Cooperative Forestry Research Unit

CFRU

2014 Annual Report

Cooperative Forestry Research Unit
2014 Annual Report

Robert G. Wagner, 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 35 member organizations including private and public forest landowners, wood processors, conservation organizations, and other private contributors. Research by the CFRU seeks to solve the most important problems facing the managers of Maine's forests.

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

Citation

Wagner, R.G. (Ed.) 2015. Cooperative Forestry Research Unit: 2014 Annual Report. University of Maine. Orono, ME. 94 p.

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.

2014 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 9).
- 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 $20.99 was leveraged from other sources (See page 11).
- CFRU is leading a statewide spruce budworm assessment and preparation plan along with the Maine Forest Service and Maine Forest Products Council (See page 17).

Silviculture & Productivity Research

- Ten-year results from the **Commercial Thinning Research Network (CTRN)** were completed this year, revealing that highest financial gains occurred in previously spaced balsam-fir stands with early commercial thinning at 33% removal (See page 22).
- The third-wave of treatments for the **Austin Pond study** were completed. An analysis of the harvest results indicated that the unit cost of production of wood chips using a whole-tree system cost less than roundwood production using a cut-to-length system. However, profits were similar for both products harvested (See page 26).
- New research was initiated at **CFRU's Weymouth Point Watershed Study** to document the long-term effect of whole-tree harvesting on 32-year biomass production (See page 30).
- An assessment of productivity and cost of logging equipment showed that the key variables influencing cycle time and productivity were stem size and number of stems per accumulation (feller-bunchers); stem size and species grouping (cut-to-length processor and stroke delimbers); skidding distance and load size (grapple skidders); and forwarding distance, log volume and logs per load (forwarders) (See page 34).
- A new 3-year study on the effects of mechanized harvesting operations on residual stand conditions was initiated (See page 42).

Growth & Yield Modeling Research

- Growth and yield data were compiled from over 20,000 permanent plots across Maine and eastern Canada that included a wide array of thinning and partial harvesting regimes. The effects of management on future forest growth were modeled and the equations incorporated into the Acadian variant of FVS developed by CFRU (See page 47).
- LiDAR coverage from a wide range of stand structures and species compositions typical for the region was evaluated. A variety of important issues in using LiDAR for operational forest planning were assessed, including robustness of developed prediction models, sample size and selection method for model calibration, and the effect of prediction tile size on overall accuracy. LiDAR was found to be a promising tool that deserves further exploration, but there are some potential issues that need to be resolved before widespread usage by CFRU members (See page 52).

- Updated depth-to-water table maps were developed for the entire State of Maine using latest DEM coverage and distributed to all CFRU members (See page 57).
- The effects of early stand management on hardwood stand biomass and leaf area development were modeled and incorporated into the Acadian variant of FVS (See page 62).

Wildlife Habitat Research

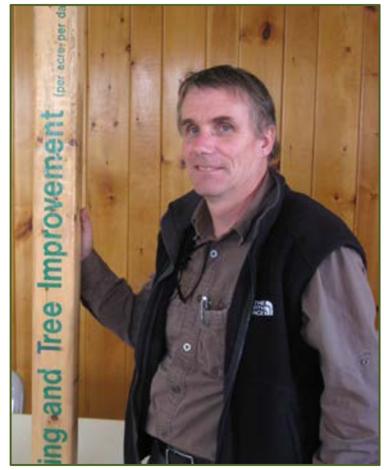
- Snowshoe hare habitat use revealed that regenerating conifer stands (16-39 years post-clearcut) serve not only as winter refugia, but are also superior hare habitat throughout the year. Regenerating conifer stands also were preferred habitat over selection harvest and mature stands during the leaf-on season. An analysis of lynx diet indicated that hares are a vital food source for lynx during both summer and winter seasons (See page 68).
- Spruce grouse males were more likely to be found in stands with increased density of conifers and in stands with presence of dead limbs near the ground. In contrast, female spruce grouse were more likely to occupy previously clearcut and precommercially thinned stands, especially stands with relatively less dense overstory canopy and with increased lateral cover and edible cover (See page 75).
- An ongoing study of bird community responses to forest management completed surveys and vegetation measurements in 117 forest stands across Maine, New Hampshire, and Vermont (See page 80).

Crop Tree Release - Wells Forest – photo Pamela Wells

Table of Contents

Bohemian Waxwing - Photo by Pamela Wells

Chair's Report



Greg Adams - CFRU Chair

My sincere thanks are extended to the whole CFRU team involved in putting together an excellent Annual Report for our membership. The 2014 report encapsulates the broad range of areas that the CFRU is involved in, but all have in common a direct link to sustainable forest management. Reviewing the annual report as one body of work really drives this home to me and I feel fortunate and proud to be associated with CFRU and depth of the work that we do. I want to make special note of the leadership role that **Bob Wagner** played in the development of the joint Spruce Budworm Task Force Report for the State. In all likelihood, spruce budworm will continue to be the dominant shaper in the forests of Northern Maine. Having recently driven through the Matapedia Valley on the Gaspé Penninsula, it brought back lots of memories of the budworm days in the late 1970's and 1980's.

Brian Roth did a great job getting CFRU members actively involved in the ramped up monitoring effort. The CFRU team organized an excellent group of speakers on spruce budworm at our fall meeting with nearly 300 in attendance.

In my view, longevity of groups like CFRU is all about having a shared vision of important work that needs to be done. I am always impressed by the engagement in CFRU meetings – there is always a sense of interest in the room and good discussion. The field tours and events like the Spruce Budworm update get great turnout. On behalf of the CFRU Executive, I extend my thanks and congratulations to all of our members for your contributions of time, financial support, field resources, and your engagement. These are critical ingredients to the ongoing success of the CFRU.

The coming year will be exciting with focused discussions around CFRU strategic directions. While looming spruce budworm threats will be important, we also have great opportunities to explore in enhanced forest inventory and intelligence through use of technologies such as LiDAR and other methods of remote sensing. Integration of forest resilience planning across the range of values in sustainable forest management will be a significant challenge, but given the CFRU record, I believe we are up for it!

Greg Adams (JD Irving)
CFRU Chair

Photo by Pamela Wells

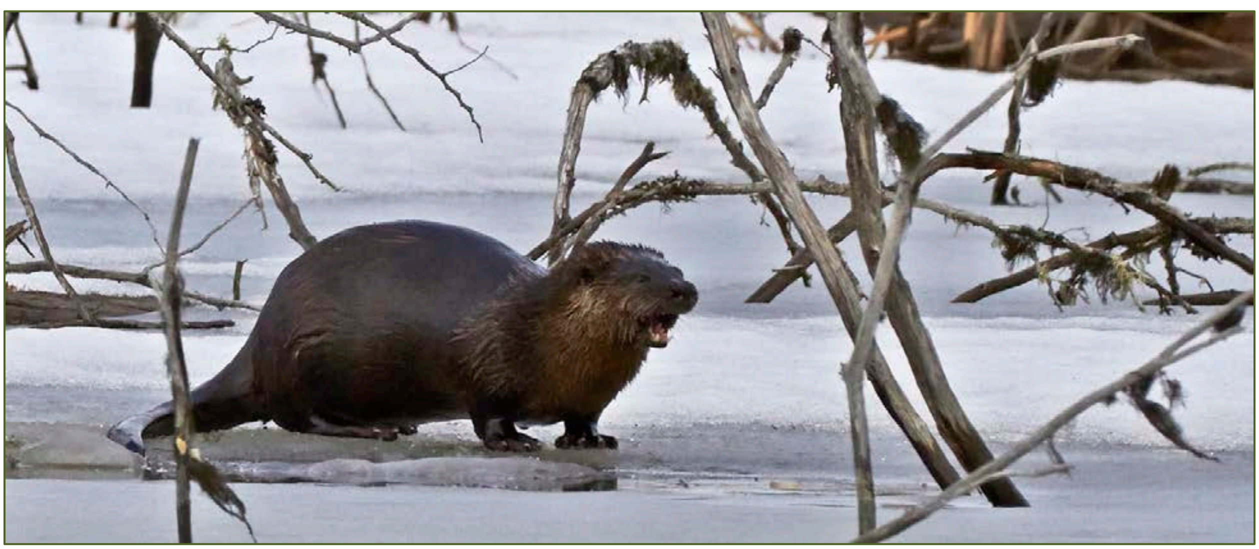
Director's Report


Robert Wagner, CFRU Director

This FY 2013-14 Annual Report details the results of twelve CFRU projects addressing our member's needs in the areas of silviculture & productivity, growth & yield modeling, and wildlife habitat. Our membership, productivity, and funding remain strong as we work with our members to meet the most pressing challenges they face in sustainably managing Maine's commercial forestlands. As CFRU completes its fourth decade of operation, we continue to provide critical leadership on key issues facing Maine's forestland managers in the region and country.

Many thanks go to all of our CFRU members, staff, Cooperating Scientists, Project Scientists, and graduate students who made another successful year possible. Special thanks go to our CFRU Executive Committee **Greg Adams** (Chair), **Eric Dumond** (Vice Chair), **Bill Paterson** (Financial Officer), and **Kenny Fergusson** (Member-at-Large) for their continued leadership and support. CFRU Cooperating Scientists (**Jeff Benjamin, Dan Harrison,** and **Aaron Weiskittel**) continued to provide us with strong research leadership in the areas of forest operations, wildlife habitat, and forest modeling. **Brian Roth** (Associate Director) and **Cindy Smith** (Administrative Specialist) continue to do a fantastic job keeping the CFRU running smoothly. **Mohammad Bataineh** (CFRU Post-doctoral Research Fellow) left for a new faculty position in Arkansas this year. We thank him for his productivity during his time with CFRU and wish him the best in his new position.

Robert G. Wagner
CFRU Director



River otter - photo Pamela Wells

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
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*
Jacob Metzler – *Forest Society of Maine*
Eben Sypitkowski – *Baxter State Park*
Ian Prior – *Seven Islands Land Company*
David Publicover – *Appalachian Mountain Club*
Tim Richards – *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
Robert Seymour, PhD, Curtis Hutchins Professor of Forest Resources
Aaron Weiskittel, PhD, Assistant Professor of Forest Biometrics and Modeling

Project Scientists

Paul Arp, PhD, University of New Brunswick
Mohammad Bataineh, PhD, CFRU Research Scientist
Mark Castonguay, MS, University of New Brunswick
Ivan Fernandez, PhD, University of Maine
Chris Hennigar, PhD, University of New Brunswick
John Kershaw, PhD, University of New Brunswick
Eric Labelle, PhD, Northern Hardwood Research Institute, New Brunswick
Cynthia Loftin, PhD, USGS Maine Cooperative Fish and Wildlife Research Unit
Jae Ogilvie, MS, University of New Brunswick
Petra Wood, PhD, USGS West Virginia Cooperative Fish and Wildlife Research Unit

Graduate Students

Patrick Clune (MS student - Wagner) - Commercial thinning
Steven Dunham (MS student - Harrison) - Spruce grouse habitat
Patrick Hiesl (PhD student - Benjamin) - Logging productivity and cost
Andrew Nelson (PhD candidate - Wagner) - Hardwood regeneration composition
Sheryn Olson (MS student - Harrison) - Snowshoe hare population dynamics
Brian Rolek (PhD student - Harrison) - Bird communities

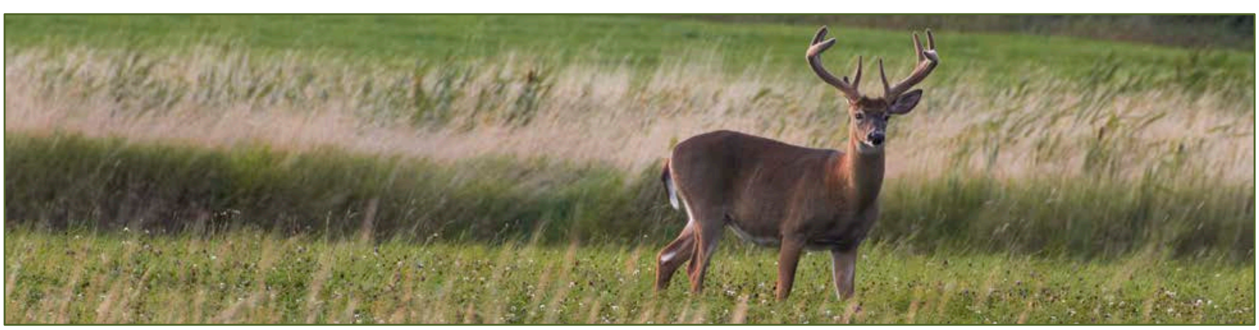


Photo Pamela Wells

Financial Report

Robert Wagner, CFRU Director

Photo - Pamela Wells

Thirty-five members representing 8.29 million acres of Maine's forestland contributed $505,025 to support CFRU this year (**Table 1**). These member contributions will be used to support research activities during FY 2014-15. The amount of acreage by our Landowner/Manager members increased by 6,282 acres (0.08%) following land sales and purchases this year. A significant addition this year was welcoming the **Downeast Lakes Land Trust (DLLT)** as a new Landowner/Manager member of CFRU. We look forward to working with DLLT in the coming years. **Old Town Fuel & Fiber** left the CFRU following the mill sale this year, and **Finestkind Tree Farms** left the CFRU after many years. We thank both organizations for their years of support. Tons of wood products produced by Wood Processor members increased (77,084 tons or 3.4%) relative to last year. With all of these changes, overall CFRU member contributions remained stable (only $977 or 0.2% less) relative to FY 2012-13. 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 $614,716 in extramural grants to support CFRU research projects. This amount included $70,000 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 48% of CFRU total income this year (**Figure 1**). In addition to extramural sources, UMaine provided $57,036 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 $113,337. Therefore, UMaine provided an additional $170,373 or 13% of total funding. In total, about 61% ($785,089) 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, $7.00 was received from other CFRU member contributions, $10.95 was contributed by external grants through CFRU scientists, and $3.04 was received from UMaine in direct and indirect contributions; for a **total leveraging of $20.99 for every $1 contributed by CFRU's largest members**.

Continued sound fiscal management by CFRU scientists and staff resulted in spending $52,846 (9.6%) less than the $550,284 that was approved by the Advisory Committee for this fiscal year (**Table 2**). Most projects came in at or near budget. Dr. Dan Harrison requested that the $29,207 surplus on his snowshoe hare project be moved forward to the following year due to hiring delays. In addition, Dr. Laura Kenefic requested a 1-year delay in her project due to delays in finding a graduate student. The Advisory Committee approved these requests at the October 2014 meeting and by email. Dr. Bob Wagner also returned $12,517 to support a silviculture post-doc due to other grant sources that were able to support his salary. Thanks to Plum Creek Timber Company and a grant obtained by Dr. Jeff Benjamin, funds were found to support the unplanned $22,269 expenditure for harvesting the unthinned portion of Austin Pond, thus bringing the project in on budget.

CFRU research expenses by category this year included 35% on seven silviculture & productivity projects, 35% on four growth & yield modeling projects, and 30% on three wildlife habitat projects (**Figure 2**).

Table 1 - CFRU member contributions received FY 2013-14 (for allocation during FY 2014-15).

CFRU Member	Acres/Tons Reported FY13-14	Acres/Tons Reported FY14-15	Changes Acres/tons	Amount Requested	Amount Received	% Received
FOREST LANDOWNERS / MANAGERS:						
Irving Woodlands, LLC	1,255,000 acres	1,255,000 acres	0	$68,804	$68,804	100%
Wagner Forest Management	1,121,037 acres	1,121,515 acres	478	$62,023	$62,023	100%
BBC Land, LLC	971,447 acres	971,178 acres	-269	$54,314	$54,314	100%
Plum Creek Timber Company, Inc.	884,000 acres	884,000 acres	0	$49,667	$49,667	100%
Prentiss and Carlisle Company, Inc.	806,419 acres	810,722 acres	4,303	$45,761	$45,761	100%
Seven Islands Land Company	721,261 acres	746,791 acres	25,530	$42,354	$42,354	100%
Clayton Lake Woodlands Holding, LL	451,160 acres	451,160 acres	0	$26,348	$26,348	100%
Maine Bureau of Parks & Public Lanc	400,000 acres	407,000 acres	7,000	$23,769	$23,769	100%
Katahdin Forest Management, LLC	299,000 acres	301,000 acres	2,000	$17,578	$17,578	100%
Canopy Timberlands Maine, LLC	294,194 acres	294,179 acres	-15	$17,180	$17,180	100%
The Nature Conservancy	170,985 acres	170,985 acres	0	$9,986	$9,986	100%
Snowshoe Timberlands, LLC	137,720 acres	137,720 acres	0	$8,043	$8,043	100%
The Forestland Group, LLC	136,965 acres	70,525 acres	-66,440	$4,119	$4,119	100%
Baskahegan Corporation	117,723 acres	117,738 acres	15	$6,876	$6,876	100%
Sylvan Timberlands, LLC	105,510 acres	105,510 acres	0	$6,162	$6,162	100%
North Woods Maine, LLC	83,409 acres	83,409 acres	0	$4,871	$4,871	100%
Appalachian Mountain Club	65,489 acres	65,489 acres	0	$3,825	$3,825	100%
Simorg North Forest LLC	61,643 acres	61,643 acres	0	$3,600	$3,600	100%
Frontier Forest, LLC	53,338 acres	53,338 acres	0	$3,115	$3,115	100%
Downeast Lakes Land Trust	0 acres	33,708 acres	33,708	$0	$1,969	
Baxter State Park, SFMA	29,537 acres	29,537 acres	0	$1,725	$1,725	100%
Robbins Lumber Company	26,771 acres	26,771 acres	0	$1,563	$1,563	100%
Timbervest, LLC	25,191 acres	25,191 acres	0	$1,471	$1,471	100%
St. John Timber, LLC	24,617 acres	24,617 acres	0	$1,438	$1,438	100%
EMC Holdings, LLC	23,526 acres	23,526 acres	0	$1,374	$1,374	100%
Mosquito, LLC	16,222 acres	16,222 acres	0	$947	$947	100%
New England Forestry Foundation	2,880 acres	2,852 acres	-28	$1,000	$1,000	100%
TOTAL	8,285,044 acres	8,291,326 acres	6,282	$467,912	$469,882	100.4%
WOOD PROCESSORS:						
SAPPI Fine Paper	1,800,797 tons	1,850,400 tons	49,603	$23,500	$23,500	100%
UPM Madison Paper	314,519 tons	342,000 tons	27,481	$4,343	$4,343	100%
Old Town Fuel & Fiber	164,834 tons	164,834 tons	0	$2,093	$0	0%
TOTAL	2,280,150 tons	2,357,234 tons	77,084	$29,937	$27,843	93.0%
CORPORATE and INDIVIDUAL MEMBERS:						
ReEnergy Holdings, LLC	1 static	1 static		$5,000	$5,000	100%
Huber Engineered Woods, LLC	1 static	1 static		$1,000	$1,000	100%
Forest Society of Maine	1 static	1 static		$1,000	$1,000	100%
LandVest	1 static	1 static		$200	$200	100%
Field Timberlands	1 static	1 static		$100	$100	100%
Finestkind Tree Farms	1 static	1 static		$100	$0	0%
TOTAL				$7,400	$7,300	98.6%
GRAND TOTAL (36 members):				$505,249	$505,025	100.0%

	Contribution Received
	Contribution Not Received
	New Member

Table 2- CFRU expenses incurred during FY 2013-14.

PROJECT	Principal Investigator	Approved Amount	Amount Spent	Balance Remaining		% Balance Remaining
Administration		**$195,502**	**$189,450**	**$6,052**		**3.1%**
Administration		$182,985	$189,450	-$6,464		-3.5%
Silviculture Post-Doc		$12,517	$0	$12,517	1	100.0%
Silviculture & Productivity:		**$124,247**	**$107,894**	**$16,353**		**13.2%**
CFRU Commercial Thinning Research Network: Continued Measurements and New Opportunities	Wagner	$43,907	$39,840	$4,067		9.3%
Assessment of Productivity and Cost for Logging Equipment in Maine's Forest Industry	Benjamin	$8,602	$7,938	$664		7.7%
Austin Pond Study: Third Wave of Treatments to Assess Rotation-Length Outcomes for Silvicultural Options in Maine's Northern Forest	Wagner	$8,952	$8,633	$319	2	3.6%
Incorporating Young Hardwood Stand Responses to Various Levels of Silviculture and Stand Composition into New CFRU Growth & Yield Models	Wagner	$23,295	$23,113	$182		0.8%
The Effects of Mechanized Harvesting Operations on Residual Stand Condition	Benjamin et al.	$14,680	$13,560	$1,120		7.6%
Identifying Attributes that Distinguish Old-and Second-Growth Northern White-Cedar Stands for Forest Management and Planning	Weiskittel	$12,000	$0	$12,000	3	0.0%
Weymouth Point: Monitoring the Effects of Whole Tree Harvesting and Intermediate Silvicultural Treatments on Long-Term Spruce-Fir Productivity.	Roth	$12,811	$14,809	-$1,998		-15.6%
Growth & Yield Modeling:		**$107,611**	**$107,981**	**-$370**		**-0.3%**
Linking LiDAR and Ground-based Forest Inventory Plots for Improving Estimation of Key Attributes	Weiskittel	$30,275	$30,577	-$302		-1.0%
Extending the Acadian variant of FVS to managed stands	Weiskittel	$18,936	$19,004	-$68		-0.4%
Maine Statewide Light Detection and Ranging (LiDAR) Data Acquisition Project	Young	$10,000	$10,000	$0		0.0%
Cartographic Depth-to-Water Mapping for Maine, State-wide, Using latest DEM Coverage, for CFRU Priority Areas	Castonguay	$48,400	$48,400	$0		0.0%
Wildlife Habitat:		**$122,924**	**$92,114**	**$30,810**		**25.1%**
Long-Term Studies of Snowshoe Hares, Canada Lynx and Forest Structure	Harrison	$71,020	$41,813	$29,207	4	41.1%
Relative Densities, Patch Occupancy, and Population Performance of Spruce Grouse in Managed and Unmanaged Forests in Northern Maine	Harrison	$22,008	$20,598	$1,410		6.4%
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	$29,896	$29,703	$193		0.6%
TOTAL		**$550,284**	**$497,438**	**$52,846**		**9.6%**

[1] Funding received from CAFS and NSRC to cover post-doctoral research fellow. Funds used to cover deficits in other accounts.

[2] Actual spending was $19,633 due to $22,269 for unplanned logging cost for unthinned half of study. Plum Creek contributed an additional $11,000 to CFRU to cover half of unplanned logging expense. The additional $10,681 in unplanned expenditures were covered by $4,699 from FarmBio project of Jeff Benjamin, and $5,982 in surplus from CFRU LiDAR project.

[3] Graduate student was delayed, so PI requested delay of project by one year. CFRU Executive Committee approved forwarding the $12,000 for FY13-14 to FY14-15, and $12,000 approved for FY14-15 moved to FY15-16 via a 3-16-2014 email.

[4] Project delayed due to support a cost-share with MDIFW for Dave Mallet's publication of work. PI requests balance of $29,207 to be forwarded to FY2014-15. Approval sought by Advisory Committee at 10-29-2014 meeting. Note that $71,020 approved amount was $49,001 originally approved plus $22,020 carryforward from FY12-13 that was approved by Advisory Committee.

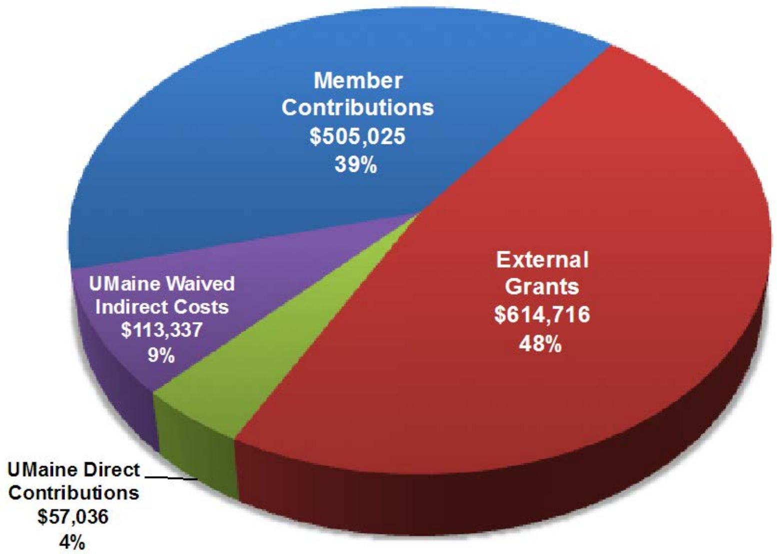


Figure 1 - CFRU income sources FY 2013-14.

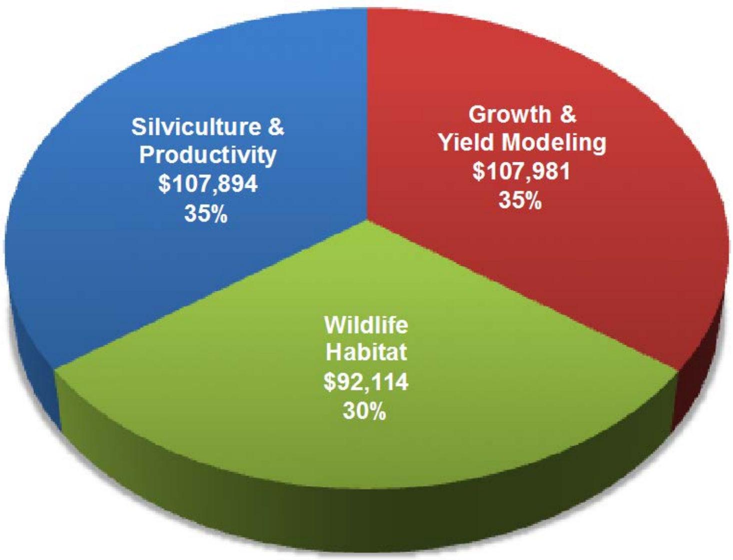


Figure 2 - CFRU research expenses FY 2013-14.

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. In 2014, Greg Adams (JD Irving) assumed the position of Chair while Bill Patterson (The Nature Conservancy) moved to the Financial Officer position previously held by Mark Doty (Plum Creek). We thank Mark for six years of service on the Executive Committee. Kenny Fergusson (Huber Resources) began a two-year term as Member-at-Large.

The Advisory Committee meets three times a year for business meetings. The first business meeting of FY 2013-14 was held on October 9, 2013 at the University of Maine (UMaine) where Andrew Willette (JD Irving) gave a presentation on efforts to mobilize ahead of the next Spruce Budworm outbreak. At the second meeting, held on January 22, 2014 at UMaine, eleven pre-proposals were presented to the Advisory Committee. Of these, nine were approved to advance to the full proposal stage and were presented at the April 23, 2014 business meeting. Six projects were approved for funding, including a major revision of the CFRU website, beginning on October 1, 2014. Look for updates on these projects in future CFRU publications and annual reports.

Cooperators

The CFRU lost two members and added one new member in 2014. The CFRU welcomed the Downeast Lakes Land Trust (DLLT), represented by Kyle Burdick, this year. Old Town Fuel & Fiber (OTFF) left the CFRU after closure and sale. Also, after being in the cooperative for over three decades, Finestkind Tree Farms ceased to be a member. We thank OTFF and Finestkind for their years of support. The only major change in land ownership for 2014 was the sale of 66,000 acres by The Forestland Group (Table 1).

Personnel

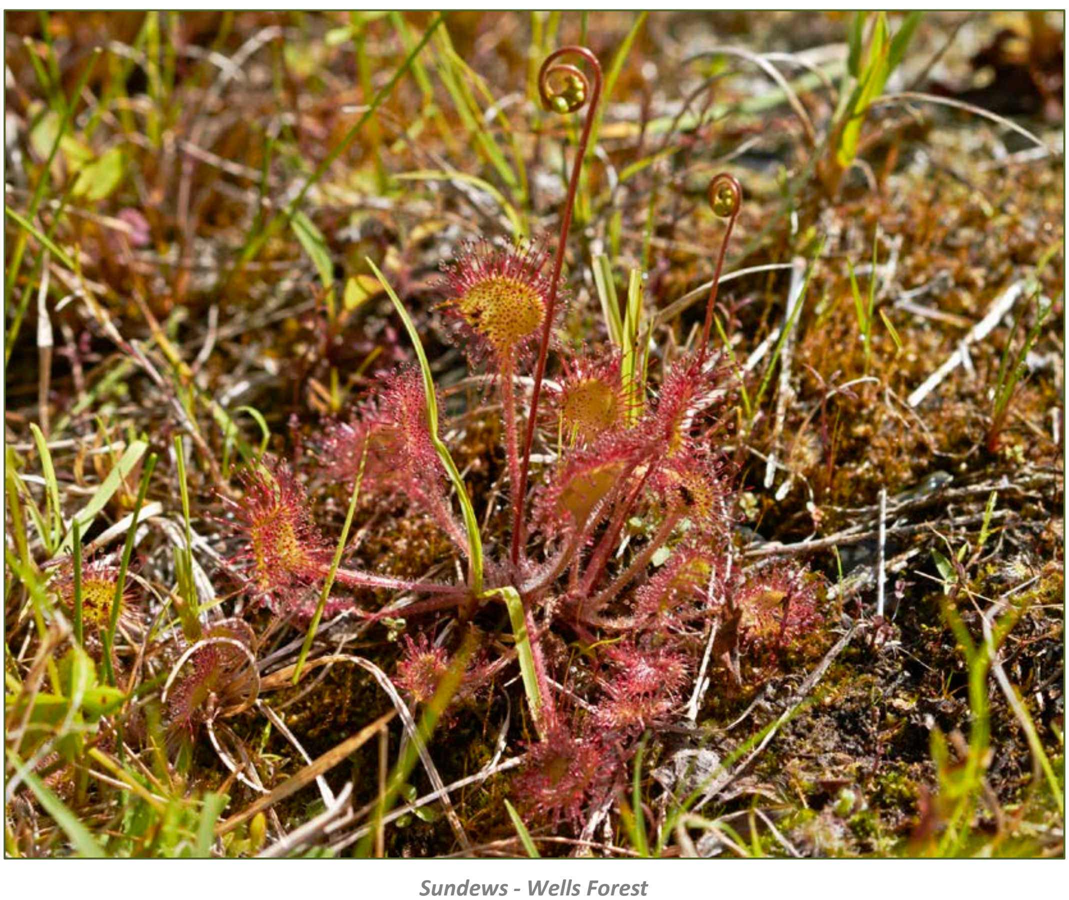
Dr. Mohammad Bataineh, CFRU/USFS Postdoctoral Research Fellow, accepted the position of Assistant Professor at the University of Arkansas at Monticello. We thank Mohammad for three very productive years and wish him the best on his continued academic career path. CFRU Director Dr. Bob Wagner completed his 5-year term as Director of the UMaine's School of Forest Resources and will focus his efforts on leading the CFRU and the CRSF (Center for Research on Sustainable Forests).

2014 Fall Workshop

In place of a fall field tour, the CFRU hosted a workshop on October 30, 2014, focused on the latest in Spruce Budworm science and management strategies ahead of the approaching outbreak. This workshop was attended by nearly 300 CFRU members and brought North America's leading SBW experts together to share the latest information about the SBW. Topics covered the current status of SBW populations in Maine and Canada, an overview of the ongoing Early Intervention Strategy (EIS) program in New Brunswick and Quebec, and a review of the operational SBW control program in Quebec managed by SOPFIM (Société de protection des forêts). The latest draft of the SBW strategic plan for the State of Maine was also presented and discussed.

Students

The CFRU continued to contribute to the development of students, with six graduate students working on CFRU projects this year. **Sheryn Olsen** completed her MS thesis on the relationships among forest harvesting, snowshoe hares and Canada lynx in Maine, under the direction of Dr. Dan Harrison. Dr. Harrison is also supervising three students: **Brian Rolek** (PhD, forest birds), **Steve Dunham** (MS, Spruce Grouse) and **Joel Tebbenkamp** (Ph.D, Spruce Grouse) working on CFRU projects. **Dr. Jeff Benjamin** is supervising two students: Patrick Hiesl (PhD, harvest productivity) and Cody Lachance (MS, stand conditions following mechanized harvesting). **Nathan Wesely** (MS, characteristics of old-growth cedar) is being supervised by **Drs. Laura Kenefic** (USFS) and **Shawn Fraver**. In addition, over a dozen undergraduate students were hired as research technicians for CFRU projects during the summer of 2014.



Sundews - Wells Forest

Spruce Budworm Assessment & Preparation Plan

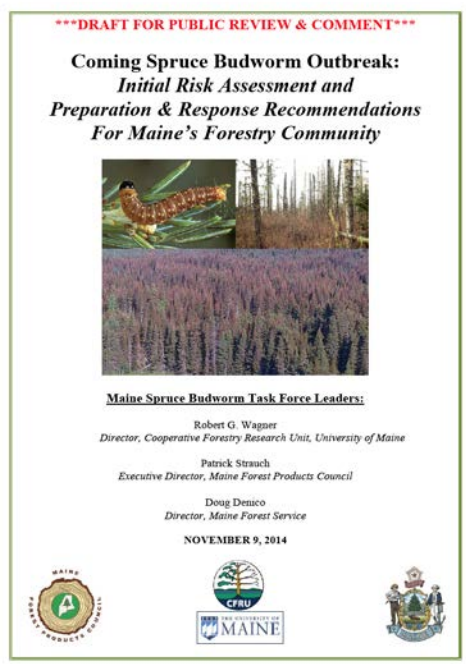
About 40 years ago, the spruce budworm (SBW) was devastating spruce-fir forests across northern Maine. This outbreak was a regional event covering more than 130 million acres across Quebec, Northern New England, and the Maritime Provinces of Canada. That outbreak lasted about 15 years (1970-85) and shaped 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 draft report that is currently undergoing 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 will be available in late summer 2015.



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

This year saw the completion of the fifth year of Phase I for the UMaine site under the Center for Advanced Forestry Systems (CAFS). CAFS is funded by the National Science Foundation (NSF) Industry/University Cooperative Research Centers Program (I/UCRC) in partnership with CFRU members. CAFS is a partnership between CFRU members and I/UCRC to support a University of Maine research site for CAFS. CAFS unites ten university forest research programs with forest industry members across the 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.

Phase 1 of CAFS contributed $70,000 per year to the University of Maine as long as CFRU members contributed a minimum of $300,000 per year to support the work of the site. This past year of CAFS funding jointly supported the advancing growth and yield models in commercially thinned stands in the Northeast. Using CAFS support, Patrick Clune (MS student) and Dr. Mohammad Bataineh modeled the growth of stands and individual trees in the CTRN.

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. Detailed proposals for CAFS research will be developed by Wagner and Weiskittel in the coming year.

CFRU staff and several Advisory Committee members represented the Maine CAFS site at the Seventh Annual CAFS Industrial Advisory Board (IAB) Meeting held May 20-22, 2014 in Coeur d'Alene, ID. 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

UF UNIVERSITY of FLORIDA

The University of Georgia

University of Idaho

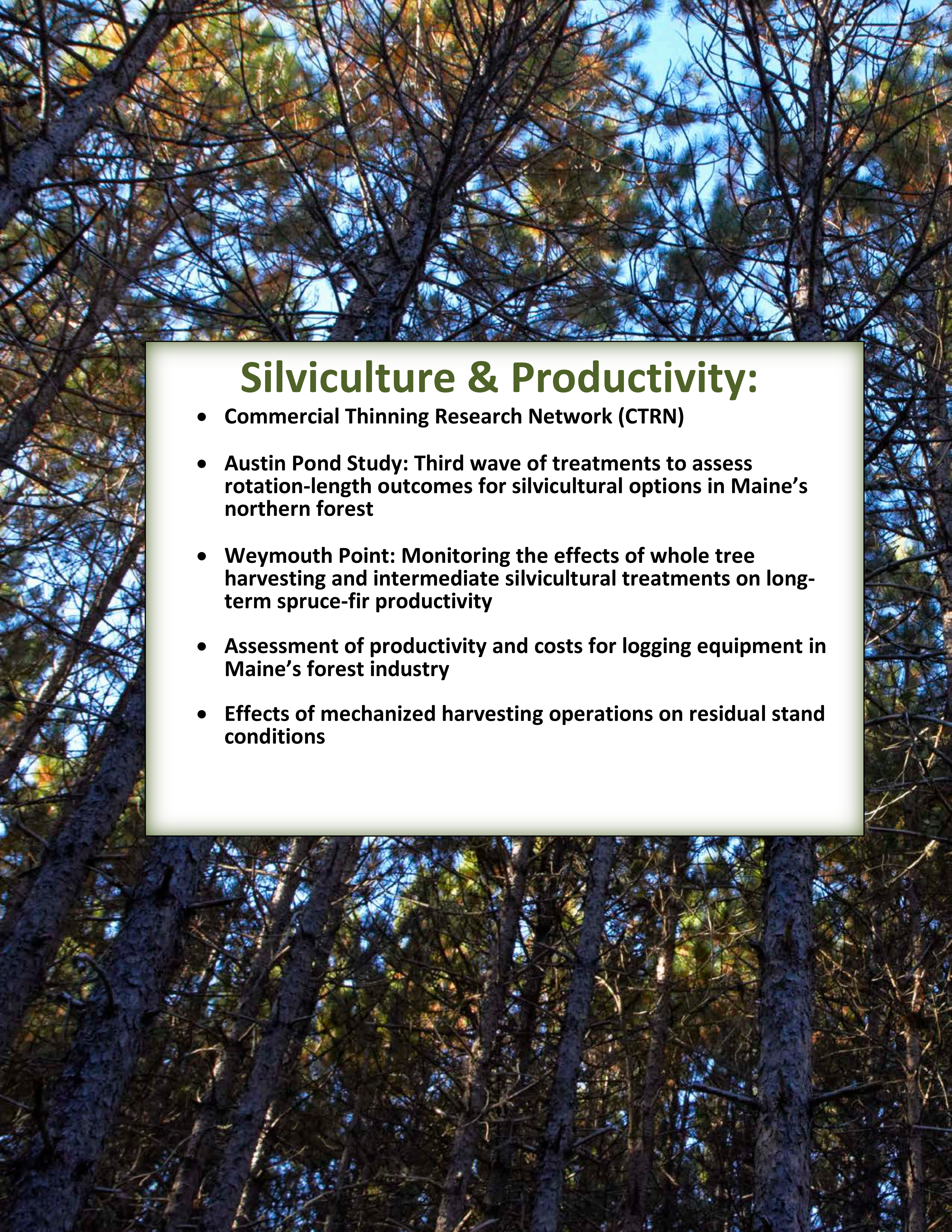
1865 THE UNIVERSITY OF MAINE

W UNIVERSITY of WASHINGTON

VirginiaTech

Common Yellow-throated Warbler - Photo Pamela Wells

Research Project Reports



Silviculture & Productivity:

- Commercial Thinning Research Network (CTRN)
- Austin Pond Study: Third wave of treatments to assess rotation-length outcomes for silvicultural options in Maine's northern forest
- Weymouth Point: Monitoring the effects of whole tree harvesting and intermediate silvicultural treatments on long-term spruce-fir productivity
- Assessment of productivity and costs for logging equipment in Maine's forest industry
- Effects of mechanized harvesting operations on residual stand conditions

Commercial Thinning Research Network (CTRN)

Robert Wagner, Patrick Clune, and Brian Roth

University of Maine

Status: Progress Report, Year 2 of 4

Crop Tree Release

Summary:

A 10-year analysis of results from the CTRN was completed this year. Growth & yield, residual stand structure, wood products, and financial value were compared following various commercial thinning methods (low, crown, dominant), removal intensities (33% and 50%), and timing of entry (thin immediately, delay 5 years) using two separate experiments on 12 study sites on CFRU member lands across northern Maine. Results from a completed MS Thesis (Clune 2013) indicated that older (34–70-year-old) spruce-fir stands that never received precommercial thinning (PCT) should not be commercially thinned (CT) from above due to wind losses to the residual stand. If CT is desired in older stands, low thinning by 33% produced the most resilient stand structure with highest net present value.

In younger (23–42-year-old) fir-spruce stands that received PCT, all CT treatments improved residual stand structure and increased growth over the unthinned control. Greatest gains in stem diameter resulted from 50% delayed thinning, while greatest increase in net merchantable volume periodic annual increment occurred with 50% early CT. Highest financial gains occurred with 33% early CT. If the objective was to increase mean tree size and reduce the age at which trees reach a minimum size, delayed CT at higher intensity removal (50%) was best. If the objective was to increase stand value and financial returns, early CT at medium intensity (33%) was indicated.

Project Objectives:

- Quantify effects of CT method (low, crown, and dominant) and intensity (33% and 50% RD reduction) in older spruce-fir stands that had never received PCT on stand structure, residual stand growth, merchantable products (sawlog and pulpwood), and financial value.
- Quantify effects of CT timing of entry (thin immediately, delay 5 years, and delay 10 years) and thinning intensity (33% and 50% relative density reduction) in previously PCT'd stands on stand structure, residual stand growth, merchantable products (sawlog and pulpwood), and financial value.

Approach:

- Used 10-year measurements from 12 study sites and two experiments (6 sites each) in the CTRN to quantify growth & yield, residual stand structure, wood products, and financial value from factorial combinations of CT method, removal intensity, and timing of entry across northern Maine.

Key Findings / Accomplishments:

For older spruce-fir stands (Figure 3):

- Both intensities of the low and crown thinning produced future stands with higher quadratic mean diameter (QMD), higher sawlog to pulpwood ratio, and higher financial value per unit volume than the control and dominant thinning treatments after 10 years.
- The net present value (NPV) of stands following 33% low thinning was higher than all other treatments.
- Results indicated that older spruce-fir stands should not be commercially thinned from above due to wind losses to the residual stand.
- If CT is desired in older stands, low thinning to one-third relative density produced the most resilient stand structure with highest stand value and NPV.

For younger fir stands that have received previous PCT (Figure 4):

- All CT treatments improved residual stand structure and increased growth over the unthinned control.
- Greatest gains in QMD resulted from 50% delayed thinning, while greatest increase in net merchantable volume PAI occurred with 50% early CT.
- Highest financial gains occurred with 33% early CT.
- If objective was to increase mean tree size and reduce the age at which trees reach a minimum size, delayed CT at higher intensity removal (50%) was best.
- If objective was to increase stand value and financial returns, early CT at medium intensity (33%) was indicated.

Enhancements to CTRN this year:

- Study sites from two other CFRU studies (Austin Pond and Early Commercial Thinning) were added to CTRN, providing an additional database consisting of over 23,000 measurements on more than 10,000 trees.

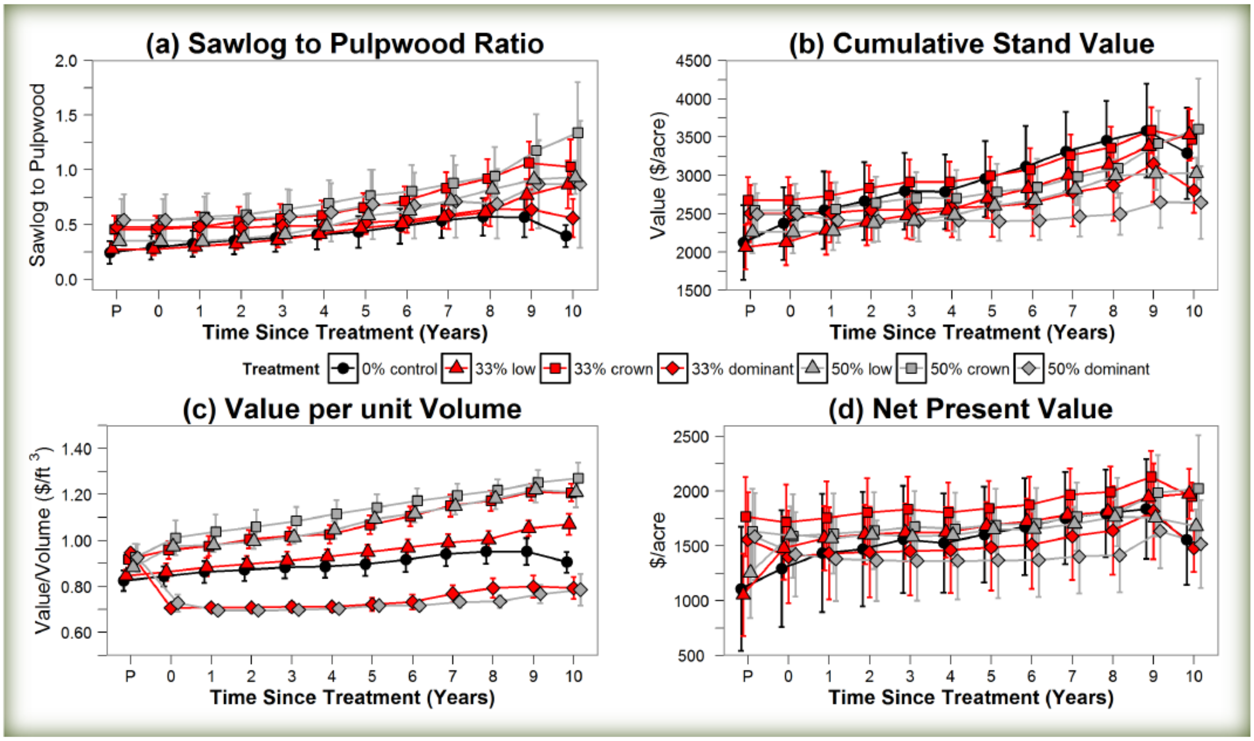


Figure 3 - (a) Mean sawlog to pulpwood ratio, (b) total stand value, (c) value per unit volume, and (d) net present value (discount rate: 4%) for 10 years following six commercial thinning treatments in six older (34–70-year-old) spruce-fir stands across northern Maine.

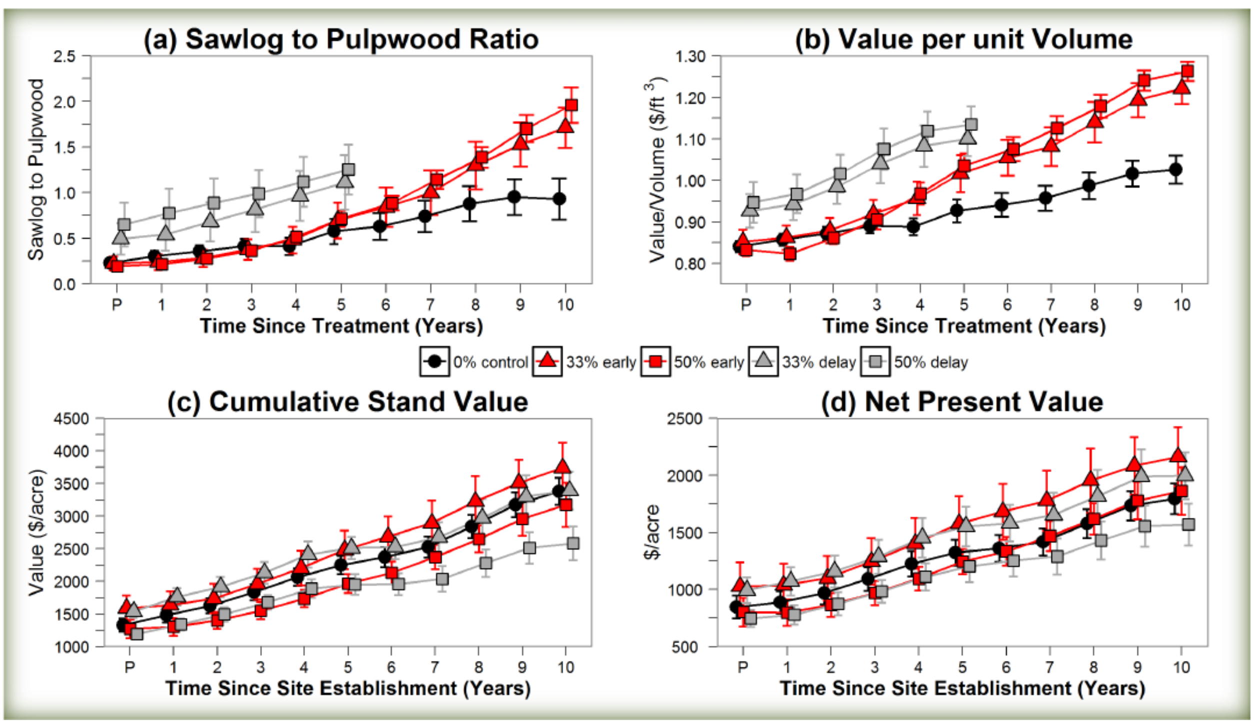


Figure 4 - (a)Mean sawlog to pulpwood ratio, (b) total stand value, (c) value per unit volume, and (d) net present value (discount rate: 4%) for 10 years following four commercial thinning treatments in six younger (23–42-year-old) fir-spruce stands across northern Maine.

Future Plans:

- Continue measurements on longer time interval to reduce measurement costs.
- Thin 5-year delay treatment at three mid-quality sites
- Measure and analyze thinning response at Austin Pond in coming years.

Products Delivered:

Journal Publications:

Olson, M.G., S.R. Meyer, R.G. Wagner, and R.S. Seymour. 2014. Commercial thinning stimulates natural regeneration in spruce–fir stands. Can. J. For. Res. 44: 173–181 (2014) dx.doi.org/10.1139/cjfr-2013-0227

Research Reports:

Seymour, R.S., S.R. Meyer, and R.G. Wagner. 2014. The Cooperative Forestry Research Unit Commercial Thinning Research Network: 9-Year Results. In: Kenefic, Laura S.; Brissette, John C., compilers. 2014. Penobscot Experimental Forest: 60 years of research and demonstration in Maine, 1950-2010. Gen. Tech. Rep. NRS-P-123. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 185 p.

Conference Papers:

Wagner, R.G., M.M. Bataineh, and M.G. Olson. 2014. Long-term stand development and financial returns following herbicide and precommercial thinning combinations in the Acadian Forest of Maine, USA. In Proc. 8th International Forest Vegetation Management Conference, August 25-28, 2014, Halmstad, Sweden.

Theses:

Clune, P.M. 2013. Growth and development of Maine spruce-fir forests following commercial thinning. M.S. thesis, University of Maine, Orono.

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

Austin Pond Study: Third wave of treatments to assess rotation-length outcomes for silvicultural options in Maine's northern forest

Brian Roth and Patrick Hiesl

University of Maine

Status: Final Report

Summary:

The third and final year of installing a third wave of treatments and evaluating harvesting productivity at Austin Pond was completed. During the winters of 2012-13 and 2013-14, the Austin Pond research site was commercially thinned using cut-to-length (CTL) and whole-tree (WT) harvesting systems in PCT and non-PCT stands, respectively. Thinning prescriptions consisted of three nominal removal intensities (33%, 50%, and 66% of the standing softwood volume) in a randomized block design. Stand density, basal area, hardwood content, and removal intensity were not significant in explaining variation in harvester and feller-buncher productivity. The unit cost of production of wood chips using a WT system was less costly than the production of roundwood using a CTL system; however, profits were similar for both products harvested.

Project Objectives:

- Commercially thin PCT and non-PCT stands using a range of commercial thinning and stand improvement treatments;
- Measure machine productivity in all harvest blocks; and
- Explore the feasibility of a whole-tree system operating in a small diameter high density stand.

Approach:

- Trees in individual stands were marked to leave.
- In the winter of 2012-13 a CTL harvest system (Ponsse Ergo harvester; Timberjack 1110 forwarder) was used to commercially thin stands that previously received a PCT treatment. Stands that did not receive a PCT treatment were commercially thinned in the winter of 2013-14 using a WT harvest system (CAT 501 feller-buncher; JD 648 GIII grapple skidder; Morbark Model 23 disk chipper).
- The roundwood produced by the CTL and the wood chips produced by the WT systems was measured for each harvest block.
- Harvest cost and profit calculations were done using a simulation of skidder and forwarder extraction times using regional cycle time equations (Hiesl and Benjamin 2013).

Key Findings / Accomplishments:

- Results from this study showed that there was no difference in productivity between the three removal intensities (33%, 50%, and 66% of the standing softwood volume) for harvester and feller-buncher, respectively (**Figure 5** and **Figure 6**).
- The unit cost of production was lower for wood chips produced by the WT system than roundwood produced by the CTL system (**Figure 7**); however, profit for both products was similar (**Figure 8**).
- Results demonstrated that a WT system could be used profitably to thin small-diameter, high-density stands, provided that a biomass market is within a 60-mile round-trip distance.

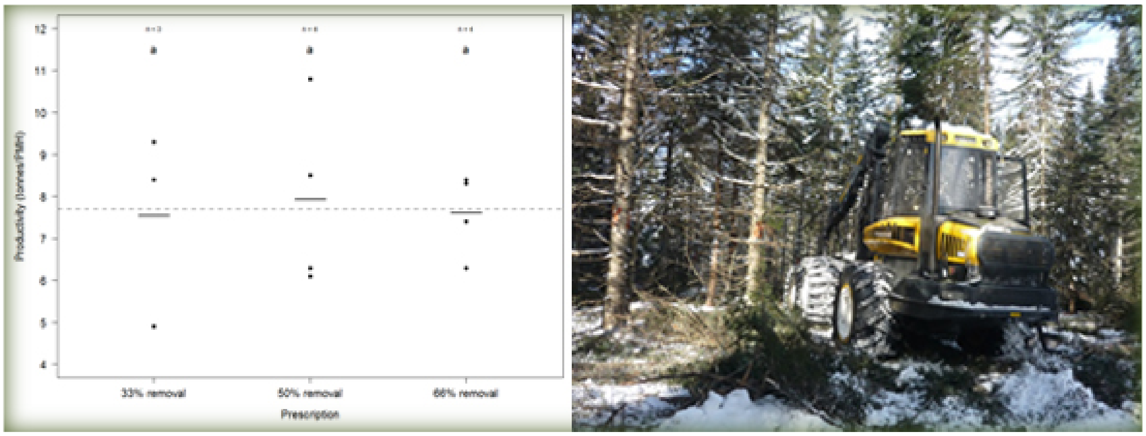


Figure 5 - [left] Harvester productivity across three different prescriptions. Black lines represent the average harvester productivity for each prescription. The gray dashed line represents the overall mean. Letters at the top of each prescription show statistically different means. [right] Ponsse Ergo harvester in a previously PCT'd stand. Photo credit: Patrick Hiesl.

Figure 6 - [left] Feller-buncher productivity across three different prescriptions. Black lines represent the average harvester productivity for each prescription. The gray dashed line represents the overall mean. Letters at the top of each prescription s show statistically different means. [right] CAT 501 feller-buncher with operator Brian Mack in a non-PCT stand (right). Photo credit: Patrick Hiesl.

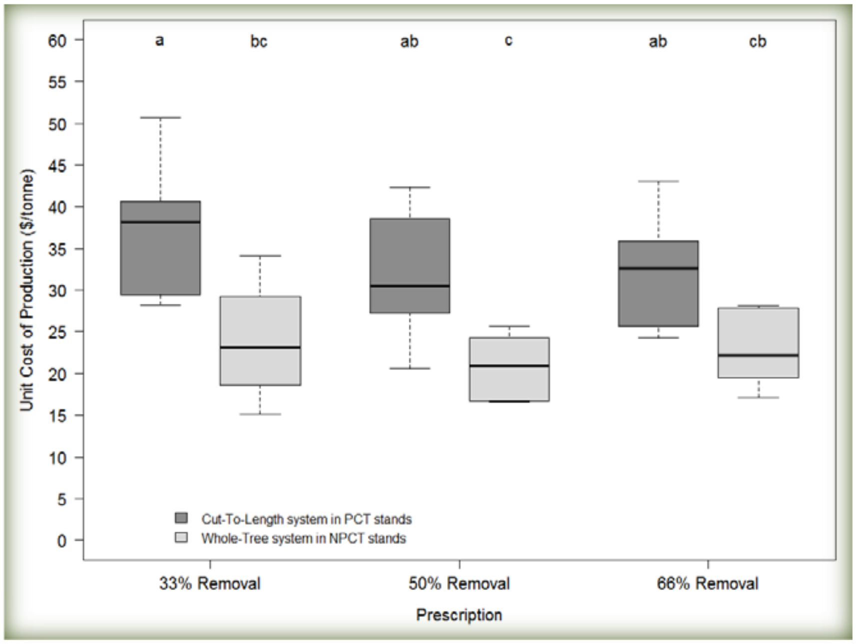


Figure 7 - Unit cost of production for mill-delivered roundwood produced by a CTL system operating in previously PCT'd stands, and wood chips produced by a WT system operating in non-PCT stands. The lower and upper lines of each box represent the minimum and maximum value, respectively. The bold black line in each box represents the median value. Letters at the top of each prescription show statistically different means.

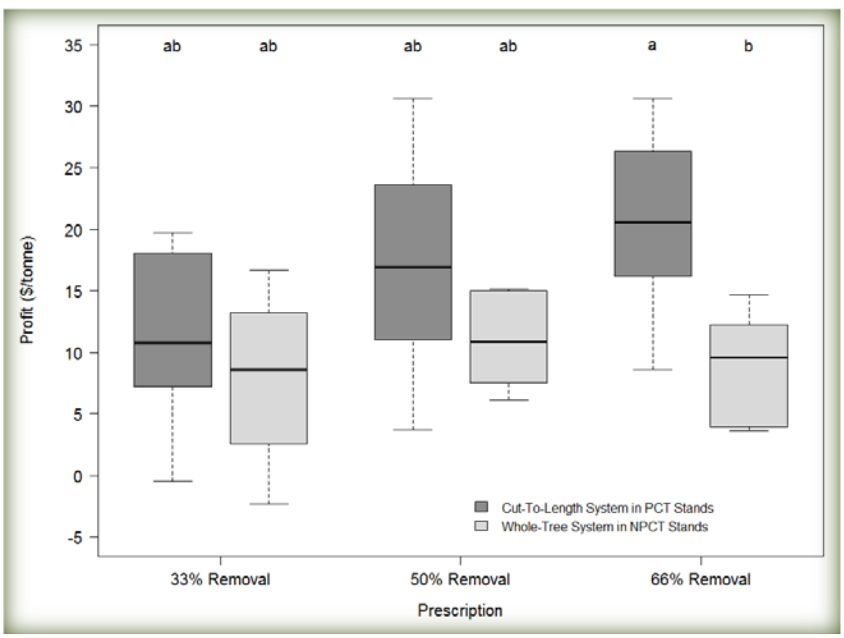


Figure 8 - Profit for mill-delivered roundwood produced by a CTL system operating in previously PCT'd stands, and wood chips produced by a WT system operating in non-PCT stands. The lower and upper lines of each box represent the minimum and maximum value, respectively. The bold black line in each box represents the median value. Letters at the top of each prescription show statistically different means.

Future Plans:

- The new experimental plots established with this study are now part of the CTRN and will be measured periodically to assess long-term growth response to the third wave of treatments.

Products Delivered:

Refereed Journal Publications:

Bataineh, M.M., R.G. Wagner, M.G. Olson, E.K. Olson. 2013. Midrotation response of ground vegetation to herbicide and precommercial thinning in the Acadian Forest of Maine, USA. Forest Ecology & Management 313: 132–143.

Bataineh, M.M., R.G. Wagner, A.R. Weiskittel. 2013. Long-term response of spruce-fir stands to herbicide and precommercial thinning: Observed and projected growth, yield, and financial returns in central Maine, USA. Canadian Journal of Forest Research 43(4): 385-395.

Research Reports:

Hiesl, P. and Benjamin, J.G. 2013. Harvesting Equipment Cycle Time and Productivity Guide for Logging Operations in Maine. Miscellaneous Publications 762. Orono, ME, USA: Maine Agricultural and Forest Experiment Station: 2013. p. 67.

Conference Papers:

Hiesl, P. and Benjamin, J.G. 2014. Harvester Productivity and Cost in Small Diameter Timber Stands in Central Maine, USA. In: Proceedings of the 37th Council on Forest Engineering: Global Harvesting Technology. Moline, IL, USA: June 22-25, 2014.

Presentations / Workshops / Meetings / Field Tours:

Wagner, R.G., Roth, B.E., Benjamin, J.G. and Hiesl, P. 2014. Plum Creek Forester's Field Tour. Austin Pond Study: Herbicide, PCT and Commercial Thinning. Bingham, ME, USA: August 7, 2014.

References:

Hiesl, P. and Benjamin, J.G. 2013. Harvesting Equipment Cycle Time and Productivity Guide for Logging Operations in Maine. Miscellaneous Publications 762. Orono, ME, USA: Maine Agricultural and Forest Experiment Station: 2013. p. 67.

Acknowledgements:

We would like to thank Plum Creek Timber Company for their ongoing support of this long-term study. Special thanks go to John Ackley of Plum Creek in Bingham, Maine, for his help and support during the study. We would also like to thank the three logging contractors and their crews for their patience and help during the harvest, as well as Derek Brockmann for his help with managing the harvests and data collection.

Weymouth Point: Monitoring the effects of whole tree harvesting and intermediate silvicultural treatments on long-term spruce-fir productivity

Brian Roth, Robert Wagner, Robert Seymour, Aaron Weiskittel, Andrew Nelson, and Mohammad Bataineh

University of Maine

Status: Progress Report, Year 1 of 1

Summary:

Despite continued interest in the long-term effects of whole-tree harvesting (WT), there are only a limited number of locations in New England where these effects can be quantified. One such location is CFRU's Weymouth Point paired watershed study, where aboveground biomass was measured 32-years following harvesting (Briggs 2000, Smith 1984). In the summer of 2014, a network of fifth-acre plots was re-established from across three existing experiments and an inventory was completed. Silvicultural treatments included precommercial thinning and fertilization. Aerial LiDAR data were collected, a detailed digital elevation model created, and a depth-to-water table map was generated. Next steps will be to use these data to estimate biomass, analyze for differences between treatments, and examine relationships with drainage class.

Project Objectives:

- Quantify the extent to which stands have recovered biomass 32 years following WT harvesting;
- Document the effects of intermediate silvicultural practices on biomass production 32 years following harvesting; and
- Examine the influence of soil drainage and its interaction with silviculture on aboveground productivity following harvesting.

Approach:

- Re-establish fifth acre measurement plots on each of the 61 existing treatment plots (**Figure 9**).
- In each measurement plot, measure all trees larger than 2.5" DBH and estimate aboveground biomass and sum to generate unit area estimates for each plot (**Figure 10**).
- Generate a LiDAR-derived DEM and associated Wet Areas Geo-rectified Map (**Figure 11**).

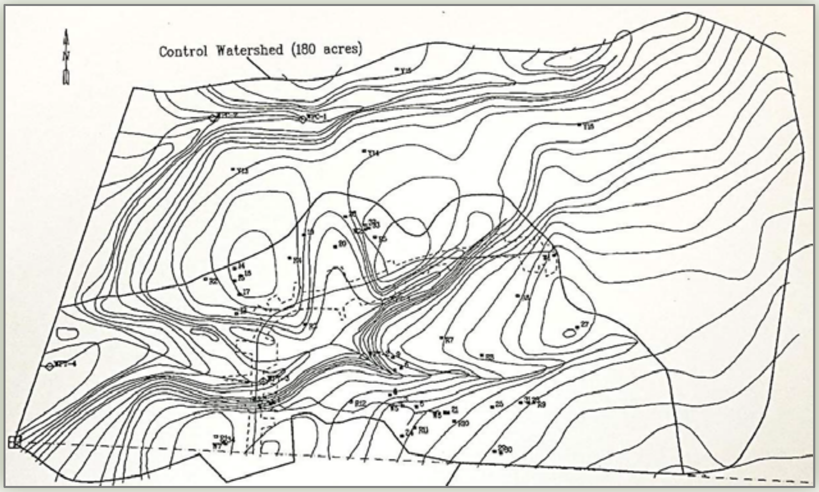


Figure 9 - General overview of the topography and layout of the paired watershed study at Weymouth Point showing the two watersheds (reference and whole tree harvested) and measurement plots from two previous studies.

Key Findings / Accomplishments:

- Digitized data from historical measurements. Build GIS database of plots, treatments, historical maps and associated data.
- Re-located and monumented 36 historical plots from across three previous studies.
- Created two-dimensional stem maps of measurement trees in plots.
- Measured species, total height, height to base of live crown and DBH on over 6,000 trees.
- Collected 3D point-cloud from LiDAR data at 6 ppm.
- Generated high resolution Digital Elevation Model across entire study site.
- Produced a depth-to-water table map at three resolutions.

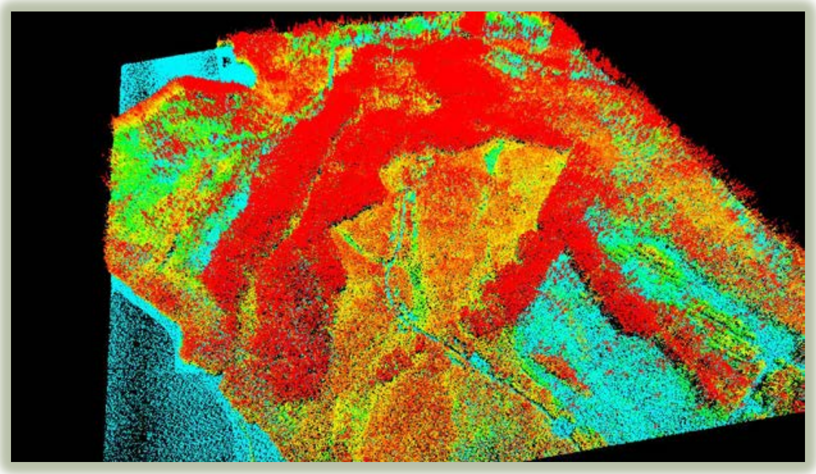


Figure 10 - LiDAR point cloud of Weymouth Point study site colorized by height above surface.

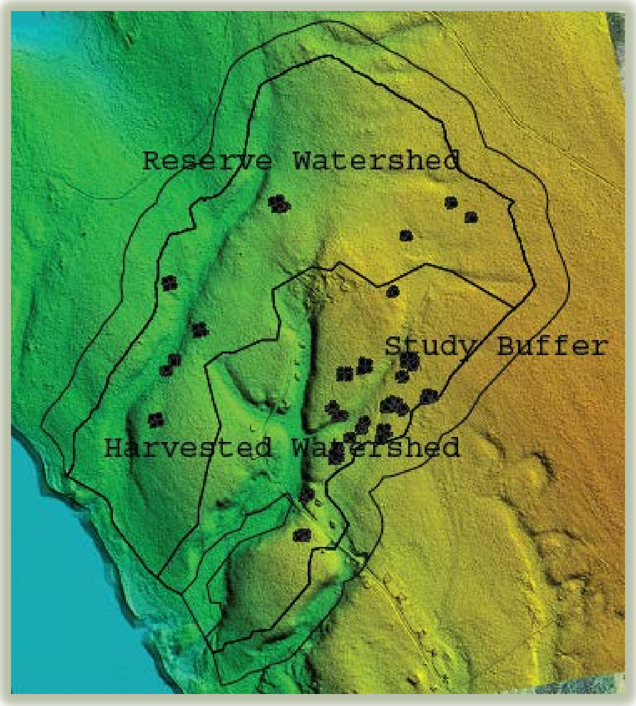


Figure 11 - Digital Elevation Model of Weymouth Point study site colorized by elevation, showing location of plots and harvest treatments.

Future Plans:

- Complete the data analysis and summarize the results.
- Host a long-term site productivity field tour.
- Link this project with the mechanical harvesting project and incorporate a second phase of harvesting in the control stand with this research.

Products Delivered:

- Over 6,000 tagged trees were added to CTRN database.
- Established 36 fifth-acre plots with tree data available for LiDAR model development.
- Collected 6 ppm LiDAR LAS database.
- Developed high-resolution Digital Elevation Model and depth-to-water table maps for study site.

References:

Briggs, R.D., Hornbeck, J.W., Smith, C.T., Lemin Jr, R.C., and M.L. McCormack Jr,. 2000. Long-term effects of forest management on nutrient cycling in spruce-fir forests. Forest Ecology and Management 138(1–3): 285-299.

Smith, C.T. 1984. Nutrient removals and soil leaching of a red spruce (Picea rubens Sarg.) - balsam fir (Abies balsamea (L.) Mill.) stand in north central Maine. Ph. D. dissertation. University of Maine. p. 214.

Acknowledgements:

The study site is located on lands owned and managed by Katahdin Forest Management, Leading Edge Geomatics (Lincoln, New Brunswick) collected and processed the LiDAR data, Elias Ayrey created the Digital Elevation Model, and the Forest Watershed Research Center at the University of New Brunswick, generated the depth-to-water table maps. This study would not be possible without the previous work of Tat Smith, Russ Briggs and Richard Cobb.

Partners / Stakeholders / Collaborators:

- Katahdin Forest Management
- Leading Edge Geomatics
- University of New Brunswick Watershed Research Center

Assessment of productivity and costs for logging equipment in Maine's forest industry

Jeffrey Benjamin and Patrick Hiesl

University of Maine

Feller-buncher – Wells Forest

Status: Final Report

Summary:

Cycle time and productivity models for harvesting equipment commonly used in Maine's logging industry were developed for partial harvest operations. Time consumption data were collected per work cycle for each machine and productivity values were developed using tree volumes estimated with samples of dbh and tree height for individual species. Data were collected from seven whole-tree partial harvests with initial stand densities between 411 and 1,027 trees per acre. Basal area ranged from 109 to 238 square feet per acre. Removal intensities ranged from 15% to 67% of the initial basal area. Data were collected from five cut-to-length partial harvests with initial stand densities between 537 and 1,948 trees per acre. Basal area ranged from 116 to 203 square feet per acre. Removal intensities ranged from 25% to 90% of the initial basal area. Key variables that influence cycle time and productivity are stem size and number of stems per accumulation (feller-bunchers); stem size and species grouping (cut-to-length processor and stroke delimbers); skidding distance and load size (grapple skidders); and forwarding distance, log volume and logs per load (forwarders).

Project Objectives:

To develop machine-level productivity functions for logging equipment (swing-to-tree feller bunchers, dangle-head processors, grapple skidders, forwarders, and stroke delimbers) operating in partial harvests throughout central Maine.

Approach:

- Sites were selected for this study based upon willingness of landowners and logging contractors to participate in time and motion studies of partial harvesting operations scheduled in the summer of 2012.
- A study area from each site was flagged for harvest to ensure a minimum sample of 250 trees per site which resulted in a range of block size from 0.2 ha to 0.9 ha. All trees in each study area were painted different colors (blue, green, orange, yellow) based on diameter classes (Benjamin et al. 2013; Eggers et al. 2010). Horizontal line samples were established to determine initial tree density and basal area.
- A description of work cycles for each machine studied is as follows:

Machine Type	Work Cycle Description
Feller-Buncher	Begins and ends at empty accumulators at the bunch and includes the time to harvest, accumulate, and place a bunch in a twitch. Time within each cycle will also be noted for trail work, removal of snags or non-merchantable stems, re-piling a twitch, and excessive travel.
CTL Processor	Begins and ends at saw cut and includes the time to fell, delimb, top, process, and select the next stem. If multi-stem processing occurs, the cycle will end after all stems have been processed and a new stem is selected with empty accumulators. Time within each cycle will also be noted for any trail work, removal of snags or non-merchantable stems, processing rot, excessive work to delimb forks, and excessive travel.
Forwarder	Begins and ends when the machine leaves the yard empty and includes the time to travel, load, unload and sort. Time within each cycle will also be noted for any trail work, wait at yard, re-piling, and excessive travel.
Grapple Skidder	Begins and ends when the machine leaves the yard empty and includes the time to travel, load, and unload. Time within each cycle will also be noted for any trail work, wait at yard, brush clean-up at yard, and excessive travel.
Stroke Delimber	Begins and ends with grabbing a tree and includes the times to delimb and pile. Extra time will be noted for brush clean-up.

- Cycle time was measured as productive machine minutes including delays less than 15 minutes (PMmin15). Production data was also collected for each cycle (e.g., stem size for harvesting; skid distance and load size for transportation). Regional tree taper and volume equations were used with a merchantable top diameter of 7.5 cm (Li et al. 2012).
- Data were entered into a Palm Tungsten E2 with the time study software UMT Plus (Laubrass, Inc., Montreal, QC, Canada).

Key Findings / Accomplishments:

- Results from this study clearly show the negative impact of stem size on cycle time and productivity for harvesting and processing (**Figures 12 - 14**). For the feller-buncher productivity curves in particular, it is important to note that the estimates shown are based on assumptions of tree size and number of trees per accumulation. A more detailed description on how these parameters can be derived in practice is provided in Hiesl & Benjamin (2013).
- Distance to roadside is the most obvious and influential factor on productivity of transportation equipment (**Figures 15 and 16**), stem size also indirectly affects skidders and forwarders through changes in load size. Average one-way transportation distances observed were 1,300 feet and 1,100 feet for grapple skidders and forwarders respectively, but observations up to 2,500 feet were also noted. These distances are much longer than those found in other harvesting equipment productivity studies (Bolding et al. 2009; Adebayo 2006; Lanford and Stokes 1996) where average skidding distances were closer to 650 feet.
- A comparison of all machines studied clearly shows the differences in machine productivity for both whole-tree and cut-to-length systems (Fig. 17) with whole-tree almost twice as productive on an hourly basis compared to cut-to-length. On an annual basis, these differences are lessened due to changes in utilization rates and amount of downtime due to weather between each system. Further, our results confirm that feller-bunchers are approximately twice as productive as grapple skidders and stroke delimbers in whole-tree systems.

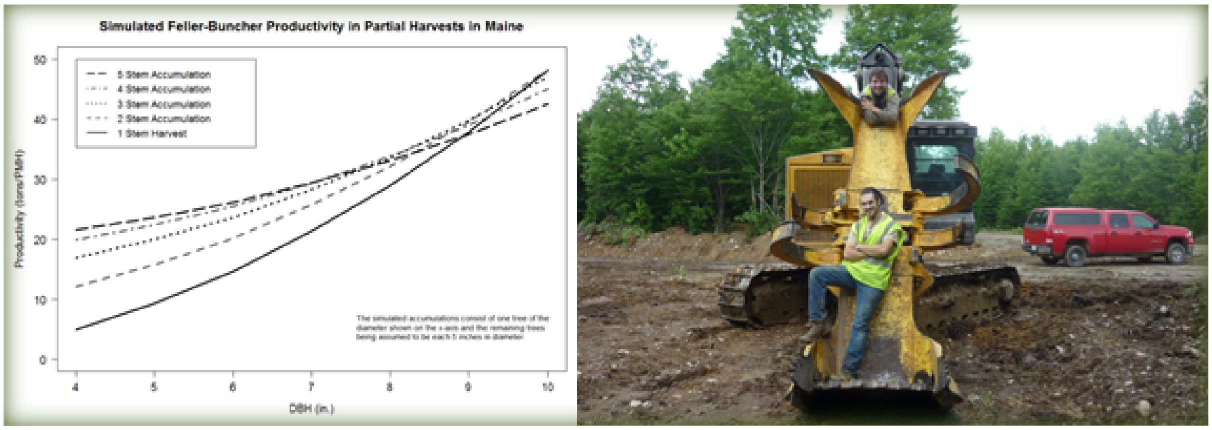


Figure 12 – [left] Productivity curve for feller-buncher with feller-buncher head accumulations of one to five trees. [right] Field workers Casey Elmer (top) and Josh Kling (bottom). Photo credit: Patrick Hiesl.

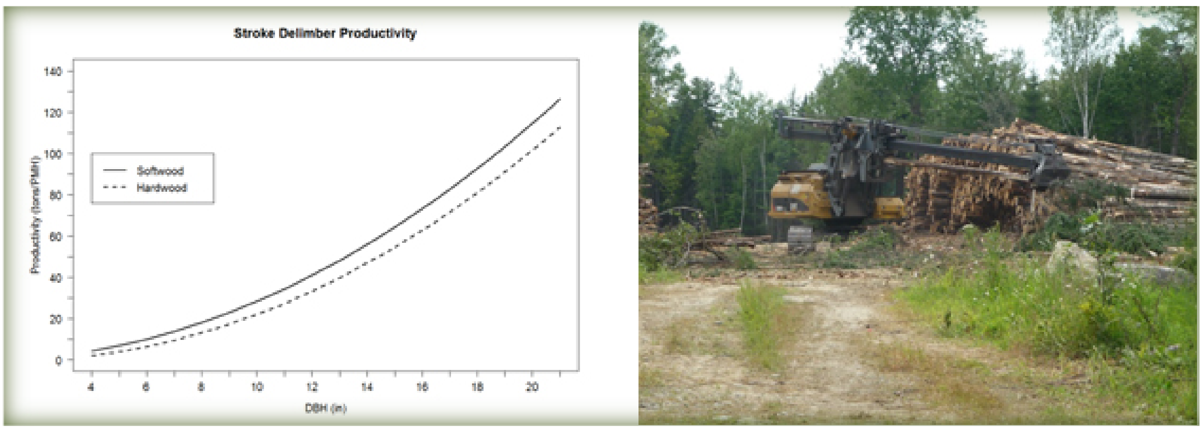


Figure 13 – [left] Productivity curves for stroke delimber showing the effect of stem size and species. [right] Stroke delimber processing a softwood tree at one of the study sites. Photo credit: Casey Elmer.

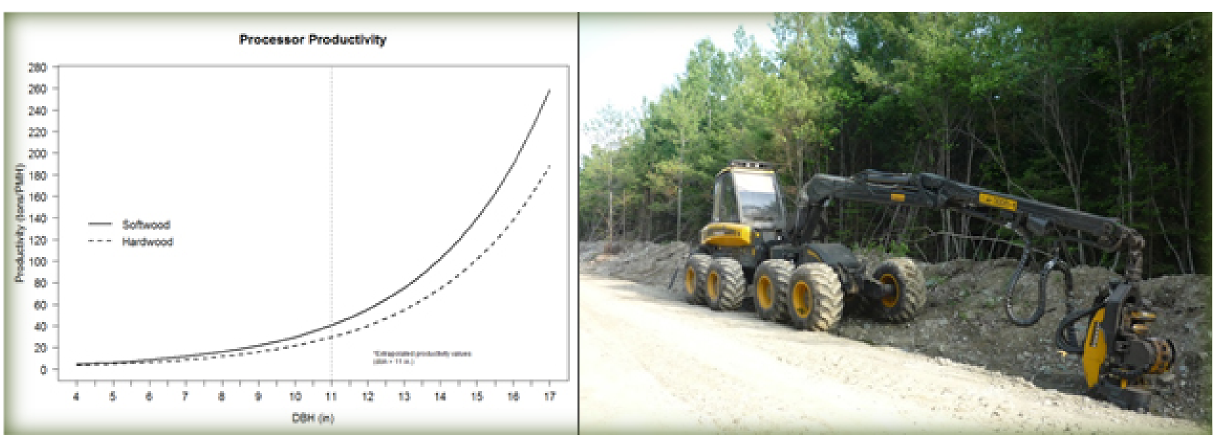


Figure 14 - [left] Productivity curves for processor showing the effect of stem size and species (left). [right] One of the studied processors ready for some maintenance work. Photo credit: Patrick Hiesl.

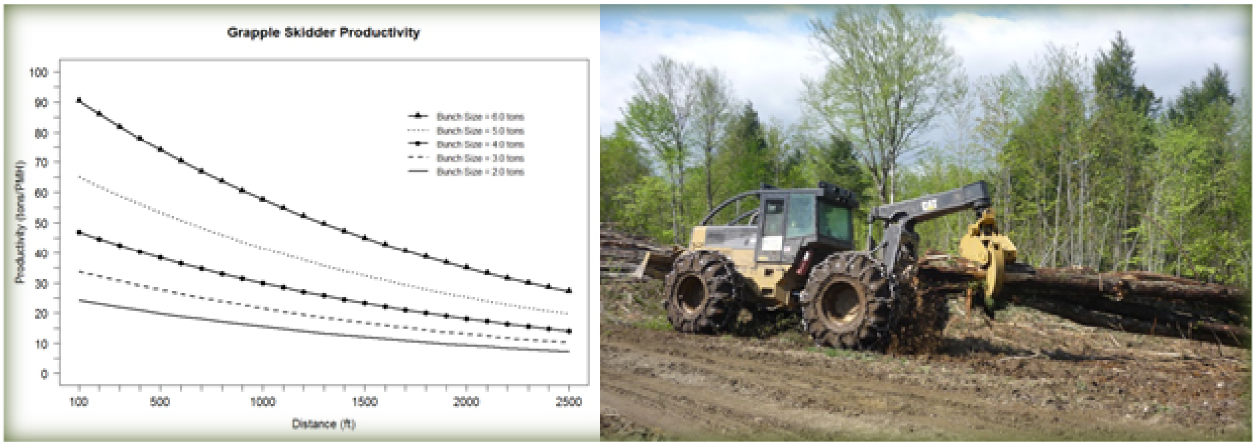


Figure 15 – [left] Productivity curves for grapple skidders showing the effect of one-way traveling distance and bunch size. [right] Grapple skidder yarding a bunch of trees to the landing. Photo credit: Patrick Hiesl.

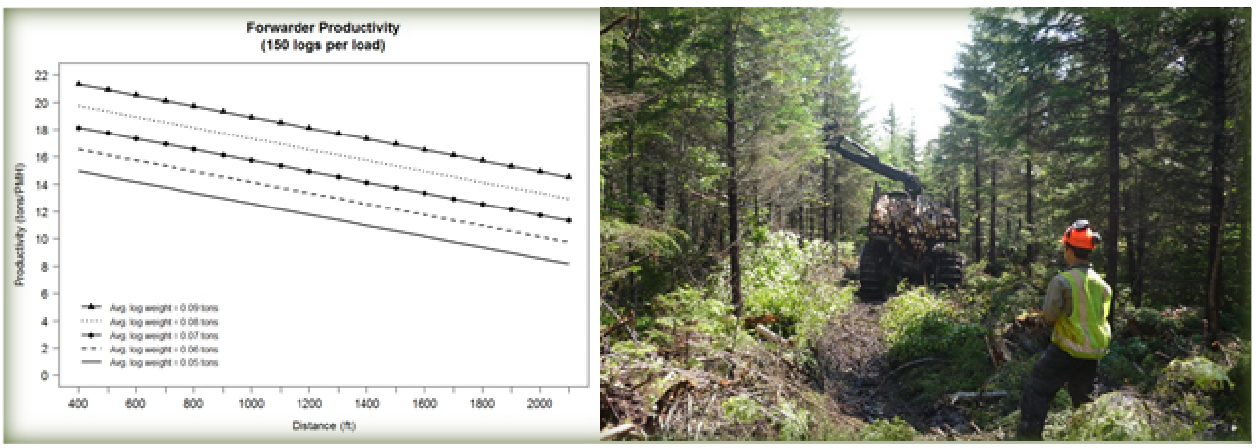


Figure 16 - [left] Productivity curves for forwarder showing the effect of one-way traveling distance and average log weight with a constant payload of 150 logs. [right] Casey Elmer following a forwarder to count the number of logs per grapple load. Photo credit: Patrick Hiesl.

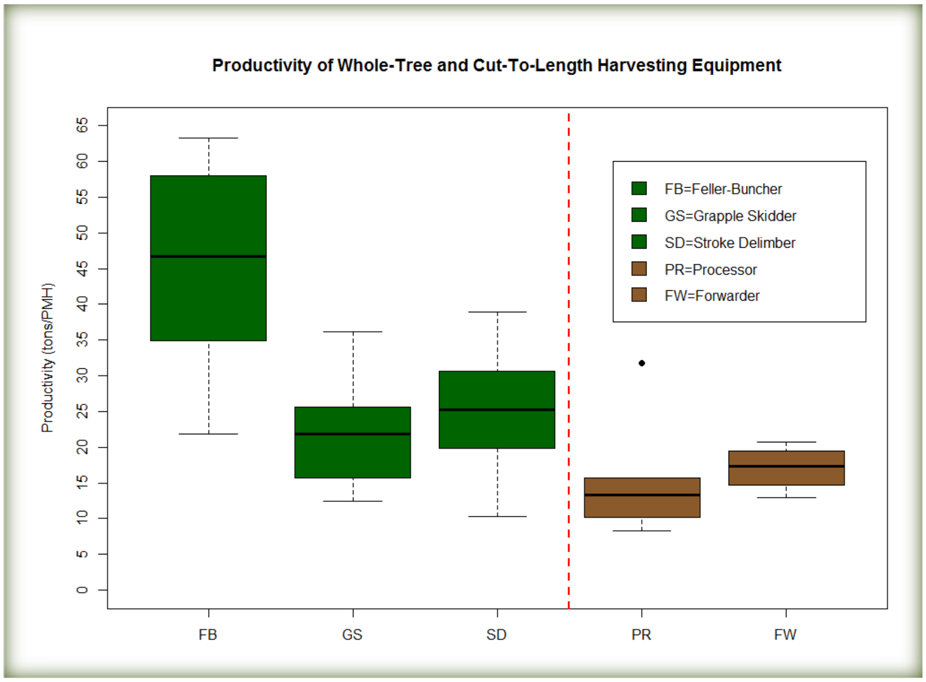


Figure 17 - Productivity of whole-tree and cut-to-length harvesting equipment.

Future Plans:

- Cycle time and productivity data will be incorporated into an updated version of PATH – Planning and Analysis in Timber Harvesting designed by Dr. Steven Bick of Northeast Forests. A copy of the program can be found at www.northeastforests.com.
- An examination of repair and maintenance costs for logging equipment has been incorporated into a MS thesis (Joe Hutton, School of Forest Resources) as part of the FarmBio3 project noted below in External Funding Sources. Graduate work is scheduled for completion in May 2015.

Products Delivered:

Refereed Journal Publications:

Hiesl, P. and Benjamin, J.G. 2014 (Accepted). Estimating processing times of harvesters in thinning operations in Maine. Forest Products Journal.

Hiesl, P. and J.G. Benjamin. 2013. A Multi-Stem Feller-Buncher Cycle Time Model for Partial Harvest of Small Diameter Wood Stands. International Journal of Forest Engineering 24(2):101-108.

Hiesl, P. and J.G. Benjamin. 2013. Applicability of International Harvesting Equipment Productivity Studies in Maine, USA: A Literature Review. Forests 4:898-921.

Research Reports:

Hiesl, P. and J.G. Benjamin. 2013. Harvesting Equipment Cycle Time and Productivity Guide for Logging Operations in Maine. University of Maine, Maine Agriculture and Forest Experiment Station. Orono, ME. Miscellaneous Publication 762. 60p.

Theses:

Hiesl, P. 2013. Productivity Standards for Whole-Tree and Cut-to-Length Harvesting Systems in Maine. M.S. thesis, University of Maine, Orono.

Conference Papers:

Hiesl, P. and J.G. Benjamin. 2014. Harvester Productivity and Cost in Small Diameter Timber Stands in Central Maine, USA. Paper presented at the 37th Council on Forest Engineering: Global Harvesting Technology. Moline, Il. June 22-25, 2014.

Benjamin, J.G. and D. Burr. 2013. Production Tracking System for Swing-to-Tree Feller Bunchers. Paper presented at the 36th Council on Forest Engineering: Forest Operations for a Changing Landscape. Missoula, MT. July 7-10, 2013.

Hiesl, P. and J.G. Benjamin. 2013. Assessment of Feller Buncher and Harvester Caused Stand Damage in Partial Harvests in Maine. Paper presented at the 36th Council on Forest Engineering: Forest Operations for a Changing Landscape. Missoula, MT. July 7-10, 2013.

Presentations / Workshops / Meetings / Field Tours:

Benjamin, J,G., P. Hiesl, J. Hutton, and C. Lachance. 2014. Mechanized Harvesting – How Productive is Your Operations? New Hampshire Timberland Owners Association – Spring 2014 Workshop. Concord, NH. June 12.

Benjamin, J,G., P. Hiesl, and J. Hutton. 2014. Stick with the Status Quo or Find the Best Flow. Productivity Improvement Workshop for Treeline Inc. Lincoln, ME. May 9.

Benjamin, J.G. 2014. Operational and Economic Aspects of Biomass Harvesting: There is No Free Lunch in the Woods. New England Society of American Foresters – 2014 Winter Meeting: Resources – Resilience – Renewal – Restoration. Nashua, NH. March 25.

Benjamin, J.G. 2013. Trends in the Northeast Logging Industry: Man, Machine and Money. 21st Loggers and truckers Convention – New Hampshire Timberland owners Association. Concord, NH. October 19, 2013.

Benjamin, J.G. and P. Hiesl. 2013. Managing Operational Costs of Maine's Hardwood Resource. Canadian Woodlands Forum 2013 Fall Meeting. Edmundston, N.B. October 1, 2013.

Benjamin, J.G. and P. Hiesl. 2013. Influence of Stem Size on Cycle Time on Harvest Productivity and Cost. Forest Bioproduct Research Institute – 2013 Fall Board Meeting. Orono, ME. October 10, 2013.

Hiesl, P. and Benjamin, J.G. 2013. CFRU Logging Cost and Productivity Study Results. 2013 Cooperative Forestry Research Unit Fall Field Tour. Overstory Removal & Regeneration: Challenges & Opportunities. University of Maine, Orono, ME: October 10, 2013.

Benjamin, J.G. and P. Hiesl. 2013. Influence of Stem Size on Cycle Time on Harvest Productivity and Cost. LP Supplier Workshop. Houlton, ME. August 21, 2013.

Benjamin, J.G. 2013. The University of Maine's iFOR Program: Innovative Forest Operations Research. Northeastern Loggers' Association Equipment Expo and Logger Workshops. Bangor, ME. May 17.

Benjamin, J.G. 2013. Forest Business Planning Workshop – NE Logging Industry Overview and Process Improvement. Vermont Forest Parks and Recreation Department. Essex Junction, VT. May 10.

Benjamin, J.G. and P. Hiesl 2013. What is the Value of Your Time? Productivity Improvement Workshop for Treeline Inc. Lincoln, ME. May 3.

Benjamin, J.G. 2013. iFOR – The University of Maine's Innovative Forest Operations Research Program. Northern Hardwood Research Institute Seminar Series. Edmundston, NB. April 10.

Benjamin, J.G. and P. Hiesl. 2013. Influence of Stem Size and Cycle Time on Harvest Cost. New England Council on Forest Engineering Annual Meeting. Legal Issues in Forestry & Foresters…..Knowing Your Costs. University of Maine, Orono, ME. March 11-12, 2013.

References:

Adebayo, A.B., Han, H.-S. and Johnson, L. 2007. Productivity and cost of cut-to-length and whole-tree harvesting in a mixed-conifer stand. Forest Products Journal 57(6), pp. 59–69.

Benjamin, J.G., R. Seymour, E. Meacham, and J. Wilson. 2013. Impact of Whole-Tree and Cut-to-Length Harvesting on Post-Harvest Condition and Logging Costs for Early Commercial Thinning in Maine. Northern Journal of Applied Forestry. 30(4):149-155.

Bolding, M.C., Kellogg, L.D. and Davis, C.T. 2009. Productivity and costs of an integrated mechanical forest fuel reduction operation in southwest Oregon. Forest Products Journal 59(3), pp. 35–46.

Eggers, J., McEwan, A. and Conradie, B. 2010. Pinus saw timber tree optimization in South Africa: a comparison of mechanised tree optimisation (harvester/processor) versus current manual methods. Southern Forests 72(1), pp. 23–30.

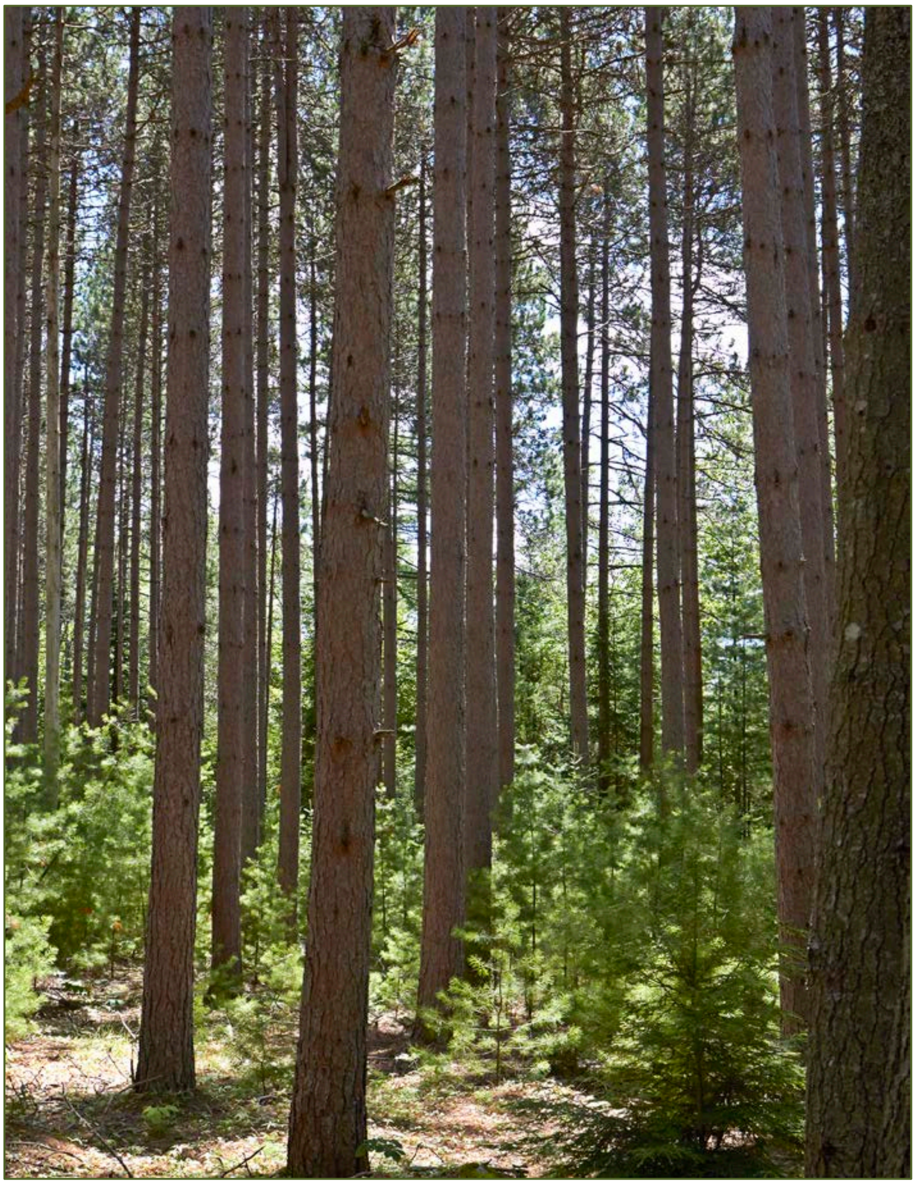
Hiesl, P. and J.G. Benjamin. 2013. A Multi-Stem Feller-Buncher Cycle Time Model for Partial Harvest of Small Diameter Wood Stands. International Journal of Forest Engineering 24(2):101-108.

Lanford, B.L. and Stokes, B.J. 1996. Comparison of two thinning systems . Part 2 . Productivity and costs. Forest Products Journal 46(11/12), pp. 47–53.

Li, R., Weiskittel, A., Dick, A.R., Jr, J.A.K. and Seymour, R.S. 2012. Regional Stem Taper Equations for Eleven Conifer Species in the Acadian Region of North America: Development and Assessment. Northern Journal of Applied Forestry 29(1), pp. 5–14.

Acknowledgements:

We thank the University of Maine's Cooperative Forestry Research Unit (CFRU) and Maine Agricultural and Forest Experiment Station (MAFES) for funding this project. Special thanks go to all the land managers, contractors and equipment operators that participated in this study. We also acknowledge the work of our field technician and student worker Casey Elmer during the summer of data collection. Finally, we would like to thank Drs. Robert Seymour and Aaron Weiskittel for their input and help during the study design and data analysis phases of this study.



Red Pine Stand - Demeritt Forest

Effects of mechanized harvesting operations on residual stand conditions

Jeffrey Benjamin[1], Eric R. Labelle[2], Robert Seymour[1], Brian Roth[1], and Ivan Fernandez[1]

[1] University of Maine

[2] Northern Hardwood Research Institute

Skidder – Wells Forest

Status: Progress Report, Year 1 of 3

Summary:

Post-harvest stand condition, including residual stems and soil properties, is greatly influenced by mechanized operations and harvest trails in particular. Studies from other regions have considered the effect of trails on regeneration, crown closure and growth of nearby trees but there is a need to consider the influence of the trails on stand condition for this region in particular. Whole tree (WT) harvesting is often associated with extensive soil disturbance ranging from removal of the forest floor to severe compaction and rutting. A site disturbance assessment was conducted as part of the Weymouth Point paired watershed study to quantify the extent and magnitude of soil disturbance following mechanized harvesting, and an opportunity exists to re-evaluate regeneration and growth of crop trees three decades after harvest. Recent soil compaction studies in New Brunswick for cut-to length (CTL) harvest systems provide great insight into site conditions following harvest, but there is a need to continue this research for WT harvest sites.

This study will determine the effects of mechanized harvest operations on residual stand condition and ultimately on the long-term growth of Maine's mixed wood forests. Specifically, this project will investigate the impact of soil disturbance on spruce-fir productivity 32 years following WT harvesting at the Weymouth Point paired watershed study. We will also establish a network of permanent research plots at 10 new harvest sites to (1) assess the impact of trails, site disturbance and soil compaction on residual stem growth, and (2) quantify damage to residual stems and determine the effect of wound size and severity level on future growth and quality. A team of experts in forest soils and stand development has been assembled from the University of Maine, the Northern Hardwood Research Institute, the Natural Resources Conservation Service, and engineering consultants to evaluate site disturbance (10-point qualitative scale and detailed terrain models pre- and post-harvest), soil compaction (nuclear moisture and density gauge and laboratory determined soil properties) and stem damage (wound size and severity ratings).

Project Objectives:

The overall objective of this research is to determine the effects of mechanized harvest operations on residual stand condition and ultimately on the long-term growth of Maine's mixed wood forests. Clearly the scope of this project extends beyond the typical project length for CFRU funded research, but it is the intent of project investigators to monitor the effects of mechanized harvesting operations over a 15–20 year period. Specifically, this project will:

1. Investigate the impact of soil disturbance on spruce-fir productivity 32 years following whole-tree harvesting at the Weymouth Point paired watershed study and in particular:
    a. Quantify regeneration with respect to species composition, trees per acre, and basal area; and
    b. Relate changes in regeneration and growth of the crop trees to the severity and type of soil disturbance at the time of harvest.

2. Establish permanent research plots at new harvest sites and over the next 5 years:
    a. Assess the impact of trails on residual stem growth by considering the effective area in trails, soil conditions, harvest method (WT or CTL), trail spacing and distance from roadside. Effective area in trails refers to that which is biologically impacted and considers crown closure, root damage and soil compaction; and
    b. Quantify damage to residual stems and determine the effect of wound size and severity level on future growth and quality.

Approach:

Phase 1 Weymouth Point

- 100 transects installed in August 1981 to quantify the extent and magnitude of soils disturbance (Martin 1988) will be re-examined to assess regeneration and growth of crop trees 32 years following harvest. Each transect is 25 meters in length with random starting points and azimuths selected using the existing grid system at the site.

- Soil disturbance and depth of displacement was categorized in 10 cm increments by subjective visual selection into one of 10 unique classes:
    - *Undisturbed* - no visual disturbance of any type;
    - *Depressed* - forest floor not disturbed laterally, but depressed by equipment or by a falling tree;
    - *Organic scarification* - forest floor disturbed laterally, but no evidence of compression by wheels, tracks, or falling trees;
    - *Mineral scarification* - complete removal of the organic horizons but no disruption of the mineral soil;
    - *Organic mounds* - mound of soil, still covered by organic material, created during harvesting usually as a berm parallel to wheel ruts or near tree roots disturbed during shearing;
    - *Mineral mounds* - mounds of mineral soil or organic soil covered by mineral soil deposits created during harvesting;
    - *Organic ruts* - shallow wheel or track ruts within the organic horizons or deep compression ruts still lined with organic soil;
    - *Mineral ruts* - wheel or track ruts in mineral soil;

- o *Dead wood* - stumps, logs in contact with the soil, or slash too dense to allow evaluation of soil disturbance; and
- o *Rock* - bare rocks that occupied 10 cm or more of the transect line.

- We will relocate the original transects and record species, dbh, and height on every crop tree (> 2.5”) along a 50 cm wide strip (n~10 per transect). We will also measure species and dbh for every tree greater than 2.5” in a circular 1/100th acre plot surrounding each ‘subject’ crop tree to adjust for competition effects on growth (**Figure 18**). Regeneration effects will be quantified using these circular plots.

Key Findings / Accomplishments:

- Located over 86 original soil disturbance transects.
- Completed measurements on individual trees along transects.

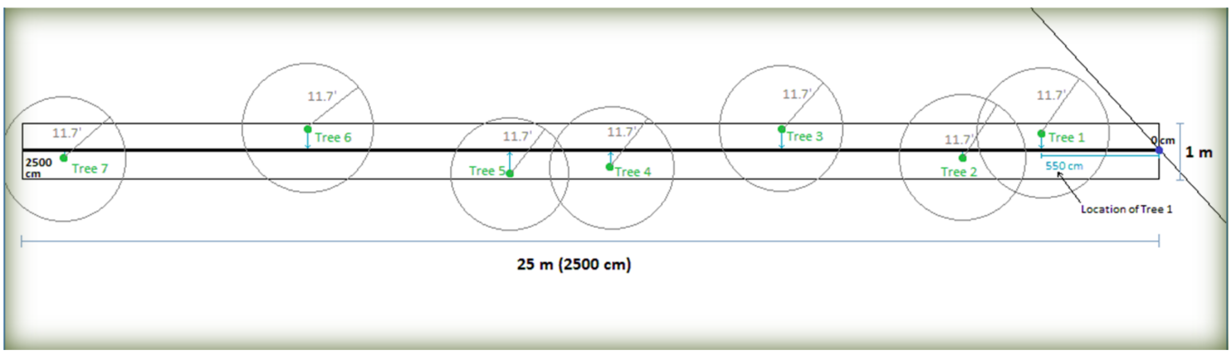


Figure 18 -Schematic diagram of tree inventory along soil disturbance transect.

Future Plans:

- Due to changes in the leadership team of this project, a revised proposal will be presented early in 2015 to reduce the scope of proposed work.

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 Katahdin Forest Management for their commitment to continuing research efforts at the Weymouth Point site.

Growth & Yield Modeling

- **Extending the Acadian variant of FVS to managed stands**
- **Linking LiDAR and ground-based forest inventory plots for improving estimation of key attributes**
- **Depth-to-water table mapping for Maine using latest DEM coverage**
- **Incorporating young hardwood stand responses to various levels of silviculture and stand composition into new CFRU growth & yield models**

Extending the Acadian variant of FVS to managed stands

Aaron Weiskittel[1], Chris Hennigar[2], and John Kershaw[2]

[1] University of Maine

[2] University of New Brunswick

Photo by Pamela Wells

Status: Final Report

Summary:

Most forest growth & yield models do not adjust their predictions for certain management activities such as precommercial or commercial thinning, which can lead to significant biases. This project's primary goal was to modify the Acadian variant of the Forest Vegetation Simulator (FVS-ACD) to account for the primary forest management activities in the region. To accomplish this, an extensive regional database of individual tree measurements from different forest management regimes was compiled. Component equations of FVS-ACD were then tested for performance in the managed stands and modified accordingly. In particular, precommercial and commercial thinning were found to significantly modify growth following treatment and the response was governed by a variety of different factors. These modifiers were incorporated into FVS-ACD and this should ensure proper representation of key forest management activities in the region. Continual improvement and modification will be completed as new data becomes available.

Project Objectives:

- Compile, document, and summarize a regional database of permanent plots in managed stands;
- Calibrate and test the performance of the current FVS-ACD equations across a range of management activities;
- Develop species- and management-specific equation modifiers to improve prediction performance; and
- Provide means to forecast stand growth with these modifiers for various management regimes with FVS-ACD and demonstrate their use.

Approach:

- Permanent plot data from Maine, New Brunswick, Nova Scotia, Prince Edward Island, and Quebec was obtained, cleaned, and compiled into a standardized relational database.
- Evaluate component equations (tree height, height to crown base, diameter and height increment, mortality) using equivalence tests.

- Develop species- and management-specific equation modifiers using nonlinear regression when sufficient data is available and equivalence test suggest dissimilarity between observed and predicted values.
- Incorporate the developed modifiers into FVS-ACD and Open Stand Model (OSM) that has been developed and maintained by Dr. Hennigar.

Key Findings / Accomplishments:

- A total of over 3 million trees from 20,068 plots across a range of locations and management regimes was obtained (**Table 3**).
- OSM has been fully documented, tested, and capability to conduct thinning/partial harvesting has been implemented.
- Modifiers for red spruce and balsam fir diameter growth response to commercial thinning was developed using the CFRU Commercial Thinning Research Network (CTRN), which was of the following form:

$$\Delta DBH_{adj} = \Delta DBH_{unadj} *[1+(b0*(\%BA_{RM}*((QMD_B/QMD_A)\text{^}b1))* \exp(b2*\log(TST+1)+b3*(TST\text{^}2)))],$$

where ΔDBH_{adj} is the adjusted annual diameter increment (cm yr^{-1}), ΔDBH_{unadj} is the unadjusted annual diameter increment (cm yr^{-1}), $\%BA_{RM}$ is the % of total basal area removed in the thinning, QMD_B is the quadratic mean diameter before thinning (cm), QMD_A is the quadratic mean diameter after thinning (cm), TST is the time since treatment (yrs), and b_i are species-specific parameters estimated from the data (**Table 4**).

- Results from the analysis indicated that red spruce generally showed a greater relative response to the commercial thinning treatments and that the diameter growth response generally peaked 5 year since the treatment, but the response varied by the intensity and type of the removal applied (**Figure 19**).
- These modifiers have been incorporated into FVS-ACD and long-term simulations for a financial assessment of commercial thinning are currently be conducted on the CTRN dataset by PhD student Patrick Hiesl.

Table 3 - Summary of plots, number of remeasurements, and tree-level measurements by geographic location and management regime.

Management	Plots	# of Plot re-measurements			Tree re-measurements (outliers excluded)*				
		Total	Mean	Max	Total	DBH	ΔDBH	HT	ΔHT
Maine									
All	10,985	30,481	14	30	551,019	495,867	281,977	382,373	165,322
None	9,369	25,993	2.8	12	478,222	427,302	241,369	326,262	136,780
Partial Cut	1,391	3,743	2.7	3	40,755	37,360	17,171	29,438	11,968
PCT	45	289	6.4	12	26,700	26,244	21,117	23,171	15,176
Planted	180	456	2.5	3	5,342	4,961	2,320	3,502	1,398
New Brunswick									

All	4,095	5,088	13	28	1,410,834	1,021,258	633,244	634,344	379,228
None	2,324	8,988	3.9	7	661,260	613,187	388,631	87,100	45,751
Partial Cut	205	414	2.0	4	61,127	54,684	19,929	14,222	5,085
PCT	508	1,611	3.2	9	383,685	204,056	130,757	246,529	150,859
Planted	1,058	4,075	3.9	8	304,762	149,331	93,927	286,493	177,533
Nova Scotia									
All	3,574	18,554	22	37	733,315	662,375	443,648	586,014	380,759
None	2,413	11,250	4.7	9	427,185	395,417	256,803	378,954	241,498
Partial Cut	807	5,690	7.1	9	215,730	186,094	125,599	182,750	121,914
PCT	53	302	5.7	8	17,238	14,939	11,895	4,540	3,383
Planted	301	1,312	4.4	11	73,162	65,925	49,351	19,770	13,964
Prince Edward Island									
All	731	4,843	21	30	287,533	287,527	212,824	21,773	16,864
None	153	1,007	6.6	11	71,470	71,467	52,923	4,643	3,607
Partial Cut	40	293	7.3	9	14,644	14,643	10,910	1,278	1,001
Planted	538	3,543	6.6	10	201,419	201,417	148,991	15,852	12,256
Quebec									
All	683	2,134	6	10	82,842	70,209	31,284	12,334	4,676
None	359	911	2.5	5	34,605	32,447	14,840	5,692	2,268
Partial Cut	324	1,223	3.8	5	48,237	37,762	16,444	6,642	2,408
Total	20,068	71,100	76	135	3,065,543	2,537,236	1,602,977	1,636,838	946,849

Table 4 - Parameter estimates and p values for the commercial thinning modifier by species.

Parameter	**Balsam fir**		**Red spruce**	
	Estimate	***p* value**	**Estimate**	***p* value**
b_0	0.0050	<0.0001	0.0021	<0.0001
b_1	0.5424	0.1331	0.5841	0.2235
b_2	0.6169	0.0345	1.3937	0.0007
b_3	-0.0151	<0.0001	-0.0236	<0.0001

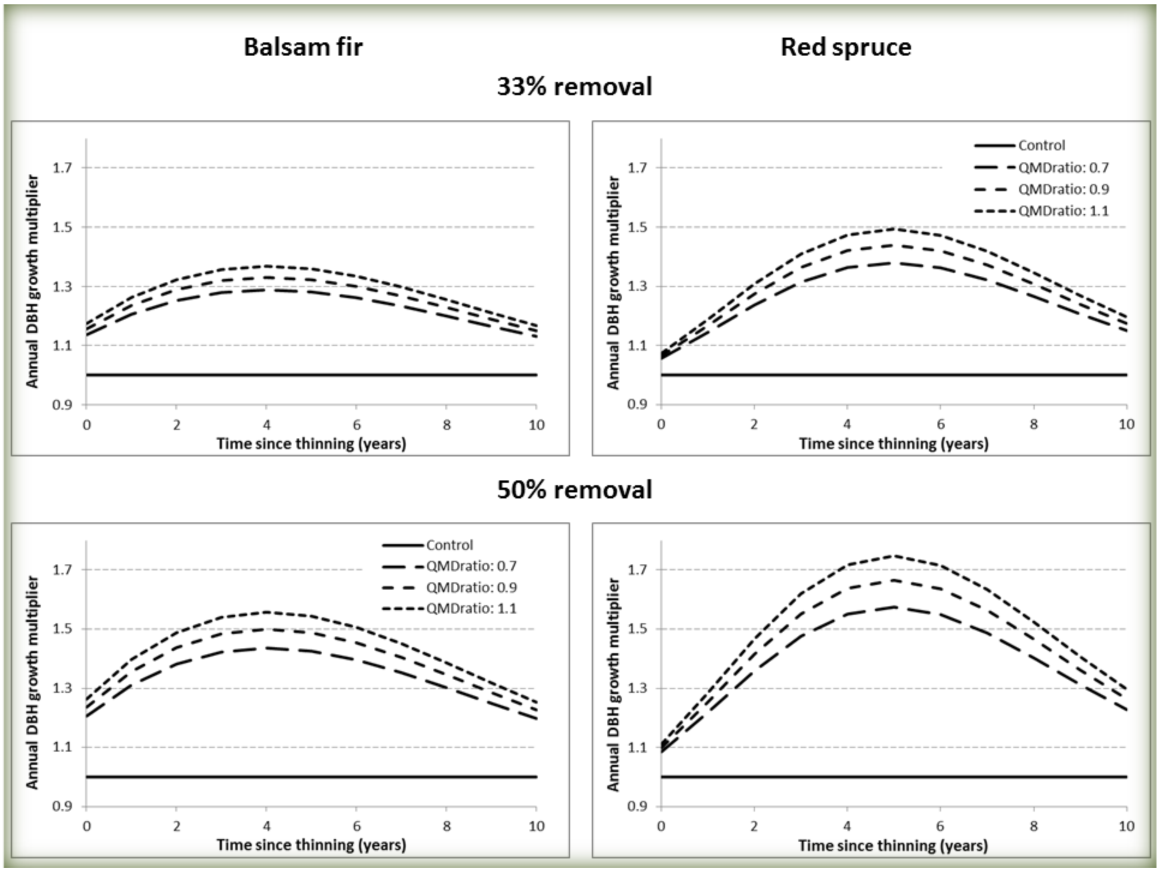


Figure 19 - Predicted diameter growth modifiers for alternative commercial thinning regimes by species. QMDratio is the ratio of quadratic mean diameter before thinning to the quadratic mean diameter after thinning.

Future Plans:

- Modifiers for additional forest management activities such as precommercial thinning, planting, and partial harvesting will be developed and tested.
- Modifiers will be incorporated into FVS-ACD and OSM, which will allow model users to evaluate the short- and long-term influence of alternative forest management regimes.

Products Delivered:

Refereed Journal Publications:

Russell, M.B., Weiskittel, A.R., and Kershaw Jr., J.A. 2014. Comparing strategies for modeling individual-tree height and height-to-crown base increment in mixed-species Acadian forests of northeastern North America. European Journal of Forest Research 133: 1121-1135.

Presentations / Workshops / Meetings / Field Tours:

Hennigar, C. 2014. Open Stand Model: Hardwood partial harvest simulation advancement. Northern Hardwoods Research Institute. Presentation on May 1, 2014. Université de Moncton. Edmundston, New Brunswick.

Software:

Hennigar, C. 2014. Open Stand Model. FORUS Research. Fredericton, New Brunswick. Available: http://www.forusresearch.com/downloadsOSM/ (User: OSM; Password: GetIt!).

Acknowledgements:

Thanks to Plum Creek, JD Irving, Quebec Ministry of Natural Resources, New Brunswick Tree Improvement Council, New Brunswick Department of Natural Resources (DNR), Nova Scotia DNR, and Prince Edward Island DNR for providing access to managed-stand data.

Balsam Fir Stand - Wells Forest

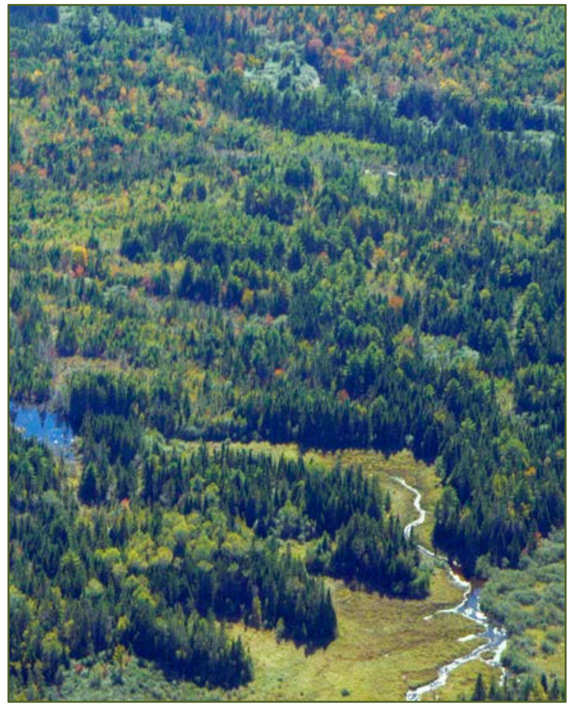
Linking LiDAR and ground-based forest inventory plots for improving estimation of key attributes

Aaron Weiskittel[1] and John Kershaw[2]

[1] University of Maine

[2] University of New Brunswick

Status: Final Report



Bog in Wells Forest

Summary:

LiDAR is emerging as a prominent technology for measuring key forest attributes like standing volume and dominant height. Limited research has been conducted on the effectiveness of LiDAR in structurally-complex, mixed-species forests that dominant in Maine. This project was initiated to evaluate the performance of LiDAR across a range of stand structures and species compositions that are typical for the region. In the process, a variety of important issues with using LiDAR for operational forest planning were evaluated including robustness of developed prediction models, sample size and selection method for model calibration, and the effect of prediction tile size on overall accuracy. We found that LiDAR is a promising tool that deserves further exploration, but there are some potential issues that need to be resolved.

Project Objectives:

- Develop and evaluate prediction algorithms for estimating key forest stand structural attributes such as basal area, stem density, top height, and volume across a range of stand structures;
- Test prediction algorithm performance on an independent dataset and explore factors that might influence accuracy such as LiDAR collection specifications, ground-based plots, and statistical approach used;
- Estimate the effect of sample size and sampling method on accuracy of LiDAR prediction algorithms; and
- Evaluate the influence of prediction tile size on estimates of stand-level volume.

Approach:

- Low- (1-3 points m-2) and high- (3-6 points m-2) density as well as network of ground-based sample plots at the Penobscot Experimental Forest (PEF) in central Maine and Noonan Research Forest (NRF) in New Brunswick, respectively, were collected and compiled.

- Prediction algorithms of key forest structural attributes (dominant height, basal area, volume, biomass) were developed using nonlinear mixed effects and random forests (a nonparametric regression technique) for both the PEF and NRF.
- Various sampling intensities and sampling schemes including random, systematic, and stratified as well as model- and design-based estimators were evaluated using bootstrapping of ground-based network at the NRF.
- Stand-level estimates of volume at the NRF using prediction tiles of 2, 4, 10, 20, and 30 m were compared with the ground-based estimates.

Key Findings / Accomplishments:

- Prediction algorithms showed high accuracy on predicting total aboveground biomass (R^2 of 0.53 – 0.70) and were relatively insensitive to the LiDAR point density (low vs. high), type of ground-based plots (variable- vs. fixed-radius), and LiDAR extraction radius used, but accuracy decreased when a non-local model was used (R^2 of 0.45 – 0.65) (**Figure 20**).
- The number of plots required for local calibration of a total aboveground biomass algorithm was generally low (1 plot per 101 acres – 801 acres) depending on the sampling scheme, estimator, and allowable error (**Figure 21**).
- Minimal differences were found between sampling methods (simple random, systematic, stratified), but stratified optimal allocation tended to perform best.
- Across all sampling methods examined, a design-based estimator (i.e., mean ratio of LiDAR average height to field-observed total aboveground biomass) was nearly as effective as a model-based estimator (i.e., random forest nonparametric regression algorithm).
- Stand-level predictions of total volume did not significantly differ between alternative tile sizes (2, 4, 10, 20, and 30 m) and all showed good agreement with estimates derived from the ground-based plots alternative cell sizes (4, 16, 64, and 100 m2) at the Noonan Research Forest in New Brunswick. The dotted line is a 1:1 line, while the solid line is lowest regression fit to the data (**Figure 22**).

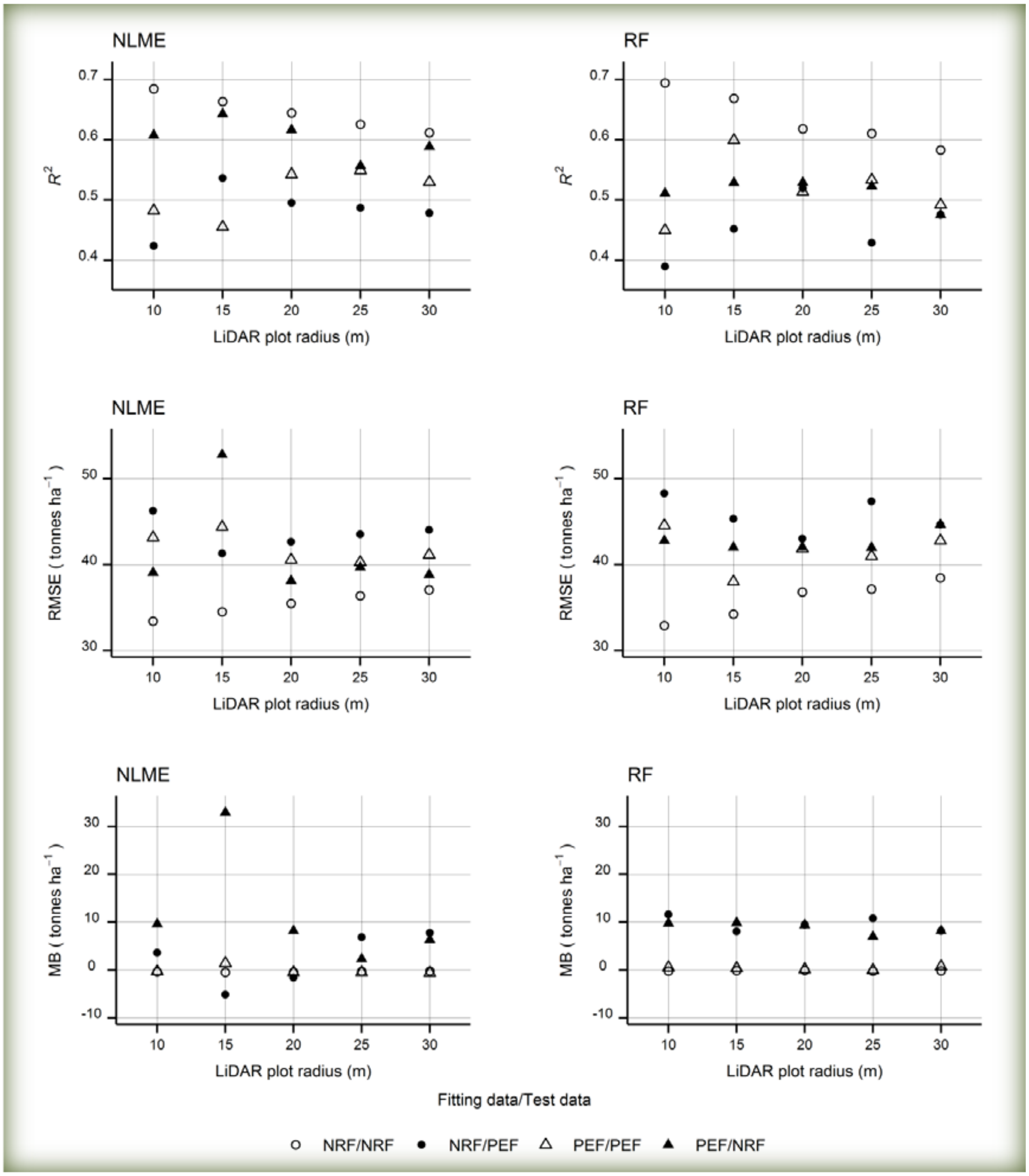


Figure 20 - Effect of LiDAR plot radii on nonlinear mixed effects (NLME) and random forest (RF) models with respect to generalized coefficient of determination (R2), root mean square error (RMSE) and mean bias (MB) for aboveground biomass (tonnes ha^{-1}) based on different fitting and test datasets. NRF and PEF are the Noonan Research Forest and the Penobscot Experimental Forest, respectively.

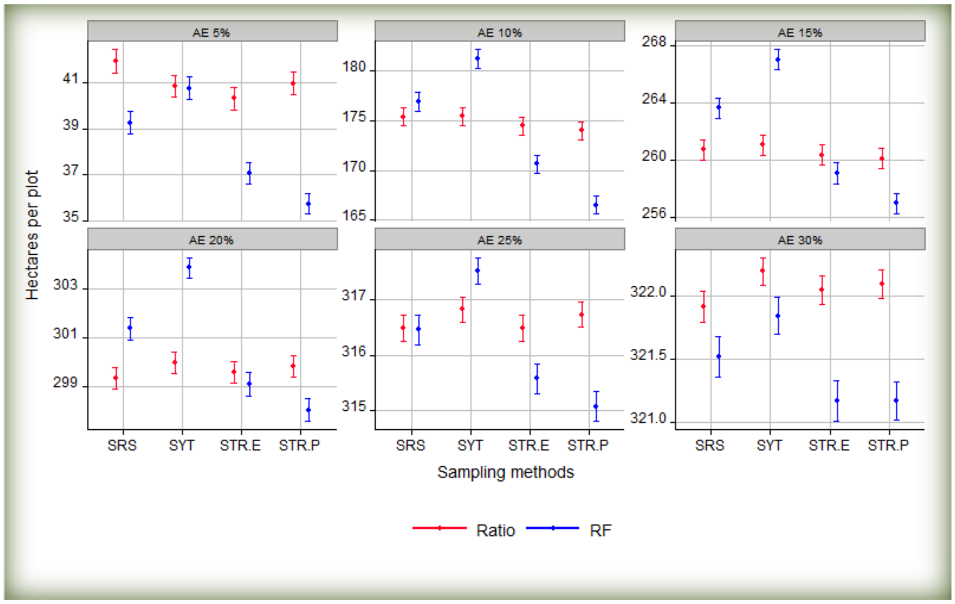


Figure 21 - Estimates of required sample size for ground-based plots to locally calibrate a total aboveground biomass model from LiDAR metrics using different estimators (random forest nonparametric regression [RF] and a ratio estimator), sampling method (simple random sampling [SRS], systematic [SYT], stratified with equal allocation [STR.E] and stratified with proposal allocation [STR.P]), and alternative levels of allowable error (AE).

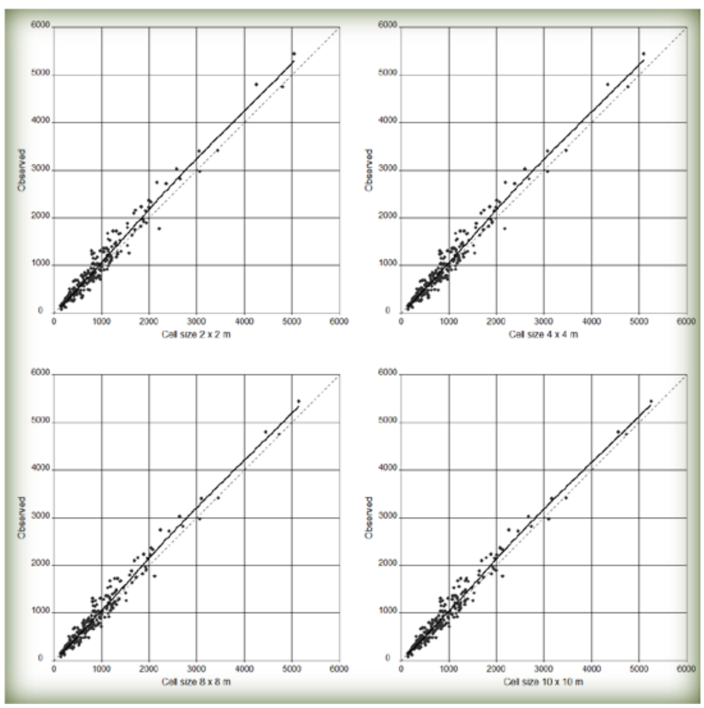


Figure 22 - Relationship between observed and predicted total stand volume estimates (m3) for alternative cell sizes (4, 16, 64, and 100 m2) at the Noonan Research Forest in New Brunswick. The dotted line is a 1:1 line, while the solid line is lowest regression fit to the data.

Future Plans:

- Continue to explore the potential of LiDAR to predict key forest metrics across the region.
- Compare the achieved accuracy to other similar remote sensing methods.
- Provide operational rasters of derived forest metrics for large areas.

Products Delivered:

Refereed Journal Publications:

Hayashi, R., Weiskittel, A. and Sader, S. 2014. Assessing the feasibility of low-density LiDAR for stand inventory predictions in complex and managed forests of northern Maine. Forests 5: 363-383.

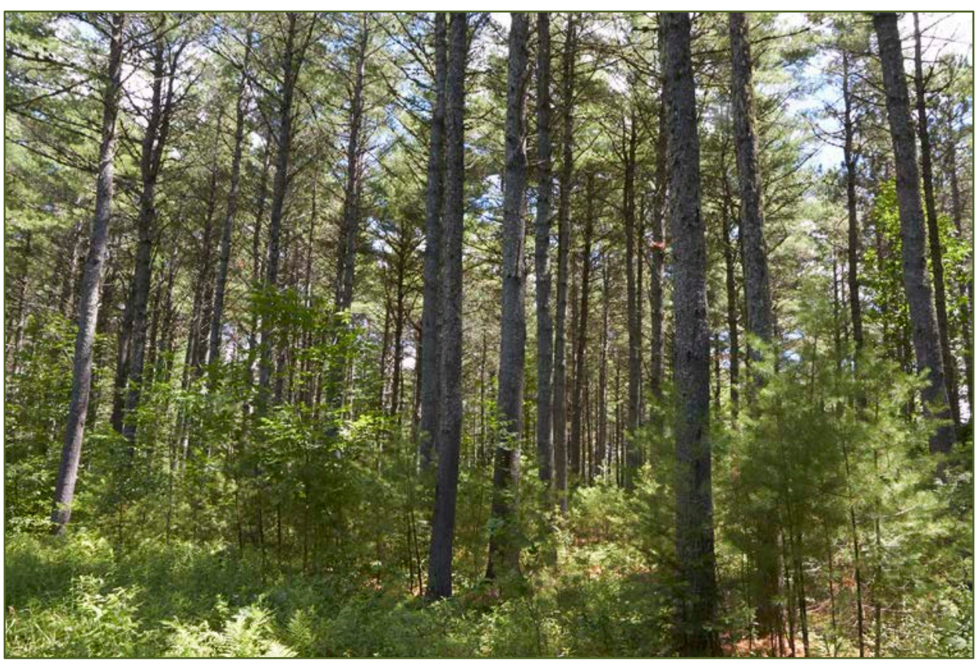
Hayashi, R. Weiskittel, A. and Kershaw, J.A. in review. Evaluation of alternative methods for using LiDAR to predict aboveground biomass in mixed species and structurally complex forests in northeastern North America. Submitted to Canadian Journal of Remote Sensing.

Theses:

Hayashi, R. Evaluations of airborne LiDAR as an assisting tool for achievement of sustainable forest management in Maine's forests. M.S. thesis, University of Maine, Orono. 64 p.

Acknowledgements:

Thanks to the University of Maine School of Forest Resources for funding a portion of Rei Hayashi's MS, the US Forest Service Penobscot Experimental Forest for providing ground data, and the Penobscot Research and Operations Team for assistance in acquiring LiDAR data in 2013. Leading Edge Geomatics, Fredericton, New Brunswick provided LiDAR data for Noonan Research Forest.



White Pine Stand – Demeritt Forest

Depth-to-water table mapping for Maine using latest DEM coverage

Mark Castonguay, Jae Ogilvie, and Paul Arp

University of New Brunswick

Status: Final Report

Sunkhaze Stream - Wells Forest

Summary:

The objective of this project was to provide CFRU members with updated wet area maps (WAM) for their lands. The previous maps built by CFRU were developed in 2005-06, but improved digital elevation maps (DEM) for the state since then provided an opportunity to greatly improve the accuracy of these maps. The analysis was conducted using the latest available geospatial data sources (National Elevation Dataset – NED via USGS) at multiple resolutions (1/3 and 1/9 arc-second – 10 m and 3 m where available). Contiguous / continuous, updated spatial maps of base elevation DEM, predicted sub-surface wetness (WAM), and enhanced hydrological flow network (unmapped streams) were created through various algorithm / GIS data processing methods. Approximately 27 million acres (including all of Maine and watersheds beyond the state borders that influenced water flow) were remapped / updated at 10m resolution (with and without the inclusion of wetlands), and 3.5 million acres at a finer 3 m resolution (without wetlands).

Project Objectives:

- Using most current / up-to-date GIS data sources (governmental) for base elevation and hydrological network data, process and produce updated / revised cartographic digital WAP dataset for the state of Maine (**Figure 23**);
- Create a deliverable, workable product for all of the CFRU members, including all relevant datasets; and
- Improve and promote the applicability of the WAM and associated datasets for many forestry and land management issues, focusing on its use for potential solutions.

Approach:

- GIS data sources from Maine, New Hampshire, Quebec, and New Brunswick were gathered from GIS data warehouses and governmental / NGO agencies.
- A seamless, mosaicked dataset was created from these data correcting for geospatial context and resolution.
- Initial processing produced WAM base-map data which was then utilized for analysis, incorporating mapped wetland data.
- Mapped wetland data was incorporated into the WAM data production process by selecting representative areas within wetland features to represent surface water reference points.

- Contributing wetland areas were then used as additional surface water features in production of the finalized secondary WAM datasets.
- All data produced from the 10 m and 3 m (**Figure 24**) processing was compiled into a working GIS project (ArcMap 10), along with all relevant contributing datasets (raster and vector), and prepared for delivery to CFRU members.

Key Findings / Accomplishments:

- Production of seamless datasets for the contiguous state of Maine (based on watershed extent), for base elevation and WAM at 10 m resolution, complete hydrographic network data for surface water features, flow networks, and mapped wetlands as vector data (**Figure 25** and **Figure 26**).
- 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.
- Moved away from the "cookie-cutter" approach to data analysis and delivery to CFRU members, adopting a more desired "statewide" approach.
- All members are being presented with the same working dataset, with no variation in data quality, quantity, or mapping extent.
- Datasets now allow the potential application of road layout / mapping tools (TRAIL).

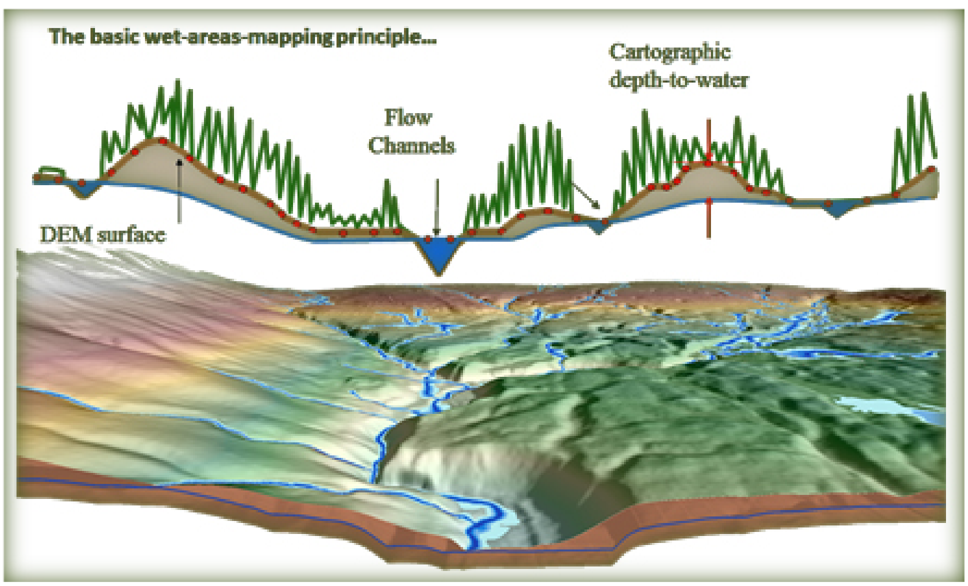


Figure 23 - Diagrammatic representation of the "depth-to-water" concept / principle, using conventional coarse (satellite captured / orthophoto interpreted) and fine resolution (LiDAR) digital elevation data. Mapped surface water features are used in reference to the topographical variations. The wet-areas-mapping concept promotes the "continuity" and "connectivity" of the hydrological network, instead of having "stand-alone" surface water features, and presents the predicted subsurface wetness conditions, seasonally at varying drainage-area thresholds (i.e, 4, 1, and 0.25 hectares).

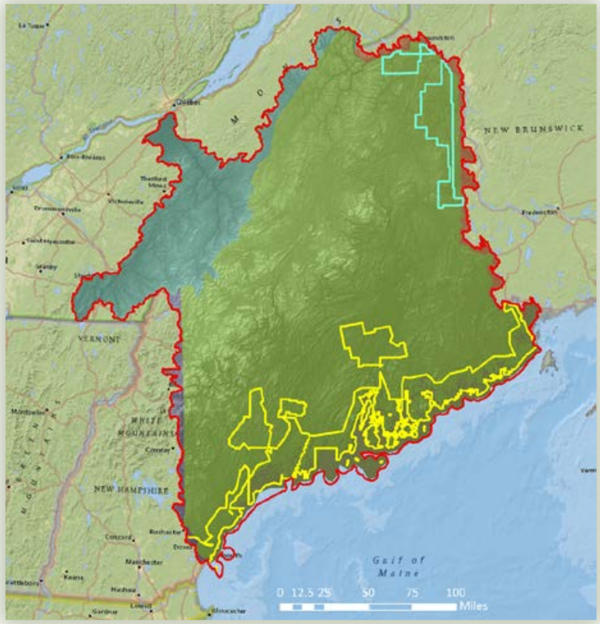


Figure 24 - Delineated mapping extent (red bold outline) for revised wet-areas mapping (10 m resolution) of Maine, based on the major contributing watershed boundaries / extent (Gulf of Maine watersheds). Contributing areas include portions of New Hampshire, Quebec, and New Brunswick. Highlighted portions of the state (light blue and yellow) indicate WAM-remapped higher resolution areas (LiDAR data at 3 m resolution).

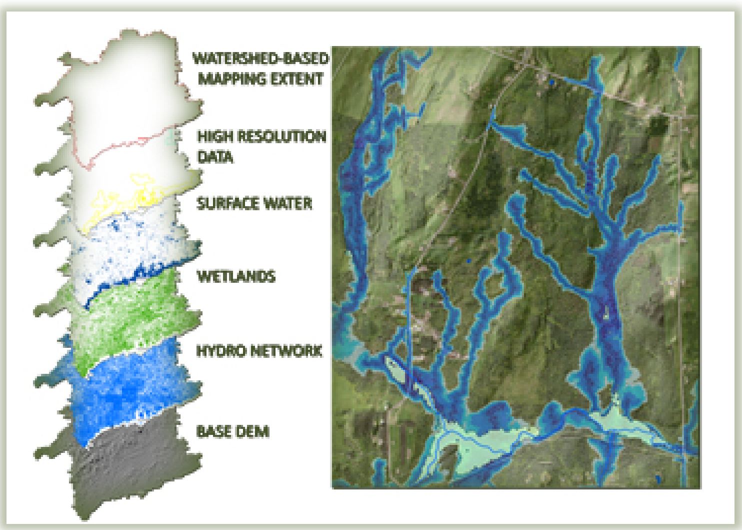


Figure 25 - Visual depiction (left-side) of the various GIS data layers required for analysis and processing of the full state, using the WAM algorithms. Resultant outcome of the analysis / mapping process (right-side with aerial photo imagery), where the dark-blue to light-blue transitioning areas indicated predicted subsurface wetness extent from 0 to 1m below surface. Predicted flow channels (intermittent / ephemeral), and extended flow network up to a four hectare drainage threshold are also presented. Lighter-blue highlighted areas in the image are extracted mapped wetland features that were used in analysis.

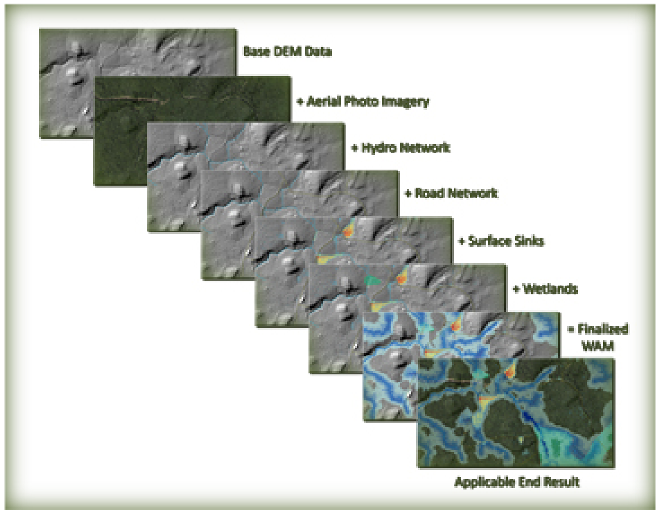


Figure 26 - Layering sequence of cartographic wet-areas-mapping data / information used for processing and production of finalized data layers for export / delivery and use. Images used above have been taken from the 2014 updated mapping effort at the University of Maine, Penobscot Experimental Forest. Important to note that both high-resolution LiDAR derived DEM data (1 m resolution) and very clear, high-resolution RGB imagery were available for analysis.

Future Plans:

- Continuing forward, as statewide LiDAR data is being flown and captured, hydrographic data is updated / revamped, and private land ownership datasets are improved, there is an opportunity to substantially improve WAM accuracy.
- The next "statewide" WAM mapping effort will probably occur when a seamless, mosaicked, high-resolution DEM is available. Statewide mapping at one meter resolution is infeasible without a continuous high-resolution, generally artifact free, and gap / hole-free DEM surface.
- Privately acquired datasets can be processed on a case-by-case basis for each CFRU member if desired.

Products Delivered:

- Each CFRU contributing member was provided a digital copy of the "Updated Maine WAM 2014" dataset, with everything contained on an external hard drive.
- Delivered data included all relevant raster and vector data (as stated earlier), statewide, and also includes produced data for the Penobscot Experimental Forest (PEF), Weymouth Point (WP), and Austin Pond (AP) study sites.
- A working, portable ESRI ArcMap project (CFRU_WAM_2014_Revised.mxd) was included for ease of use and correct visualization of the finalized datasets, saved in various software version formats (**Figure 27**).

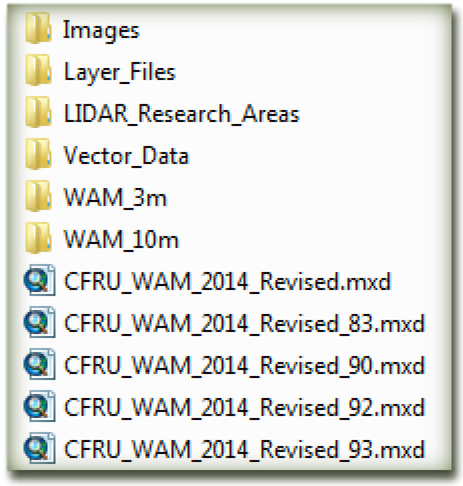


Figure 27 - Delivered GIS data products in relation to the updated wet-areas-mapping project for Maine, as organized in sub-folders dependent upon format and resolution, with various *.mxd project files (last two numbers indicate ESRI ArcMap software version, i.e. "93" indicates software version "9.3"). "LiDAR Research Areas" relates to the PEF, WP, and AP research study sites that were mapped in greater detail at higher resolution.

Presentations / Workshops / Meetings / Field Tours:

Castonguay, M. A. 2013. CFRU Advisory Committee Meeting - Project Proposal – "Cartographic Depth-to-Water Mapping for Maine, state-wide using latest DEM data coverage, for CFRU priority areas", January 23rd, 2013, Wells Conference Center, University of Maine, Orono, ME.

Castonguay, M. A. 2014. CFRU Advisory Committee Meeting – Final Project Report – "Revised Cartographic Depth-to-Water Mapping for Maine, State-Wide Using Latest Data Sources", October 29th, 2014, Wells Conference Center, Room 2, University of Maine, Orono, ME.

Acknowledgements:

We thank all of the contributing CFRU members for their foresight and willingness to improve the available statewide GIS datasets for the state of Maine. Many thanks to Brian Roth and Bob Wagner for their continued belief and support in the potential benefits of this mapping work, for all of the CFRU members, and for making projects like this advance.

We also thank Stéphanie Murray at Ducks Unlimited Canada as well as all of the following groups for their data contribution:

- Maine Office of GIS (MEGIS)
- U.S. Geological Survey (USGS)
- U.S. Fish and Wildlife Service
- New Hampshire Geographically Referenced Analysis and Information Transfer System (NH GRANIT)
- Government of New Brunswick

Incorporating young hardwood stand responses to various levels of silviculture and stand composition into new CFRU growth & yield models

Andrew Nelson, Robert Wagner, and Aaron Weiskittel

White Birch - Demeritt Forest

Status: Final Report

Abstract:

This report completes the third and final year of this project. We used an established experiment on the Penobscot Experimental Forest to: (1) examine the response of early successional stands to combinations of two management intensities (with and without enrichment planting and different levels of vegetation control) and three compositional objectives (hardwood, mixedwood and conifer); (2) compare the biomass production of planted white spruce and hybrid poplar plantations (four clones) in monoculture and in mixture of the two on a typical reforestation site in Maine; and (3) develop branch, crown and vertical leaf area distribution models for various hardwood species. A PhD dissertation was completed and three journal papers were published.

Project Objectives:

Using an established experiment on the Penobscot Experimental Forest (PEF), we quantified how young hardwood stands responded to various levels of silviculture. The specific objectives were to:

- Examine the response of early successional stands to combinations of two management intensities (with and without enrichment planting and different levels of vegetation control) and three compositional objectives (hardwood, mixedwood and conifer);
- Compare biomass production of planted white spruce and hybrid poplar plantations (four clones) in monoculture and in mixture of the two on a typical reforestation site in Maine; and
- Develop branch, crown, and vertical leaf area distribution models for important hardwood species.
- Incorporate derived relationships into the growth & yield simulator developed by Weiskittel et al. to simulate future stand development under various levels of silviculture and mixedwood composition.

Approach:

- The experiment included a wide range of silvicultural treatments that represent the breadth of management options currently available in the region, including conifer release treatments, hardwood PCT, and a combination of the two to promote continued mixedwood stand development.
- We documented initial differences in stand productivity among the three compositional objectives and determined whether increased management intensity, including vegetation control and enrichment planting, increased the productivity of stands for all three compositional objectives.
- We tested the hypotheses that: (1) hardwood plantations would out yield conifer plantations, with mixed-species plantations intermediate in aboveground biomass yields; (2) aboveground biomass yield among four hybrid poplar clones would not differ in either pure or mixed-species plantings, but the yields of individual clones would be greater in pure plantings because of higher densities; and (3) aboveground biomass yield of improved white spruce would not differ among pure or mixed-species plantings.
- To better understand the combined influence of inherent species differences and potential responses to management intensity on forest productivity, the leaf area of young hardwood trees were quantified at multiple scales, including: (1) branch-level, (2) total crown-level, and (3) vertical distribution within crown.

Key Findings / Accomplishments:

- Seven years after treatment, yields of the two hardwood thinning treatments ranged from 43.4 to 56.6 Mg/ha, which were similar to the 52.9 Mg/ha yield of the untreated control but with 17 and 46% lower densities, respectively (**Figure 28**).
- In the conifer release treatments, removal of hardwoods promoted conifer dominance and resulted in yields between 19.9 and 30.4 Mg/ha 7 years after treatment. The conifer release treatments will likely be dominated by conifers in the future with varying hardwood densities due to hardwoods establishing in gaps without conifers.
- After 7 years, yields of mixedwood treatments were between 19% and 47% greater than the conifer release treatments due to the retention of thinned hardwood stems and represent stands that dominate much of the forestland in the region.
- Three years following planting, hybrid poplar height and ground line diameter growth rates began to diverge among clones, and by 6 years, the *Populus nigra* x *Populus maximowiczii* (NM6) clone clearly outperformed three *Populus deltoides* x *Populus nigra* clones (D51, DN10 and DN70) both in pure stands and in mixtures with white spruce (**Figure 29**). In mixture, we found the yield of white spruce to decline as the yield of hybrid poplar increased (**Figure 30**).
- A nonlinear model including branch diameter, branch tip height, and height to the start of the foliage was found to provide the best fit for predicting branch leaf area. Branch leaf area ranged from 0.05 to 0.37 m^2 for *Populus grandidentata* and *Betula populifolia* for an averaged sized branch, respectively.

- The best model for crown leaf area was a nonlinear form accounting for stem diameter and crown length. Crown leaf area ranged from 3.26 to 9.85 m^2 for *Populus tremuloides* and *Betula populifolia* for an averaged sized tree, respectively.
- Vertical leaf area distribution was best fit using a right-truncated Weibull distribution and showed a peak in the middle third of the crown for most of species.
- In addition, leaf area production varied among four hybrid poplar clones in plantations, suggesting a strong genetic control over crown form. Overall, leaf area varied among species at all levels, suggesting that coexistence of hardwood saplings was strongly influenced both by inherent species-specific leaf area production and vertical distribution.
- Results from this study demonstrated that early successional stands can be effectively managed during early stand development to improve growth and the longer-term composition.
- Hardwood models and relationships derived from this work were incorporated into the FVS Acadian variant by Weiskittel et al.

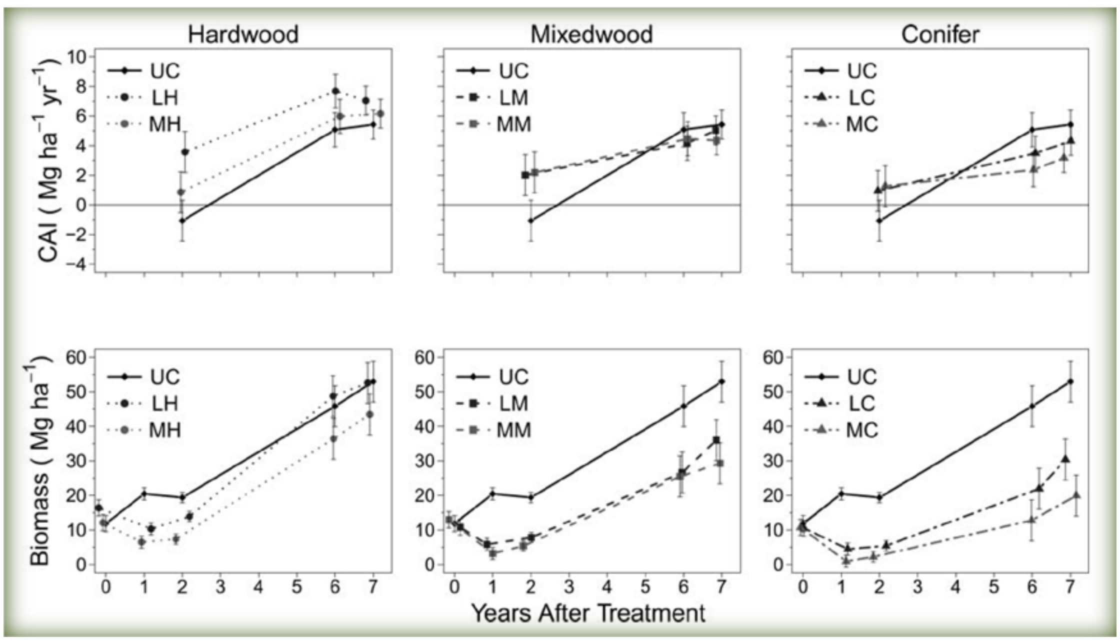


Figure 28 - Current annual increment (Mg/ha/year) and cumulative biomass (Mg/ha) for hardwood, mixedwood and conifer species composition treatments and two different management intensities for each species composition. Current annual increment (CAI) was calculated as the actual change of total aboveground dry mass between two consecutive years. CAI and biomass of the untreated control (UC) are shown as reference for each of the three species composition. The other treatments are: low hardwood (LH), low mixedwood (LM), low conifer (LC), medium hardwood (MH), medium mixedwood (MM) and medium conifer (MC). (From Nelson et al. 2013b)

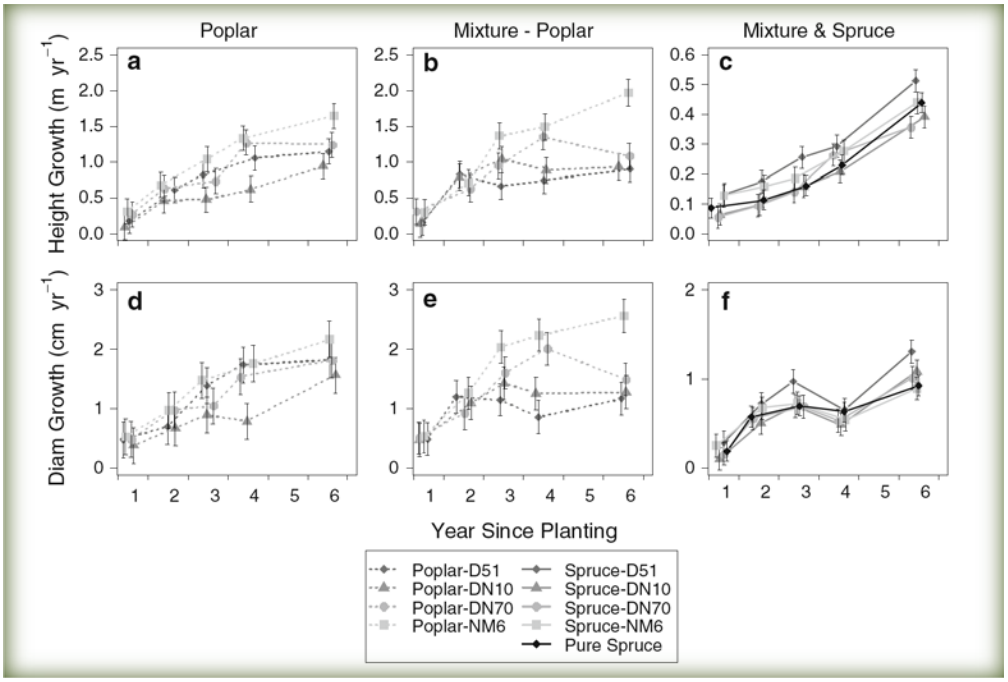


Figure 29 - Species-specific least square mean growth rates of height (m/year) and ground line diameter (cm year-1) by year following planting of the four hybrid poplar clones in the Pure Poplar (a, d) and Mixture (b, e) stands and for white spruce in Mixture and Pure Spruce stands (c, f). Error bars represent ±1 standard error. (From Nelson et al. 2103a).

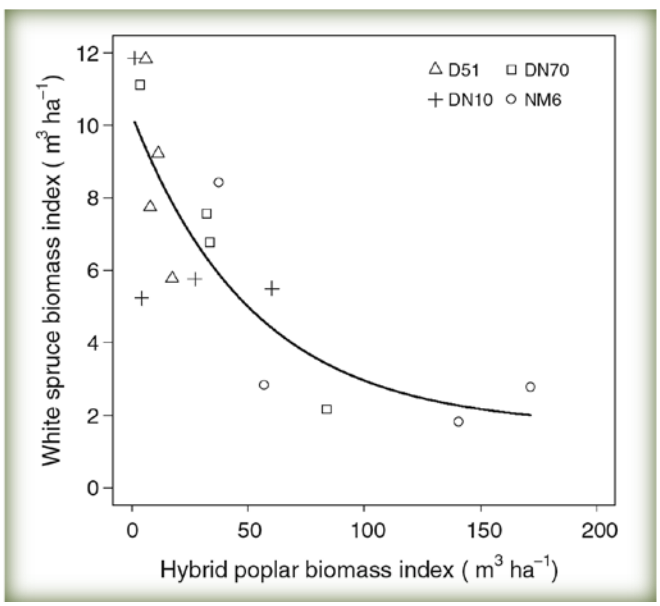


Figure 30 - Nonlinear relationship between white spruce biomass index and hybrid poplar biomass index in the Mixture treatment. The different symbols represent the four hybrid poplar clones. The regression was developed from the pooled data of the four replicates. The R2 of the model fit was 0.68 (From Nelson et al. 2013a).

Products Delivered:

Refereed Journal Publications:

Nelson, A.S., M.R. Saunders, R.G. Wagner, and A.R. Weiskittel. 2013a. Early stand production of hybrid poplar and white spruce in mixed and monospecific plantations in eastern Maine. New Forests 43(4): 519-534.

Nelson, A.S., R.G. Wagner, M.R. Saunders, and A.R. Weiskittel. 2013b. Influence of management intensity on the productivity of young early successional Acadian stands in eastern Maine. Forestry 86 (1): 79-89.

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.

Theses:

Nelson, A.S. 2013. Production ecology and stand dynamics of young Acadian forest stands in response to silvicultural intensity and compositional objectives. PhD thesis, University of Maine, Orono.

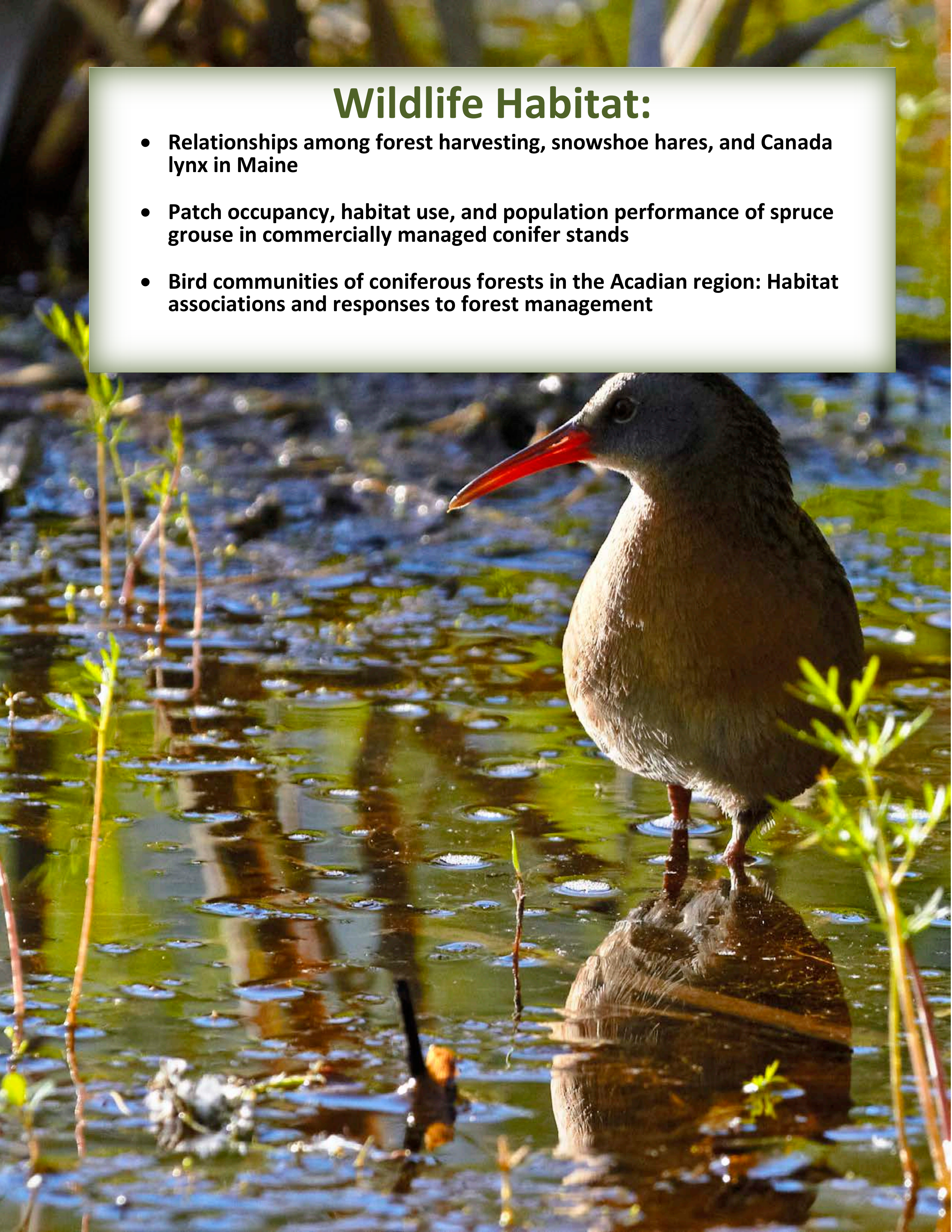
Acknowledgements:

We thank the USFS Northeastern States Research Cooperative for their financial support on this project.

Stump Sprout - Post Pre-commercial Thinning Project – Wells Forest

Wildlife Habitat:

- **Relationships among forest harvesting, snowshoe hares, and Canada lynx in Maine**
- **Patch occupancy, habitat use, and population performance of spruce grouse in commercially managed conifer stands**
- **Bird communities of coniferous forests in the Acadian region: Habitat associations and responses to forest management**



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

Sheryn Olson and Daniel Harrison

University of Maine

Status: Final Report

Snowshoe Hare - Photo Pamela Wells

Summary:

We investigated whether snowshoe hare pellet densities were different between two seasons across three forest stand-types: regenerating (RG) coniferous-dominated (19-39 years post-harvest), selection harvested (SEL) mixed coniferous-deciduous (8-18 years), and mature (42-80 years). We then evaluated which vegetation characteristics most strongly influenced hare densities between seasons across 26 forest stands. Hare densities, indexed by pellet densities, were measured semi-annually in 41 stands from 2005–2012. Densities were significantly higher during leaf-off (winter) than leaf-on (summer) periods in RG stands, but not in mature or SEL stands. Pellet densities were greater in RG than other stand-types during both seasons, and unexpectedly, significantly higher during the leaf-on season. These results suggest greater winter survival or movement to RG from summer to winter, and relatively higher summer survival and juvenile recruitment in RG. Seasonal differences in pellet densities across 26 stands were most strongly influenced by conifer sapling density [68% relative importance weight (RIW)] and total sapling density (11% RIW). During the leaf-off season when snow may interact with vegetation, the strongest influence on pellet densities was percent understory coverage of all conifer foliage (RIW 88.9%).

During 2014 we also completed our investigations of lynx food habits which were targeted at evaluating whether lynx are less specialized on hares at the southeastern limit of their range. We documented food habits using scats genetically confirmed as lynx during a summer-lower (2007-2012, 0.92 hares/ha, n=199 scats) and a winter-higher (2001-2006, 1.98 hares/ha, n=125) hare density period. Lynx had higher dietary breadth during the summer-low compared to the winter-high hare density period ($F_{4,322}$=0.0068). Frequency of occurrence of hares in lynx diets declined during the summer-low (75.2%, n=230 food item categories) period compared to during the winter-high (92.1%, n=127) hare density period. Despite evidence that lynx broaden their dietary niche during summer, high occurrence of hares in lynx diets during both seasons and across periods of changing hare density indicate that lynx are obligatory specialists on snowshoe hares near the southeastern limit of their geographic range. These results suggest that management for high-density snowshoe hare habitat should be a continued focus of lynx conservation in this region.

Project Objectives:

- Assess the extent that hare densities changed between seasons across regenerating conifer (16-39 years post-harvest), selection harvest, and mature conifer/mixed forest stands;

- Evaluate which structural and vegetative characteristics within forest stands most strongly influence seasonal changes in hare densities; and
- Assess evidence to support or refute the hypothesis that Canada lynx at the southeastern extent of their range have a broader dietary niche than lynx inhabiting the boreal forests of Canada and Alaska.

Approach:

- Conducted semi-annual (May and September) pellet surveys within 41 different regenerating-conifer, selection harvest, and mature conifer/mixed stands during 2005-2012.
- Measured a range of structural and vegetation characteristics in 26 forest stands during the summers of 2010-2013.
- Documented seasonal foods habits of lynx using scats collected during 2001-2012, and partitioned scats into: (A) those collected during the winter and during a period of relatively higher hare density; and (B) those collected during the summer and during a period of lower hare density.
- Quantified summer scats with aid of a specially trained dog and trainer from University of Washington.
- Genetically identified scats to species. Only those confirmed as being deposited by lynx were used in analyses.

Key Findings / Accomplishments:

- We sampled 41 stands across 16 seasons and counted hare pellets in 13,509 plots across 459 stand-seasons (**Figure 31**). Number of plots surveyed per stand averaged 29.7 (SE $\pm$ 0.3, range 22-43, mode = 28) and number of stands sampled each season ranged from 26-38.
- Seasonal change in the density of hare pellets was significantly greater in regenerating conifer stands compared to selection harvest and mature stands. Contrary to expectations for the leaf-on season, pellet densities in regenerating stands were 3.1 x greater than densities in selection harvest, and 9.3 greater than densities in mature stands (**Figure 32**). This suggests that regenerating conifer stands 16-39 years post-clearcut do not just serve as winter refugia, but are superior habitat for snowshoe hares throughout the year.
- Conifer sapling density was the most important vegetative and structural variable influencing the extent of hare density change across seasons (**Table 5**). Stands with high conifer densities maintained the highest hare densities across seasons and had the greatest increase in numbers of hare pellets from summer to winter.
- We confirmed that a subsample of 199 scats that we collected during the summer period and 125 collected during the winter period were deposited by lynx. Food items were identified in all of those scats.
- The frequency of occurrence of hares during the summer-low density period represented 75% of the 230 prey items identified (**Figure 33**). During the winter-high hare density period, frequency of occurrence of hares increased to 92.1% of 127 prey items identified.

- There was an increase in dietary breadth from the winter-higher hare density period (3.0%, of scats with multiple prey items; n=125 scats) to the summer-lower hare density period (16.9% of scats with multiple prey items; n=199 scats).

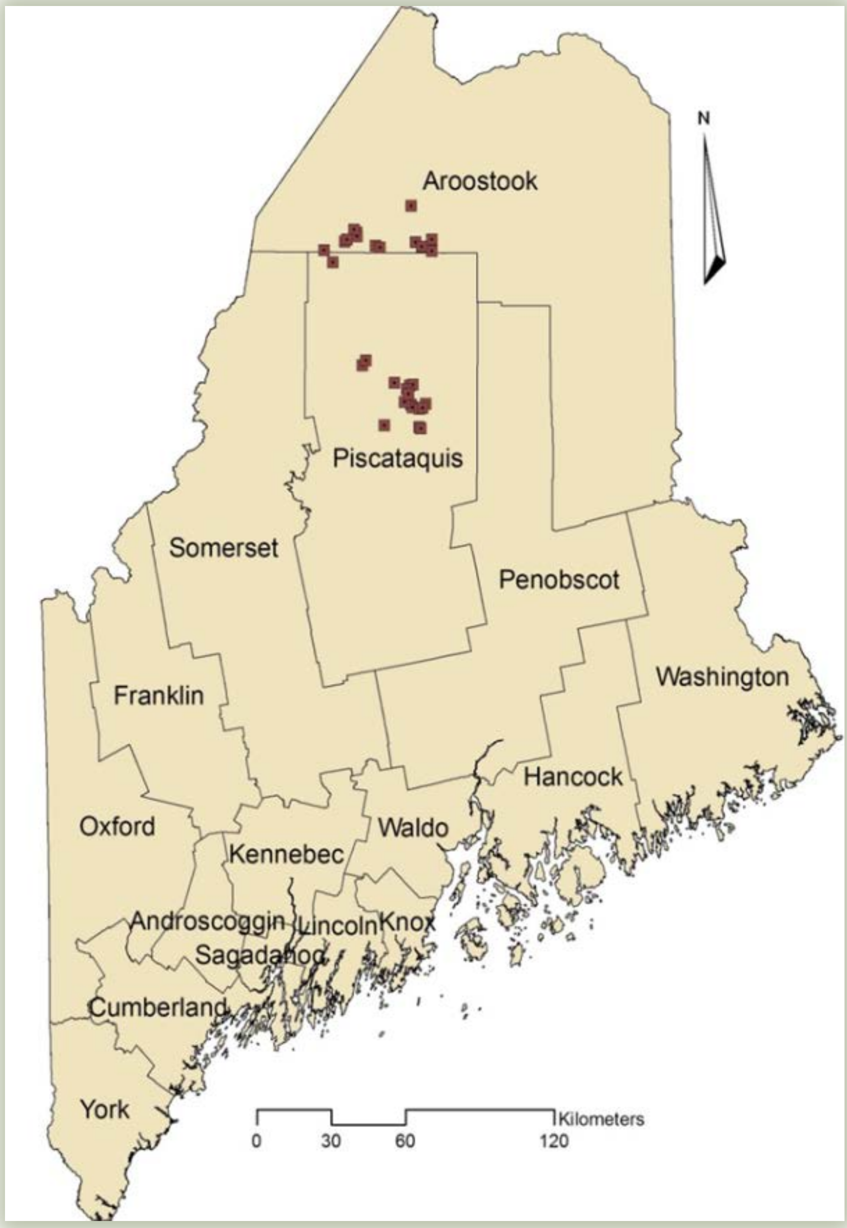


Figure 31 - Location and extent of the 2,516 km2 study area and stand locations in Piscataquis and Aroostook Counties, Maine, USA. Depicted are locations of 29 stands surveyed for hare pellets and vegetation in 2012.

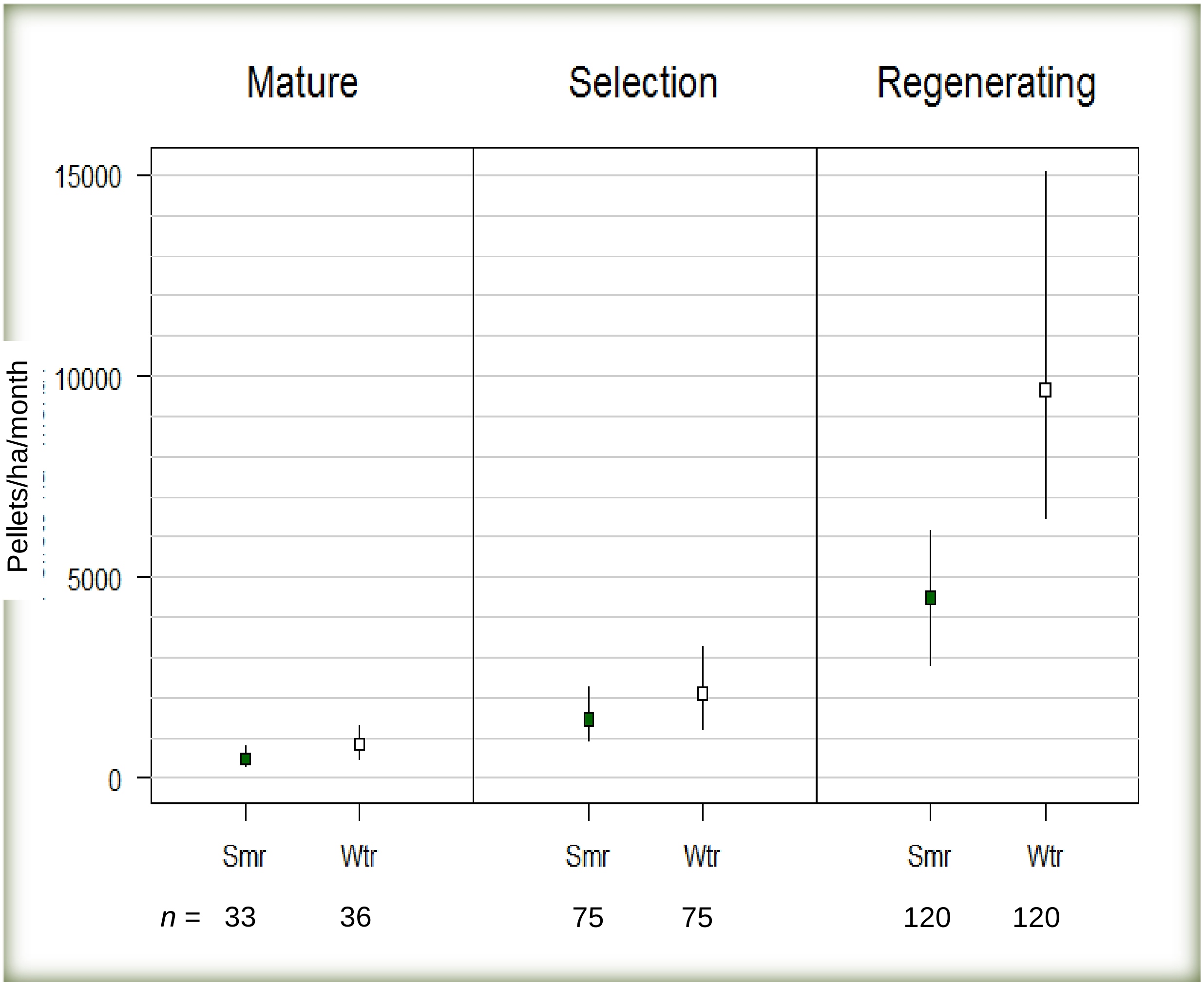


Figure 32 - Estimates generated with a generalized linear mixed model of the difference in seasonal pellet densities (Pellets/ha/month) across mature mixed, selection harvest mixed, and regenerating conifer stand types in northern Maine (2005-2012). The regenerating conifer stand-type had greater seasonal pellet differences and greater inter-stand variation. Each season's sample size n is a repeated measure of 41 stands among all stands and years (n = 459 stand-years). Year is included in models as a random variable. Smr is leaf-on (summer) and Wtr is leaf-off (winter). Closed squares represent summer, open squares winter and lines define 95% credible intervals.

Table 5 - Effects of vegetation covariates from the top five candidate models that describe seasonal changes in snowshoe hare pellet densities during leaf-on 2010 to leaf-off 2013, in Maine, USA. Generalized linear mixed models, number of parameters (K), model differences (ΔAICc), and Akaike Information Criteria for small sample size weights (wi). Interactive and additive effects of winter relative to summer with the covariate's influence on pellet density differences in 26 stands. The significance of the covariates is derived from approximated Wald |z| values.

Models [a]	K	ΔAIC_c	w_i	Summer to winter change	
				Interactive	Additive [b]
conifer saplings	8	0	0.684	+ ***	0
total saplings	8	3.6	0.113	+ ***	0
% understory coverage	8	4.3	0.081	+ *	+ *
% understory conifer	8	4.7	0.065	+ **	0
deciduous trees	8	5.4	0.046	– **	0

[a] *generalized linear mixed models included season as an interacting covariate and year as a random covariate.*

[b] *Significance: Probability (Wald |z|) ≤ 0 '***', 0.001 '**', 0.01 '*', 0.05 '.', 0.1 ' '.*

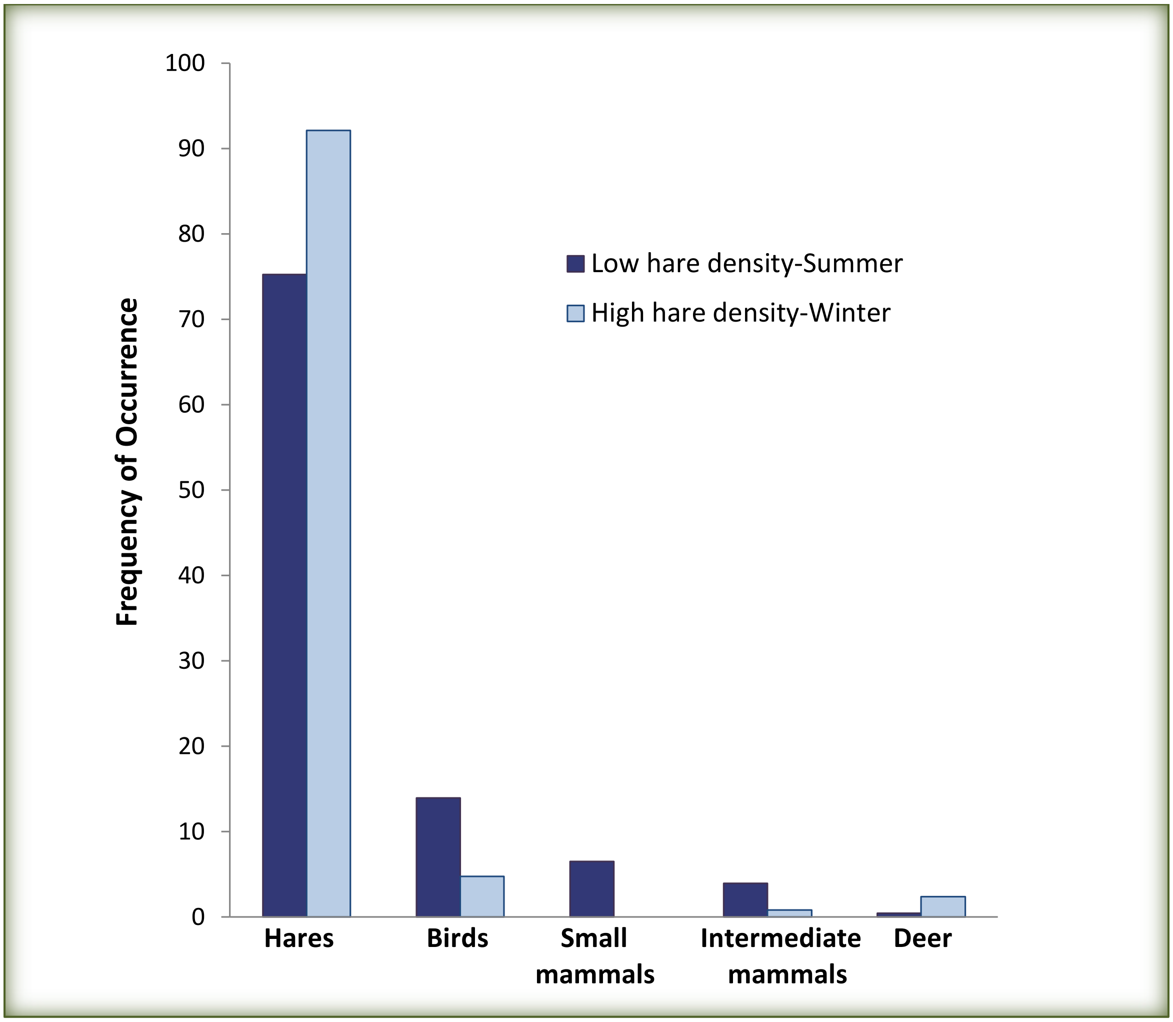


Figure 33 - Frequency of occurrence of food items in lynx scats collected in northern Maine, 2001-2012, during summer-lower hare density (n = 230 food item categories) and winter-higher hare density (n = 127 food item categories) periods. Categories include: snowshoe hares (Lepus americanus); birds; small mammals ≤42 g (voles, mice, shrews, and a bat); and intermediate mammals ≥70 g (red squirrels, flying squirrels, muskrats, and a chipmunk). Frequency of occurrence = (100 X number of occurrences of a given food item)/total number of food items in each season-period. Scats from the lower hare density period (2007-2012) were collected during summer, and scats from the higher hare density period (2001-2006) were collected during winter.

Future Plans:

- We will conduct the final pellet surveys within our benchmark stands during fall 2014 and spring 2015.
- We will conduct a meta-analysis to evaluate evidence for cyclicity in Maine's population of snowshoe hares by analyzing pellet surveys conducted across stands surveyed during 2001-2015.

Products Delivered:

Research Reports

Harrison, D., S. Olson, D. Mallett, A. Fuller, and J. Vashon. 2014. Relationships among forest harvesting, snowshoe hares, and Canada lynx in Maine. Pages 57-62 in B.E. Roth, editor, Cooperative Forestry Research Unit: 2013 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.

Mallett, D. 2014. Spatial and habitat responses of Canada lynx in Maine to a decline in snowshoe hare density. M.S. Thesis, University of Maine, Orono, 170pp.

Conference Reports:

Olson, S. and D. Harrison. 2014. Seasonal influences of vegetation on snowshoe hare pellet densities across forest management types in Maine. Presentation at 70th Northeast Fish and Wildlife Conference, Portland, Maine, April 14.

Olson, S. and D. Harrison. 2014. Snowshoe hare response to seasonal changes in Acadian managed forests of northern Maine. Presentation at American Society of Mammalogists Annual Conference, Oklahoma City, Oklahoma, June 10.

Partners/Stakeholders/Collaborators:

- Maine Agricultural and Forest Experiment Station, McIntire-Stennis Grant MEO-9660-05 from the USDA National Institute of Food and Agriculture.
- Department of Wildlife, Fisheries, and Conservation Biology, The University of Maine.
- U.S. Fish and Wildlife Service
- Maine Department of Inland Fisheries and Wildlife

Acknowledgements:

We appreciate 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 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. Angela Fuller and Jennifer Vashon shared lynx scats collected during studies that they supervised as part of the food habits study.

Patch occupancy, habitat use, and population performance of spruce grouse in commercially managed conifer stands

Stephen Dunham and Daniel Harrison

University of Maine

Status: Progress Report, Year 3 of 4

Summary:

This study investigates patterns of breeding season patch occupancy, brood rearing home range characteristics, and annual survival trends of spruce grouse among stands representing 5 forest management treatments in Maine. During the 2012-2014 breeding seasons (May-June) and brood rearing seasons (June-Aug) we conducted repeated call-back surveys in 28-41 stands annually, which represented mature conifer/mixed stands, regenerating conifer-dominated clearcuts, two ages of precommercially thinned stands, and selection harvests. Responding grouse were captured and marked with colored leg bands, and females were equipped with a necklace mounted VHF transmitter. Marked individuals were monitored regularly until brood break-up (October 1). Vegetation data was collected both within the surveyed stands and within the home ranges of marked birds. Preliminary results indicate that males have a high probability of occupancy within the studied stands (~76%) and that they are more likely to be found in stands with increased density of conifers > 3 inches dbh and in stands with presence of dead limbs near the ground. Additionally, females were more likely to occupy previously clearcut and precommercially thinned stands, especially stands with relatively less dense overstory canopy and with increased lateral cover and edible cover (food resources with a height <0.5 m).

Project Objectives:

- Quantify patch occupancy of breeding spruce grouse across a variety of harvested and unharvested stands to determine the link between measurements of forest structure and breeding habitat occupancy.
- Document home range and within-stand habitat selection by female spruce grouse with broods and relate their patterns of selection to forest vegetation, within-stand structure, and with harvest history.
- Document survival of both banded and telemetered adult spruce grouse, as well as brood survival, as indices of relative reproductive success across forest management treatments.

Approach:

- During the month of May and early June we performed three cantus call surveys for male spruce grouse within 41 forest stands distributed across our 5 harvest treatments. Responding grouse were captured and marked with colored leg bands.

- During June and early July we conducted surveys using chick distress calls to elicit responses of brood rearing females. All responding female grouse were captured and marked with colored leg bands and necklace mounted VHF radio transmitters.
- During the period from June to September we located all VHF-equipped females using radio telemetry 3-5 times per week.
- Vegetation measurements were conducted at 15 telemetry locations used by each of our radioed females monitored during the previous summer (2013).

Key Findings / Accomplishments:

- During May and June of 2014 we conducted breeding season occupancy surveys in 41 stands and captured and banded 8 new males, 1 new female (radioed), and had 13 observations of previously marked males and 2 observations of previously marked females.
- During late June and early July we conducted brood surveys within 30 stands to capture females with broods. We were successful in capturing and banding 9 new females, 8 of which were equipped with radio transmitters.
- We obtained telemetry locations of radioed females during July and August approximately 3-5 times/week; locations were verified via sighting and GPS.
- Of the 8 females, 5 survived the summer monitoring season (July-Sept. 1).
- During August 2014 vegetation measurements were taken at 15 known locations for the 10 birds tracked in 2013 that had at least 15 locations.
- Preliminary analysis suggests that studied stands had a 0.76 probability of occupancy by male spruce grouse and that detection probability during our surveys was approximately 0.50. Male occupancy was positively associated with density of conifer trees > 3 inches dbh and was negatively associated with the height of the first dead limb above ground-level.
- Preliminary results for females suggest that they occupied intensively managed stands more frequently than unharvested stands (**Figure 34**). Additionally, radio locations of females were associated with areas of higher lateral cover and with the presence of edible cover (edible plants with a height <0.5 m; (**Figure 35**).

Incoming Ph.D. student Joel Tebbenkamp handling a female spruce grouse captured during a brood survey in June 2014 in Piscataquis County, Maine. Photo taken by Rebecca Fontes.

Undergraduate field technician Rebecca Fontes using radio telemetry equipment to locate a marked female grouse in July 2014 in Piscataquis County, Maine. Photo taken by Joel Tebbenkamp.

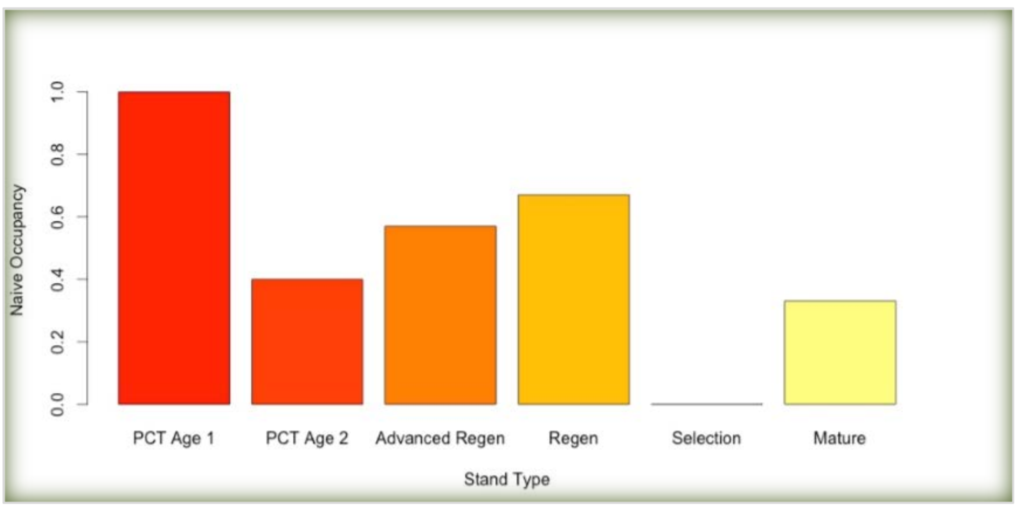


Figure 34 - Native occupancy estimates of females in the brood rearing season for each stand type (PCT = precommercially thinned, category was divided into two age classes).

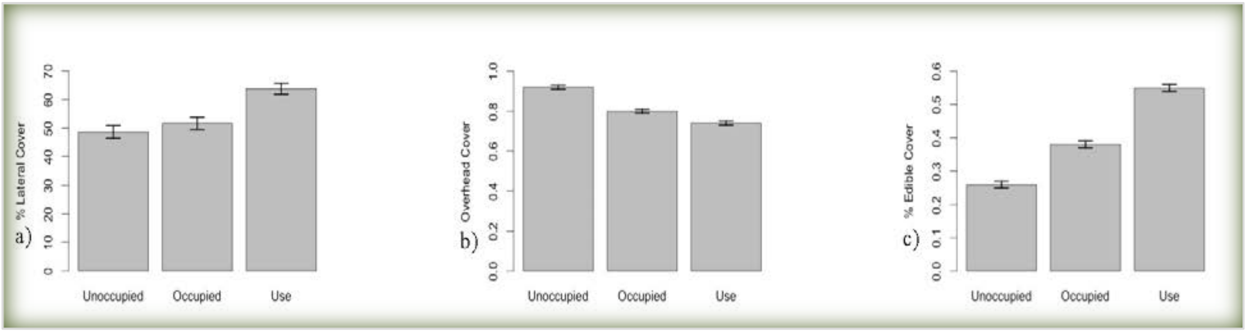


Figure 35 - Mean lateral cover (a), overhead cover (b), and edible cover (c) for the unoccupied stands, occupied stands, and measured telemetry points. Error bars represents 1 standard error. Differences among groups tested with Mann-Whitney U test and all were significant (p<0.01) except for Lateral cover between unoccupied and occupied.

Future Plans:

- Final data analysis and thesis completion will occur by May FY 2015.
- Vegetation data from locations taken on the birds captured in FY 2014 will be taken in July 2015 for inclusion into one of two articles to be prepared for submission to peer-reviewed journals by the end of FY 2015.

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 63-66 *in* B.E. Roth, editor, Cooperative Forestry Research Unit: 2013 Annual Report, University of Maine, Orono.

Conference Reports:

Dunham, S. and D. Harrison. 2014. Spruce grouse breeding season patch occupancy and Home range comparisons across forest management treatments in Maine. Presentation at 70th Northeast Fish and Wildlife Conference, April 14th, Portland, Maine.

Dunham, S. and D. Harrison. 2014. Habitat selection of female spruce grouse during brood Rearing in commercially managed forests. Presentation at Annual Meeting of the American Ornithologists Union, September 27, Estes Park, Colorado.

Parkhill, N.S., D. Harrison, and S. Dunham. 2014. Effects of forest vegetation on spruce grouse nest-site selection across 2 spatial scales. Poster at 70th Northeast Fish and Wildlife Conference, April 14, Portland, Maine.

Presentations/Workshops/Meetings/Field Tours:

Dunham, S.D. 2014. Foolhens and timberdoodles: a pair of interesting forest birds. Sunkhaze Café. April 19, Old Town, Maine.

Harrison, D., S. Olson, S. Dunham, B. Rolek, and C. Loftin. Updates of research findings from studies of snowshoe hares, Canada lynx, spruce grouse and forest songbirds funded by the Maine Cooperative Forestry Research Unit (CFRU). Presentation at winter meeting of CFRU Advisory Committee, January 22, Orono, Maine.

Acknowledgements:

We appreciate 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. Additionally, personnel associated with Baxter State Park, particularly Rick Morril and Jean Hoekwater were helpful with logistics and accommodating to our study, Finally, Larry Pelletier of Gerald Pelletier Inc. has been very accommodating to our field crews at the CFRU's Telos Camp.

Partners/Stakeholders/Collaborators:

- Maine Agricultural and Forest Experiment Station, and McIntire-Stennis Grant MEO-9660-05 from the USDA National Institute of Food and Agriculture
- Department of Wildlife, Fisheries, and Conservation Biology, The University of Maine

Grouse Print in Snow

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

Brian Rolek[1], Daniel Harrison[1], Cynthia Loftin[1,2], and Petra Wood[3]

[1] University of Maine
[2] USGS Maine Cooperative Fish and Wildlife Research Unit
[3] USGS West Virginia Cooperative Fish and Wildlife Research Unit, West Virginia University

Status: Progress Report, Year 2 of 3

Blackburnian Warbler

Summary:

We sampled birds across sites located within the Acadian Forest Region, which coincides roughly with Bird Conservation Region 14 in the United States. 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 NWR, Umbagog NWR, Moosehorn NWR, and Aroostook NWR). In 2013, we surveyed 110 forest stands with approximately 3 to 8 survey locations per stand for a total of 609 sampled points. In 2014, we added 48 points in 7 stands to increase sample size in shelterwood harvests, increasing total samples to 657 point locations in 117 stands. Across all study areas, we recorded 19,431 detections of 123 bird species in 2013 and 22,784 detections of 134 bird species in 2014. We adapted methods from the Forest Inventory Analysis and Breeding Bird Research and Monitoring Database 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.

Project Objectives:

Our goals are to investigate factors influencing the distribution and abundance of bird species that represent the Acadian coniferous forests and to assess the influence of prevalent forest management practices on the Acadian forest bird community. Our specific 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 (**Figure 36**) 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 6**).
- We surveyed birds using point counts at 657 point-locations (**Table 7**) within our 117 focal stands (**Figure 37**).
- We adapted methods from the Forest Inventory Analysis and Breeding Bird Research and Monitoring Database to measure vegetation at each point count location. Data collected included 22 different structural and compositional measurements (**Table 8**).

Key Findings / Accomplishments:

- We surveyed birds using point counts at 657 point-locations within our 117 focal stands.
- We navigated to predetermined locations, and counted the number of individuals of each bird species that were audibly or visually detected for 10 minutes. We revisited each site 3 times during the season and those repeated surveys will allow us to account for the probability that an undetected bird was present during a survey. Across all study areas, we recorded 19,431 detections of 123 species in 2013 and 22,784 detections of 134 species in 2014 (**Table 9**).
- We completed 1,320 vegetation plots and measured 15,024 trees.

Future Plans

A third field season focused on bird surveys will be conducted during May-August 2015 and data analysis and report preparation will be primary activities during fall 2015 and in spring 2016.

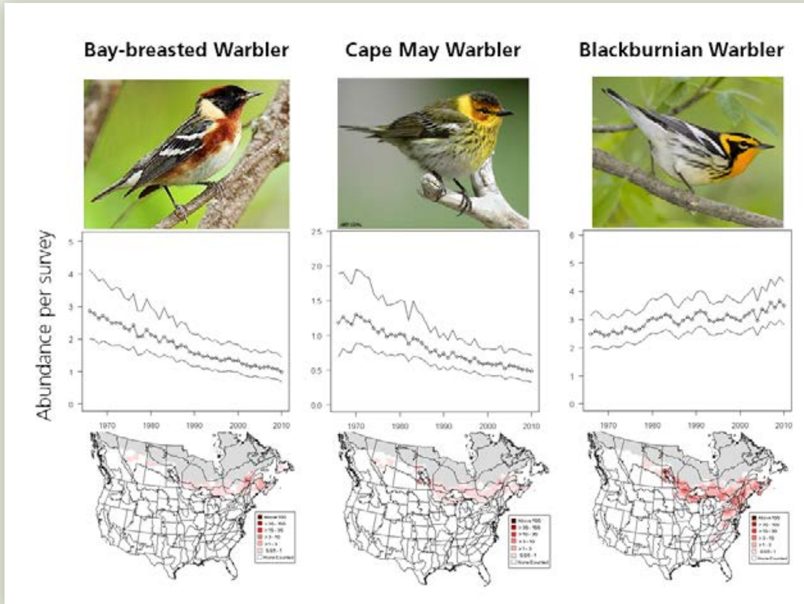


Figure 36 - Several species of concern, their estimated population trends in Bird Conservation Region 14 from USGS Breeding Bird Survey data, and breeding distributions. Photo credits: Bay-breasted Warbler by Bill Majoros, Cape May Warbler and Blackburnian Warbler from USGS Breeding Bird Survey.

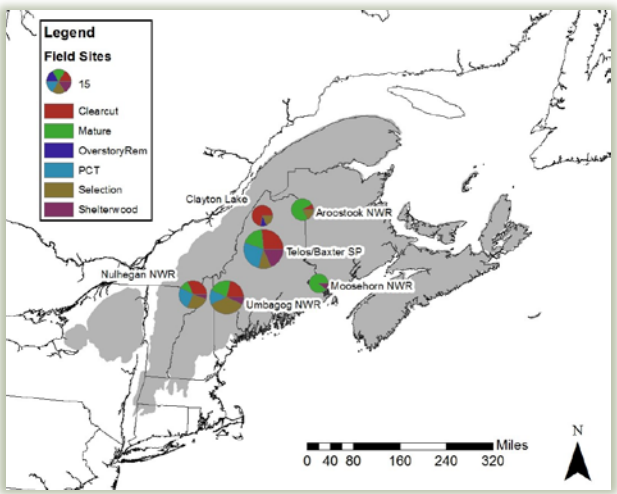


Figure 37 - Survey areas in Northern New England. The size of each pie chart is proportional to the number of stands surveyed in each area; pie charts show the proportion of stands in each treatment category; the shaded gray area is Bird Conservation Region 14.

Table 6 - The number of stands in each treatment class at each property that were surveyed in 2013 and/or 2014.

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 7 - The number of point count locations in each treatment class at each property that were surveyed in 2013 and/or 2014.

Site	Number of point counts in each treatment						
	Conifer Regen	Mature	Overstory Removal	PCT	Selection	Shelterwood	Total
Aroostook NWR	3	28	0	0	9	0	40
Baxter State Park	0	25	0	0	0	33	58
Clayton Lake	50	0	5	0	12	0	67
Moosehorn NWR	0	46	0	0	0	6	52
Nulhegan NWR	54	11	0	33	31	3	132
Telos	55	27	0	47	23	0	152
Umbagog NWR	23	51	0	20	54	8	156
Total	185	188	5	100	129	50	657

Table 8 - Vegetation variables measured in 2014.

Scale	Vegetation variable	Variable type	Description
Individual tree	Basal area	Count	2 factor metric glass prism, tree counts ≥10cm dbh (diameter at breast height)
	Tree dbh	Continuous (cm)	For all tree counted as 'in' using the glass prism using a Biltmore stick
	Tree species	Category	Identified all trees to genus or species
	Crown class	Category	Visual estimate of relative position of tree crown to other tree crowns
	Crown condition	Category	Visual estimate of fullness of crown
	Height	Continuous (m)	Measured with a clinometer and range finder
	Live crown length	Continuous (m)	Measured with a clinometer and range finder
	Live or dead	Binary	Whether a standing tree living or dead
Plot level	Canopy gaps	Continuous (%)	Percent canopy gaps within 30m defined as
	Canopy density	Continuous (%)	Both gridded plexiglass and densiometer
	Midstory density	Continuous (%)	Gridded plexiglass
	Elevation	Continuous (m)	GPS unit reading
	Water	Category	Standing water present, running, or none
	All green cover	Continuous (%)	Visual estimate of all green ground cover excluding moss
	Moss cover	Continuous (%)	Visual estimate
	Total cover 0.5 to <2m	Continuous (%)	Visual estimate
	Deciduous cover 0.5 to <2m	Continuous (%)	Visual estimate
	Coniferous cover 0.5 to <2m	Continuous (%)	Visual estimate
	Dominant species 0.5 to <2m	Category	Species or genus
	Large downed logs	Binary (y/n)	Present or absent
	Tip ups	Binary (y/n)	Present or absent
	Leaf litter cover	Continuous (%)	Visual estimate

Table 9 - Average number of birds detected (Mean) within 50m during surveys for each species and standard deviation (SD). These average counts have not been adjusted for detection probability and were averaged from the maximum number detected at each survey location from all repeated surveys within each year.

	2013		2014	
Common name	**Mean**	**SD**	**Mean**	**SD**
American black duck	0.002	0.040	0.000	0.000
Alder flycatcher	0.077	0.322	0.055	0.253
American crow	0.031	0.182	0.020	0.178
American goldfinch	0.011	0.120	0.014	0.129
American kestrel	0.000	0.000	0.002	0.039
American redstart	0.192	0.437	0.182	0.465
American robin	0.382	0.687	0.179	0.453
American woodcock	0.008	0.201	0.002	0.039
American three-toed woodpecker	0.006	0.080	0.000	0.000
Baltimore oriole	0.003	0.057	0.000	0.000
Black-and-white warbler	0.277	0.546	0.204	0.459
Bay-breasted warbler	0.074	0.291	0.155	0.445
Black-backed woodpecker	0.005	0.069	0.021	0.144
Black-capped chickadee	0.703	0.918	0.465	0.742
Belted kingfisher	0.006	0.080	0.000	0.000
Blue-headed vireo	0.284	0.515	0.207	0.441
Blackburnian warbler	0.232	0.525	0.274	0.504
Blue jay	0.329	0.595	0.161	0.450
Blackpoll warbler	0.035	0.217	0.036	0.218
Bobolink	0.002	0.040	0.000	0.000
Boreal chickadee	0.300	0.668	0.222	0.568
Brown creeper	0.131	0.369	0.071	0.275
Black-throated blue warbler	0.277	0.543	0.252	0.506
Black-throated green warbler	0.561	0.798	0.419	0.629
Broad-winged hawk	0.019	0.149	0.014	0.140
Canada goose	0.002	0.040	0.000	0.000
Canada warbler	0.266	0.513	0.260	0.518
Cedar waxwing	0.232	0.583	0.055	0.281
Chipping sparrow	0.032	0.225	0.024	0.181
Chimney swift	0.000	0.000	0.002	0.039
Cape may warbler	0.006	0.080	0.012	0.110
Common grackle	0.000	0.000	0.009	0.110
Cooper's hawk	0.002	0.040	0.002	0.039
Common merganser	0.002	0.040	0.015	0.390
Common nighthawk	0.010	0.098	0.006	0.078
Common raven	0.031	0.236	0.003	0.055

Common yellowthroat	0.356	0.620	0.287	0.572
Chestnut-sided warbler	0.134	0.402	0.058	0.252
Downy woodpecker	0.045	0.237	0.012	0.123
Eastern kingbird	0.002	0.040	0.000	0.000
Eastern phoebe	0.019	0.138	0.005	0.087
Eastern wood-pewee	0.034	0.198	0.018	0.134
Evening grosbeak	0.003	0.080	0.000	0.000
Fox sparrow	0.015	0.133	0.052	0.241
Great-crested flycatcher	0.011	0.106	0.000	0.000
Golden-crowned kinglet	0.976	0.704	0.752	0.676
Great horned owl	0.005	0.069	0.000	0.000
Gray jay	0.085	0.496	0.027	0.181
Gray catbird	0.026	0.159	0.005	0.067
Golden-winged warbler	0.000	0.000	0.002	0.039
Hairy woodpecker	0.058	0.234	0.073	0.266
Hermit thrush	0.963	0.932	0.521	0.740
House finch	0.002	0.040	0.000	0.000
Killdeer	0.000	0.000	0.002	0.039
Least flycatcher	0.166	0.436	0.064	0.339
Lincoln's sparrow	0.005	0.090	0.006	0.078
Magnolia warbler	1.139	0.938	1.178	0.910
Mourning dove	0.047	0.226	0.006	0.095
Mourning warbler	0.006	0.080	0.006	0.078
Myrtle warbler	0.535	0.715	0.576	0.714
Nashville warbler	0.644	0.794	0.625	0.765
Northern cardinal	0.013	0.139	0.000	0.000
Northern parula	0.503	0.713	0.369	0.551
Northern waterthrush	0.205	0.529	0.131	0.384
Orange-crowned warbler	0.003	0.057	0.000	0.000
Olive-sided flycatcher	0.040	0.234	0.035	0.184
Ovenbird	0.560	0.859	0.381	0.611
Philadelphia vireo	0.005	0.069	0.000	0.000
Pine warbler	0.148	0.422	0.071	0.269
Pileated woodpecker	0.044	0.212	0.014	0.116
Purple finch	0.113	0.332	0.079	0.286
Rose-breasted grosbeak	0.031	0.190	0.006	0.078
Red-breasted nuthatch	0.455	0.617	0.427	0.637
Ruby-crowned kinglet	0.187	0.455	0.132	0.373
Red crossbill	0.002	0.040	0.002	0.039
Red squirrel	0.632	0.771	1.065	0.866
Red-eyed vireo	0.531	0.644	0.412	0.621
Ruby-throated hummingbird	0.016	0.126	0.018	0.145
Rusty blackbird	0.005	0.090	0.000	0.000
Ruffed grouse	0.037	0.267	0.014	0.160

Red-winged blackbird	0.013	0.126	0.002	0.039
Savannah sparrow	0.013	0.139	0.005	0.087
Slate-colored junco	0.185	0.475	0.277	0.559
Scarlet tanager	0.008	0.106	0.006	0.078
Sora	0.003	0.080	0.002	0.039
Song sparrow	0.026	0.178	0.017	0.140
Spruce grouse	0.006	0.080	0.014	0.129
Sharp-shinned hawk	0.013	0.126	0.003	0.055
Swamp sparrow	0.019	0.169	0.024	0.190
Swainson's thrush	0.655	0.784	0.739	0.863
Tennessee warbler	0.016	0.126	0.003	0.055
Veery	0.087	0.315	0.021	0.155
Virginia rail	0.002	0.040	0.000	0.000
White-breasted nuthatch	0.010	0.127	0.005	0.067
Wilson's snipe	0.000	0.000	0.003	0.055
Wild turkey	0.011	0.120	0.000	0.000
Wilson's warbler	0.015	0.133	0.018	0.165
Winter wren	0.689	0.749	0.441	0.587
Wood duck	0.002	0.040	0.000	0.000
Wood thrush	0.002	0.040	0.000	0.000
White-throated sparrow	0.808	1.034	0.565	0.820
White-winged crossbill	0.000	0.000	0.003	0.078
Yellow-bellied flycatcher	0.311	0.522	0.450	0.623
Yellow-bellied sapsucker	0.106	0.339	0.100	0.369
Yellow warbler	0.008	0.090	0.005	0.067
Yellow palm warbler	0.197	0.568	0.081	0.342
Yellow-shafted flicker	0.134	0.372	0.062	0.248
Yellow-throated vireo	0.002	0.040	0.000	0.000

Products Delivered:

Research Reports:

Rolek, B., D. Harrison, and C. Loftin. 2014. Bird communities of coniferous forests in the Acadian Region: Habitat associations and response of birds to forest management. Pages 67-73 in B.E. Roth, editor, Cooperative Forestry Research Unit: 2013 Annual Report, University of Maine, Orono.

Conference Reports:

Rolek, B., C.S. Loftin, D. Harrison, and P.B. Wood. 2014. The influence of silviculture on New England bird communities in northern coniferous forests. Presentation at 70th Northeast Fish and Wildlife Conference, April 13-15, Portland, Maine.

Presentations/Workshops/Meetings/Field Tours:

Harrison, D., S. Olson, S. Dunham, B. Rolek, and C. Loftin. Updates of research Findings from studies of snowshoe hares, Canada lynx, spruce grouse and forest songbirds funded by the Maine Cooperative Forestry Research Unit (CFRU). Presentation at winter meeting of CFRU Advisory Committee, January 22, Orono, Maine.

Acknowledgements:

We appreciate 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. Additionally, personnel associated with Baxter State Park, particularly Rick Morrell and Jean Hoekwater were helpful with logistics and accommodating to our study. Additionally, Larry Pelletier of Gerald Pelletier Inc. has been very accommodating to our field crews at the CFRU's Telos Camp.

Biologists and managers at Aroostook, Moosehorn, Nulhegan, and Umbagog National Wildlife Refuges have graciously assisted with locating field sites, logistics, housing, and vehicles. We appreciate the professional advice, help, and support that has been provided by many U.S. Fish and Wildlife Service Biologists, namely Thomas LaPointe, Mitch Hartley, and Randy Dettmers.

Partners/Stakeholders/Collaborators:

- Maine Agricultural and Forest Experiment Station, and McIntire-Stennis Grant MEO-9660-05 from the USDA National Institute of Food and Agriculture
- Department of Wildlife, Fisheries, and Conservation Biology, The University of Maine
- USGS, Maine Cooperative Fish and Wildlife Research Unit, The University of Maine
- U.S. Fish and Wildlife Service Migratory Office and the Northeast Region of U.S. Fish and Wildlife Service, National Wildlife Refuges.

Ruby-crowned kinglet - photo by Pamela Wells

APPENDIX

CFRU Products Delivered During 2014

CFRU Publications

Refereed Journal Publications:

Bataineh, M.M., R.G. Wagner, M.G. Olson, E.K. Olson. 2013. Midrotation response of ground vegetation to herbicide and precommercial thinning in the Acadian Forest of Maine, USA. Forest Ecology & Management 313: 132–143.

Bataineh, M.M., R.G. Wagner, A.R. Weiskittel. 2013. Long-term response of spruce-fir stands to herbicide and precommercial thinning: Observed and projected growth, yield, and financial returns in central Maine, USA. Canadian Journal of Forest Research 43(4): 385-395.

Hayashi, R., Weiskittel, A. and Sader, S. 2014. Assessing the feasibility of low-density LiDAR for stand inventory predictions in complex and managed forests of northern Maine. Forests 5: 363-383.

Hayashi, R. Weiskittel, A. and Kershaw, J.A. in review. Evaluation of alternative methods for using LiDAR to predict aboveground biomass in mixed species and structurally complex forests in northeastern North America. Submitted to Canadian Journal of Remote Sensing.

Russell, M.B., Weiskittel, A.R., and Kershaw Jr., J.A. 2014. Comparing strategies for modeling individual-tree height and height-to-crown base increment in mixed-species Acadian forests of northeastern North America. European Journal of Forest Research 133: 1121-1135.

Hiesl, P. and Benjamin, J.G. 2014 (Accepted). Estimating processing times of harvesters in thinning operations in Maine. Forest Products Journal.

Hiesl, P. and J.G. Benjamin. 2013. A Multi-Stem Feller-Buncher Cycle Time Model for Partial Harvest of Small Diameter Wood Stands. International Journal of Forest Engineering 24(2):101-108.

Hiesl, P. and J.G. Benjamin. 2013. Applicability of International Harvesting Equipment Productivity Studies in Maine, USA: A Literature Review. Forests 4:898-921.

Hiesl, P. and Benjamin, J.G. 2013. Harvesting Equipment Cycle Time and Productivity Guide for Logging Operations in Maine. Miscellaneous Publications 762. Orono, ME, USA: Maine Agricultural and Forest Experiment Station: 2013. p. 67.

Nelson, A.S., M.R. Saunders, R.G. Wagner, and A.R. Weiskittel. 2013a. Early stand production of hybrid poplar and white spruce in mixed and monospecific plantations in eastern Maine. New Forests 43(4): 519-534.

Nelson, A.S., R.G. Wagner, M.R. Saunders, and A.R. Weiskittel. 2013b. Influence of management intensity on the productivity of young early successional Acadian stands in eastern Maine. Forestry 86 (1): 79-89.

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.

Olson, M.G., S.R. Meyer, R.G. Wagner, and R.S. Seymour. 2014. Commercial thinning stimulates natural regeneration in spruce–fir stands. Can. J. For. Res. 44: 173–181 (2014) dx.doi.org/10.1139/cjfr-2013-0227.

Research Reports:

Hiesl, P. and J.G. Benjamin. 2013. Harvesting Equipment Cycle Time and Productivity Guide for Logging Operations in Maine. University of Maine, Maine Agriculture and Forest Experiment Station. Orono, ME. Miscellaneous Publication 762. 60p.

Seymour, R.S., S.R. Meyer, and R.G. Wagner. 2014. The Cooperative Forestry Research Unit Commercial Thinning Research Network: 9-Year Results. In: Kenefic, Laura S.; Brissette, John C., compilers. 2014. Penobscot Experimental Forest: 60 years of research and demonstration in Maine, 1950-2010. Gen. Tech. Rep. NRS-P-123. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 185 p.

Theses:

Clune, P.M. 2013. Growth and development of Maine spruce-fir forests following commercial thinning. M.S. thesis, University of Maine, Orono.

Hayashi, R. Evaluations of airborne LiDAR as an assisting tool for achievement of sustainable forest management in Maine's forests. M.S. thesis, University of Maine, Orono. 64 p.Hiesl, P. 2013. Productivity Standards for Whole-Tree and Cut-to-Length Harvesting Systems in Maine. M.S. thesis, University of Maine, Orono.

Mallett, D. 2014. Spatial and habitat responses of Canada lynx in Maine to a decline in snowshoe hare density. M.S. Thesis, University of Maine, Orono, 170pp.

Nelson, A.S. 2013. Production ecology and stand dynamics of young Acadian forest stands in response to silvicultural intensity and compositional objectives. PhD thesis, University of Maine, Orono.

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.

Conference Papers:

Benjamin, J.G. and D. Burr. 2013. Production Tracking System for Swing-to-Tree Feller Bunchers. Paper presented at the 36th Council on Forest Engineering: *Forest Operations for a Changing Landscape.* Missoula, MT. July 7-10, 2013.

Dunham, S. and D. Harrison. 2014. Habitat selection of female spruce grouse during brood Rearing in commercially managed forests. Presentation at Annual Meeting of the American Ornithologists Union, September 27, Estes Park, Colorado.

Hiesl, P. and J.G. Benjamin. 2013. Assessment of Feller Buncher and Harvester Caused Stand Damage in Partial Harvests in Maine. Paper presented at the 36th Council on Forest Engineering: *Forest Operations for a Changing Landscape.* Missoula, MT. July 7-10, 2013.

Hiesl, P. and Benjamin, J.G. 2014. Harvester Productivity and Cost in Small Diameter Timber Stands in Central Maine, USA. In: *Proceedings of the 37th Council on Forest Engineering: Global Harvesting Technology*. Moline, IL, USA: June 22-25, 2014.

Olson, S. and D. Harrison. 2014. Seasonal influences of vegetation on snowshoe hare pellet densities across forest management types in Maine. Presentation at 70th Northeast Fish and Wildlife Conference, Portland, Maine, April 14.

Olson, S. and D. Harrison. 2014. Snowshoe hare response to seasonal changes in Acadian managed forests of northern Maine. Presentation at American Society of Mammalogists Annual Conference, Oklahoma City, Oklahoma, June 10.

Parkhill, N. S., D. Harrison, and S. Dunham. 2014. Effects of forest vegetation on spruce grouse nest-site selection across 2 spatial scales. Poster at 70th Northeast Fish and Wildlife Conference, April 14, Portland, Maine.

Wagner, R.G., M.M. Bataineh, and M.G. Olson. 2014. Long-term stand development and financial returns following herbicide and precommercial thinning combinations in the Acadian Forest of Maine, USA. In Proc. 8th International Forest Vegetation Management Conference, August 25-28, 2014, Halmstad, Sweden.

Software:

Hennigar, C. 2014. Open Stand Model. FORUS Research. Fredericton, New Brunswick. Available: http://www.forusresearch.com/downloadsOSM/ (User: OSM; Password: GetIt!).

Presentations/Workshops/Meetings/Field Tours

Benjamin, J,G., P. Hiesl, J. Hutton, and C. Lachance. 2014. Mechanized Harvesting – How Productive is Your Operations? New Hampshire Timberland Owners Association – Spring 2014 Workshop. Concord, NH. June 12.

Benjamin, J,G., P. Hiesl, and J. Hutton. 2014. Stick with the Status Quo or Find the Best Flow. Productivity Improvement Workshop for Treeline Inc. Lincoln, ME. May 9.

Benjamin, J.G. 2014. Operational and Economic Aspects of Biomass Harvesting: There is No Free Lunch in the Woods. New England Society of American Foresters – 2014 Winter Meeting: Resources – Resilience – Renewal – Restoration. Nashua, NH. March 25.

Benjamin, J.G. 2013. Trends in the Northeast Logging Industry: Man, Machine and Money. 21st Loggers and truckers Convention – New Hampshire Timberland owners Association. Concord, NH. October 19, 2013.

Benjamin, J.G. and P. Hiesl. 2013. Managing Operational Costs of Maine's Hardwood Resource. Canadian Woodlands Forum 2013 Fall Meeting. Edmundston, N.B. October 1, 2013.

Benjamin, J.G. and P. Hiesl. 2013. Influence of Stem Size on Cycle Time on Harvest Productivity and Cost. Forest Bioproduct Research Institute – 2013 Fall Board Meeting. Orono, ME. October 10, 2013.

Benjamin, J.G. and P. Hiesl. 2013. Influence of Stem Size on Cycle Time on Harvest Productivity and Cost. LP Supplier Workshop. Houlton, ME. August 21, 2013.

Benjamin, J.G. 2013. The University of Maine's iFOR Program: Innovative Forest Operations Research. Northeastern Loggers' Association Equipment Expo and Logger Workshops. Bangor, ME. May 17.

Benjamin, J.G. 2013. Forest Business Planning Workshop – NE Logging Industry Overview and Process Improvement. Vermont Forest Parks and Recreation Department. Essex Junction, VT. May 10.

Benjamin, J.G. and P. Hiesl 2013. What is the Value of Your Time? Productivity Improvement Workshop for Treeline Inc. Lincoln, ME. May 3.

Benjamin, J.G. 2013. iFOR – The University of Maine's Innovative Forest Operations Research Program. Northern Hardwood Research Institute Seminar Series. Edmundston, NB. April 10.

Benjamin, J.G. and P. Hiesl. 2013. Influence of Stem Size and Cycle Time on Harvest Cost. New England Council on Forest Engineering Annual Meeting. Legal Issues in Forestry & Foresters…..Knowing Your Costs. University of Maine, Orono, ME. March 11-12, 2013.

Castonguay, M. A. 2013. CFRU Advisory Committee Meeting - Project Proposal – "Cartographic Depth-to-Water Mapping for Maine, state-wide using latest DEM data coverage, for CFRU priority areas", January 23rd, 2013, Wells Conference Center, University of Maine, Orono, ME.

Castonguay, M. A. 2014. CFRU Advisory Committee Meeting – Final Project Report – "Revised Cartographic Depth-to-Water Mapping for Maine, State-Wide Using Latest Data Sources", October 29th, 2014, Wells Conference Center, Room 2, University of Maine, Orono, ME.

Dunham, S.D. 2014. Foolhens and timberdoodles: a pair of interesting forest birds. Sunkhaze Café. April 19, Old Town, Maine.

Harrison, D., S. Olson, S. Dunham, B. Rolek, and C. Loftin. Updates of research findings from studies of snowshoe hares, Canada lynx, spruce grouse and forest songbirds funded by the Maine Cooperative Forestry Research Unit (CFRU). Presentation at winter meeting of CFRU Advisory Committee, January 22, Orono, Maine.

Hiesl, P. and Benjamin, J.G. 2013. CFRU Logging Cost and Productivity Study Results. 2013 Cooperative Forestry Research Unit Fall Field Tour. Overstory Removal & Regeneration: Challenges & Opportunities. University of Maine, Orono, ME: October 10, 2013.

Hennigar, C. 2014. Open Stand Model: Hardwood partial harvest simulation advancement. Northern Hardwoods Research Institute. Presentation on May 1, 2014. Université de Moncton. Edmundston, New Brunswick.

Rolek, B., C.S. Loftin, D. Harrison, and P.B. Wood. 2014. The influence of silviculture on New England bird communities in northern coniferous forests. Presentation at 70th Northeast Fish and Wildlife Conference, April 13-15, Portland, Maine.

Wagner, R.G., Roth, B.E., Benjamin, J.G. and Hiesl, P. 2014. Plum Creek Forester's Field Tour. Austin Pond Study: Herbicide, PCT and Commercial Thinning. Bingham, ME, USA: August 7, 2014.

Wagner, R.G. 2014. Outcome-based Forestry policy implementation. 1-day field tour with Maine Legislature Agriculture, Forestry, and Conservation Committee, JD Irving lands, Presque Isle, ME

Wagner, R.G. 2014. Methods of managing beech-dominated hardwoods stands. 1-day field tour with Seven Islands Land Co.

Wagner, R.G. 2014. Results from CFRU Thinning Research. Seven Islands Land Company Annual Forestry Meeting. Penobscot Experimental Forest, Bradley, ME

Wagner, R.G. 2014. Overview of CFRU Research. Wagner Forest Management Annual Forestry Staff Meeting, Comstock, ME

Wagner, R.G. 2014. The Spruce Budworm is Knocking at Our Door Once Again: How is Maine Planning to Answer. Maine Pesticide Recertification Meetings, April 2, 2014, Spectacular Event Center, Bangor, ME and April 3, 2014, Ramada Inn, Lewiston, ME.

Wagner, R.G. 2014. Spruce Budworm – Human Response Cycle: How it shaped everything in Maine forestry for the past 40 years. NERCOFE Workshop, University of Maine, Orono, ME. March 10, 2014.

Wagner, R.G. 2014. Maine SBW Outbreak Assessment, Preparation & Response Strategy: Wood Supply Impacts. NERCOFE Workshop, University of Maine, Orono, ME. March 10, 2014.

Wagner, R.G. 2013. Overview of Center for Sustainable Forests Research. University of Maine Research Center Director's Meeting, Orono.

Wagner, R.G. 2013. Spruce Budworm – Human Response Life Cycle: How it shaped everything in Maine forestry for the past 40 years. Forestry Noontime Seminar, School of Forest Resources, University of Maine, Orono.

Wagner, R.G. 2013. Influence of Partial Harvesting on Hardwood Regeneration. Financially Feasible Hardwood Silviculture: Sustaining a Competitive Hardwood Value Chain, Edmundston, NB. October 1-2, 2013.

Sunset Wells Forest