*Junco hyemalis*	316	257	0.48 (0.67)	0.39
SOSP	SONG SPARROW	*Melospiza melodia*	28	25	0.04 (0.22)	0.04
SWSP	SWAMP SPARROW	*Melospiza georgiana*	34	26	0.05 (0.27)	0.04
SWTH	SWAINSON'S THRUSH	*Catharus ustulatus*	814	528	1.24 (0.86)	0.8

TEWA	TENNESSEE WARBLER	*Oreothlypis peregrina*	12	12	0.02 (0.13)	0.02
VEER	VEERY	*Catharus fuscescens*	73	63	0.11 (0.36)	0.1
WIWA	WILSON'S WARBLER	*Cardellina pusilla*	37	32	0.06 (0.26)	0.05
WIWR	WINTER WREN	*Nannus troglodytes*	596	454	0.91 (0.74)	0.69
WTSP	WHITE-THROATED SPARROW	*Zonotrichia albicollis*	701	436	1.07 (1.05)	0.66
YBFL	YELLOW-BELLIED FLYCATCHER	*Empidonax flaviventris*	458	362	0.7 (0.73)	0.55
YEWA	YELLOW WARBLER	*Iduna natalensis*	11	11	0.02 (0.13)	0.02
YPWA	PALM WARBLER	*Setophaga palmarum*	164	114	0.25 (0.61)	0.17

Products Delivered:

Research Reports:

Rolek, B., D. Harrison, C. Loftin, and P. Wood. 2015. Bird communities of coniferous forests in the Acadian Region: Habitat associations and response of birds to forest management. Pages 80-88 in R.G. Wagner, editor, Cooperative Forestry Research Unit: 2014 Annual Report, University of Maine, Orono.

Rolek, B., D. Harrison, C. Loftin, and P. Wood. 2015. Bird communities of coniferous forests in the Acadian Region: Habitat associations and response of birds to forest management: Annual report to Baxter State Park.

Rolek, B., D. Harrison, C. Loftin, and P. Wood. 2015. Bird communities of coniferous forests in the Acadian Region: Habitat associations and response of birds to forest management: Annual report to Fish and Wildlife Service and National Wildlife Refuges.

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Presentations/Workshops/Meetings/Field Tours:

Rolek, B.W., C. Loftin, D. Harrison, and P. Wood. 2015. Softwood Forest Birds and Silviculture in New England. Baxter State Park Annual Meeting. Augusta, ME, USA. Spring 2015.

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Acknowledgements:

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Ruby-crowned kinglet - photo by Pamela Wells

Moose Density and Forest Regeneration Relationships in Maine

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Alces alces in Maine – photo Sue Aygarn

Status: progress report, year 1 of 2

Summary:

High moose density that 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 summer 2015, 64 younger-aged (5-20 years) stands were measured with a milacre plot protocol; 4 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 damage; relative damage (light crook) was consistently higher in hardwood plots and declined with age. 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.

Project Objectives:

The overall objective of this project is to assess the influence of moose browsing on regeneration and composition of commercial forests of Maine. Specific objectives are to:

- measure the presence and stocking rate of commercial species, relative stem height (</>3.0 m), and browsing damage in 3 age classes (5-10, 10-15, 15-20 years) in 2 harvest regimes (clear-cut, partial harvest) within 3 forest types (softwood, hardwood, mixed wood),

- conduct a standard forest inventory within 10-15 stands >25 years old with known silvicultural history to assess composition and quality in older stands subjected to moose browsing, and

- identify suitable sites for establishing permanent plots to assess forest regeneration long-term relative to a range of moose density.

Approach:

- Younger aged stands (5-20 years) were assessed with methods employed in New Hampshire and Vermont for similar research (Leak 2007, Bergeron et al. 2011, Andreozzi et al. 2014). Small-plot surveys using milacre plots (~2.3 m diameter, 100-400 per site) were used to identify the dominant stem (commercial or not) and measure its relative height and degree of damage (none, crook severity, broom, fork).

- Older stands (>25 years) were measured with a standard forest inventory using a 10/20 factor prism where the dbh of sample trees was measured to calculate basal area. Sample trees were assessed for commercial quality with the New Brunswick NHRI classification protocol (Pelletier *et al.* 2013) that assigns form (F1 to 8) and vigor (R1 to 4) ratings from observed tree characteristics.

- Permanent plots will be located within MDIFW Wildlife Management Districts (WMD) reflecting a typical range of moose density (~1.0-3.0 moose km^{-2}) in the core moose range of Maine (Kantar *et al.* 2013). Study plots will reflect a mix of the 3 major stand types (hardwood, softwood, mixed wood) and 2 harvest practices (clearcut, partial harvesting) that constitute the sampling strategy described in Objective 1. The goal is to establish at least 120 plots (20 plots/forest type/harvest treatment) in the 0-5 and/or 5-10 year age classes.

Accomplishments:

- During spring 2015 we met with land managers and identified a subset of forest stands which met the criteria for forest type, harvest category, and stand age for the milacre sample plots (Objectives 1 and 3). We also identified the location of 12 older stands with known harvest histories (30 years old, Objective 2).

- We focused sampling on Plum Creek properties near Moosehead Lake in summer 2015 to establish and modify the milacre plot protocol and sample nearby older plots; the study will expand geographically in 2016. In total, we sampled 6600 milacre plots within 64 younger stands and conducted a forest inventory in 4 older stands (Fig. 28).

- The dominant stem in the milacre plots was a commercial species regardless of stand age, harvest practice, or forest type. The most common commercial species were red maple, balsam fir, red spruce, and sugar maple (Fig. 29) which combined, represented >65% of stems. Likewise, commercial stems dominated the older stands with sugar and red maple, balsam fir, white spruce, and yellow and paper birch (Fig. 30) representing >80% of stems.

- The majority (52-96%) of stems in the younger aged stands had no damage with 3 exceptions in hardwood stands: below 1.5 m in 5-10 year old (31%) and 10-15 year old clear-cuts (43%), and at 1.5-3.0 m in 10-15 year old partial harvest stands (Table 9). Damage in softwood stands was negligible (81-96% had no damage).

- In older stands the majority of stems had no damage (62-100%) at 0-3 m height; at 1.5-3.0 m height, 80% were classified with no damage. Damage was mostly limited (17%) to light crooks (<30°) (Fig. 31).

- The majority (~80%) of trees in the >30 year old plots were commercial species, undamaged, and of Form 1 or 2 (single stem) and vigor R1 or R2 (96%) indicating that stands had commercial value relative to these criteria (Table 10).

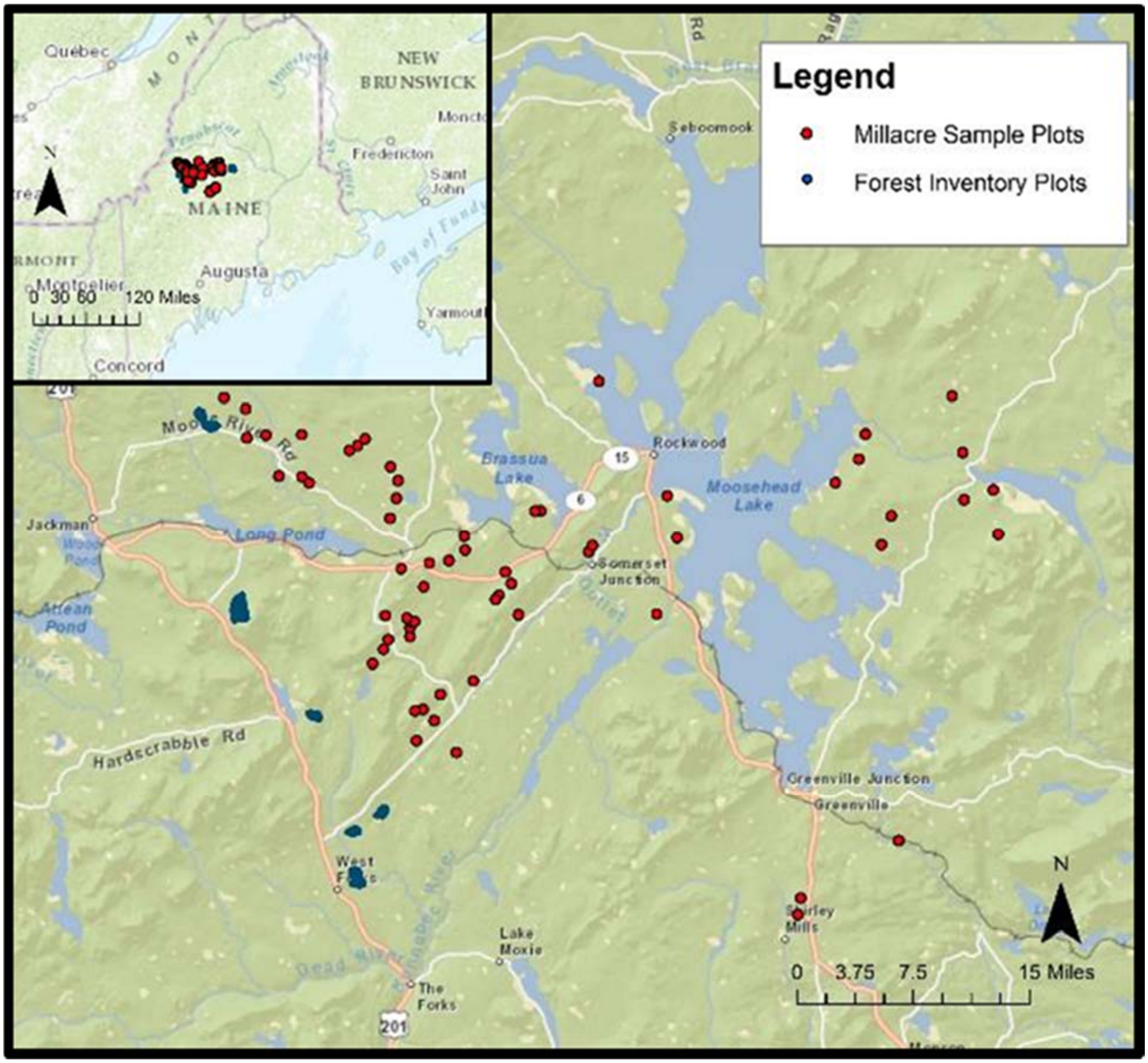

Figure 28. *The location of forest stands sampled using milacre plots (5-20years) or a standard forest inventory (>20 years) during the summer of 2015.*

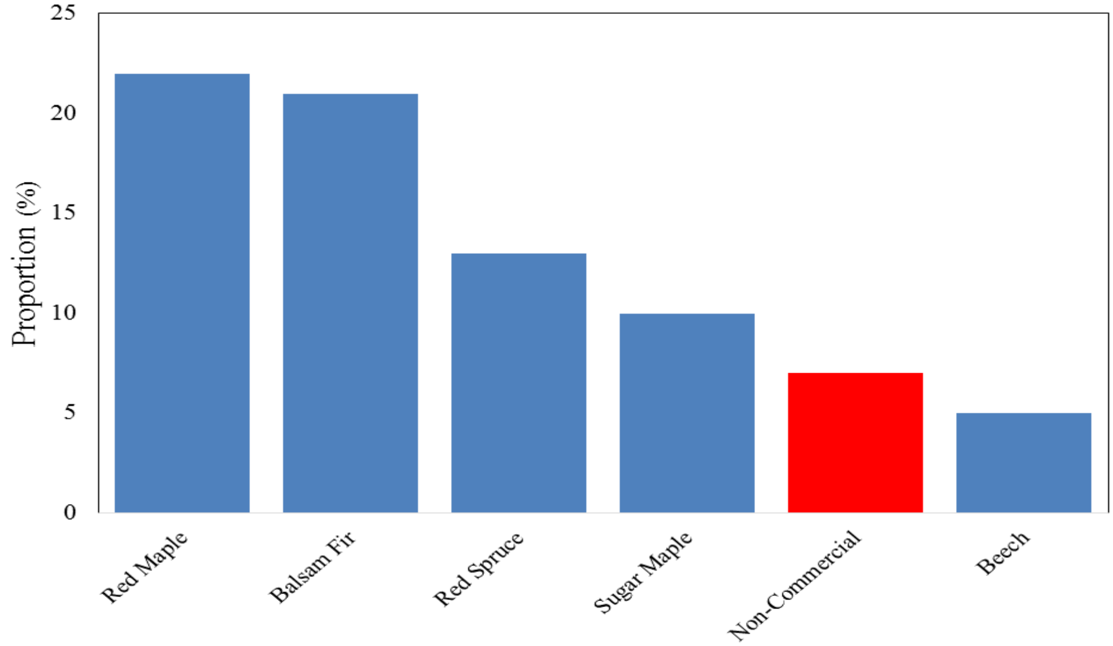

Figure 29. *The percent composition of commercial and non-commercial tree species (≥5% total) recorded in the 6,608 milacre plots during the summer of 2015. Results are combined across age class, harvest category, and forest type.*

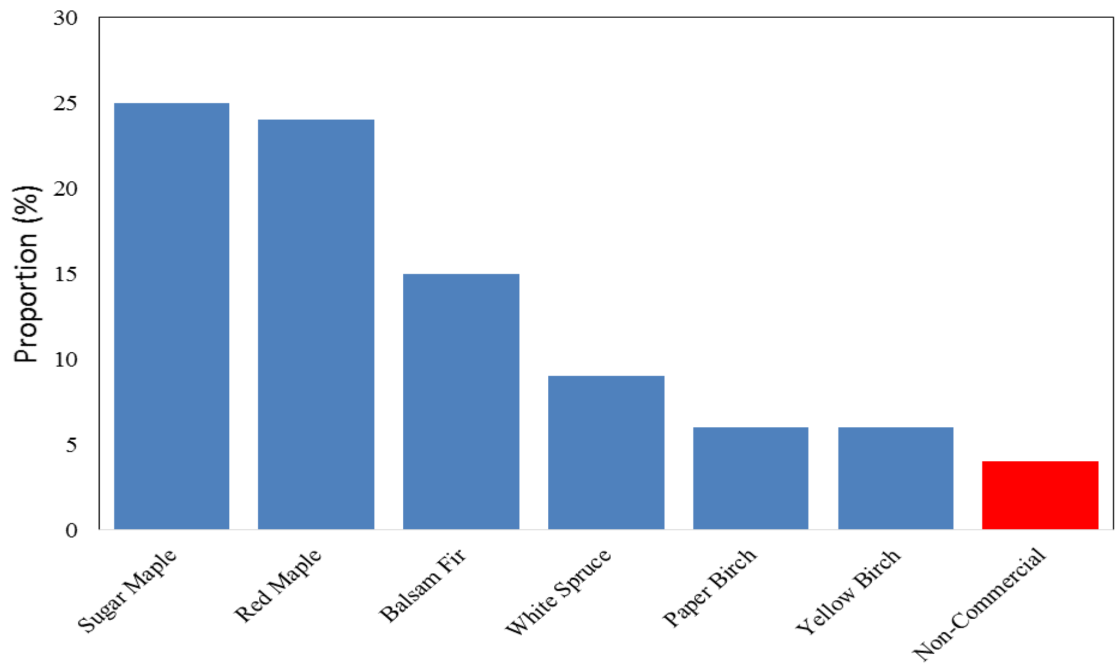

Figure 30. *The percent composition of commercial and non-commercial tree species (≥5% total) within 8 forest stands >30 years post-harvest. Quality and vigor ratings assigned to sample trees (n = 691) indicated that the majority were either F1 (51%) or F2 (27%) and R1 (60%) or R2 (36%). Overall, 76% of trees were a combination of F1/2 and R1/2 indicating commercial value.*

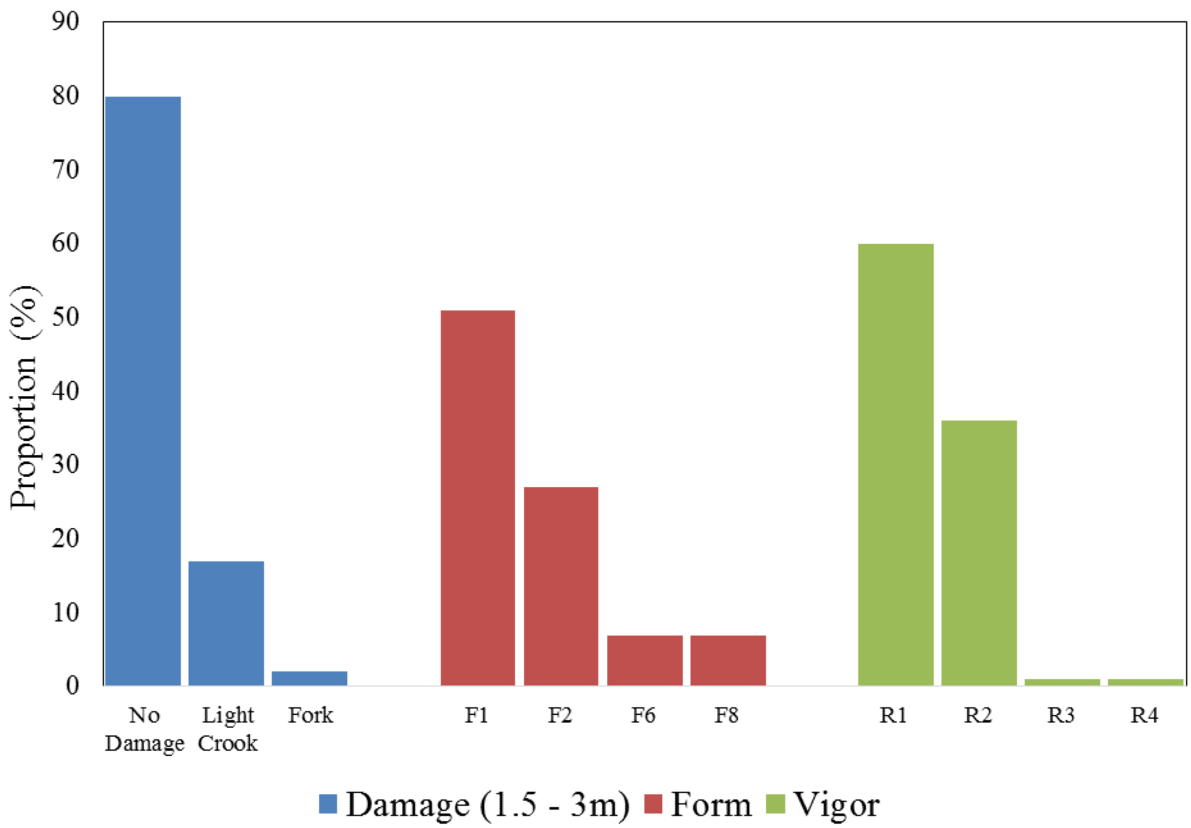

Figure 31. *The proportion of damaged (1.5-3.0 m) trees, and the proportional distribution of form and vigor ratings as measured in 8 forest stands >30 years post-harvest. The majority of trees had no damage and negative form and vigor were uncommon.*

Tree shelter tubes on Aspen seedlings to protect from browsing moose and deer – photo Brian Roth

Table 1. Proportion of total plots sampled within each group (forest type, harvest category, age class) which contained damage. Proportions calculated based on the Total Plots Sampled row at bottom of table. There were a total of 64 stands sampled over the summer of 2015.

	Hardwood						Mixed Wood						Softwood					
	Clear Cut			Partial Harvest			Clear Cut			Partial Harvest			Clear Cut			Partial Harvest		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Damage Below 1.5m																		
Broom	0.03	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Light Crook (<30°)	0.36	0.30	0.14	0.19	0.26	0.20	0.20	0.19	0.20	0.21	0.26	0.10	0.05	0.02	0.05	0.04	0.05	0.11
Moderate Crook(30° –60°)	0.08	0.13	0.03	0.06	0.10	0.07	0.09	0.08	0.03	0.11	0.07	0.01	0.01	0.01	0.01	0.01	0.05	0.03
Severe Crook (> 60°)	0.05	0.04	0.01	0.02	0.04	0.03	0.02	0.04	0.02	0.06	0.04	0.01	0.01	0.00	0.01	0.01	0.01	0.01
Fork	0.16	0.10	0.03	0.09	0.08	0.08	0.10	0.05	0.04	0.06	0.06	0.02	0.01	0.02	0.01	0.02	0.03	0.03
No Damage	0.31	0.43	0.77	0.64	0.52	0.63	0.57	0.64	0.71	0.55	0.58	0.85	0.91	0.96	0.92	0.92	0.86	0.81
Damage 1.5m - 3m																		
Broom	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Light Crook (<30°)	0.12	0.23	0.21	0.23	0.36	0.21	0.06	0.22	0.20	0.11	0.19	0.08	0.02	0.03	0.04	0.03	0.06	0.05
Moderate Crook(30° –60°)	0.07	0.04	0.05	0.06	0.11	0.07	0.01	0.04	0.02	0.03	0.05	0.01	0.00	0.00	0.01	0.00	0.01	0.02
Severe Crook (> 60°)	0.01	0.01	0.01	0.01	0.01	0.02	0.00	0.01	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.00
Fork	0.14	0.15	0.06	0.10	0.14	0.15	0.03	0.06	0.05	0.08	0.11	0.04	0.01	0.02	0.01	0.04	0.03	0.03
No Damage	0.66	0.57	0.66	0.60	0.38	0.54	0.90	0.67	0.72	0.76	0.65	0.86	0.96	0.95	0.93	0.93	0.89	0.90
Browsing in Plot	0.69	0.80	0.63	0.53	0.76	0.71	0.43	0.60	0.65	0.66	0.73	0.15	0.04	0.03	0.23	0.13	0.35	0.20
Bark Stripping in Plot	0.00	0.06	0.16	0.03	0.01	0.10	0.01	0.02	0.15	0.04	0.14	0.03	0.01	0.00	0.02	0.00	0.05	0.02
Moose Pellets in Plot	0.01	0.03	0.02	0.03	0.04	0.00	0.00	0.01	0.02	0.01	0.00	0.02	0.01	0.04	0.02	0.03	0.03	0.04
Plots with No Damage (#)	57	74	241	104	10	47	195	239	235	204	151	201	302	297	451	194	170	161
Total Plots Sampled (#)	252	358	573	317	104	179	361	495	478	464	393	285	349	327	520	227	223	210
Total Stands Sampled (#)	3	5	5	3	1	3	4	5	5	5	4	3	4	3	5	2	2	2

Table 2. Proportional distribution of form and vigor ratings as assigned by the New Brunswick classification protocol in older stands (>30 years old). The majority of trees were F1/F2 (78%) or R1/R2 (96%) indicating commercial value; 39% had the highest combined rating (F1-R1).

	Vigor				
Form	R1	R2	R3	R4	**Form Totals**
F1	0.39	0.11	0.01	0.00	0.51
F2	0.13	0.13	0.00	0.00	0.27
F3	0.01	0.01	0.00	0.00	0.03
F4	0.00	0.00	0.00	0.00	0.01
F5	0.00	0.01	0.00	0.00	0.02
F6	0.03	0.04	0.00	0.00	0.07
F7	0.01	0.01	0.00	0.00	0.02
F8	0.03	0.04	0.00	0.00	0.07
Vigor Totals	0.60	0.36	0.01	0.01	1.00

Future Plans

- In consultation with additional land managers, we will identify suitable forest stands in northern and eastern Maine to meet our target sample size and coverage area.

- We will locate additional stands that are >30 years post-harvest to conduct our forest inventory, form, and vigor assessments; these stands are critical because they provide unique measurements to assess long-term damage.

- Sampling will conclude in summer-fall 2016, after which we will identify potential permanent plots for long-term monitoring, analyze data, and submit the final report and conclusions in spring 2017.

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APPENDIX

CFRU Products Delivered During 2015

CFRU Publications

Refereed Journal Publications:

Greenwood, M.S., B. E. Roth, D. Maass and L. C. Irland. 2015. Near rotation-length performance of selected hybrid larch in Central Maine. Silvae Genetica 64(1-2):73-80.

Kuehne, C., A.R. Weiskittel, R.G. Wagner, 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 (15): 84–95.

Nelson, A.S., R.G. Wagner, M.E. Day, A.R. Weiskittel, and M.R. Saunders. 2015. Effects of species composition, management intensity, and shade tolerance on vertical distribution of leaf area index in juvenile stands in Maine, USA. *European Journal of Forest Research* 134 (2): 281-291.

Nelson, A.S., Weiskittel, A.R., R.G. Wagner, and M.R. Saunders. 2014. Development and evaluation of aboveground small tree biomass models for naturally regenerated and planted species in eastern Maine, U.S.A. *Biomass and Bioenergy* 68: 215-227.

Nelson, A.S., and R.G. Wagner. 2014. Spatial coexistence of American beech and sugar maple regeneration in post-harvest northern hardwood forests. *Annals of Forest Science* 71: 781–789.

Nelson, A.S., A.R. Weiskittel, and R.G. Wagner. 2014. Development of branch, crown, and vertical distribution leaf area models for contrasting hardwood species in Maine, USA. *Trees* 28(1): 17-30.

Rice, B., A.R. Weiskittel, and R.G. Wagner. 2014. Efficiency of alternative forest inventory methods in partially harvested stands. *European Journal of Forest Research* 133(2): 261-272.

Research Reports:

Dunham, S., and D. Harrison. 2014. Patch occupancy, habitat use, and population performance of spruce grouse in commercially managed conifer stands. Pages 75-79 *in* R.G. Wagner, editor, Cooperative Forestry Research Unit: 2014 Annual Report, University of Maine, Orono.

Harrison, D., and S. Olson. 2015. Relationships among forest harvesting, snowshoe hares, and Canada lynx in Maine. Pages 68-74 *in* R.G. Wagner, editor, Cooperative Forestry Research Unit: 2014 Annual Report, University of Maine, Orono.

Rolek, B., D. Harrison, C. Loftin, and P. Wood. 2015. Bird communities of coniferous forests in the Acadian Region: Habitat associations and response of birds to forest management. Pages 80-88 in R.G. Wagner, editor, Cooperative Forestry Research Unit: 2014 Annual Report, University of Maine, Orono.

Rolek, B., D. Harrison, C. Loftin, and P. Wood. 2015. Bird communities of coniferous forests in the Acadian Region: Habitat associations and response of birds to forest management: Annual report to Baxter State Park.

Rolek, B., D. Harrison, C. Loftin, and P. Wood. 2015. Bird communities of coniferous forests in the Acadian Region: Habitat associations and response of birds to forest management: Annual report to Fish and Wildlife Service and National Wildlife Refuges.

Rolek, B., D. Harrison, C. Loftin, and P. Wood. 2015. Bird communities of coniferous forests in the Acadian Region: Habitat associations and response of birds to forest management: Annual report to USGS Maine Cooperative Fish and Wildlife Research Unit.

Wagner, R.G. 2015. Spruce budworm is back: Start managing the Great North Woods now. *Timber Crier*. New Hampshire Timberland Owners Association (NHTOA). Spring 2015 Issue, pg 28.

Wagner, R.G., J. Bryant, B. Burgason, M. Doty, B.E. Roth, P. Strauch, D. Struble, and D. Denico. 2015. Coming Spruce Budworm Outbreak: Initial Risk Assessment and Preparation & Response recommendations for Maine's Forestry Community. Cooperative Forestry Research Unit, University of Maine, Orono. 77p.

Theses:

Hiesl, P. 2015. Forest Harvesting Productivity and Cost in Maine: New Tools and Processes. Ph.D. Dissertation, University of Maine, Orono. 142 p.

Olson, S. 2015. Seasonal influences on habitat use by snowshoe hares: implications for Canada lynx in northern Maine. M.S. Thesis, University of Maine, Orono, 153pp.

Software:

LAS files, 1 meter digital elevation models, 2' contour lines, hillshade and slope models. Available at Maine GIS catalogue website.

Site predictions for Acadian Region as a 20 X 20 m raster grid; available on CFRU Website.

Presentations/Workshops/Meetings/Field Tours

Castle, M. 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, Vermont.

Dunham, S. W., and D. J. Harrison. 2014. Spruce grouse breeding season patch occupancy and female home range use across forest management treatments in Maine. *Poster presented at the Annual Conference of The Wildlife Society, Pittsburgh, Pennsylvania,* October 27-28.

Dunham, S. W., D. J. Harrison, and E. J. Blomberg. 2015. Spruce grouse (*Falcipennis canadensis)* patch occupancy and abundance estimates in the commercially managed forests of Maine. *Presentation at the 13th International Grouse Symposium, Reykjavik, Iceland,* September 8.

Dunham, S. W., and D. J. Harrison. 2015. Spruce Grouse Breeding Season Patch Occupancy and Female Home Range Use Across Forest Management Treatments in Maine. Poster presented at the Annual USGS Maine Cooperative Fish and Wildlife Research Unit Coordinating Committee Meeting, Orono, Maine.

Hennigar, C. 2015. Design and performance of an Acadian forest site productivity index: Prince Edward Island results. Presentation on Dec 4th, 2015. Charlottetown, PEI.

Hennigar, C. 2015. Design and performance of an Acadian forest site productivity index. Presentation on Oct 6th, 2015. Canadian Woodlands Forum, Fredericton, New Brunswick.

Hennigar, C. 2014. Acadian site model: New Brunswick results. Presentation on Feb 11th, 2015. New Brunswick Growth and Yield Unit, Fredericton, New Brunswick.

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Kenefic, L.S., Larouche, C., Lessard, G., Ruel, J.C., Tardif, C., Tremblay, S., Wesely, N. 2014. New Northern White-Cedar Research and Opportunities for Collaboration. Cedar Club Research Meeting, October 16, 2014, Rimouski, Quebec.

Kenefic, L.S., Larouche, C., Lussier, J.M., Ruel, J.C., Tardif, C., Wesely, N. 2015. Northern White-Cedar Management in the Acadian Forest: New Findings. Maine SAF Field Tour, September 23, 2015, Solon, ME.

Rolek, B.W., C. Loftin, D. Harrison, and P. Wood. 2015. Softwood Forest Birds and Silviculture in New England. Baxter State Park Annual Meeting. Augusta, ME, USA. Spring 2015.

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Rolek, B.W., C. Loftin, D. Harrison, and P. Wood. 2015. Habitat Associations, Forestry, and Coniferous Forest Birds. Downeast Birding Festival. Machias, ME, USA. 22 May 2015.

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Wagner, R.G. and M. Doty. 2015. Coming Spruce Budworm Outbreak: Initial risk assessment and preparation & response recommendations for Maine's forestry community. Professional Logging Contractor's of Maine, March 26, 2015, Augusta, ME.

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