



# Cooperative Forestry Research Unit

2017 Annual Report



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Jenna M. Zukswert (M.Sc.), 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 34 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**

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<http://www.umaine.edu/cfru/>

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### ***Front Page Photo***

Ferry crossing on the St. John River. Photo by Ryan Wishart, Seven Islands Land Company.

### ***Credits***

Final layout by Jenna Zukswert. Individual sections were written by authors as indicated. Photography compliments of CFRU archives 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.

*Photo: P. Wells/Oakleafs Studios*



# 2017 CFRU Highlights

- CFRU membership and funding has remained relatively stable this year, with 34 member organizations representing half (8.1 million acres) of Maine's commercial forests (see page 11).
- CFRU continued to leverage a wide variety of funding sources to support member research priorities. For every \$1 contributed by CFRU's largest members, an additional \$11.45 was leveraged from other sources (see page 11).
- Establishment of the Maine Adaptive Silviculture Network (MASN) commenced this year with three sites selected on land owned by BBC Land, LLC, Irving Woodlands, LLC, and Seven Islands Land Company. This new network is a statewide series of operational-scale silvicultural treatments where future research on forest productivity and sustainability will be studied. The MASN installation owned by BBC Land, LLC, was harvested in July 2017 (see page 28).

## Silviculture & Productivity Research

- Economic projections of longstanding spruce-fir trials at the Austin Pond Study Area reveal that PCT reduced time to economic maturity by 11 years, increased maximum net present value (NPV) by \$1,500/ha, and more than doubled average stem size. A separate analysis of Commercial Thinning Research Network (CTRN) data from unthinned stands indicated that thinning from below returned the highest maximum NPV and double average stem size compared to the control (see page 21).
- The CFRU embarked on an ambitious new study series: Maine's Adaptive Silviculture Network (MASN). The first installation of 18 that are planned for the state has been established with five treatments in Grand Falls Township on BBC Land, LLC with two more installations selected on Irving Woodlands and Seven Islands Land Company. (see page 28).
- A literature review of peer-reviewed articles on forest products transportation revealed two main themes in the literature to be 'roads and route planning' and 'supply chain and optimizations'. Locally, a cross-sectional survey and series of in-person interviews revealed the major challenges facing the forest products transportation industry in Maine to be availability of markets and lack of skilled labor (see page 32).
- A new study examining the long-term impacts of whole-tree harvesting was initiated on the Weymouth Point Study Area. Preliminary analysis indicates that aboveground biomass, 35 years after harvesting, did not vary by harvest type or soil rock volume after adjusting for differences in stand density (see page 42).
- Beech bark disease is a major problem in the Northeast. An analysis of USFS Forest Inventory Analysis (FIA) data identified five stand archetypes where beech was present. The archetypes take into account the position of beech in the canopy and the proportion of beech in the stand. From these archetypes, it is possible to make specific management recommendations for reducing diseased beech by taking into account (see page 50).

## **Growth & Yield Modeling Research**

- The 2017 overwintering second larval instar spruce budworm (L2) survey was completed with the collaboration of CFRU members collecting branches. The survey revealed very low levels of overwintering spruce budworm larvae in northern Maine, but highlighted a few areas with higher L2 densities that will be closely monitored in the future (see page 56).
- Data from pheromone traps and spruce budworm L2 density sampling, obtained across over 250 sites on CFRU landowner property in northern Maine, were used to model spruce budworm moth and larval abundance. Location was important, as were mapped forest conditions, with percentage of high-risk forest (mature forest with  $\geq 75\%$  of host tree species) within 500 meters of a trap being the most influential factor in predicting abundance (see page 59).
- Landsat imagery and derived vegetation indices (VIs) were used to model current-year spruce budworm defoliation in Quebec and Maine. The most effective model used a combination of VIs to predict defoliation, with accuracy greater than 50% across all defoliation severity classes. This method was found to be comparable to aerial sketch maps in terms of accuracy (see page 62).
- Phase two of a three-phase initiative to complete LiDAR acquisition for the entire state of Maine was completed this year leveraging CFRU member funds to attract Federal and State funding (see page 68).

## **Wildlife Habitat Research**

- More than 50% of radio-marked spruce grouse hens nested successfully in intensively-managed forests in Piscataquis County. Models suggest that reproductive success increases when spruce grouse nest sites are located in areas with greater structural complexity (see page 72).
- A region-wide, geospatial analysis of deer-wintering areas (DWA) has been completed. Economic analyses suggest that financial loss is not universal and is highly dependent on landowner objectives and stand conditions at the start of the simulation (see page 77).



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# Chair's Report

I am pleased to introduce the 2017 CFRU Annual Report. While the saying "What's old is new again" is most often associated with cultural trends like fashion or entertainment, this report shows it can also pertain to research sites. Highlighted in this report are updates on recent studies being conducted on two of the original CFRU research sites: Austin Pond (est. 1977) and Weymouth Point (est. 1979). It is commendable that throughout the years, the various cooperating members managing these sites have recognized their value as long-term research sites. The entire CFRU membership and researchers have benefitted greatly from their generosity over the years.



Also new in 2017 was the establishment of an adaptive silvicultural study (a.k.a., MASN) that has evoked great interest by members and researchers alike. This is just a few of the many interesting CFRU-funded projects that can be found within the pages of this report.

The 2016-17 fiscal year presented some unique administrative challenges for CFRU. As you know, CFRU is housed within the Center for Research on Sustainable Forests (CRSF), currently under the direction of Acting Director Dr. Aaron Weiskittel. CRSF is undergoing a University review process, which should be completed by 2018. The Executive Committee of CFRU has been asked to participate in this process and should meet with the review team in the near future. While CFRU is not under review, its University "home" actually is. That in turn has presented financial support and personnel administration challenges. Thankfully, membership recognized these challenges and supported funding to fill the vacant Research & Communications Coordinator position. We anticipate filling this important position by the end of 2017.

I would like to personally thank Acting CRSF Director Weiskittel and Acting CFRU Director Roth for their support, guidance, and patience with this process. Thanks also to the many research scientists that provided CFRU with their research talents and thoughtful proposals. I would also like to thank the CFRU Executive Committee for their wise counsel and support this past year. Finally, I would like to thank the membership for their continued enthusiastic participation and financial support of this unique, world-class research cooperative.

Sincerely,

A handwritten signature in blue ink, appearing to read "Gordon Gamble".

Gordon Gamble



# Acting Director's Report

This has been a year of uncertainty and challenges for the CFRU with the departure of Dr. Bob Wagner for Purdue University and an ongoing review of the CRSF by the Vice President of Research Office at the University of Maine. It is also a time to look to the future and build a strong foundation that will support the next generation of applied research and technology transfer for a changing forest ownership and forest products marketplace. Along with Aaron Weiskittel, I have visited with a majority of CFRU membership in your offices and on the lands you own or manage to learn about how we can better serve you. One of the most common themes we heard was a need to get the valuable information that the CFRU generates out into the hands of the foresters and managers who can make use of it. To this end, I am thrilled that the Advisory Committee has approved a plan to fill the position of Research and Communications Coordinator. A search will be conducted in the Fall of 2017 with the goal of having the position filled early in 2018.

As I begin my first full year leading the CFRU, I am impressed by the amount of research that continues on long-term CFRU research areas such as the Austin Pond and Weymouth Point Studies. There clearly is much value in leveraging the data and investment that has accumulated over time on these studies to answer new questions that were not envisioned when these were installed. There is also considerable value in having an established network of study locations across the region, which allows for the results to be applicable to a wider range of stand types and site conditions. I am very excited that membership is supporting a new long-term study network that will include a wide range of operational silvicultural prescriptions. Maine's Adaptive Silviculture Network is unique in that it will have very large treatment units where studies on wildlife habitat, remote sensing, growth & yield, forest and operations productivity, hydrology, and forest regeneration will take place. This outdoor laboratory will attract researchers from around the region to study issues of importance to CFRU membership.

I am grateful for the trust and confidence that CFRU membership has placed in me to lead the Cooperative in to support of Maine's forest landowners, forestry community, and policymakers. I remain open to hearing your concerns and suggestions for how we can keep the CFRU relevant in these times of uncertainty. It is my goal to keep the CFRU well positioned to continue providing valuable information to members in support of both sustainable forestry practices and science-based forest policies.



Dr. Brian E. Roth

# Membership

## **FOREST LANDOWNERS / MANAGERS:**

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

## **WOOD PROCESSORS:**

SAPPI Fine Paper

## **CORPORATE / INDIVIDUAL MEMBERS:**

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

## **ADVISORY COMMITTEE:**

### **Chair**

Gordon Gamble – *Wagner Forest Management*

### **Vice Chair**

Ian Prior – *Seven Islands Land Company*

### **Financial Officer**

Greg Adams – *Irving Woodlands, 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 – *Baskahegan Corporation*  
Elizabeth Farrell – *American Forest Management*  
Tom Charles – *Maine Bureau of Parks & Public Lands*  
Brian Condon – *The Forestland Group, LLC*  
Frank Cuff – *Weyerhaeuser Company*  
Dave Dow – *Prentiss and Carlisle Company, Inc.*  
Alec Giffen – *New England Forestry Foundation*  
Eugene Mahar – *LandVest [Frontier Forest, LLC; Clayton Lake Woodlands Holding, LLC; EMC Holdings, LLC, Mosquito, LLC, The Tall Timber Trust]*  
Brittany Mauricette – *Downeast Lakes Land Trust*  
Kevin McCarthy – *SAPPI Fine Papers*  
Scott Joachim – *Katahdin Forest Management, LLC*  
Wil Mercier – *J.W. Sewall Company*  
Jacob Metzler – *Forest Society of Maine*  
Eben Sypitkowski – *Baxter State Park*  
Nancy Sferra – *The Nature Conservancy*  
Steve Tatko – *Appalachian Mountain Club*  
Jim Robbins, Jr. – *Robbins Lumber Company*  
Tim Richards – *ReEnergy Holdings, LLC*  
Dan Pelletier – *Huber Engineered Woods, LLC*



# Research Team

## Staff

- Brian Roth, PhD, Acting CFRU Director
- Cynthia Smith, Administrative Specialist

## Project Scientists

- Erik Blomberg, PhD, University of Maine
- Arun Bose, PhD, University of Maine
- Russell Briggs, PhD, State University of New York – Environmental Science and Forestry
- John Campbell, PhD, U.S. Forest Service Center for Research on Ecosystem Change
- Mindy Crandall, PhD, University of Maine
- Ivan Fernandez, PhD, University of Maine
- Shawn Fraver, PhD, University of Maine
- Anthony Guay, MS, University of Maine
- Daniel Harrison, PhD, University of Maine
- Daniel Hayes, PhD, University of Maine
- Patrick Hiesl, PhD, Paul Smith's College
- Daniel Kneeshaw, PhD, Université du Québec à Montréal
- Kasey Legaard, PhD, University of Maine
- David MacLean, PhD, University of New Brunswick
- Gaetan Pelletier, PhD, University of Moncton
- Parinaz Rahimzadeh, PhD, University of Maine
- Amber Roth, PhD, University of Maine
- Brian Roth, PhD, University of Maine, Cooperative Forestry Research Unit
- Erin Simons-Legaard, PhD, University of Maine
- C. T. (Tat) Smith, PhD, University of Toronto
- Robert Wagner, PhD, Purdue University
- Dan Walters, MS, U.S. Geological Survey
- Aaron Weiskittel, PhD, University of Maine
- Joseph Young, Maine Office of GIS



*CFRU cooperators and scientists discuss ideas during the 2016 Listening Session in October.  
Photo: B. Roth*

## Graduate Students

- Karin Bothwell (MS student – Crandall and A. Roth): Deer wintering habitat
- Anil Koirala (MS student – Kizha.): Forest trucking industry in Maine
- Christopher Preece (MS student – Smith): Whole-tree harvesting at Weymouth Point
- Joel Tebbenkamp (PhD student – Blomberg and Harrison): Spruce grouse habitat

## Undergraduate Students

- Griffin Archambault (BS student – Blomberg): Spruce grouse habitat
- Cassandra Carroll (BS student – Crandall): Deer wintering habitat
- Jillian Demus (BS student – Blomberg): Spruce grouse habitat

## Technical Assistance

- Devin Hoffer
- Adrianna Bessenaire



*MS graduate Karin Bothwell (right) and her advisors Dr. Mindy Crandall (left) and Amber Roth (center).*



# Financial Report

**Brian Roth**

**CFRU Acting Director**

Thirty-four members representing 8.14 million acres of Maine's forestland contributed \$467,353 to support the CFRU this year (Table 1). These member contributions will be used to support research activities during FY 2017-18. The amount of acreage represented by our Landowner/Manager members decreased by 52,074 acres (0.6%) which was largely due to the sale of **Simorg North Forests, LLC**. The new owners are actively being recruited to join the CFRU. Other notable changes included the sale of **Canopy Timberlands Maine, LLC** to the **Tall Timber Trust**. This property in extreme northern Maine is managed by LandVest, and they have chosen to join with the CFRU in support of their long-term view of sustainable forest management. We welcome Tall Timber Trust and look forward to having them as a member of the CFRU. Tons of wood products produced by Wood Processor members continued to decrease (289,200 tons or 13.5%) relative to last year. This was due to the loss of the **UPM Madison Mill**, which has closed. We continue to be concerned about the stability of membership in this class, however, **SAPPI Fine Paper** continues to be a strong partner. **ReEnergy Holdings, LLC** is experiencing some financial difficulties given competition from low fuel prices and changes in regulations in the marketplace. We appreciate that they were still willing to make a reduced contribution this year. Overall, CFRU member contributions are less than last year (a \$31,137 or 6.2% decrease) relative to FY 2015-16. While some of this decrease was due to the changes described above, the **Maine Bureau of Parks and Lands** contribution was not received due to lack of a signature by the Governor and is therefore not included in this report. We expect that this contribution will only be delayed and appreciate the continuing support the State of Maine provides for the CFRU. We thank all of our members for their continued financial and in-kind contributions, as well as the trust in the CFRU and the University of Maine that these contributions represent.

In addition to member financial contributions, CFRU Cooperating and Project Scientists were successful at leveraging an additional \$138,047 in extramural grants to support CFRU research projects. This amount does not include \$1,153,165 in leveraged funding for LiDAR acquisition from Federal and local sources and \$60,000 from the **National Science Foundation** as part of CFRU's membership in the national **Center for Advanced Forestry Systems (CAFS)**, which is supporting the Commercial Thinning Research Network and Growth & Yield modeling projects. These external grants made up 19% of CFRU total income this year (Figure 1). In addition to extramural sources, the University of Maine provided \$44,719 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 \$77,068. Therefore, the University of Maine provided an additional \$121,787 or 17% of total funding. In total, about 68% (\$690,997) of all CFRU funding came from external sources or from direct and indirect support from the University of Maine.

As a result, for every \$1 contributed on average by CFRU's five largest members (**Irving Woodlands, LLC**, **Wagner Forest Management, BBC Land, LLC**, **Weyerhaeuser Company**, and **Prentiss & Carlisle Company, Inc.**) this year, \$6.64 was received from other CFRU member contributions, \$2.55 was contributed by external grants through CFRU scientists, and \$2.25 was received from the University of Maine in direct and indirect contributions, for a **total leveraging of \$11.45 for every \$1 contributed by CFRU's largest members**.

Continued sound fiscal management by CFRU scientists and staff resulted in spending \$24,240 (4.9%) less than the \$493,674 that was approved by the Advisory Committee for this fiscal year (Table 2). All projects came in at or near budget; Dr. Anil Kizha. requested the surplus from his soil disturbance project be carried forward into FY17-18 to take advantage of the upcoming MASN harvest in Grand Falls Township.

CFRU research expenses by category this year included 40% on six silviculture and productivity projects, 33% on three growth and yield modeling projects, and 27% on two wildlife habitat projects (Figure 2).

**Table 1.** CFRU member contributions received FY 2016-17 (for allocation during FY 2017-18).

CFRU Member	FY15-16	FY16-17	Changes Acres/tons	Assessed Amount	Received as of 09/19/2016
<b>FOREST LANDOWNERS / MANAGERS:</b>					
Irving Woodlands, LLC	1,255,000 acres	1,255,000 acres	0	\$68,804	\$68,804
Wagner Forest Management	1,129,024 acres	1,031,451 acres	-97,573	\$57,448	\$57,448
BBC Land, LLC	973,230 acres	971,299 acres	-1,931	\$54,320	\$54,320
Plum Creek Timber Company, Inc.	865,000 acres	851,661 acres	-13,339	\$47,944	\$47,944
Prentiss and Carlisle Company, Inc.	778,166 acres	764,543 acres	-13,623	\$43,300	\$43,300
Seven Islands Land Company	746,791 acres	746,791 acres	0	\$42,354	\$42,354
Clayton Lake Woodlands Holding, LLC	464,178 acres	489,176 acres	24,998	\$28,568	\$28,568
Maine Bureau of Parks & Public Lands	407,000 acres	418,500 acres	11,500	\$24,440	\$24,440
Katahdin Forest Management, LLC	299,000 acres	299,000 acres	0	\$17,462	\$17,462
Canopy Timberlands Maine, LLC	294,179 acres	294,202 acres	23	\$17,181	\$17,181
The Nature Conservancy	158,723 acres	158,723 acres	0	\$9,269	\$9,269
Snowshoe Timberlands, LLC	137,720 acres	137,720 acres	0	\$8,043	\$8,043
Baskahegan Corporation	117,953 acres	117,853 acres	-100	\$6,883	\$6,883
Sylvan Timberlands, LLC	105,510 acres	105,510 acres	0	\$6,162	\$6,162
Sandy Gray Forest, LLC	0 acres	100,013 acres	100,013	\$5,841	\$5,841
North Woods Maine, LLC	83,409 acres	83,409 acres	0	\$4,871	\$1,834
The Forestland Group, LLC	70,525 acres	13,069 acres	-57,456	\$763	\$1,000
Appalachian Mountain Club	65,489 acres	69,534 acres	4,045	\$4,061	\$4,061
Simorg North Forests, LLC	61,643 acres	61,643 acres	0	\$3,600	\$3,600
Frontier Forest, LLC	53,338 acres	53,338 acres	0	\$3,115	\$3,115
Downeast Lakes Land Trust	33,808 acres	33,808 acres	0	\$1,974	\$1,974
EMC Holdings, LLC	31,689 acres	40,406 acres	8,717	\$2,360	\$2,360
Baxter State Park, SFMA	29,537 acres	29,537 acres	0	\$1,725	\$1,725
Robbins Lumber Company	26,786 acres	26,786 acres	0	\$1,564	\$1,564
Timbervest, LLC	25,191 acres	0 acres	-25,191	\$0	\$0
St. John Timber, LLC	24,617 acres	24,617 acres	0	\$1,438	\$1,438
Mosquito, LLC	16,222 acres	16,222 acres	0	\$947	\$1,000
New England Forestry Foundation	2,852 acres	2,852 acres	0	\$1,000	\$1,000
<b>TOTAL</b>	<b>8,256,580 acres</b>	<b>8,196,663 acres</b>	<b>-59,917</b>	<b>\$465,437</b>	<b>\$462,690</b>
<b>WOOD PROCESSORS:</b>					
SAPPI Fine Paper	1,850,400 tons	1,850,400 tons	0	\$23,500	\$23,500
UPM Madison Paper	336,000 tons	289,200 tons	-46,800	\$3,673	\$0
<b>TOTAL</b>	<b>2,186,400 tons</b>	<b>2,139,600 tons</b>	<b>-46,800</b>	<b>\$27,173</b>	<b>\$23,500</b>
<b>CORPORATE and INDIVIDUAL MEMBERS:</b>					
ReEnergy Holdings, LLC	1 static	1 static		\$5,000	\$5,000
James W. Sewall Company	1 static	1 static		\$5,000	\$5,000
Huber Engineered Woods, LLC	1 static	1 static		\$1,000	\$1,000
Forest Society of Maine	1 static	1 static		\$1,000	\$1,000
LandVest	1 static	1 static		\$200	\$200
Field Timberlands	1 static	1 static		\$100	\$100
<b>TOTAL</b>				<b>\$12,300</b>	<b>\$12,300</b>
<b>GRAND TOTAL (34 members):</b>				<b>\$504,910</b>	<b>\$498,490</b>



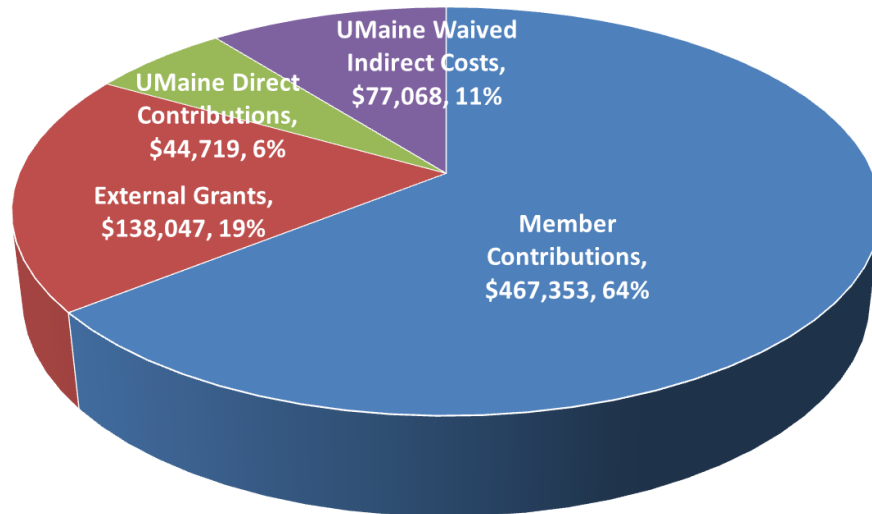
**Table 2.** CFRU expenses incurred during FY 2016-17.

PROJECT	Principal Investigator	Approved Amount	Amount Spent To-Date	Balance Remaining	% Balance Remaining
<b>Total Administration</b>		\$197,358.00	\$191,316.08	\$15,591.92	7.9%
Administration***	Roth	\$197,358.00	\$191,316.08	\$15,591.92	7.9%
<b>Research Projects</b>					
<b>Silviculture and Productivity:</b>		\$121,104.04	\$115,837.63	\$5,266.41	4.3%
Strategies for rehabilitating beech-dominated stands	Roth	\$22,000.00	\$22,201.09	-\$201.09	-0.9%
Long-term Impacts of Whole Tree Harvesting: Weymouth Point Study	Smith/Roth	\$18,150.00	\$15,551.35	\$2,598.65	14.3%
A Decision Support System for Selecting Efficient Harvesting Systems	Kizha	\$15,815.00	\$15,777.50	\$37.50	0.2%
Maine's Adaptive Silviculture Experimental Network (MASEN)	Roth	\$32,094.00	\$31,847.62	\$246.38	0.8%
Eval Timber Harvest Op on Soil *	Kizha	\$18,370.04	\$15,785.07	\$2,584.97	14.1%
Harvest Costs and Economic Benefits of PCT: Austin Pond Case Study	Hiesl/Crandall	\$14,675.00	\$14,675.00	\$0.00	0.0%
<b>Growth &amp; Yield Modeling</b>		\$94,548.00	\$95,307.21	-\$759.21	-0.8%
Maine Statewide Light Detection and Ranging (LiDAR) Data Acquisition Project **	Roth	\$36,600.00	\$36,600.00	\$0.00	0.0%
Identifying relationships between spruce budworm larval density, moth abundance, and forest conditions at the onset of an outbreak	Simons-Legaard & Legaard	\$35,200.00	\$35,642.04	-\$442.04	-1.3%
Development an application of early detection and monitoring of SBW defoliation using remote sensing	Rahimzadeh	\$22,748.00	\$23,065.17	-\$317.17	-1.4%
<b>Wildlife Habitat:</b>		\$80,664.00	\$76,523.00	\$4,141.00	5.1%
Populations Dynamics Spruce Grouse	Harrison	\$29,954.00	\$29,792.10	\$161.90	0.5%
Landscape-level Evaluation of Deer Wintering Habitat in Northern Maine	Crandall	\$50,710.00	\$46,730.90	\$3,979.10	7.8%
<b>Total</b>		<b>\$493,674.04</b>	<b>\$478,983.92</b>	<b>\$24,240.12</b>	<b>4.9%</b>

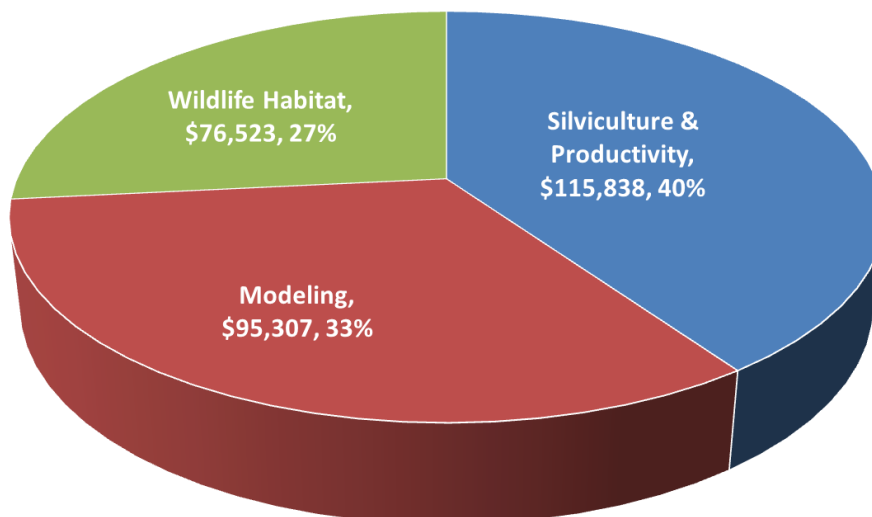
\* Kizha requested these funds to be available early to take advantage of MASEN harvest. Remainder to roll over to FY17-18.

\*\* LiDAR Acquisition: \$50,000 over 5 years. FY16-17 \$36,600 spent. FY17-18 remaining \$13,400 proposed.

\*\*\* Approved amount does not include \$9,550 in revenue earned from the Forest Pest Management Course held in the Spring of 2017



**Figure 1.** CFRU income sources FY 2016-17.



**Figure 2.** CFRU research expenses FY 2016-17.

# Activities

## 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. Due to the retirement of **Eric Dumond (ReEnergy Holdings, LLC)** and his resignation as Chairperson in the fall of 2016, the current executive is in the second year of a three year term. **Gordon Gamble (Wagner Forest Management)** is Chairperson, the Vice Chairperson is **Ian Prior (Seven Islands Land Company)**, **Greg Adams (Irving Woodlands, LLC)** is the Financial Officer and **Kenny Fergusson (Huber Resources)** is the Member-at-Large. The Advisory Committee will hold an election in the fall of 2019 to select the incoming Vice Chairperson and Member-at-Large.

The Advisory Committee meets three times a year for business meetings. The first business meeting of FY 2016-17 was held on October 19, 2016 at the Buchanan Alumni House at the University of Maine in Orono, ME, following which **Dr. Robert Wagner** named **Dr. Brian Roth** the **Acting Director** of the **CFRU** and named **Dr. Aaron Weiskittel** the **Acting Director** of the **Center for Research on Sustainable Forests (CRSF)**. At the second meeting, held on January 25, 2017 at the Wells Conference Center at the University of Maine, sixteen pre-proposals were presented to the Advisory Committee. Of these, eleven were approved to advance to the full proposal stage and were presented at the April 12<sup>th</sup> Advisory Committee meeting. Eight projects were approved for funding to begin on October 1, 2017. Look for updates on these projects in future CFRU presentations, publications, and annual reports.

## Cooperators

CFRU membership decreased slightly in 2016-17 which resulted in a minor loss in acres managed (Table 1). Canopy Timberlands Maine, LLC, Simorg North Forests, LLC, and Timbervest, LLC left the CFRU, as did UPM Madison Paper. Plum Creek Timber Company merged with Weyerhaeuser Company in 2016; they continue to belong to the CFRU. Thom Dodd with Acadia Forestry has since joined the cooperative; welcome to the CFRU, Thom!

## Personnel

Drs. **Arun Bose** and **Christian Kuehne** continue work on CFRU projects as postdoctoral scholars through the support of the **Center for Advanced Forest Systems (CAFS)**. Dr. Bose is working on forest regeneration patterns while Dr. Kuehne is using the CTRN dataset to develop thinning modifiers for existing growth and yield models. **Cindy Smith** continues to do a fantastic job with CFRU administration duties. With the retirement of CFRU Director, **Dr. Bob Wagner** in July of 2016, **Dr. Brian Roth** assumed leadership duties as the Acting Director. Brian reports to **Dr. Aaron Weiskittel**, who serves as the **Acting Director** of the **Center for Research on Sustainable Forests (CRSF)**. The CFRU Executive Committee has made a recommendation to the **University of Maine Interim Vice President for Research (VPR)**, **Dr.**



**Carol Kim**, that these appointments become permanent. This decision is delayed by a pending review of the CRSF by the VPR's office.

## Students

The CFRU continues to contribute to the development of students, with three graduate students completing degrees funded by CFRU projects this year. **Karin Bothwell** has completed her MS degree, studying economic and spatial impacts of wildlife habitat policy with a focus on deer wintering area; she was co-advised by **Drs. Mindy Crandall** and **Amber Roth**. **Mark Castle** completed his MS degree on hardwood stem form, growth and yield; he was advised by **Dr. Aaron Weiskittel**. **Anil Koirala** has completed his MS degree, determining opportunities and challenges of the forest products trucking industry; he was advised by **Dr. Anil Kizha**. We wish Karin, Mark and Anil all the best in their new endeavors following graduate school.

There are currently two graduate students working on CFRU funded projects: **Joel Tebbenkamp** (Ph.D., Spruce Grouse) is co-advised by Drs. **Erik Blomberg** and **Dan Harrison**, and **Christopher Preece** (MFC, Weymouth Point) is advised by Dr. Tat Smith of the University of Toronto.

In addition, almost a dozen undergraduate students were hired as research technicians for CFRU projects during the summer of 2017.

## Forest Vegetation Management Course

From February 27 through March 2, 2017, the CFRU partnered with the Maritime College of Forest Technology to host a short course in Orono, Maine on herbicide application and risk management. This course included presentations and lectures from a variety of experts in the field. There were 21 participants from across Maine, Vermont, Massachusetts, New Hampshire, New Brunswick, and Nova Scotia. This course was worth 24 Category 1 credits from the Society of American Foresters and 25 pesticide-licensing credits from the state of Maine.



*Course attendees learn about herbicide effects on wildlife habitat.  
Photo: B. Roth*





# Center for Advanced Forestry Systems (CAFS)

## Aaron Weiskittel

The Center for Advanced Forestry Systems (CAFS) is funded by the National Science Foundation (NSF) Industry/University Cooperative Research Centers Program (I/UCRC) in partnership with CFRU members. The Maine CAFS site is currently in year 4 of 5 for Phase II of I/UCRC funding. In Phase II, NSF will provide \$60,000 per year for 5 years if CFRU members contribute a minimum of \$350,000 per year. Phase I of CAFS contributed \$70,000 per year to the University of Maine since CFRU members contributed a minimum of \$300,000 per year to support the work of the site. The intent of NSF in later phases is to reduce the amount of support, while increasing the amount of industry contributions in an effort to 'graduate' the Center as self-sustaining. There is the potential for a final 5-year Phase III similar in funding to Phase II, which will require continual CFRU membership contributions and a new proposal to National Science Foundation that is due in the late fall of 2018.

CAFS unites nine university forest research programs with forest industry members across the US to collaborate on solving complex, industry-wide problems at multiple scales. The mission of CAFS is "to optimize genetic and cultural systems to produce high quality raw forest materials for new and existing products by conducting collaborative research that transcends species, regions, and disciplinary boundaries". CAFS is a multi-university center that works to solve forestry problems using multi-faceted approaches and questions at multiple scales, including molecular, cellular, individual-tree, stand, and ecosystem levels. Collaboration among scientists with expertise in biological sciences (biotechnology, genomics, ecology, physiology, and soils) and management (silviculture, bioinformatics, modeling, remote sensing, and spatial analysis) is at the core of CAFS research efforts.

In September 2018, four of the original CAFS universities (North Carolina State University, Oregon State University, Purdue, and Virginia Tech) will graduate as they decided not to pursue a Phase III. This leaves University of Maine, Auburn University, University of Washington, University of Georgia, and University of Idaho as the five remaining sites. Since CAFS requires a lead institution and North Carolina State University had served this role for the last 10 years, the University of Maine has volunteered to serve as the lead institution and host the eleventh annual CAFS Industrial Advisory Board (IAB), which will be in Burlington Vermont on June 12-13, 2018.

The University of Maine currently has two funded CAFS projects (16.65 and 17.70). CAFS project 16.65 was a two-year NSF Fundamental Research Project and a partnership with Virginia Tech and the University of Washington aimed at understanding and modeling competition effects on tree growth and stand development across varying forest types and management intensities. As part of this project, CAFS post-doc Arun Bose analyzed long-term results from Douglas-fir, loblolly pine, and spruce-fir thinning trials. The analysis suggested that the stand-level relative volume growth was generally increased, but depended heavily on time since treatment, particularly for spruce-fir. The cumulative volume growth was generally higher in unthinned stands across all three forest types. The results were published in

volume 409 of *Forest Ecology and Management*. CAFS project 17.70, The Rise of Commercially Less Desirable Species in Maine: Identification, Characterization, and Associated Driving Factors, was also led by CAFS post-doc Arun Bose. This analysis examined long-term trends in both occurrence and abundance for yellow/paper birch, red/sugar maple, and American beech. Occurrence and abundance of American beech have increased substantially over the past three decades, whereas the occurrence and abundance of the other deciduous species have decreased. However, these changes in beech occurrence and abundance were not as drastic in Maine as they were in New Hampshire, New York, and Vermont. Regardless, the distribution of increased occurrence and abundance of beech relative to the other deciduous species were associated with higher temperature and precipitation, which suggests that this trend may continue occur into the future.

CFRU staff and several Advisory Committee members represented the Maine CAFS site at the Tenth Annual CAFS IAB Meeting held May 2-4, 2017 in Portland, Oregon. The meeting was well attended by scientists, graduate students, and forest industry representatives who met to review and approve all CAFS projects nationwide as well as beginning discussions about entering Phase III of the program. The CFRU will stay involved in the collaboration between the NSF I/UCRC through CAFS and the CRSF as long as there is value for the effort.







# Research Project Reports

*Photo: P. Wells/Oakleafs Studios*



The background of the slide is a photograph of a forest. The upper portion shows tall, thin trees with green foliage against a bright sky. The lower portion shows a forest floor covered in brown pine needles and some green evergreen branches. A white rectangular box with a thin black border is centered in the upper half of the image, containing the title and a list of bullet points.

## **Silviculture & Productivity**

- **Harvest Costs and Economic Benefits of Pre-Commercial Thinning in Spruce-Fir Stands: The Austin Pond Case Study**
- **Maine's Adaptive Silviculture Network (MASN)**
- **Developing Management Guidelines for the Forest Products Trucking Industry in Maine**
- **Long-term Impacts of Whole Tree Harvesting: Weymouth Point Study**
- **Strategies for Rehabilitating Beech-Dominated Stands**

*Photo: R. Wischart*



# Harvest Costs and Long-Term Economic Benefits of Pre-Commercial Thinning in Spruce-Fir Stands: The Austin Pond Case Study

Patrick Hiesl<sup>1</sup>, Mindy S. Crandall<sup>2</sup>

<sup>1</sup>*Paul Smith's College*

<sup>2</sup>*University of Maine*

**Status: Final Report**



*PCT in Austin Pond in 2014. Photo: P. Hiesl.*

## Summary:

Available information on the long-term economic impact of pre-commercial thinning (PCT) in spruce-fir stands is limited. At the Austin Pond study site, a spruce-fir stand that was partially treated with PCT allowed for long-term projections of stand growth and net present value (NPV). These projections indicated that PCT reduced the time to economic maturity by 11 years but also increased maximum NPV by approximately \$1,500/ha. In addition, PCT more than doubled the average stem size. Compared to the control, commercial thinning (CT) reduced maximum NPV by approximately \$200/ha for every 10% of basal area removal. However, CT also increased the average stem size. A separate analysis of Commercial Thinning Research Network (CTRN) data from unthinned locations further indicated that thinning from below returned the highest NPV compared to dominant and crown thinning, and doubled the average stem size compared to the control.

## Project Objectives:

- Determine the economic impact of PCT using thinned and unthinned plot data from the Austin Pond site.
- Determine the impact of the choice of harvesting system on NPV in combination with PCT at the Austin Pond site.
- Determine the economic differences between thinning methods using CTRN data from previously unthinned sites.

## Approach:

- Plot-level data measured in 2014 and 2015 from the Austin Pond site (Newton, Cole, White, *et al.* 1992; Newton, Cole, McCormack, *et al.* 1992; Hiesl *et al.* 2015) were projected forward for an additional 30 years using the Acadian variant of the Forest Vegetation Simulator (FVS). Cut-to-length and whole-tree harvest costs and revenues were estimated using regional cycle time equations, machine rates, and product values. NPV's were calculated for all basal area removal intensities. Linear mixed-effects models were developed to quantify the impact of basal area removal on maximum NPV, timing of maximum NPV, and average stem size.
- Plot-level data measured in 2011 from six previously unthinned CTRN sites (Saint Aurelie, Golden Road, Harlow Road, Rump Road, Sarah Road, Schoolbus Road; Wagner *et al.* 2001) were projected forward for an additional 30 years using the Acadian variant of the Forest Vegetation Simulator (FVS; Weiskittel *et al.* 2017; Weiskittel *et al.* 2015). Cut-to-length harvest costs and revenues were estimated using regional cycle time equations, machine rates, and product values (e.g., Hiesl *et al.* 2015; Hiesl and Benjamin 2013). NPVs were calculated for three thinning methods (low, dominant, and crown). Linear mixed-effect models were developed to determine the impact of thinning method on maximum NPV, timing of maximum NPV, and average stem size.

## Key Findings/Accomplishments:

- At the Austin Pond site, results indicated that PCT reduced the time to economic maturity by 11 years (PCT = 54 years; no PCT, or NPCT = 65 years). Basal area removal was not a significant factor in influencing stand age at time of economic maturity (Figure 3).
- PCT increased the maximum NPV by approximately \$1,500 USD ha<sup>-1</sup> compared to untreated plots (Eqn. 1; Figure 4). Maximum NPV decreased by approximately \$200 USD ha<sup>-1</sup> for every 10% of basal area removal compared to the control.

$$\text{Maximum NPV } (\$ \cdot \text{ha}^{-1}) = 5,287 + 1,479 \times PCT - 20.7 \times BArem \quad (\text{Eqn. 1})$$

where *PCT* is a dummy variable with the value of 1 for PCT-treated plots and the value of 0 for untreated plots. *BArem* is the basal area removal in percent.  $R^2$  was 0.36.

- PCT more than doubled the average stem size compared to untreated plots (Eqn. 2; Figure 5). Average stem size also increased with increasing basal area removal.

$$\text{Average Stem Size } (m^3) = 0.151 + 0.219 \times PCT + 0.005 \times BArem \quad (\text{Eqn. 2})$$

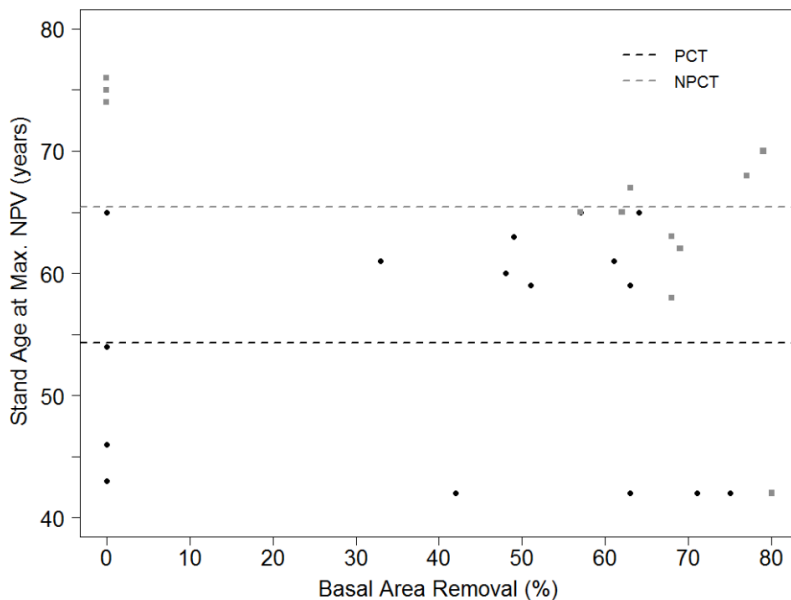
where *PCT* is a dummy variable with the value of 1 for PCT-treated plots and the value of 0 for untreated plots. *BArem* is the basal area removal in percent.  $R^2$  was 0.73.

- When comparing the maximum NPV achieved using a whole-tree (WT) and cut-to-length (CTL) harvesting systems, the results indicated that a CTL system increased maximum NPV by approximately \$2,000 USD ha<sup>-1</sup> (Eqn. 3). Control plots were not included in this particular analysis due to gross overestimation of feller-buncher time consumption in these plots.

$$\text{Maximum NPV (\$} \cdot \text{ha}^{-1}) = 2,161 + 1,090 \times PCT + 2,016 \times SYS \quad (\text{Eqn. 3})$$

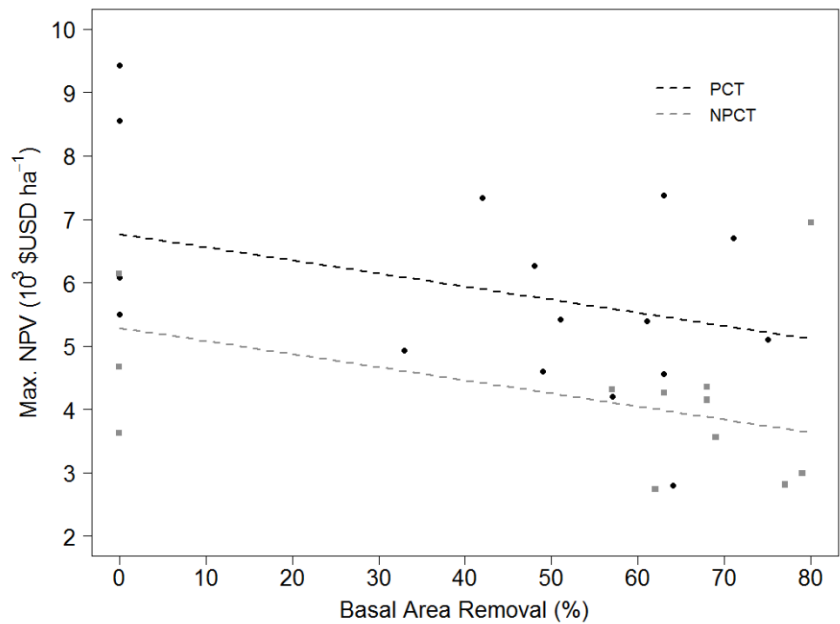
where *PCT* is a dummy variable with the value of 1 for PCT treated plots, and the value of 0 for untreated plots. *SYS* is a dummy variable for the type of harvesting system with a value of 1 for CTL and a value of 0 for WT. *R*<sup>2</sup> was 0.59.

In previously unthinned spruce-fir stands belonging to the CTRN network, thinning from below returned the highest NPV of all three thinning methods tested (Figure 6). However, NPV of the control was highest. Thinning from below increased the average stem size the most and doubled the average stem size compared to the control.

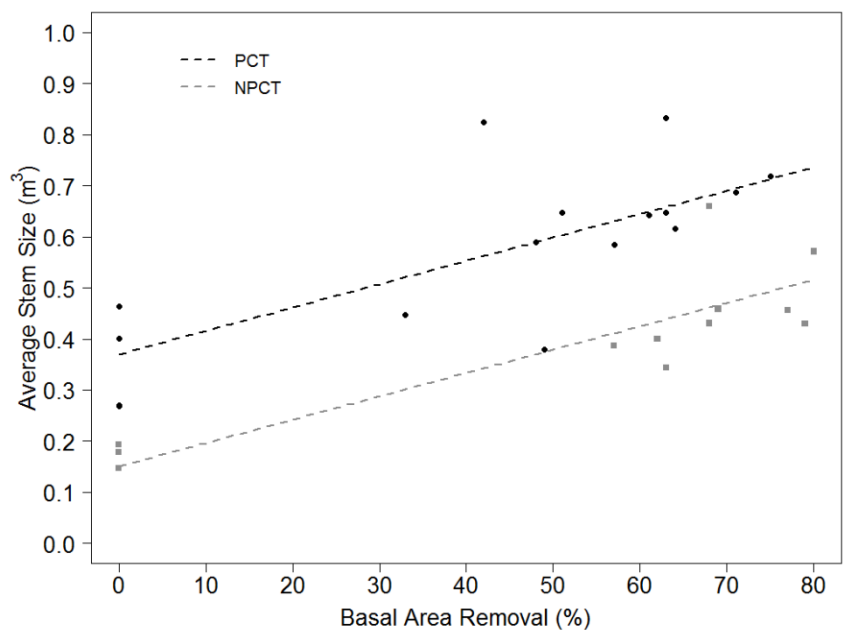


**Figure 3:** Scatterplot of stand age at maximum NPV (economic maturity) over basal area removal from multiple measurement plots at the Austin Pond site. Dashed lines represent the average stand age at economic maturity. Basal area removal was not a significant predictor for estimating stand age (PCT: plots that previously received a PCT treatment. NPCT: plots that did not receive a PCT treatment in the past).

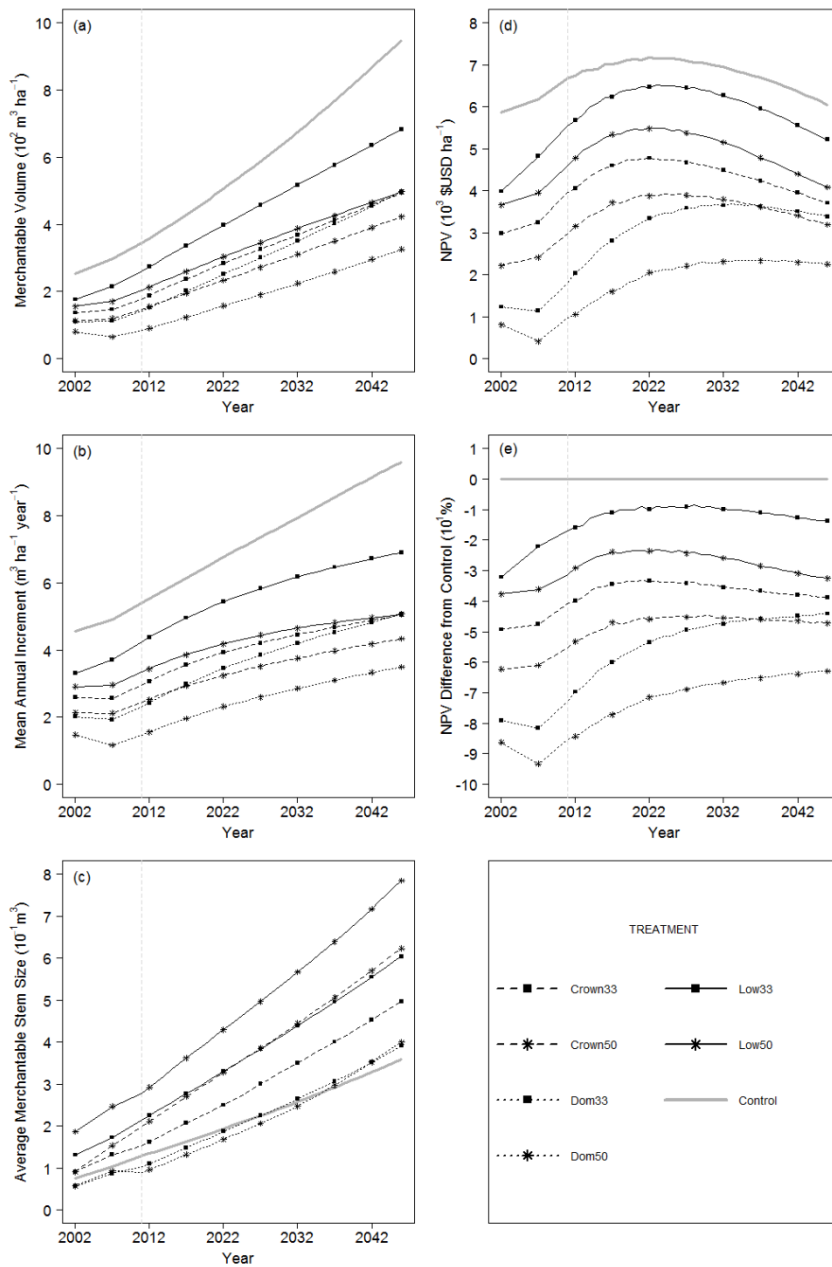
**Figure 4:** Scatterplot of maximum NPV over basal area removal from multiple measurement plots at the Austin Pond site. Dashed lines represent the average maximum NPV for the different basal area removal intensities (PCT: plots that previously received a PCT treatment. NPCT: plots that did not receive a PCT treatment in the past).



**Figure 5:** Scatterplot of average stem size over basal area removal from multiple measurements at the Austin Pond site. Dashed lines represent the average stem size for the different basal area removal intensities (PCT: plots that previously received a PCT treatment. NPCT: plots that did not receive a PCT treatment in the past).







**Figure 6:** Average projection results (30 years) across the various treatments for previously unthinned sites in the CTRN: merchantable volume (a); mean annual increment (b); average merchantable stem size (c); net present value (NPV) (d); and percent difference in NPV from control (e).

## Future Plans:

- Results indicated that PCT provides some benefits at the Austin Pond site. A future analysis could include data from all of the CTRN measurement plots (both PCT and no PCT, or NPCT), to conduct a more comprehensive analysis of the benefits of PCT while also incorporating more site specific variables such as biomass growth index, depth to water table, and QMD ratio. Stand growth projections for most measurement plots have been completed.
- Results indicated that the CTL system yields a higher maximum NPV than a WT system. This raises the question of whether the forest industry is using the right equipment for softwood stands. Alternatively, this finding could be the result of an undocumented limitation to the WT cycle time equations in small-diameter stands, with WT equations possibly over-predicting time required to harvest small-diameter trees (<5 cm DBH). A more extensive cycle time and productivity study with CTL equipment in small diameter softwood stands could help to confirm findings of this study.
- The data analysis has shown that there is a limitation of the feller-buncher cycle time model in control plots. These plots generally consist of a large number of trees of less than 5 inches in diameter. A cycle time study on feller-bunchers operating in stands of such a characteristic could take place to refine and update the existing feller-buncher cycle time model.

## References:

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Weiskittel, A. R., C. R. Hennigar, and J. A. Kershaw. 2015. Extending the Acadian variant of FVS to managed stands. In R. G. Wagner, ed. Cooperative Forestry Research Unit 2014 Annual Report. Orono, ME, USA: University of Maine: 47–51.

## Acknowledgements

We would like to thank the Cooperative Forestry Research Unit for funding this project and making long-term data available. We also acknowledge Clemson University for generous allotment of computing time on the Palmetto cluster.



*PCT plot after thinning with a harvester. Photo: P. Hiesl*

# Maine's Adaptive Silviculture Network (MASN)

Brian Roth<sup>1</sup>, Aaron Weiskittel<sup>2</sup>, Anil Raj Kizha.<sup>2</sup>, and Amber Roth<sup>2</sup>

<sup>1</sup>*Cooperative Forestry Research Unit*

<sup>2</sup>*University of Maine*

**Status: Progress Report, Year 1**



*Treatment layout at installation in Grand Falls Township on land owned by BBC Land, LLC.. Image: B. Roth.*

## Summary:

CFRU members embarked on an ambitious new study series in 2017: Maine's Adaptive Silviculture Network. Considerable value has been realized from earlier CFRU long-term study areas such as the Weymouth Point Study (1981-), the Austin Pond Study (1978-), and the Commercial Thinning Research Network (2001), and these studies continue to provide useful data. However, these studies have limitations for various reasons: 1) little to no replication across the landscape, 2) small treatment areas, 3) lack of operational treatments, 4) limited range of treatments, and 5) focus on softwood stand types. The MASN study will be the backbone for new research in the areas of growth and yield, wildlife habitat, harvest productivity, regeneration dynamics, remote sensing of inventory, forest health, and many more.

## Project Objectives:

- Establish a network of operational research installations across Maine representing low, medium and high site productivities across hardwood, mixedwood, and softwood stand types (Table 3).
- Encourage researchers to make use of these outdoor field laboratories for researching problems applicable to CFRU members.

**Table 3.** Matrix of forest types and site productivities in MASN.

	STAND TYPE		
SITE QUALITY*	SOFTWOOD	MIXEDWOOD	HARDWOOD
High (BGI > 4000)	2 installations	2 installations	2 installations
Medium (BGI = 2500 - 4000)	2 installations	2 installations	2 installations
Low (BGI <2500)	2 installations	2 installations	2 installations

Note: BGI is Biomass Growth Index (kg/ha/yr).



## Approach:

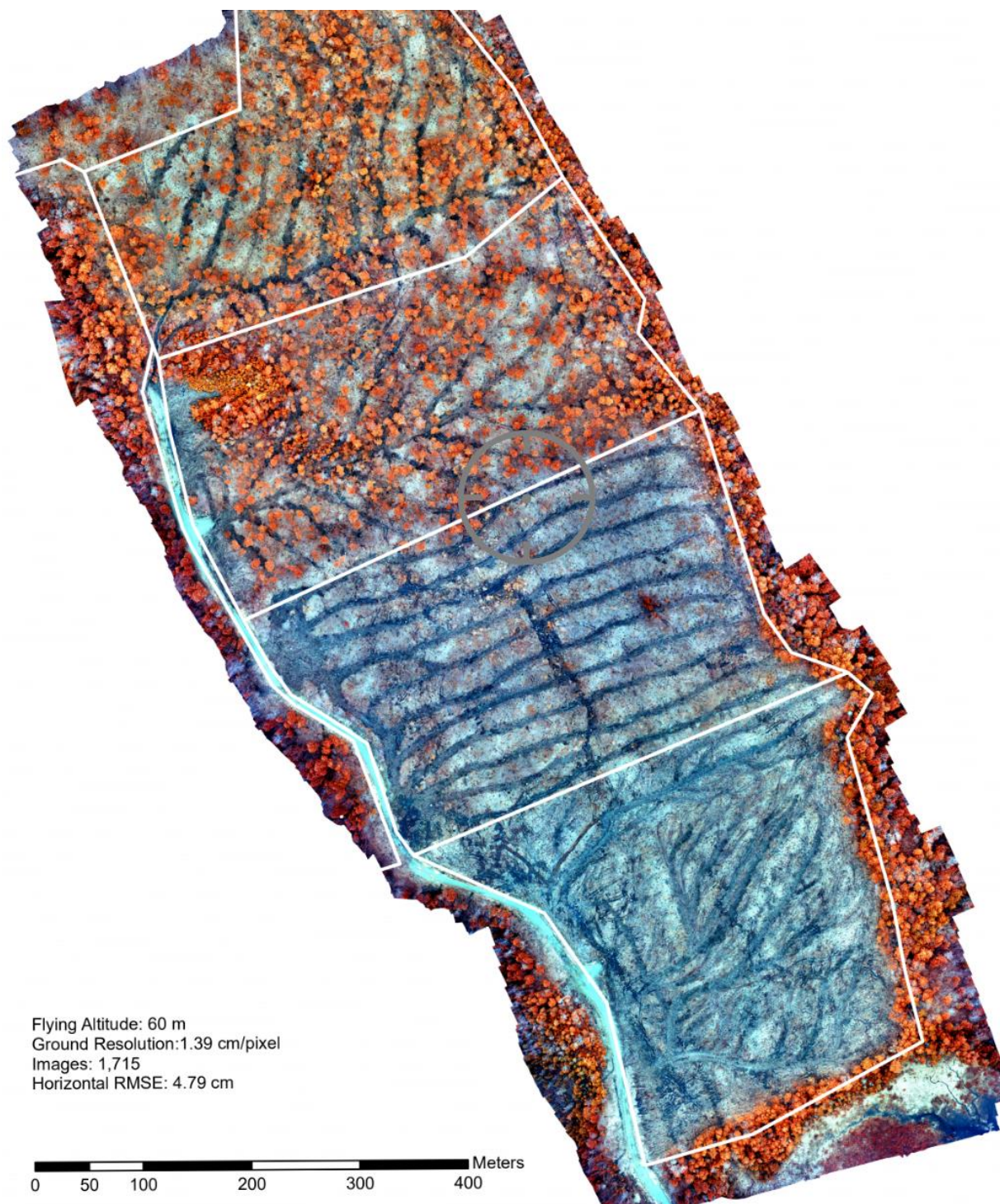
- Working with regional forest managers, identify potential areas with uniform soils, drainage class, topography, stand type and recent harvest history.
- For each installation, delineate four to seven treatment blocks and randomly assign and implement various operational silvicultural treatments representing the full range of operational harvest conditions found in Maine (e.g., clearcut, overstory removal, crop tree release, first and second entry thinning). A delayed harvest control block will be included.
- Across a grid of permanent sample points on each installation, collect baseline pre- and post-harvest data, including overstory and understory vegetation inventories, forest bird surveys, tree damage assessments, 360 degree photography, high resolution aerial imagery, and more.

## Key Findings/Accomplishments:

- Three mixedwood locations were identified for the first installations: Grand Falls TWP (BBC Land, LLC), T16 R8 (Irving Woodlands, LLC), and T13 R15 (Seven Islands Land Co.).
- The Grand Falls TWP installation, a mixedwood site (hardwood and softwood) dominated by Eastern hemlock and yellow birch, was harvested in July/August of 2017 by SF Madden Logging of Greenbush, Maine. The stand was most likely harvested last by a conventional logging system (chainsaw and cable skidder) in the early 1980s during the last spruce budworm outbreak in Maine.
- Four treatments were installed at Grand Falls TWP in addition to the delayed harvest control, each approximately 25 acres in size: clearcut (2,080 tons from 27 acres), overstory removal (2,109 tons from 28 acres), diameter limit (1,269 tons from 25 acres) and crop tree release (1,137 tons from 26 acres; Figure 7).
- A field tour with the national Council on Forest Engineering (COFE) was held on the Grand Falls MASN site on August 1, 2017 with over 60 research scientists and students from around North America in attendance (Figure 8).

## Future Plans:

- In 2018, we will continue with site selection according to the matrix in Table 3. We expect to select another four or five locations.
- Harvesting will continue with completion expected on the remaining two sites selected this year.
- We intend to partner with the Forest Watershed Centre at the University of New Brunswick to produce high resolution wet areas maps for these installations.
- We will continue hosting field tours and recruiting for research projects on these sites.



**Figure 7.** High resolution near-infrared mosaic digital orthoimage from the Grand Falls TWP MASN installation following harvesting. Orange colors are softwood trees while dark blue are wet exposed soils. Photo courtesy of the Barbara Wheatland Geospatial Lab at the University of Maine.





**Figure 8.** Dr. Anil Kizha. (School of Forest Resources, University of Maine) and Allen LeBrun (American Forest Management) describe the harvest operation at the Grand Falls TWP MASN installation on August 1<sup>st</sup>, 2017 for field tour attendees from the National Council on Forest engineering (COFE).

## Acknowledgements:

We would like to thank Madden Logging, American Forest Management, Seven Islands Land Company, and Irving Woodlands, LLC for collaborating with us on this initiative.

# Developing Management Guidelines for the Forest Products Trucking Industry in Maine

Anil Raj Kizha.<sup>1</sup>, Brian Roth<sup>2</sup>, Anil Koirala<sup>1</sup>

<sup>1</sup>*University of Maine*

<sup>2</sup>*Cooperative Forestry Research Unit*

**Status: Final Report**



*Photo: A. Kizha.*

## Summary:

Secondary forest products transportation is one of the major components in timber harvesting operations in terms of economics, public visibility, and safety. This study was designed to document the challenges and opportunities within the trucking industry for the state of Maine and develop management guidelines. An extensive scientific literature was carried out, in which a total of 131 scientific articles published from 2000 to 2015 were collected and categorized into six different research themes. This helped in better understanding the current trends and advances in the field. A cross sectional survey was conducted in a conference setting to document and rank the major challenges. The survey yielded a 31% response rate, and the major challenge for the state was determined to be the availability of market and lack of skilled labor. For developing a management guideline with validated resolutions for the trucking-related problems, a qualitative case study method with semi-structured interviews was implemented. The primary intention was to understand the perspectives of stakeholders on field level solutions.

## Project Objectives:

- **Objective 1:** Document and evaluate the problems associated with the forest trucking sector of Maine.
- **Objective 2:** Validate potential solutions, obtained through literature, with the stakeholders in the state.
- **Objective 3:** Explore field level solutions that are tailored for the state of Maine

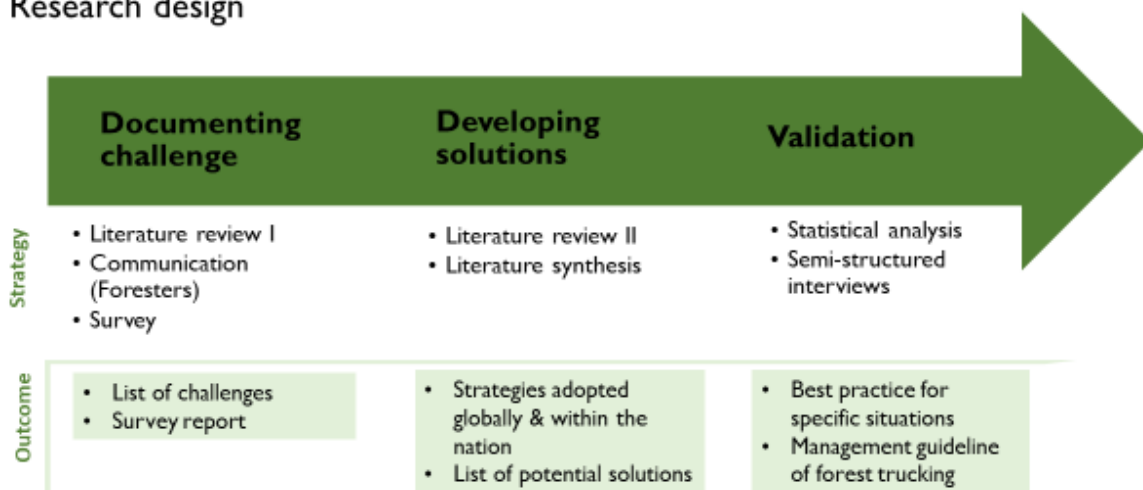
## Approach:

- **Objective 1: Literature Collection and Synthesis.** One-hundred and thirty-one articles from peer-reviewed journals and trade magazines were obtained for this synthesis.



- **Objective 2: Cross-Sectional Survey.** This survey was conducted at a regional forest engineering conference. Twenty-two questions (including 15 major questions and 7 sub-questions) were asked. Surveys took about 10 to 13 minutes, and asked mostly closed-ended questions, though some open-ended questions were asked as well. The major focus of this survey was challenges that face the forest products transportation industry.
- **Objective 3: Qualitative Case Study.** Participants for this case study, consisting of semi-structured interviews, were selected through snowball sampling and had to meet certain criteria. During this interview, 50 questions were asked, including 13 major open-ended questions, and an average of four probing questions were asked. Thirteen semi-structured interviews were performed, which took an average of 51 minutes; these interviews were transcribed verbatim. Responses were classified based on themes.

## Research design



**Figure 9.** Flow chart for the methodology used to accomplish the objectives of this study.



*Photo: A. Kizha.*

## Key Findings/Accomplishments:

### Objective 1:

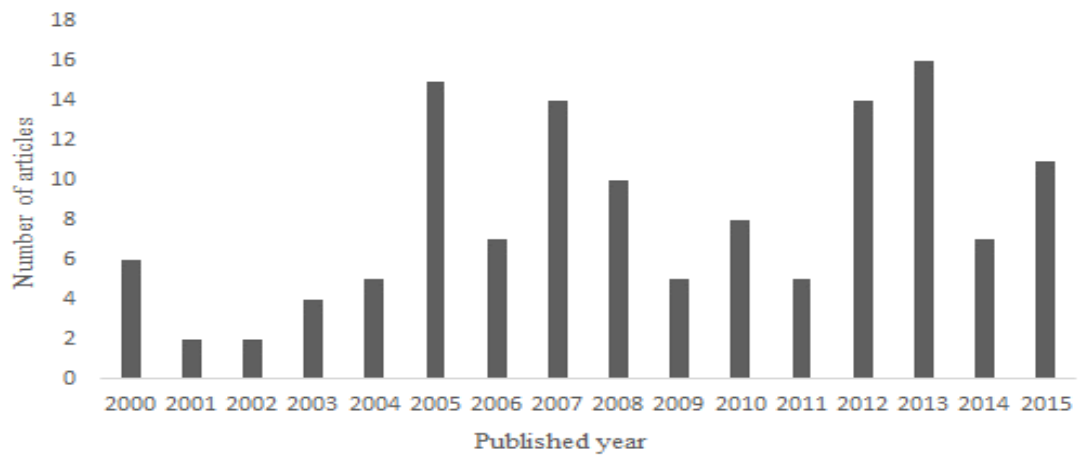
- 131 peer-reviewed articles relating to forest products transportation from 2000 through 2015 were found (Table 4). Most of these were from Europe, and then North America (Table 5). The bulk of these articles were written from 2005 onwards; more articles per year were found after this time (Figure 10).
- The two major research themes that emerged from the literature were 'roads and route planning' and 'supply chain and optimizations' (Figure 11).

**Table 4.** Peer-reviewed journals that published articles related to transportation from 2000-15.

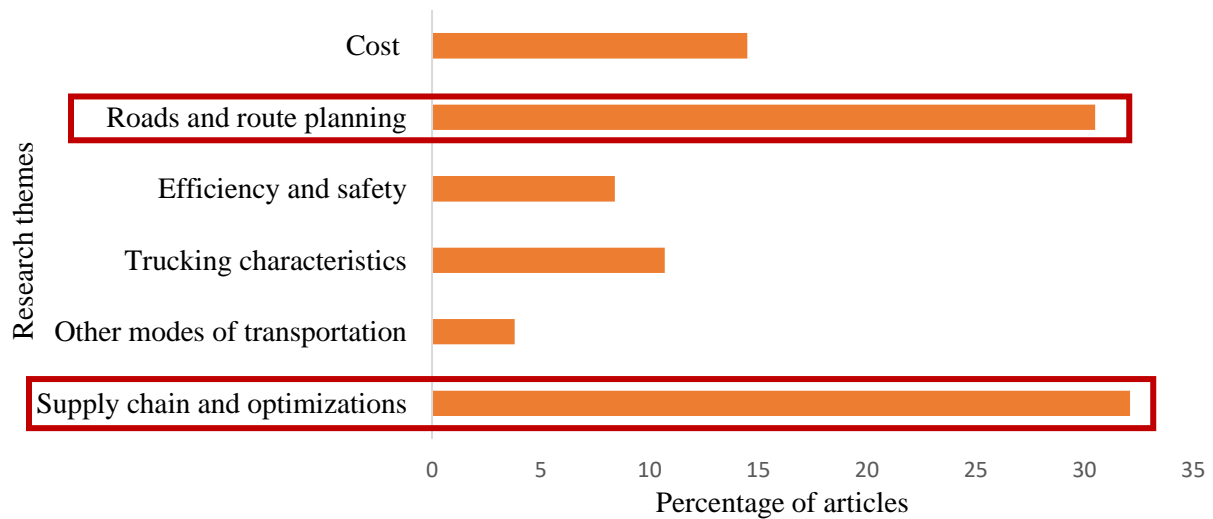
Journals	Number of publication
Biomass and Bioenergy	29
Croatian Journal of Forest Engineering	26
International Journal of Forest Engineering (Journal of Forest Engineering before 2001)	25
Renewable and Sustainable Energy Reviews	10
European Journal of Operational Research	3
Forest Policy and Economics	3
Transportation Research: Part A	2
European Journal of Forest Research	2
Canadian Journal of Forest Research	2
Journal of Cleaner Production	2
Western Journal of Applied Forestry	2
European Journal of Forest Engineering	2
Others (Journals with single publication)	23
Total	131

**Table 5.** Geographic distribution of studies reviewed. Articles are categorized based on the study area of the study. First author primary address was used for articles without clear indication of study area.

Region	Number of articles
Europe	73 (55.72%)
North America	43 (32.82%)
Asia	8
Australia & New Zealand	3
Africa	2
South America	2



**Figure 10.** Publication frequency of the articles related to transportation from 2000-15.



**Figure 11.** Distribution of articles according to research themes.

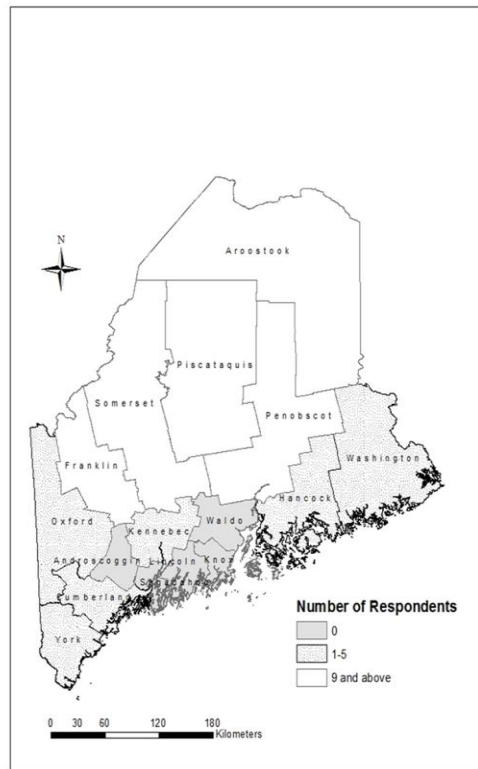
## Objective 2:

- In total, 285 questionnaires were distributed at the regional forest engineering conference, and 89 responses were received (31.2% response rate).
- Most respondents were affiliated with a company, and most dealt primarily with sawlogs and specialty lumber. Respondents had been working in the industry for 22 years on average (Table 6). Eleven of Maine's 16 counties were represented in the survey, with most respondents coming from northern Maine (Figure 12).
- Respondent estimates of distance traveled by a single truck ranges from 3.5 to 322 kilometers, with greatest distances reported for transporting sawlogs and pulpwood (Table 7).
- The three major problems reported by respondents include location/availability of markets, lack of skilled drivers and operators, and conditions of roads (Figure 13).
- Respondents provided recommendations for minimizing turnaround time (Table 8).
- In short, it was clear that the recent closing of several mills has affected the entire industry, and that labor shortage may become more severe in the future.

**Table 6.** Summary of demographic characteristics of respondents. Respondents were divided based on their primary of location into northern and southern regions of Maine.

Characteristics	Categories	Total n (%)
Affiliation	Company (logging, trucking, and pulp & paper enterprises)	65 (73.1)
	State or federal agencies	13 (14.6)
	Contractor	6 (6.7)
	Others (Forester, academics and unspecified)	5 (5.6)
Work experience in forestry sector	Less than 10 years	17 (19.1)
	10 to 15 years	12 (13.5)
	15 to 20 years	11 (12.3)
	20 to 25 years	14 (15.7)
	25 to 30 years	7 (7.9)
	More than 30 years	28 (31.5)
	Average work experience	22 years
Major forest products dealt with	Sawlogs/Speciality	36 (40.4)
	Pulp/groundwood	28 (31.5)
	Biomass (hogfuels)	13 (14.6)
	Wood chips	12 (13.5)

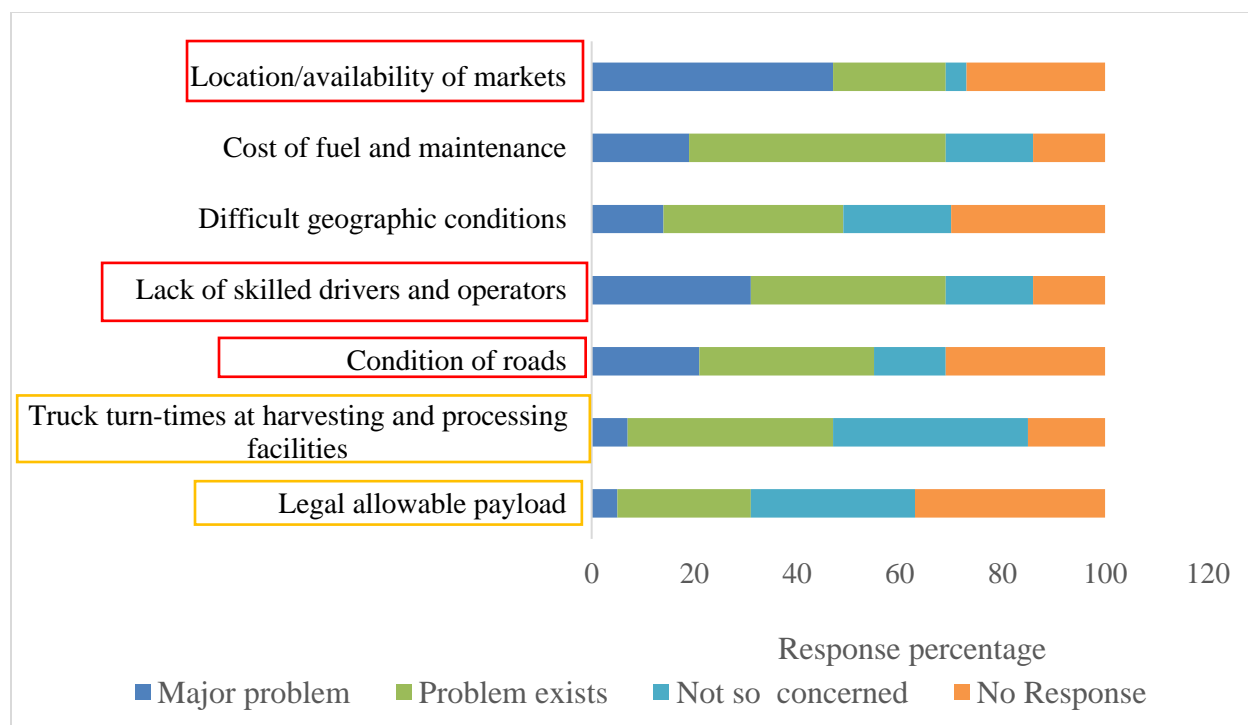




**Figure 12.** Map of Maine showing countywide representation of survey respondents. Eleven out of 16 counties of Maine were represented.

**Table 7.** Average reported distance (in km) traveled by a single truck one-way

Forest products	Maximum	Minimum	Mean
Sawlogs	322	3.5	95
Pulpwood	322	3.5	109
Hog fuels	200	19	94
Woodchips	240	3.5	93



**Figure 13.** Ranking of the major problems faced by forest trucking industry. Problems boxed in red represent the most severe challenges. Problems marked in yellow were considered less of a concern.

**Table 8.** Respondents' recommendations to minimize truck turnaround times. Direct quotations of respondents are presented for harvesting sites and processing facilities separately.

Harvesting sites	Processing facilities
"Adequate turnaround close to landing sites."	"Text messaging wait time and website with up to date information on unloading equipment, crane, dumpers."
"Skilled crane operators."	"Additional cranes to unload during busier times."
"Pave more roads and landings."	"Longer hours open during busier times."
"Wider roads at yards to accommodate traveling and traffic passage."	"Scheduling focused on light traffic times of the day."
"Decoupling services."	
"Utilizing smaller log trucks."	
"Utilizing more center mount trucks for saw log transportation."	
"Having crane operator or contractor be in charge of the operation at the landing, not the driver."	
More reliable equipment. Sand steep sections of road in winter. Plan roads ahead so not trucking on "fresh" roads.	
Utilizing satellite yards to accumulate more "loaded miles".	
"Increasing two shift trucks/team hauling the loads."	
"More cut-to-length operation."	

### Objective 3:

- Interviewees included foresters (both company-based and consultant), truck owners/logging contractors, professional society representatives, and procurement managers (Table 9).
- From these interviews, it was inferred that disintegrating trucking from harvesting could be productive (Table 10).
- Constant collaboration among forest products companies, contractors, and foresters was found to be important to resolve supply chain issues like trucks dispatching, turnaround times, and backhauling (Table 10).
- Coordination with public and policymakers for issues related to public road conditions and safety was found to be vital for better trucking business (Table 10).

**Table 9.** Description of participants interviewed for the study.

Stakeholder categories	Number of participants (by sub regions of Maine)	Average experience
Foresters (company based and consultant)	5 (Central = 3, North =1, South = 1)	30
Truck owners / Logging contractors	2 (All regions = 2)	28
Professional society representative	2 (South = 1, All regions = 1)	25
Procurement managers	4 (North = 3, South = 1)	19



*Photo: A. Kizha.*

**Table 10.** Summary and highlights of the potential mitigation measures. The measures are represented as views and suggestions of participants. The stakeholder groups favoring those strategies are also included.

Challenges	Views and suggestions	Favoring stakeholder group(s)
Present market conditions	New technologies, new investments, and marketing new products	All
	Opportunities to negotiate with new markets which was not accessible before	All
	Favorable policies for startup businesses and subsidies in certain products	Trucking contractors and procurement managers
	Attracting new investors; showing the potentiality of the state in terms of forest products	All
Manpower shortage	Good benefits, proper training, more vocational schools.	All
	More extension activities; showing young generation the modern technologies currently used in forest trucking	All
	US forest service and DOT as lead organizations to attract youths	Forester and professional society
	Change in payment methods to truck drivers from load based to hour based	Forester
	Ownership sharing mechanism to drivers (giving certain percentage of truck shares)	Forester and procurement manager
	Flexible time schedule and independency to drivers	Forester and professional society
	Developing a well maintained and disciplined trucking fleets	Professional society and forester
Roads and payload	More federal and state budget for maintenance of public roads	Procurement managers and foresters from North
	Avoiding public roads (not interstate highway) as much as possible due to aesthetic issues	Forester and professional society representative from South
	East to west interstate highway in Maine	Professional society representative
	Different measures to clean truck tires before entering public roads	Professional society representative and Foresters from south
	Straight forest roads as much as possible	All
	Minimize repeated maintenance of private forest roads by constructing them properly at the beginning	Trucking contractors and foresters
	Increasing legal allowable payload in interstate highways for certain situations	Trucking contractors and procurement managers
	Not increasing legal allowable payload in interstate highways to insure public safety and minimize impacts on the roads	Foresters and professional society
	Light trailers to increase capacity of trucks	Trucking contractors
Turnaround time	More unloading cranes at the mill; example: overhead cranes used by big mills	Trucking contractor and procurement managers
	Adding some self-loading trucks in the fleets	All



	More concentrated landing sites	Trucking contractor and forester
	Pavements in wood landing sites	Forester
	Proper coordination in dispatching between different mills in same area	Procurement manager
Back-hauling of empty trucks	Long distance hauling of the forest products; an opportunity to back-haul	All
	More concentrated landing sites	All
	Proper networking between mills from different regions.	All
	Dynamic trucking configurations to accommodate various products	All
Seasonal and topographic barriers	Using trucks for other works during mud season when timber harvesting stops	Forester
	Learning road building knowledge from other US states, mainly for steep terrain	Forester
	Use of stud tires during snow season	All
	Learning new innovations from other countries for winter transportation	Trucking contractors and procurement managers
Fuel efficiency	Using air deflectors in the trucks	Procurement manager
	Increasing payload	Trucking contractors
Contractors	Separating harvesting and trucking parts, i.e. using two different contractors for each work	Forester and procurement manager
	Proper dispatching strategy to minimize competition between contractors	Forester and procurement manager

## Future Plans:

- The findings of this study suggest that the current trucking situation in Maine needs further attention and investigation.
- A study on the productivity of different truck configurations is planned for the future.

## Acknowledgements:

The PI would like to thank all collaborators/ stakeholders (i.e. Huber Resources, Seven Islands Land Company, JD Irving Ltd. Woodland Divisions, and American Forest Management) for participating in the study at various levels.

# Long-Term Impacts of Whole-Tree Harvesting: The Weymouth Point Study

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<sup>4</sup>*University of Maine*

<sup>5</sup>*Cooperative Forestry Research Unit*



Processed soil samples packaged at University of Maine and ready to ship for chemical analysis.

Photo: C. Preece

## Status: Progress Report, Year 2

### Summary:

The Weymouth Point study was initiated in 1979 to determine the effects of whole-tree clearcutting a spruce-fir forest on watershed nutrient cycling and budgets. The experimental design, which includes fixed-area plots established on two adjacent watersheds (uncut and clearcut), enables evaluation of long-term effects of harvest residue treatments on tree growth and long-term dynamics in soil and whole ecosystem carbon and nutrient pools. Between 1979 and 2015, 58 permanent study plots were established across three soil drainage classes in the uncut and clearcut watersheds. Residue treatments applied to 12 plots of the watershed that was harvested in 1981 include: whole-tree removal (WTH), return of lopped and scattered delimbing residues to the site (LOP), and return of chipped delimbing residues to the site (CHP). The residue treatment CHP significantly ( $\alpha = 0.1$ ) affected DBH, height, and biomass of the naturally regenerated trees. However, tree growth was significantly affected by differences in stand density but not by residue treatment nutrients returns or soil stone-volume. The variation in stand density across treatments suggests that chipped residue application reduced stand density by 600 stems per hectare on CHP sites, which significantly enhanced growth of remaining trees. Analysis of tree growth and nutrient loading associated with residue removal (WTH) or addition (CHP, LOP) 35 years after harvest suggests that whole-tree harvesting has not reduced stand growth.

## Project Objectives:

- **Objective 1:** Quantify trends in ecosystem carbon and nutrient pools 35 years after clearcutting a balsam fir-red spruce forest at Weymouth Point Study Area (WPSA).
- **Objective 2:** Compare 35-year ecosystem carbon pool dynamics with carbon dynamics predicted by an IPCC-relevant forest carbon budget model (CBM-CFS3 is proposed).
- **Objective 3:** Inform development of criteria and indicators of sustainable forest management (SFM) in forest policy and certification systems adopted for balsam fir-red spruce forests in northern New England.

## Approach:

### Objective 1:

- Measure all trees over 5 cm diameter at breast height (DBH) on 52 permanent study plots (this was done in 2016, and a complete tree audit was completed in 2017 to verify those results).
  - Measure saplings (< 5 cm DBH) in a 1-m<sup>2</sup> subplot on each plot.
  - Use allometric equations to estimate aboveground biomass.
  - Measure individual tree species' dimensions (DBH and height).
  - Estimate above-ground biomass of trees (kg/tree) and plots (Mg/ha) using equations developed by Smith et al. (1986) for balsam fir and red spruce and Young et al. (1980) for other species.
  - Measure effects of treatments (WTH, LOP, CHP) 35 years after harvest (WTH and SOH).
  - Measure effects of fertilization (FERT) and precommercial thinning (PCT) on standing biomass 35 years following harvest.
- Inventory fine and coarse woody debris (FWD and CWD), stumps, and snags in 25, 20 x 20-m permanent study plots.
  - Analyze the effect of treatment (WTH, LOP, CHP) on FWD and CWD as well as an interaction with drainage class on the 25, 20 x 20-m permanent study plots established on the paired watersheds
- Collect forest floor samples on 49 permanent study plots; dry and prepare for lab analysis.
- Excavate and process whole-pit and subsamples collected from 25, 0.5 m<sup>2</sup> quantitative soil pits and document soil properties (horizon depth, color) in 25 morphological soil pits (one of each per permanent study plot).
  - Determine depth to seasonal and permanent wetness in morphological soil pits.
  - Estimate rock volumes and fine earth fragment mass in quantitative pit samples.
  - Estimate total carbon and soil nutrients (N, P, K, Ca, Mg) from quantitative pit samples.
- Use the mass of each nutrient (N, P, K, Mg and Ca) contained in the forest floor in 1980 prior to harvesting (quantified by C. T. Smith) and current mass to determine whether changes in nutrient pools relate to tree growth after 35 years.
  - Analyze effect of treatment (WTH, LOP, CHP) on nutrient pools (N, P, K, Mg, and Ca)



## Key Findings/Accomplishments:

### Key Accomplishments:

- Field work completed in 2017 will enable timely completion of Objective 2 and 3 targets.
- Tree inventory completed in 2017 season will enable estimation of aboveground living biomass in 52 permanent study plots.
- Samples were collected on 25 residue-treated plots and 27 PCT and PCT-FERT plots (noting reduced sample collection on PCT and PCT-FERT plots due to plot design differences).
- The field crew completed excavation and preliminary processing of all soil samples from 25 quantitative and 25 morphological soil pits.
- Soil sample preparation and processing were completed for all samples collected in the 2017 season. Subsamples were sieved (2 mm), dried (60°C), and delivered to SUNY-ESF for analysis.
- Depth to seasonal and permanent wetness were determined. Drainage class was assigned to all 25 study plots. Drainage was also assigned to PCT, PCT-FERT plots using 1991 data.
- Inventories of all stumps, snags, and fine and coarse woody debris on 25 of the permanent study plots (R1-R12, Y13-Y16, 1a-5a, 1b-4b) were completed.
- Sampling of forest floor using a 15 x 15-cm sampling frame generated 114 samples across 49 permanent study plots in 2016; samples were dried and prepared for laboratory analysis.
- Sapling data were recorded on 1-m<sup>2</sup> frame for 49 permanent study plots

### Objective 1 Key Findings:

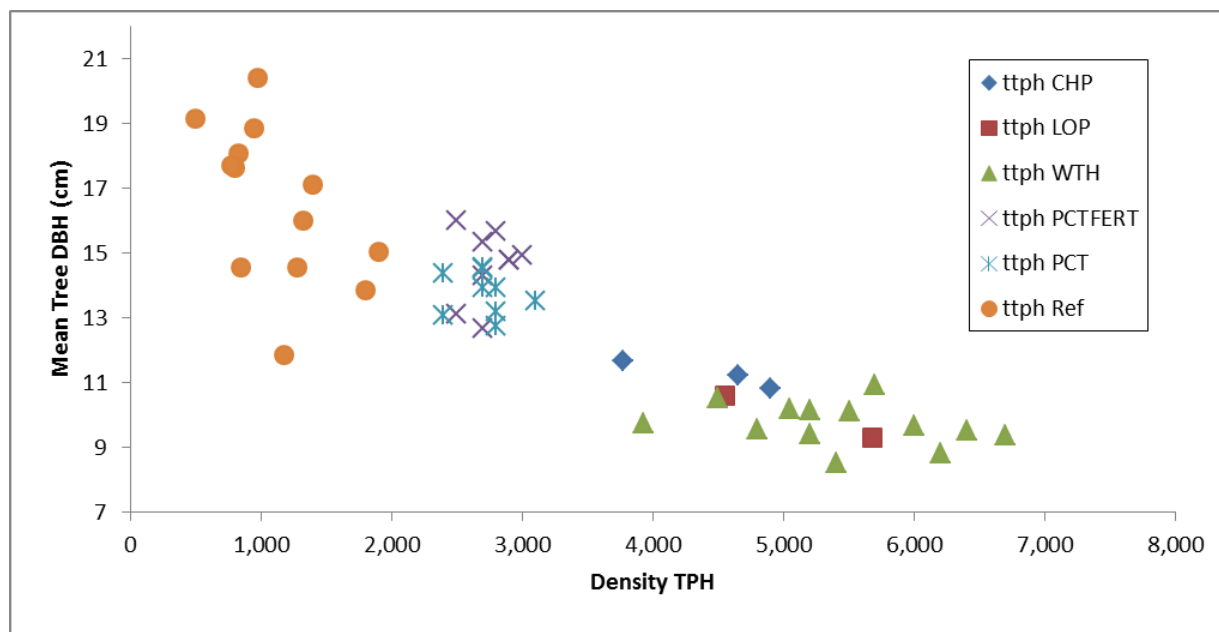
- Aboveground living biomass was estimated; no significant differences in forest productivity between LOP and WTH 35 years after harvest were found (Figures 14, 15).
- No apparent effect of forest floor nutrients pre-harvest or added in the form of (LOP, CHP) on tree growth (though more work remains to be done on this topic, Table 11).
- No forest productivity differences were found among soil drainage classes (moderately well drained, somewhat poorly drained, and very poorly drained) on the harvested watershed.
- Significant differences were found among drainage classes in mature uncut stand; average tree biomass increases from poorly drained to moderately well-drained soils.
- The CHP treatment appeared to reduce stand density by 600 stems/ha. Mean tree DBH was greater on CHP-treated plots (Figures 16, 17).
- No differences in forest productivity were found between WTH and LOP treatments.

## Other Findings:

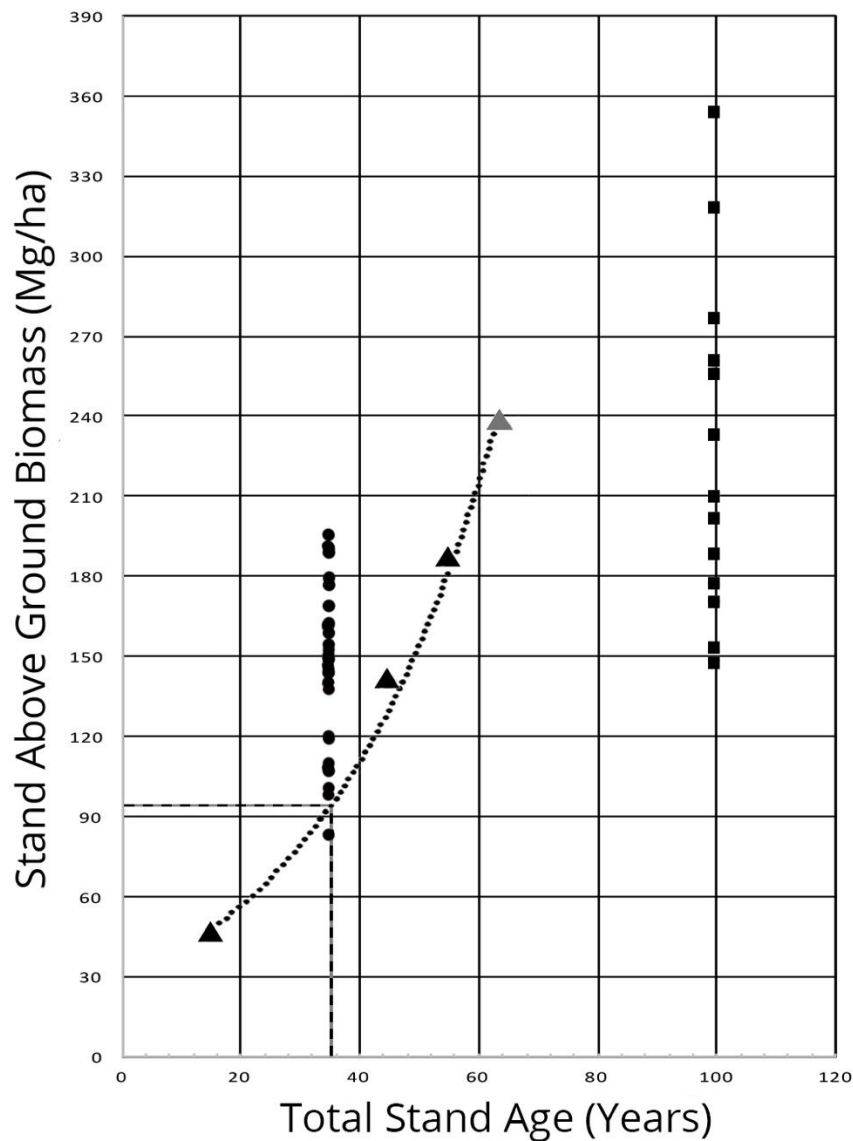
- Conifer release treatment (aerially-applied trichlopyr) maintained a fir-spruce dominated forest.
- Highly variable, over-stocked stands were observed on the 25, 20 x 20-m permanent study plots located on uncut and harvested watersheds.

**Table 11.** Treatment plot, soil drainage class, aboveground biomass, mean tree biomass, DBH, mean height, mean DBH of the 100 largest trees, and stand density for 9 of 12 plots treated with delimbing residues in 1981. Drainage class and depth were determined in 2017; tree sampling data were collected in 2015.

Plots	Treatment	Drainage Class	Drainage Depth (cm)	Above-Ground Biomass (t/ha)	Mean Tree Biomass (kg)	Mean Tree Height (m)	Mean Tree DBH (cm)	Mean DBH of 100 Largest Trees (cm)	Stems/ ha (#)
R4	CHP	VPD	10	161.79	33.02	11.35	10.82	15.26	4,900
R7	CHP	VPD	10	179.18	38.53	12.66	11.22	13.93	4,650
R3	CHP	MWD	40	151.99	40.26	12.80	11.65	13.50	3,775
R12	LOP	MWD	40	119.95	21.14	11.33	9.30	12.20	5,675
R11	LOP	SWP	18	120.97	26.59	9.50	10.60	13.80	4,550
R10	WTH	VPD	10	90.02	22.93	9.83	9.74	11.17	3,925
R8	WTH	MWD	40	148.39	29.38	12.30	10.19	12.80	5,050
R9	WTH	SWP	18	161.36	25.21	11.35	9.53	12.58	6,400
R2	WTH	SWP	18	108.02	22.50	10.07	9.57	11.83	4,800



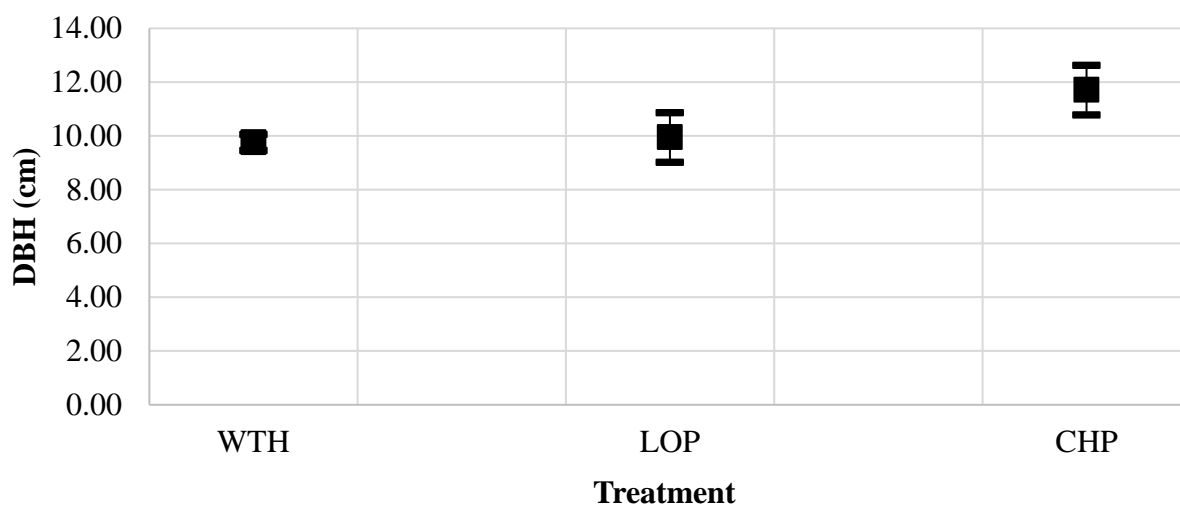
**Figure 14.** Relationship between tree DBH (cm) and density (trees/ha) for all plots located in the uncut reference watershed (ref) and on the harvested watershed (by treatment) in 2016.



**Figure 15.** Relationship between stand age and aboveground biomass (oven-dry t/ha above stump) for red spruce-balsam fir stands at Weymouth Point. This shows the 35-year old naturally regenerated plots (black circles) with Young et al. (1979) biomass equation estimates for various years (black triangles) and Smith et al. (1986) estimate for the 65-year old pre-harvest forest (gray triangle) and the current biomass of the 100-year old reference (uncut) forest (black squares).

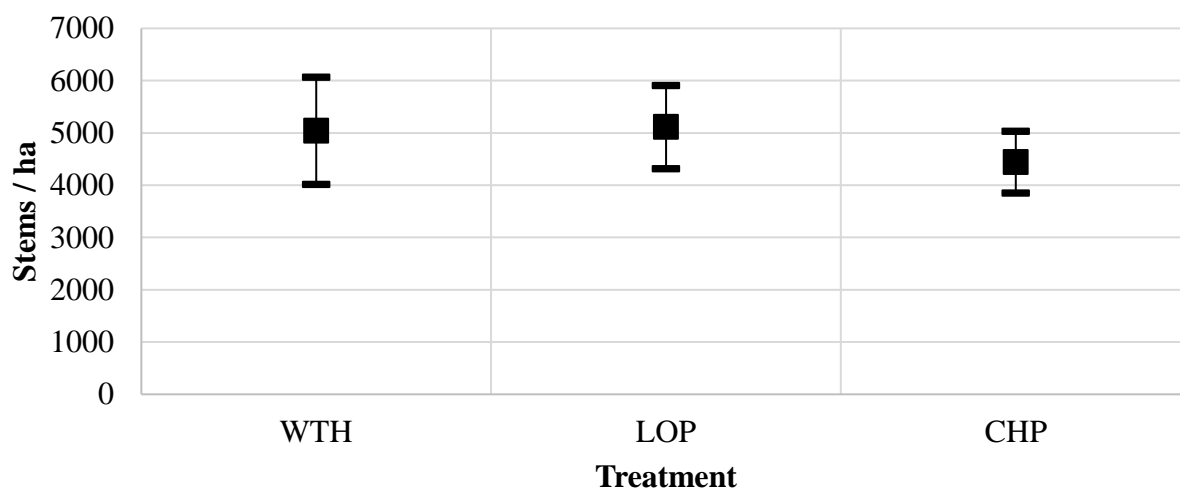


## Average Tree DBH



**Figure 16.** Mean tree DBH by residue treatment. Trees on CHP-treated plots have a greater mean DBH than trees on WTH- and LOP-treated plots.

## Number of Stems/ha



**Figure 17.** Mean number of stems per hectare by harvesting residue treatment. The stand density of plots treated with CHP was about 600 stems per hectare lower than that in the WTH and LOP treatments.

## Future Plans:

### Objective 1:

- Analyze tree data from PCT and PCT-FERT treated plots (DBH, total height, tree and stand aboveground biomass) to determine if aboveground standing biomass was affected by silviculture treatments.
- Analyze tree biomass samples (balsam fir and red spruce) from all treatments to see if they have different aboveground biomass nutrient concentrations.
- Analyze forest floor samples to identify if elemental concentrations (mg element/kg soil) and content (kg element/ha) of forest floor is equal to pre-harvest estimates and is related to soil drainage classes as observed in October 1980.
- Quantify how much carbon is in the harvested forest above and below ground and whether this differs among residue treatments and from the uncut forest.
- Complete mineral soil preparation for chemical analysis and associated data analysis for 25 permanent study plots located in uncut and harvested (and residue-treated) plots.
- Complete forest floor preparation for chemical analysis and associated data analysis.
- Complete analysis of standing and down dead wood (snag, stump) and woody debris (CWD and FWD) data analysis. Analyze for differences among soil drainage classes and residue treatments (WTH, LOP, CHP).
- A masters degree student from the University of Toronto, Adriana Rezai-Stevens, will initiate work on the project in Spring 2018 with the objective of completing her MFC capstone paper at the Faculty of Forestry, University of Toronto in December 2018. She will focus on belowground carbon and nutrient dynamics.

### Objective 2:

- Two masters degree students from the University of Copenhagen, Bruna Barusco and Agne Grigaite, have been recruited to complete this carbon modeling objective under the supervision of Professor Inge Stupak. Their work will begin during the summer of 2018.

### Objective 3:

- Project collaborators are planning an event 7-8 June 2018 entitled “Long-Term Site Productivity Research: Lessons from Other Regions and Opportunities for Maine.” This workshop will provide colleagues with an opportunity to discuss these Weymouth Point results as well as findings from other parts of Europe and North America (e.g., British Columbia, Ontario, and Quebec).

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## Acknowledgements:

We acknowledge CFRU for hosting and helping with field crew work this past summer, as well as Tat Smith, Brian Roth, Ivan Fernandez, Russell Briggs, Marie Cecile-Gruselle, Shawn Fraver, and University of Toronto for supplying valuable knowledge on research protocols and study objectives.



*Quantitative soil pit excavation on a moderately well drained (MWD) site. Sieving and weighing of soil samples was conducted by field crew members Keegan Ferro and Chris Preece.*

*Photo: J. Parent.*



# Strategies for Rehabilitating Beech-Dominated Stands

**Robert Wagner<sup>1</sup>, Aaron Weiskittel<sup>2</sup>,  
Arun Bose<sup>2</sup>, Brian Roth<sup>3</sup>, and Gaetan  
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**<sup>2</sup>University of Maine, USA**

**<sup>3</sup>Cooperative Forestry Research Unit, USA**

**<sup>4</sup>University of Moncton, Canada**



*Gaetan Pelletier describes diseased beech problems to members of the CFRU in a stand of diseased beech in Aroostook County.*

*Photo: B. Roth*

**Status: Final Report**

## Summary:

High densities of naturally regenerated American beech following single- or multiple-entry selection or shelterwood harvesting in hardwood stands is a problem, and beech regeneration is most often infected with beech bark disease, rendering it of little or no value for forest products. Infected beech regeneration generally grows faster than other hardwood species under most overstory conditions and is able to competitively suppress the natural regeneration of high-value hardwood species such as sugar maple, yellow birch, and red maple. Using data from FIA plots in the northeastern USA, beech stands were grouped into five distinct stand structural and compositional stand types. Strategies are identified for managing beech in these various stand types.

## Project Objectives

- Classify beech-dominated stands based on their species composition, productivity, and silvicultural difficulty and project future stand conditions for the derived stand classifications.
- Suggest operational strategies for reducing beech to shift the composition to higher-value tree species.

## Approach:

- The occurrence of different stand types where beech was present was modelled as a function of time (past 16 years) as well as a function of key biotic and abiotic factors.

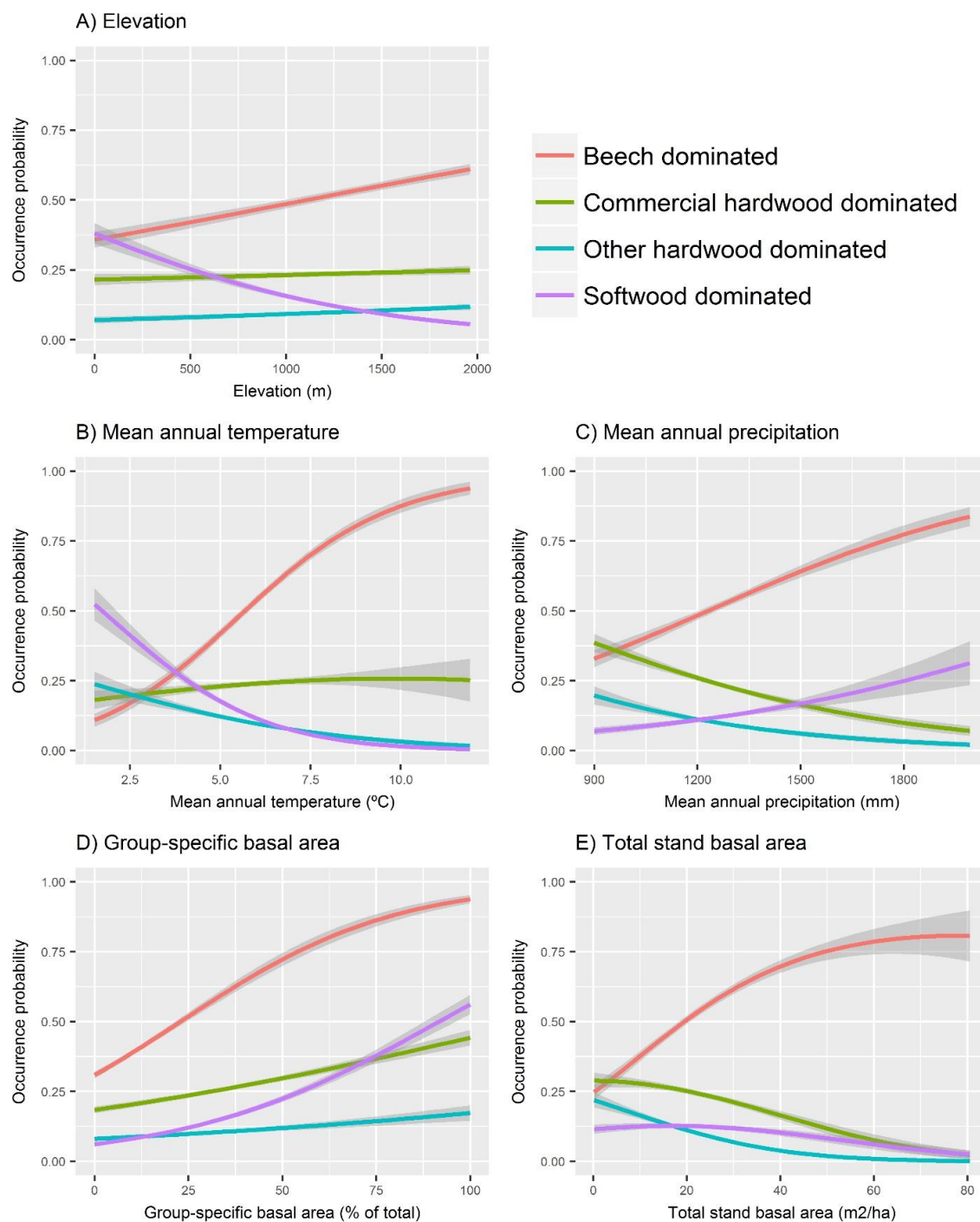
- Using U.S. Forest Service Forest Inventory and Analysis (FIA) data containing at least one beech tree, stands were classified/grouped using the hierarchical cluster analysis into five unique archetypes.
- Operational management strategies were developed by archetype to promote higher value species.

## Key Findings/Accomplishments:

- Our results showed that an increasing mean annual precipitation and an increasing overstory basal area had positive effects on the occurrence probability of beech-dominated stand type, but negative effects on the occurrence probabilities of the other identified stand types. Beech-dominated stands were generally associated with higher elevations, greater mean annual precipitation, higher temperatures, and higher overstory basal area (Figure 18).
- Based on the understory, midstory, and overstory characteristics, five distinct stand types where beech was present were identified, including i) dead beech & maple overstory with mixed beech and maple understory, ii) beech dominated midstory, iii) beech dominated midstory and understory, iv) beech dominated overstory, midstory and understory, and v) dead beech dominated overstory (Figure 19).
- Silvicultural prescriptions should focus on reducing the relative abundance of beech in the sapling layer (midstory) to release other species in the seedling layer (understory). However, if beech dominates (i.e.  $\geq 50\%$  of total under- and midstory density), then a more aggressive treatment such as clearcut followed by chemical site preparation and planting commercial species should be prescribed (Figure 20).

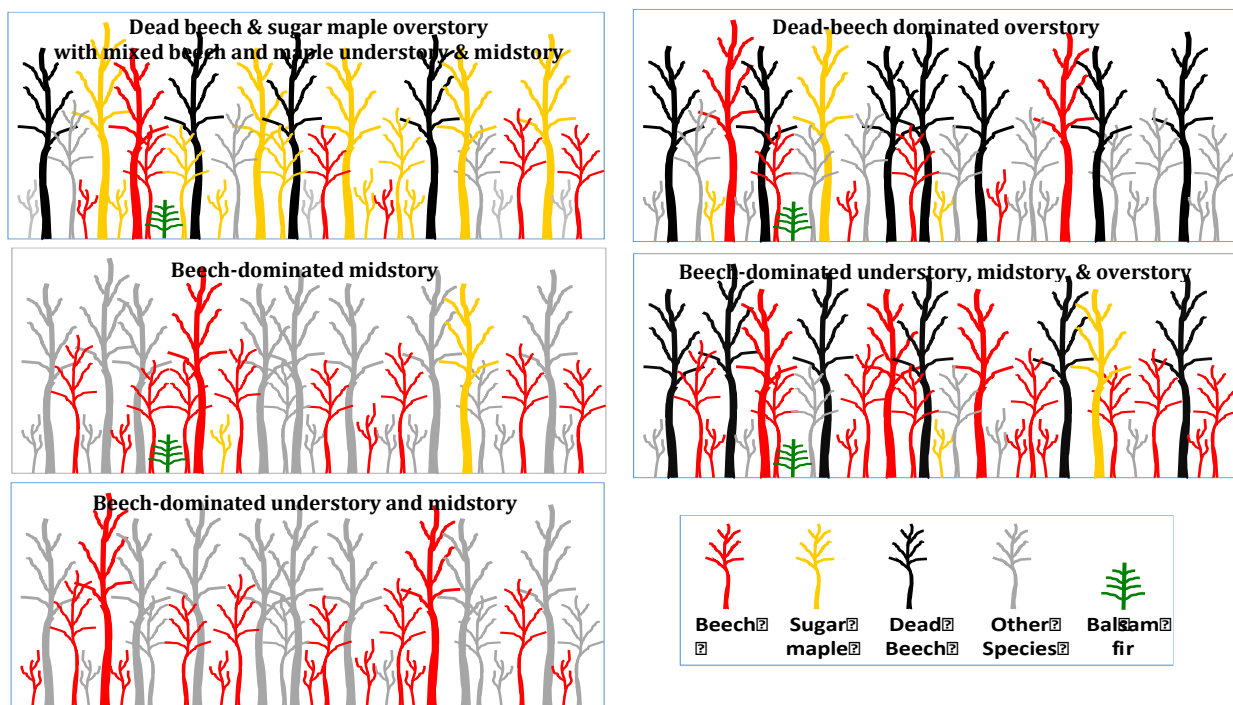


*This aerial photograph shows openings in the canopy of a mixed species stand of hardwood trees made several years earlier from commercial harvesting. The rusty brown colors of beech foliage are typical of dense regeneration of beech saplings in the openings and understory. These dense thickets tend to exclude regeneration of the diverse mix of hardwood species present in the original stand. Photo: M. McCormack*

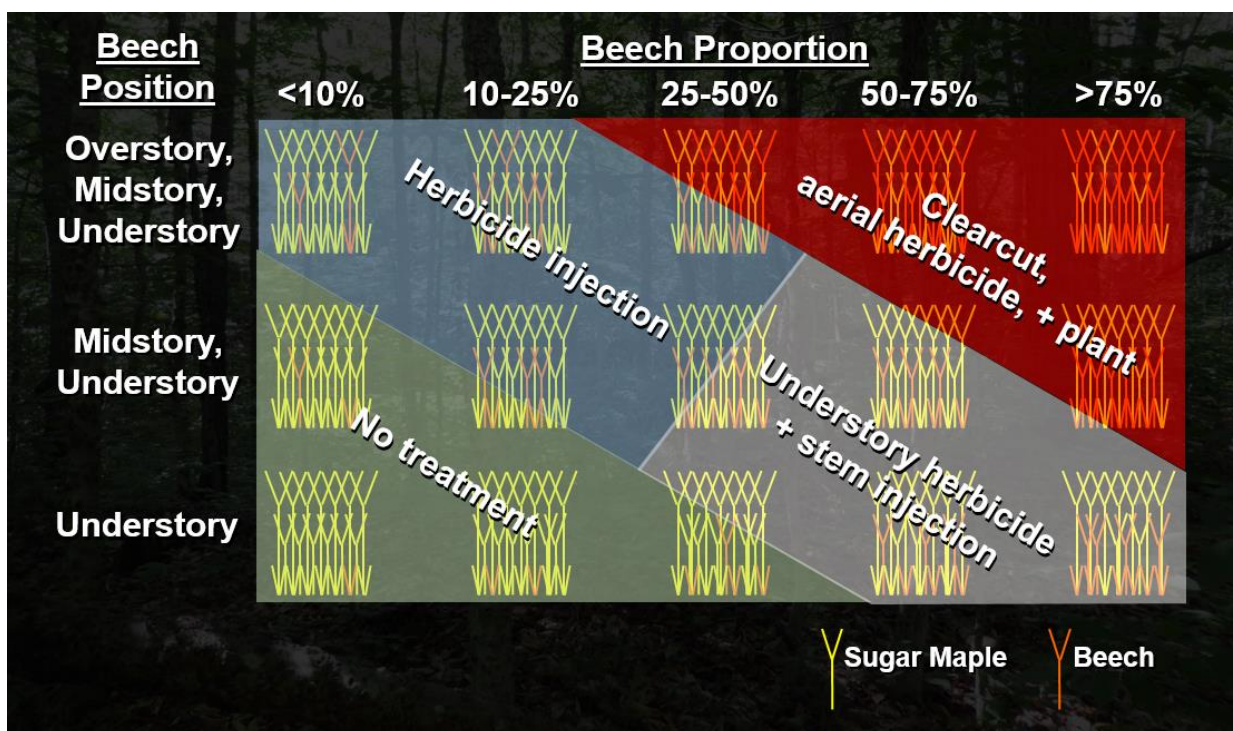


**Figure 18.** Predicted changes in occupation (% of total forest area in the region) with 95% confidence intervals for four stand types over the past 16 years for four northeastern states of USA.





**Figure 19.** Conceptual structural and compositional characteristics of five archetypal stand types containing beech.



**Figure 20.** Management recommendations based on beech relative abundance at under- mid- and overstory layers of the stand structure.

## Future Plans:

- In collaboration with forest managers in northern Maine, identify and test various management strategies for controlling diseased beech on an operational scale. We will use qualitative methods to determine general recommendations in agreement with our findings.

## Acknowledgements:

Funding for this work was provided by the National Science Foundation Center for Advanced Forestry Systems (CAFS) and the Cooperative Forest Research Unit (CFRU), University of Maine. We gratefully acknowledge the contributions of Sharad Baral and Gabriel Danyagri of the Northern Hardwood Research Institute of New Brunswick.



*When diseased beech is cut down, the extra sunlight stimulates a vigorous flush of dense beech sprouts from stumps and roots, as is evident in this photo (young beech retains brown foliage in the fall and early winter). These small saplings tend to exclude other native hardwood trees from regenerating, effectively converting the stand to one dominated by beech, and the cycle repeats as these beech trees become infected with bark disease. Photo: B. Roth*



A dark-themed map of the New Brunswick and Maine region. The map shows the coastline of New Brunswick to the north and east, and Maine to the south. Numerous small white dots are scattered across the landmasses, representing monitoring locations for Spruce Budworm. Labels for 'NEW BRUNSWICK', 'Edmundston', 'ribou', 'Millinocket', 'MAINE', and 'Lincoln' are visible. A semi-transparent white box with a green border is centered on the map, containing the title and a list of bullet points.

## Growth & Yield Modeling

- **Spruce Budworm Population Monitoring: L2 surveys**
- **Identifying Relationships between Spruce Budworm Larval Density, Moth Abundance, and Forest Conditions**
- **Early Detection and Monitoring of Spruce Budworm Defoliation using Remote Sensing**
- **Statewide Light Detection and Ranging (LiDAR) Data Acquisition**

*Image: Healthy Forest Partnership*

# Spruce Budworm Population Monitoring: L2 Surveys

**Brian Roth<sup>1</sup>, Erin Simons-Legaard<sup>2</sup>, and Kasey Legaard<sup>2</sup>**

**<sup>1</sup>Cooperative Forestry Research Unit**

**<sup>2</sup>University of Maine**

**Status: Progress Report, Year 1**



*Pruning pole used to sample branches for L2 counts.  
Photo: Spruce Budworm Task Force.*

## Summary:

Sampling the second instar (L2) larval populations of spruce budworm (SBW) can identify areas of local population growth (versus immigration) and help managers anticipate the degree of defoliation to be expected during the next growing season. Although there is generally thought to be a positive relationship between pheromone trap catch and larval abundance, the strength of that relationship is likely to vary in space and time. In Maine and New Brunswick, L2 counts have so far been highly variable in areas with high moth trap catch and overall rates of L2 occurrence across plots have been relatively low. This project aims to collect data on pheromone trap catch and larval abundance in northern Maine ahead of the next outbreak.

## Project Objectives:

- The main objective for this project is to support repeat sampling of spruce budworm larval (L2) densities from 2017 to 2019 across northern Maine.
- In combination with ongoing pheromone trapping, the information gained via this project would allow assembly of a long-term time series of budworm population monitoring data for more than 250 locations broadly distributed across northern Maine.

## Approach:

- Collect one branch sample from each of three trees co-located with pheromone traps during the fall and winter. Locations are selected in areas where pheromone trap catches had been high, modeling had predicted at-risk stands, or previous samples had been collected.
- Collected branch samples are transported to the Canadian Forest Service Insect Laboratory in Fredericton, New Brunswick for processing. Data and maps are shared annually (Figure 21).



## Key Findings/Accomplishments:

- Data from the winter of 2017-18 indicate that there are very low levels of overwintering SBW larvae in northern Maine (Table 12).
- Certain areas exhibited higher L2 densities; these areas will be watched closely in future years (Figure 22).

**Table 12.** Results from the 2017-18 overwintering SBW larvae surveys. Out of 255 sampling locations, 5.1% were positive for L2, but no location averaged more than 3 larvae per branch.

Town	County	Site ID	L2/ 30 inch Branch
Connor Twp	Aroostook	MFS-CON	0.3
Cross Lake Twp	Aroostook	MFS-175	1.3
Cross Lake Twp	Aroostook	MFS-175-ALT	0.3
Fort Kent	Aroostook	MFS-FTK	0.7
Fort Kent	Aroostook	MFS-FTK-2	2.3
Hamlin	Aroostook	IRV-HML-48	0.3
Madawaska	Aroostook	MFS-MAD	1
Saint John Plt	Aroostook	MFS-SAJ	0.7
T11 R8 WELS	Aroostook	SI-118	0.3
T17 R4 WELS	Aroostook	IRV-174-56	0.3
T9 R9 WELS	Aroostook	SI-99	0.3
TC R2 WELS	Aroostook	IRV-TC2-05	2.3
Wallagrass	Aroostook	IRV-WAL	0.3

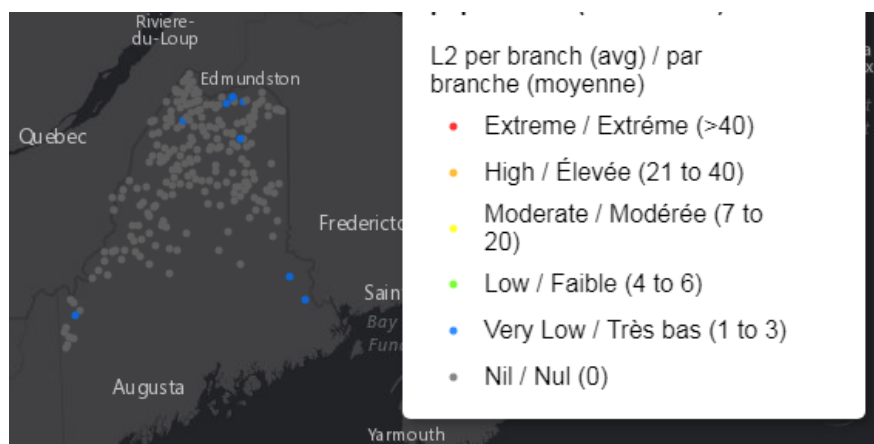
## Future Plans:

- Continue L2 monitoring surveys and if populations increase substantially, link pheromone trap counts to larval densities; this will provide the information needed to project population levels and near-term risk.



**Figure 21.** Dr. Rob Johns and Emily Owens at the Canadian Forest Service Atlantic Forestry Centre laboratory in Fredericton, NB where SBW L2 branch samples are processed.

**Figure 22.** Overwintering second instar larvae (L2) per branch sampled across Maine in the winter of 2017-18.



## Acknowledgements:

We would like to acknowledge Canadian Forest Service, Maine Forest Service, Irving Woodlands, LLC, Weyerhaeuser Company, Seven Islands Land Company, LandVest, Huber Resources, and Baxter State Park for collaborating with us. We would also like to acknowledge Noah Coogan, who served as a project coordinator this season.

# Identifying Relationships between Spruce Budworm Larval Density, Moth Abundance, and Forest Conditions

Erin M. Simons-Legaard<sup>1</sup>, Kasey R. Legaard<sup>1</sup>, Brian E. Roth<sup>2</sup>

<sup>1</sup>*University of Maine*

<sup>2</sup>*Cooperative Forestry Research Unit*

**Status: Progress Report, Year 2**



*Spruce budworm larva.  
Photo: Spruce Budworm Task Force.*

## Summary:

Risk of defoliation and damage due to spruce budworm varies in space and time as an outbreak develops. Our approach to providing the information needed for understanding changing budworm population conditions is based on repeat sampling of pheromone traps and larval (L2 instar) density using a network of locations established across northern Maine in Year 1. Trap and L2 locations provide the basis for developing predictive models of moth or larval abundance. As of winter 2016, the number of sampled locations with L2 remained low, failing to provide a sufficient sample size for modeling larval abundance. Comparing mapped forest conditions with average trap catch (2015-16), we determined that ~60% of the variability in catch could be explained, and that trap location (i.e., latitude and longitude) and percent of high-risk forest (i.e., mature forest with  $\geq 75\%$  host) within 500m of a trap location were the most influential factors.

## Project Objectives:

- Develop and implement a population study design based on moth and larval (L2) sampling.
- Identify forest and landscape features that promote population establishment and growth, and identify areas where immigrant moths are more likely to seed local populations.
- Develop predictive models of next-generation L2 abundance from annual moth trap catch and forest/environmental covariates.
- Produce wall-to-wall maps of predicted moth abundance, associated larval density, prediction uncertainty, and measures of local population change.

## Approach:

- Continue to coordinate sampling for L2 larvae (winter 2016) and pheromone trapping (summer 2017) with MFS and cooperating landowners.
- Generate maps of moth abundance using 2014-16 trap outcomes and compare to identify regions of sustained or increasing population levels. Integrate 2017 pheromone trap data when it becomes available.
- Model average moth abundance (2015-16) using Random Forest to evaluate associations with mapped forest conditions at two scales (500 m and 2500 m), including tree species composition and stand impact classes developed by the Canadian Forest Service.

## Key Findings/Accomplishments:

- Of the 219 locations sampled for L2 in winter 2016, larvae were only found at 9. Abundance was low (~1 L2 per group of three branches).
- Semivariance analysis of trap catch indicates weak spatial dependence between trap averages, with approximately 50% of the variability occurring within 5 km of traps. To better resolve variability at smaller scales, trap density would need to be more than 1 trap per township.
- Although moth abundance was generally depressed in 2016 relative to previous years, spatial patterns of stable or increasing catch were evident (Figure 23).
- A Random Forest analysis of average trap catch (2015-2016) was able to explain 60-61% of the variability in the data. Approximately 30% of the variability in average catch could be explained by latitude and longitude, suggesting that regional population dynamics (e.g., distance from source populations in Canada) continue to play a dominant role in Maine. An additional ~30% could be explained by a combination of mapped forest conditions and indicated that the percent of high risk forest (i.e., mature forest with  $\geq 75\%$  host) within 500 m of a trap location was the factor that was most influential. Average amount of softwood and non-host in the larger 2500 m landscape were also identified as important, highlighting the inherent multi-scale nature of budworm population dynamics.

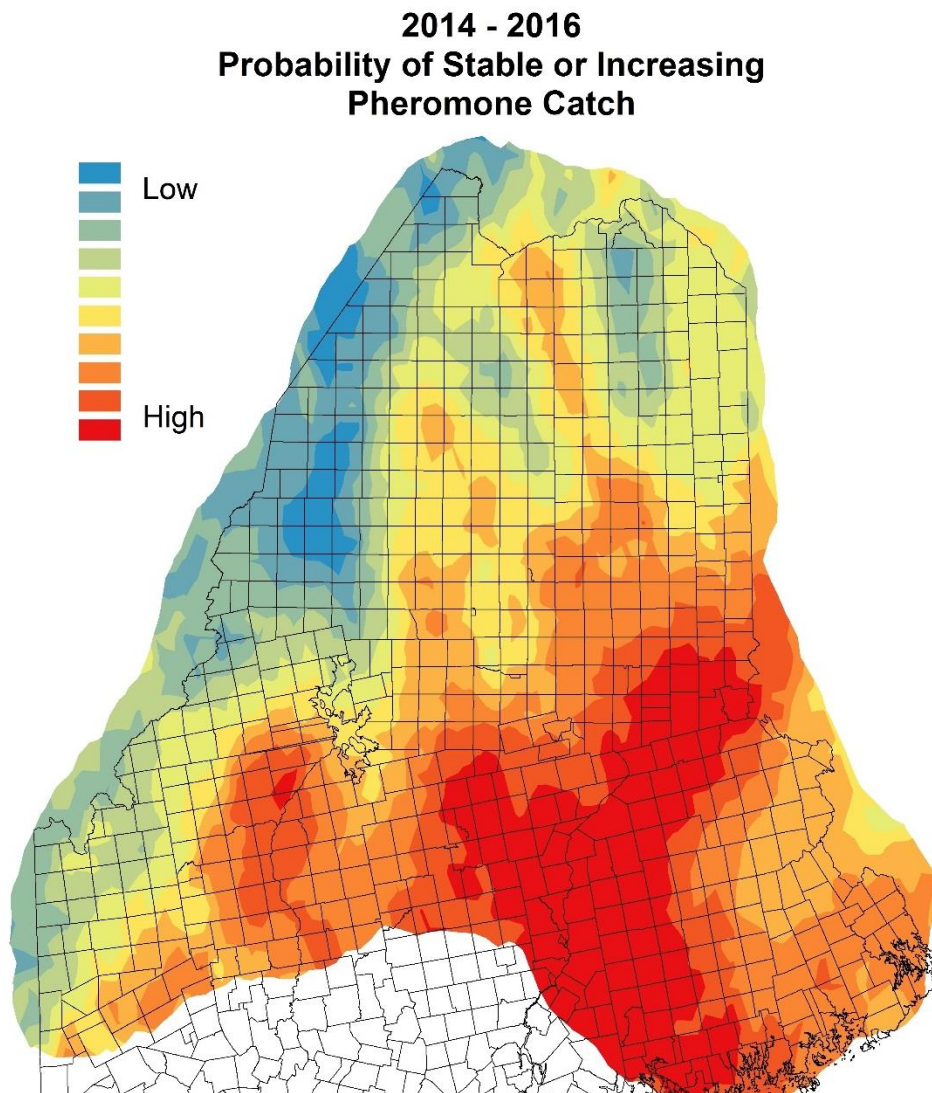
## Future Plans:

- Extend the multivariate analysis with additional covariates, including terrain and weather.
- Repeat sampling at L2 locations will be conducted in winter 2017.
- As larval densities increase in subsequent years to yield sufficient sample sizes for modeling purposes, we will evaluate hypothesized associations between early population establishment and forest/environmental covariates by modeling next-generation L2 detection and abundance



from repeated surveys. Model outcomes will identify factors influencing early population growth and provide a linkage between moth trap catch and near-term risk.

- An updated map of spruce budworm vulnerability and pheromone trap catch information will be made available via a new web-based mapping application, the Maine ForEST (Forest Ecosystem Status and Trends) App, currently under development with funding from the UMS Research Reinvestment Fund and USDA Agricultural Research Service.



**Figure 23.** Probability of stable or increasing pheromone catch, modeled throughout the study area using the data collected from pheromone traps from 2014 through 2016.

# Early Detection and Monitoring of Spruce Budworm Defoliation using Remote Sensing

Parinaz Rahimzadeh<sup>1</sup>, Aaron Weiskittel<sup>1</sup>, Daniel Kneeshaw<sup>2</sup>, David MacLean<sup>3</sup>

<sup>1</sup>*University of Maine*

<sup>2</sup>*Université du Québec à Montréal*

<sup>3</sup>*University of New Brunswick*



*Defoliation from spruce budworm.  
Photo: Spruce Budworm Task Force.*

**Status: Final Report**

## Summary:

This project was conducted to develop a cost-effective, rapid, and accurate method for timely detection of annual spruce budworm (SBW) defoliation using satellite remote sensing technology. This tool will be an essential need for timely planning and management of the new SBW outbreak in Maine. Landsat satellite imagery were applied for detection and quantification of current/annual SBW defoliation on landscape scale in Quebec (North Shore region). Several Landsat-derived vegetation indices (VIs) were estimated over a period of four years to detect and quantify SBW defoliation using a non-parametric statistical method. The results showed that the VIs can effectively detect (around 95%) and classify areas of defoliation. This model can be used to detect and estimate SBW severity for the future SBW outbreak in Maine similar to aerial sketch maps (ASM), but more accurately, near-timely, more cost effective, and not subjective.

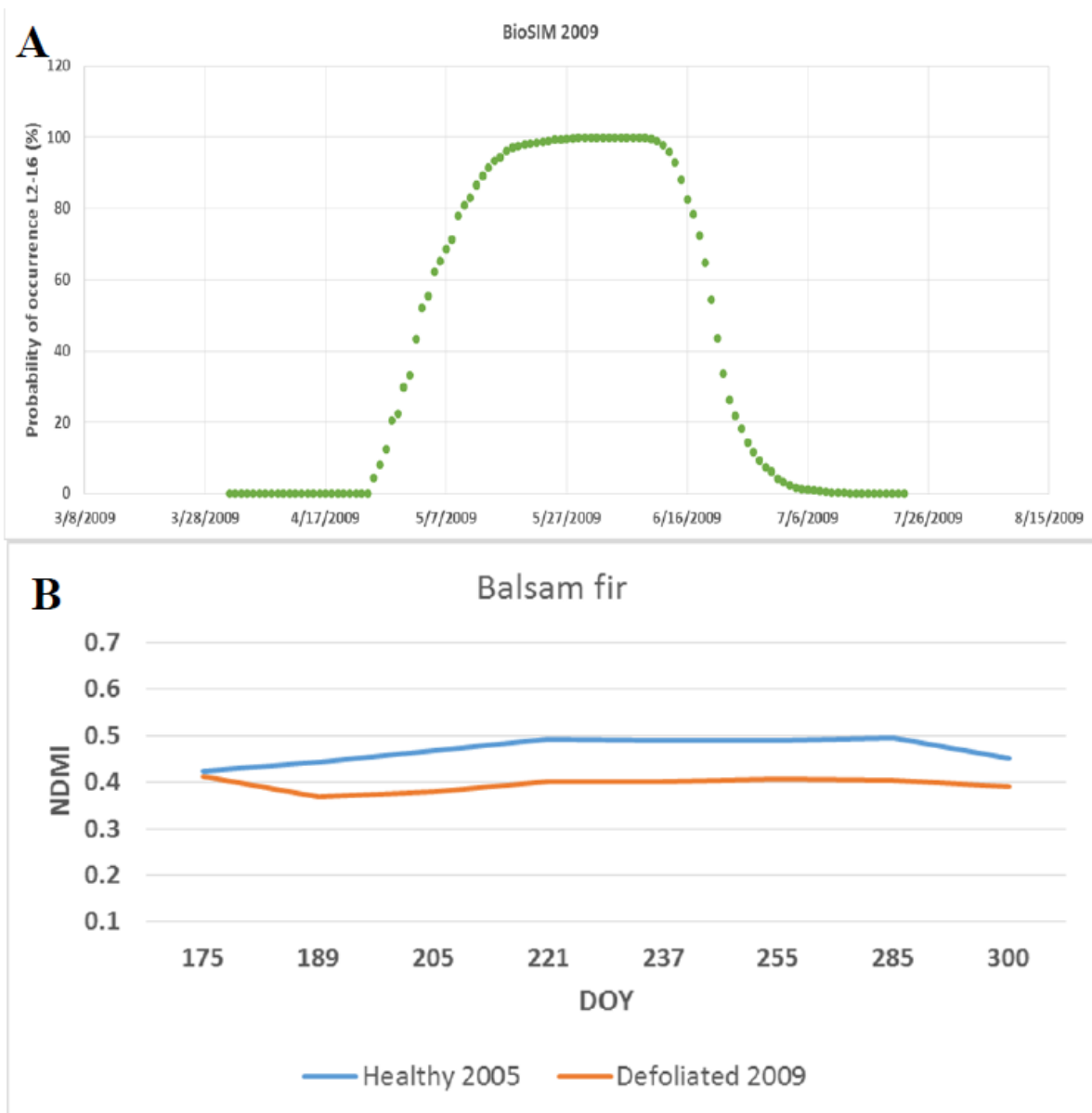
This research was largely completed in the first year of the project; the focus of this second and final year was on documenting and presenting findings as well as preparing follow-up research grant proposals.

## Project Objectives:

- Develop a model based on fine-resolution RS data and other required ancillary data for the early detection of SBW defoliation, its extent and location in infested stands of susceptible forests in Maine.
- Test and verify the developed model using available field data and geospatial maps of active SBW defoliation areas in Quebec or New Brunswick.

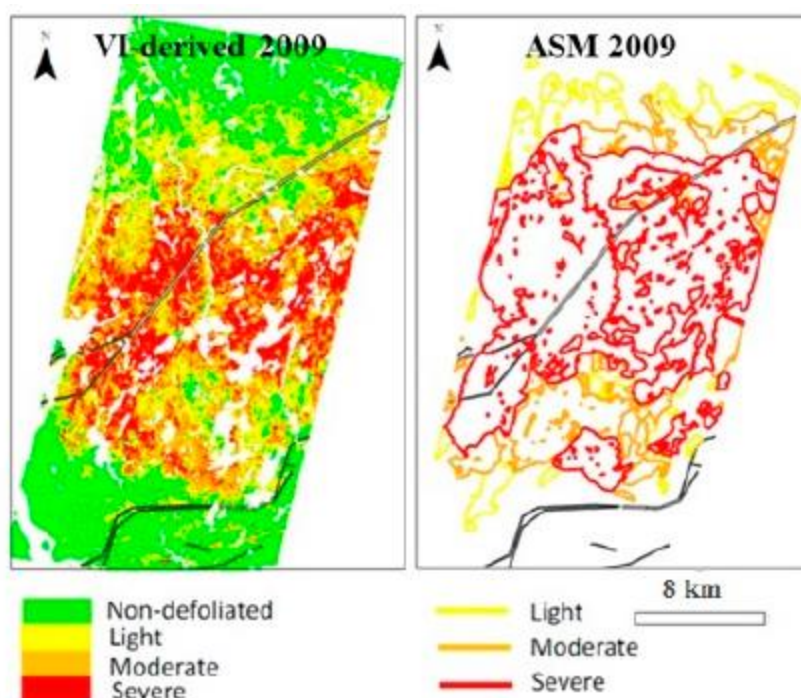
## Approach:

- Eleven Landsat imagery (path/row 12/26 and 11/26) having 30 meter spatial resolution were collected for two non-defoliated years (2004 and 2005) and two defoliated years (2008 and 2009) and were pre-processed to produce several cloud-free vegetation indices (VIs) for this project.
- Seven VIs were estimated, including enhanced vegetation index (EVI), normalized difference vegetation index (NDVI), green chlorophyll index (Chlgreen), greenness normalized difference vegetation index (GNDVI), normalized difference moisture index (NDMI), normalized burn ratio1 (NBR1) and 2 (NBR2). These were used for SBW defoliation detection and severity classification (Rullan-Silva et al., 2012; Townsend et al., 2012). These indices have information on vegetation pigment content, water content and foliage amount.
- Defoliation was detected by studying reflectance changes in defoliated forest stands compared to their healthy condition before the damage occurrence. Defoliated forest stands exhibit progressive decrease in near-infrared reflectance but an increase in short-wave infrared and visible reflectance due to changes in canopy cover chlorophyll content, water content and foliage amount.
- Timing for current year defoliation detection for years 2008 and 2009 was estimated using SBW phenology data simulated by BioSIM model (Régnière et al. 1995). (Figure 24a) and vegetation phenology information derived from Landsat imagery (Figure 24b).
- Ecoforest maps of MRN Quebec – 3rd Inventory data having 25-meter spatial resolution were used to extract information of susceptible forest stands. Five species groups (balsam fir, black spruce, spruce mixed with other conifers, balsam fir mixed with other conifers and balsam fir mixed with broad leaves) were selected.
- Annual ASM maps of SBW defoliation were applied as our field data for model training and validation (400 samples) using stratified random sampling method. Plot data on SBW defoliation available for New Brunswick for year 2015 and 2016 could not be used due to unavailability of corresponding satellite imagery.
- Training and validation data were extracted from five species groups for four severity classes: Nil (0-5% defoliation), Light (5-35%), Moderate (36-70%), and Heavy (70-100%).
- Random Forest (RF), a non-parametric method (Breiman 2001), was employed to evaluate the performance of VIs for SBW defoliation detection and severity classification. RF training algorithm applies a bagging (bootstrap aggregation) operation where a number of trees are created based on a random subset of samples derived from the training data. RF algorithm gives an error rate called the OOB (out-of-bag) error for each input variable using the data that are not in the trees.



**Figure 24.** A) SBW probability of occurrence for a balsam fir forest stand in North Shore region in Quebec simulated by BioSIM model for spring and summer 2009. B) Change in foliage water content in a balsam fir forest stand before and after defoliation using NDMI (DOY: Day of the year).

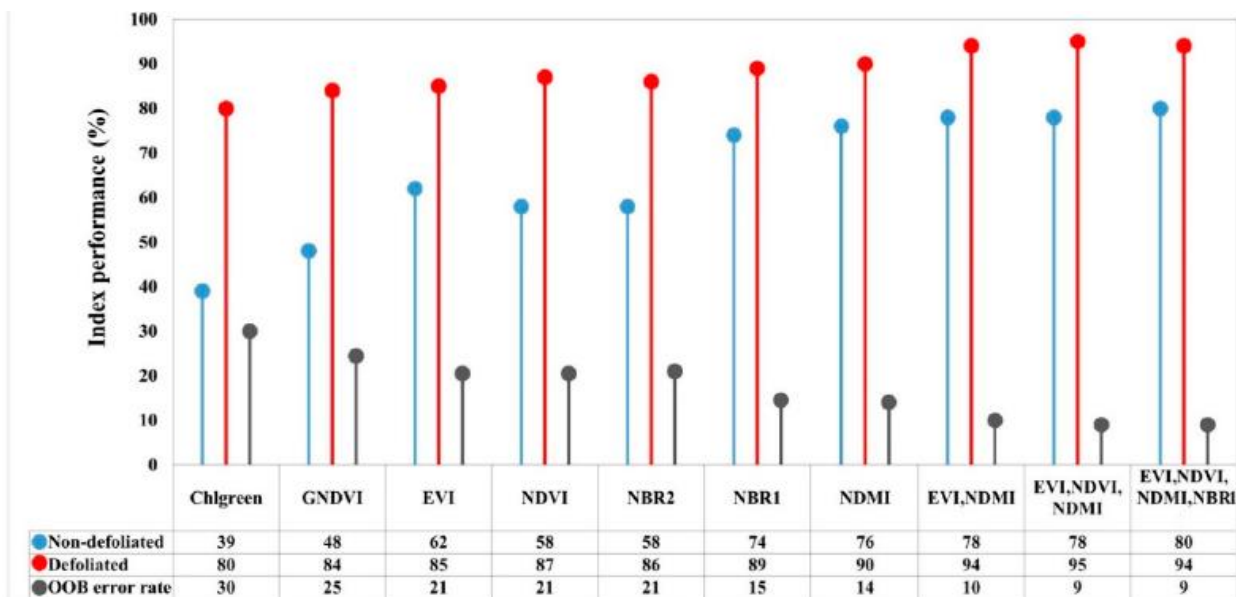




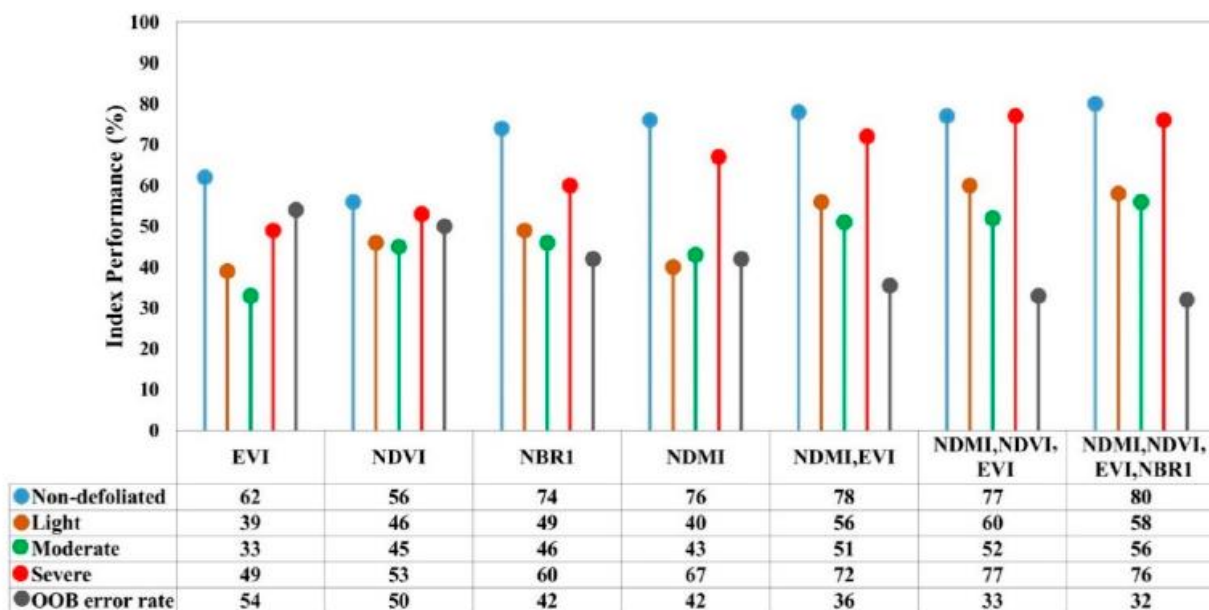
**Figure 25.** Left: SBW defoliation severity map derived from Landsat NDMI, EVI and NDVI using RF model; Right: Aerial sketch map of SBW defoliation severity for North Shore, Quebec.

## Key Accomplishments:

- Landsat imagery can be used successfully for annual SBW defoliation detection and severity classification (Figure 25). The suggested methodology has been shown to effectively detect (around 95%) and classify areas of defoliation. The model is suggested to be applied for future SBW outbreak monitoring and severity quantification in Maine.
- Based on the RF model, the best VIs for defoliation detection and classification are NDMI, NBR1, EVI and NDVI, respectively. Combination of two or three indices gives better performance than a single index for SBW defoliation detection and quantification (Figures 26, 27).
- The lower accuracy in detecting and classifying low-medium intensity defoliation might not be related to the method, but instead to the subjectivity of ASM. Incorporation of field data other than ASM can improve severity classification accuracy (Table 13).



**Figure 26.** Comparison of the performance of seven vegetation indices (VIs) and best combinations thereof to detect defoliated versus non-defoliated forests in the current spruce budworm outbreak in Quebec, using the random forest model. OOB is the out-of-bag error rate.



**Figure 27.** Comparison of the performance of best single VIs and best combinations thereof to classify different severities of defoliation in the current spruce budworm outbreak in Quebec, using the random forest method. OOB is the out-of-bag error rate.

**Table 13.** Error matrix and accuracy estimate (%) for the Quebec study area for the 2008 and 2009 SBW defoliation maps, derived from VIs versus ASMs (PA: producer's accuracy, UA: user's accuracy). Bold values are % correct classes. Confidence intervals are calculated at a 95% confidence level.

	No Defoliation	Light Defoliation	Moderate Defoliation	Severe Defoliation	PA	UA	PA Conf. Interval	UA Conf. Interval
<b>2008</b>								
No defoliation	<b>93.4</b>	15.7	6.2	0.1	93.4	85.9	92–94	84–87
Light defoliation	6.6	<b>67.3</b>	35.4	6.0	67.3	55.0	65–70	52–57
Moderate defoliation	0.0	14.9	<b>53.1</b>	25.8	53.1	56.3	50–56	54–59
Severe defoliation	0.0	2.0	5.4	<b>68.1</b>	68.1	91.0	66–70	89–93
Overall Acc. and Kappa Coeff.: 72.4%, 0.63								
<b>2009</b>								
No defoliation	<b>62.2</b>	20.1	0.5	0.0	62.2	81.9	60–64	80–84
Light defoliation	24.2	<b>49.5</b>	4.4	0.6	49.5	55.3	47–52	53–58
Moderate defoliation	13.1	29.0	<b>67.8</b>	21.5	67.8	48.0	65–70	46–50
Severe defoliation	0.5	1.2	27.3	<b>78.1</b>	78.0	65.7	75–80	63–68
Overall Acc. and Kappa Coeff.: 64%, 0.50								

## Future Plans:

- Three grant proposals were developed and submitted to federal grant agencies based on the findings of this research and intensive literature review made through this research. One of the three was funded. The future plan is to revisit and resubmit the two other proposals.
- As the developed model seems to be a sound tool for SBW defoliation detection and classification, an attempt is already being made to apply the method for recent satellite sensors (Landsat-8 and Sentinel-2 satellites) to produce end-use products on SBW defoliation for Maine and NB.

## References:

- Breiman, L. 2001. Random forests. *Machine Learning* 45(1): 5-32.
- Régnière, J., B. J. Cooke, and V. Bergeron. 1995. BioSIM: A computer-based decision support tool for seasonal planning of pest management activities: user manual. Information report, LFC-Quebec, Natural Resources Canada.

## Acknowledgements:

We thank CFRU for funding this project.

# Statewide Light Detection and Ranging (LiDAR) Data Acquisition

**Brian Roth<sup>1</sup>, Joseph Young<sup>2</sup>, and Dan Walters<sup>3</sup>**

*<sup>1</sup>Cooperative Forestry Research Unit*

*<sup>2</sup>Maine Office of GIS & the Maine GeoLibrary Board*

*<sup>3</sup>U.S. Geological Survey*



*3D point cloud derived from LiDAR.  
Image: Sourced by J. Young.*

**Status: Progress Report, Year 4**

## Summary:

Light detection and ranging (LiDAR) is a remote-sensing technology that uses pulses of light to generate a three-dimensional map of objects that reflect the light. These 3D point clouds can be combined with ground-truthed data from field plots to generate algorithms that predict forest metrics such as merchantable volume, basal area, canopy height, and stem density on a raster basis across the landscape. Combined with Geographic Information Systems (GIS), forest managers have the capability of making accurate, large-scale assessments of forest resources across the landscape. The goal of this project is to assemble a complete statewide base LiDAR data set. This would provide a historic benchmark for comparing future acquisitions of LiDAR data.

## Project Objectives:

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

## Approach:

- Solicit large landowners, communities and other stakeholders in the unorganized territories to partner on LiDAR acquisition projects.
- The Maine GeoLibrary Board is actively pursuing legislation to establish a Geospatial Data Reserve Fund, which will match outside funding sources with State funds on a 1 to 1 basis.
- Partner with the USGS, NRCS, FEMA, and other agencies to cost share LiDAR acquisition projects.

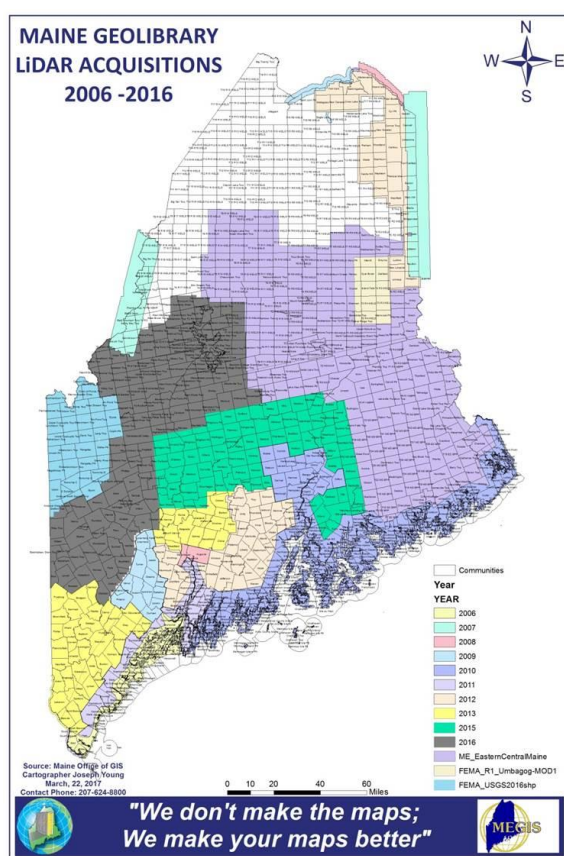


## Key Findings/Accomplishments:

- A Geospatial Data Reserve Fund has been authorized, which will match outside funding sources with State funds on a 1 to 1 basis.
- Phase 2 of the three-year acquisition plan (Figure 28) has been completed.
- Application for funding for a 2018 acquisition to complete the state was submitted to the USGS for consideration. It received approval and is scheduled for acquisition in the spring of 2018.

## Future Plans:

- Develop models to predict Enhanced Forest Inventory (EFI) metrics from LiDAR data and apply statewide to generate EFI maps.
- Demonstration and training of easy to use tools for managing EFI products.
- Update statewide Wet Area Maps at high resolution and inform digital soil mapping efforts.



**Figure 28.** Map of LiDAR coverage for the entire state of Maine through 2016. Funding for the final acquisition area in northern Maine (in white) has been secured and flights are scheduled for the spring of 2018.

## Acknowledgements:

We would like to acknowledge the Maine Office of GIS and the GeoLibrary Board, US Geological Society, Quantum Spatial, Weyerhaeuser, Baxter State Park, Maine Bureau of Parks and Land, Maine Department of Transportation, Maine Center for Disease Control, Clayton Lake Woodland Holdings, Seven Islands Land Company, LandVest, The Nature Conservancy, and others (see below for logos of partners in this project):





# Wildlife Habitat

- **Population Dynamics of Spruce Grouse in the Managed Forest Landscapes of Northern Maine**
- **Landscape-Level Evaluation of Deer Wintering Habitat in Northern Maine**

*Photo: K. Bothwell*

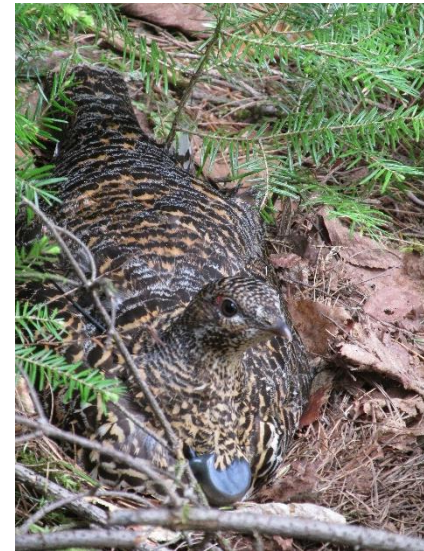


# Population Dynamics of Spruce Grouse in the Managed Forest Landscapes of Northern Maine

Joel M. Tebbenkamp, Erik J. Blomberg,  
and Daniel J. Harrison

*University of Maine*

**Status: Progress Report, Year 3**



*Spruce grouse hen.*

## Summary:

Spruce grouse rely extensively on conifer-dominated forests throughout the year and frequently use forest stands with a history of clearcutting, herbicide application, and precommercial thinning for both breeding and brood rearing. Reproductive success and survival of spruce grouse inhabiting intensively-managed forests, however, remain unknown. To assess habitat relationships and link demographic responses of spruce grouse to commercial forest management, we have radio-marked and monitored 114 (66 female, 48 male), spruce grouse in Piscataquis County, Maine during 2015 – 2017. We have located and monitored success of 22 nests, and monitored locations and survival of 27 broods. Based on nest survival models, the probability of a nest successfully hatching was 0.56, and increased with greater visual concealment and decreased with greater basal area of saplings. This suggests that, on average, more than 50% of hens nest successfully each year (a relatively high value for a ground-nesting bird) and that females can increase their likelihood of success further by choosing nest sites with greater structural complexity. Apparent brood success was 74%, and the majority (5 of 7) of brood failures were due to females being killed by predators during brood rearing. We are currently in the process of evaluating how structure, composition, and harvest treatments affect probability of brood success and adult survival.

## Project Objectives:

- **Objective 1:** Estimate demographic rates (annual survival of adults, nest success, and brood success) of spruce grouse using a combination of radio-telemetry and capture-mark-recapture methods and determine how habitat associations affect demographic rates most closely linked to population performance.
- **Objective 2:** Evaluate resource selection by spruce grouse at the sub-stand scale (e.g., understory composition, canopy cover, tree basal area) and stand scale (e.g., time since harvest and type of commercial and pre-commercial treatments) during nesting and brood rearing, and relate habitat choices by spruce grouse to forest harvesting.



- **Objective 3:** Relate objectives 1 and 2 to population performance using predictive stage-structured population models.
- **Objective 4:** Develop management guidelines and produce recommendations related to spruce grouse conservation in managed conifer forests.

## Approach:

- Radio-mark and track spruce grouse to monitor reproductive success (nesting and brood rearing), habitat use, movements, and survival.
- Quantify forest characteristics relating to structure and composition at locations used during reproduction as well as random points to assess selection.
- Use appropriate data analysis methods to link forest characteristics to spruce grouse habitat use (resource selection functions), demographics (mark-recapture analyses), and population dynamics (stage-based population models).

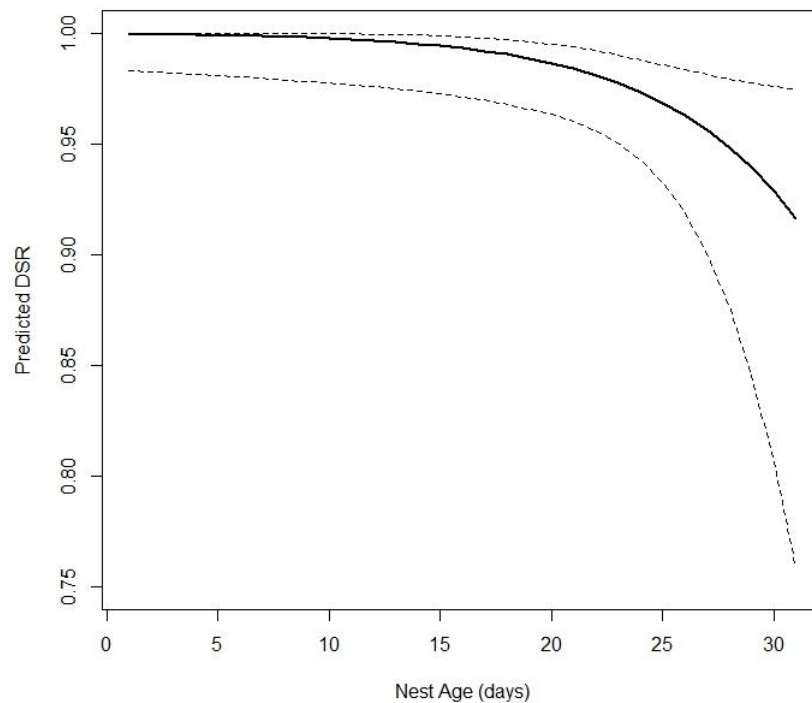
## Key Findings/Accomplishments:

- Radio-marked and monitored 114 spruce grouse (Female = 66, Male = 48) during 2015 – 2017.
- Obtained 212 weekly locations from 40 spruce grouse (Female = 32, Male = 8) during the brood-rearing period (June – August) and measured vegetation at use and associated random points.
- Apparent brood success (fledged  $\geq 1$  chick) was 74% (20/27); 5 of the 7 failures were attributed to mortality of the female.
- The average probability of a nest successfully hatching was 0.56 based on 22 nests monitored between 2015 – 2017.
- Models including nest age, visual concealment at nests, and basal area of saplings best explained variation in daily survival rates (DSR) (Table 14). DSR decreased with nest age ( $\beta = -0.172$ , 95% CI =  $-0.318 - -0.026$ ; Figure 29) and sapling basal area ( $\beta = -0.745$ , 95% CI =  $-1.423 - -0.062$ ; Figure 30). DSR increased with greater visual concealment at the nest ( $\beta = 0.721$ , 95% CI =  $0.118 - 1.342$ ; Figure 31).
- On average, more than 50% of hens nest successfully each year (a relatively high value for a ground-nesting bird); females can increase their likelihood of success further by choosing nest sites with greater structural complexity.

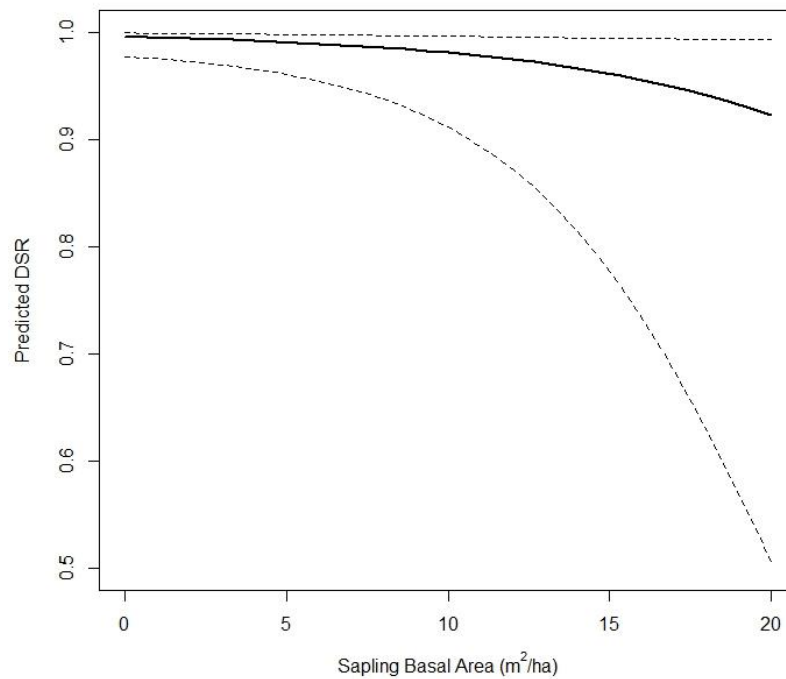
**Table 14.** Models, number of parameters (K), Akaike's information criterion adjusted for small sample size ( $AIC_c$ ), change in  $AIC_c$  relative to the top model ( $\Delta AIC_c$ ), and model weight ( $w_i$ ) from the nest survival analysis best explaining daily survival rate of spruce grouse nests in Piscataquis County, Maine, USA from 2015 – 2017. Models that did not outperform the null (intercept only) model are not shown.

Model <sup>1</sup>	K	$AIC_c$	$\Delta AIC_c$	$w_i$
Nest VC + Nest Age	3	49.6465	0.0000	0.4418
Sapling Basal Area + Nest Age	3	50.6336	0.9871	0.2697
Nest Age	2	52.3180	2.6716	0.1162
Nest VC	2	54.8673	5.2208	0.0325
Nest VC + Sapling Basal Area	3	55.0779	5.4314	0.0292
Sapling Basal Area	2	55.2425	5.5960	0.0269
Null	1	56.3550	6.7085	0.0154

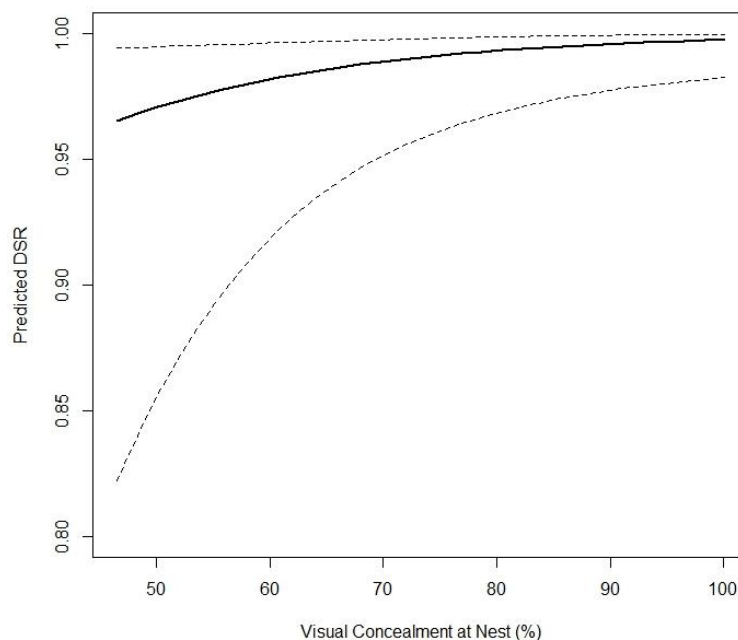
<sup>1</sup> Nest VC = average visual concealment measurements from cover board readings taken from each cardinal direction at the nest bowl; Nest Age = linear time trend of nest age; Sapling Basal Area = basal area of all saplings measured using a metric 2-factor prism.



**Figure 29.** Predicted daily survival rate (DSR) as a function of nest age for spruce grouse nests monitored in Piscataquis County, Maine between 2015 – 2017.



**Figure 30.** Predicted daily survival rate (DSR) of spruce grouse nests across the range of observed values for sapling basal area in Piscataquis County, Maine between 2015 – 2017.



**Figure 31.** Predicted daily survival rate (DSR) of spruce grouse nests across the range of observed values for visual concealment at nests in Piscataquis County, Maine between 2015 – 2017.

## Future Plans:

- Incorporate data collected by Stephen Dunham (2012 - 2014) to provide an assessment of brood success and adult survival spanning 6 years.
- Locate and monitor nests of females that still have functioning radio collars during spring 2018.
- Complete demographic analyses necessary to understand the link between forest management practices and spruce grouse population performance.

## Acknowledgements:

We appreciate the participation of Katahdin Forest Management, LLC and Prentiss and Carlisle for providing unrestricted use of their land under their ownership and/or management during this ongoing study. Additionally, personnel associated with Baxter State Park, particularly Jensen Bissell, Jean Hoekwater, and Eben Sypitkowski, were helpful with logistics and were accommodating during our study. We thank Brad Allen and Kelsey Sullivan, and Warden Pilots Jeffrey Beach, Jeffrey Spencer, and Christopher Hilton from MDIFW for their collaboration on the project. Finally, the staff of the North Maine Woods at the Telos checkpoint and Larry and Aaron Pelletier of Gerald Pelletier Inc. have been very accommodating to our field crews at the CFRU's Telos Camp.

This project received additional financial support from the Maine Outdoor Heritage Fund, Maine Department of Inland Fisheries and Wildlife, and Maine Agricultural and Forest Experiment Station, McIntire-Stennis Grants MEO-041602, MEO041608, MEO-00470, and MEO-021422.



*Radiotelemetry to locate a spruce grouse in a shelterwood stand.  
Photo: D. Harrison.*



# Landscape-Level Evaluation of Deer Wintering Habitat in Northern Maine

Mindy S. Crandall<sup>1</sup>, Amber Roth<sup>1</sup>, Karin Bothwell<sup>1</sup>, Erin Simons-Legaard<sup>1</sup>, Daniel Hayes<sup>1</sup>, Anthony Guay<sup>1</sup>, Brian Roth<sup>2</sup>

<sup>1</sup>*University of Maine*

<sup>2</sup>*Cooperative Forestry Research Unit*



*Probable deer wintering area.  
Photo: K. Bothwell.*

**Status: Progress Report, Year 1 of 2**

## Summary:

The goal of this project is to expand current wildlife habitat, forest management, and landscape dynamics knowledge in a novel way, bridging previous work and newly available spatial data to contribute information that will help *reduce landowner uncertainty and achieve better habitat results in deer wintering areas*. To date, we have completed a region-wide analysis to identify areas that currently exhibit the characteristics of white-tailed deer winter habitat and a quantitative evaluation of that habitat's distribution. Results confirmed the original zones effectively protected patches of softwood-dominated forest from intensive timber harvests; many patches of potential wintering habitat persist across northern Maine and tend to be aggregated on the landscape. In addition, through the combination of digital data acquisition and the development and analysis of existing data, we have begun development of habitat maps that incorporate historical information, expert opinion, and the best available technology (EFI and LiDAR).

## Objectives:

- Quantify the quality and distribution of all deer winter habitat, at broad- and fine-scales.
- Compile spatial and temporal maps of deer occupancy for Maine across ownerships and agencies using best knowledge available over the past 40 years.
- Expand and standardize recent Landsat habitat evaluation maps to cover northern Maine.
- Scale up the estimation of opportunity costs associated with habitat management for deer.

- Develop two predictive spatially explicit habitat quality models (HQMs) from digital elevation models (DEMs), Enhanced Forest Inventory (EFI) metrics derived from LiDAR, traditional forest inventories and expert observer opinion.
- Develop ecological based habitat models using winter occupancy of deer as quality indicator.
- Map the existing distribution of deer winter habitat quality on a landscape level using a combination of available 3-D LiDAR and Landsat imagery.
- Assess landscape-level risk of spruce budworm induced tree mortality in deer winter habitat in northern Maine as expected during the next outbreak.
- Quantify the economic and ecological costs and benefits of various deer habitat management scenarios at the broad-scale with input from DIF&W and CFRU members.

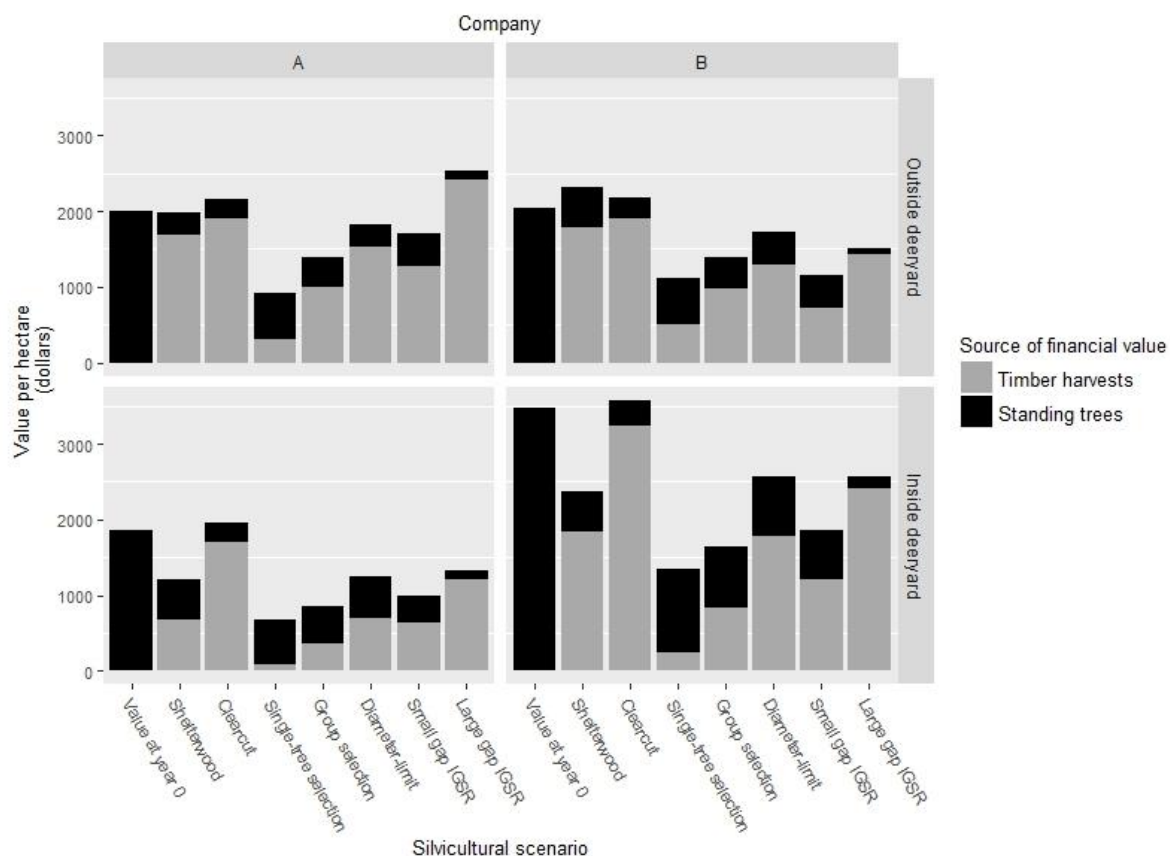
## Approach:

- *Deer occupancy map development* is being generated from existing information from landowners and agencies, and combined into a single spatial data layer (GIS map).
- *Expanded habitat quantity map development* will utilize a newly-available dataset of forest disturbance and high-resolution predictions of tree species percent biomass to generate a refined map of potential deer wintering habitat spanning 10 million acres.
- *Habitat quality models* are in the process of being developed from EFI data from LiDAR, state guidelines for deer winter habitat, and deer occupancy information. The study area for this effort is restricted to areas with access to EFI as well as historical occupancy information.
- *Expanded management cost estimates* will combine information from the stand-level work, updated maps of forest disturbance and biomass, and allometric equations to estimate management costs.
- *Landscape simulations and accounting for disturbance risk*: Risk of mortality by spruce budworm and the impacts on deer habitat areas will be assessed using LANDIS-II.

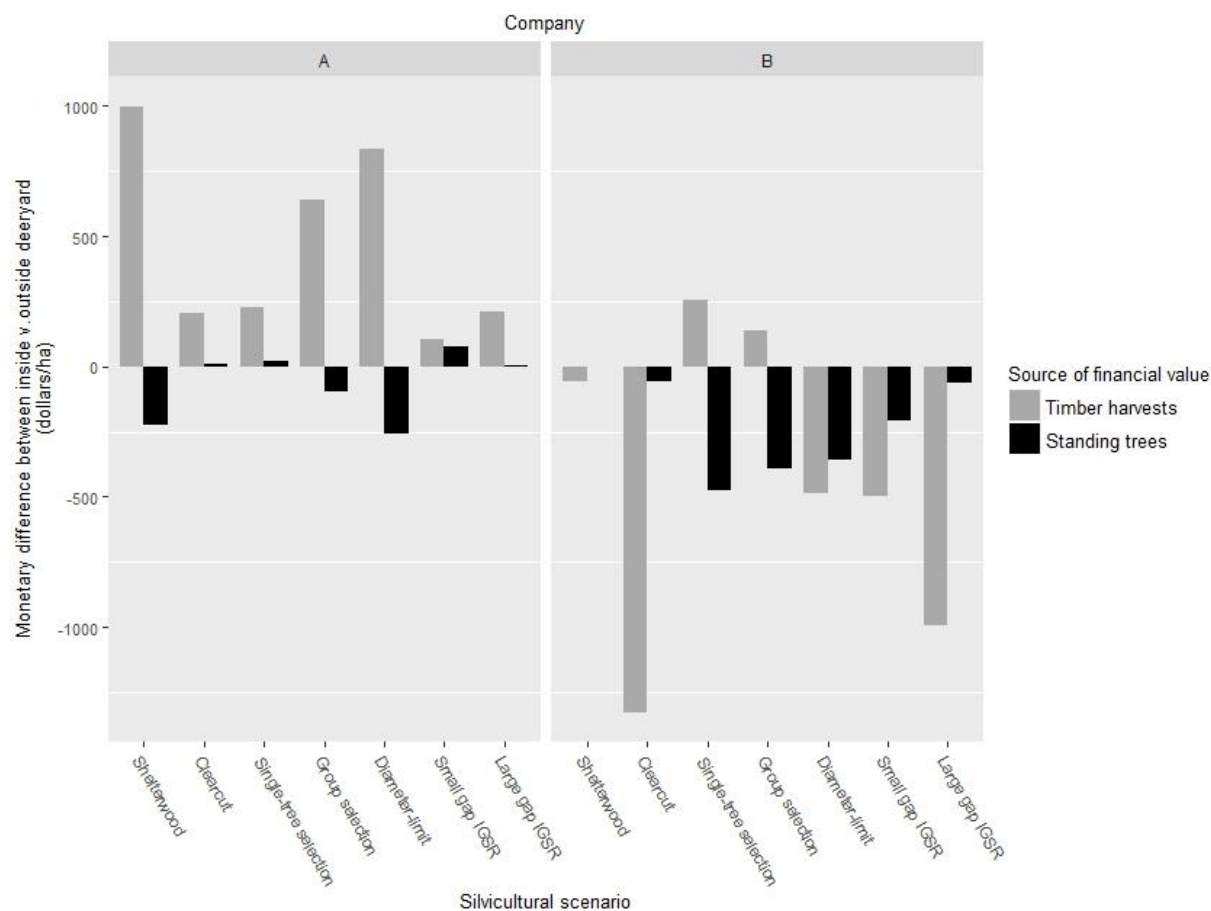
## Key Findings/Accomplishments:

- While DWA management restrictions can result in a financial loss relative to a business-as-usual scenario, this finding is not universal and is highly dependent on landowner objectives and starting stand conditions (Figures 32, 33).
- Clearer habitat management guidelines based on standard forest inventory metrics may facilitate the harvest approval process and help foresters realize the potential of silvicultural management within deeryards.

- Digital information on historical habitat occupancy was clipped to the CFRU boundary and acquired from Maine Department of Inland Fisheries and Wildlife (DIF&W).
- Working in conjunction with DIF&W, mylar maps of habitat occupancy for various decades were geo-referenced and digitized when missing from the current digital layer.
- Preliminary forest cover typology and processing methodology was developed for use with the expanded Landsat dataset.
- We have successfully acquired most of the spatially referenced deer and LiDAR-based datasets needed for development of the expert-derived and deer-derived models of winter habitat quality.
- The Phase 1 expert-derived model, based on DIF&W's deer wintering areas management guidelines, has been developed, though refinement of the forest canopy closure variable is on-going.
- Preliminary mapping of the existing distribution of deer winter habitat quality using a combination of available 3-D LiDAR imagery was completed for the Allagash region (Figures 34, 35).



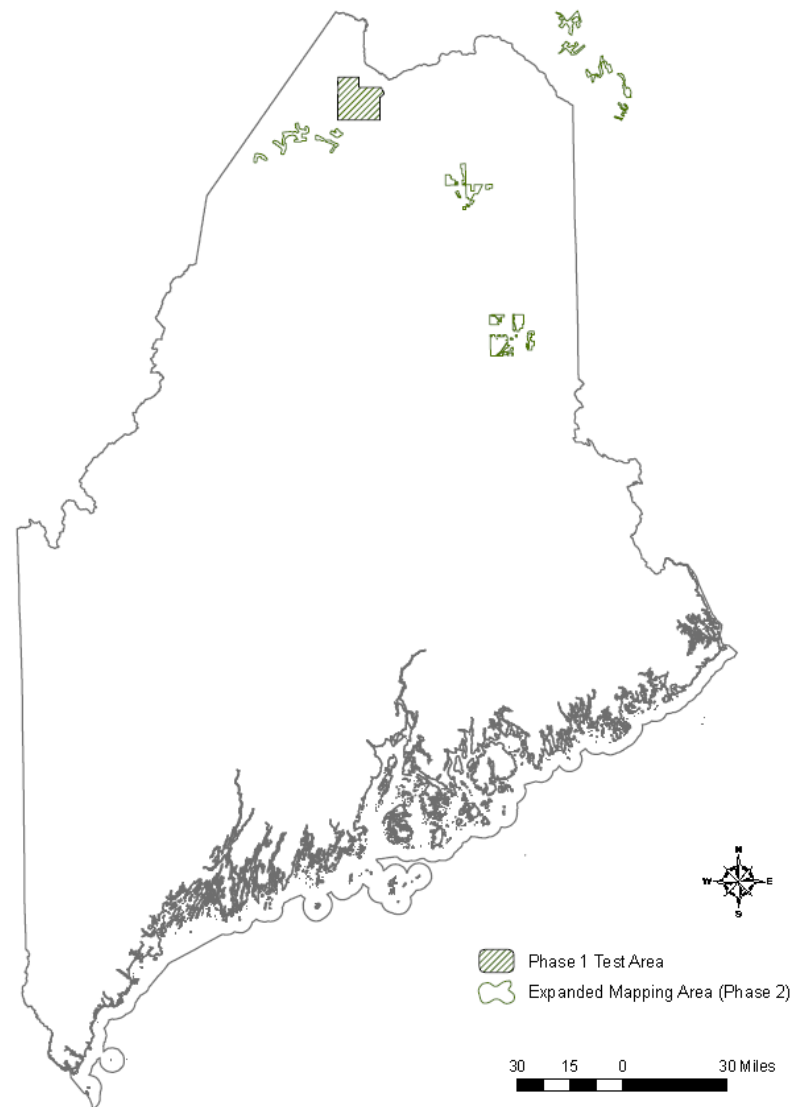
**Figure 32.** Economic returns per hectare of modeled management scenarios inside and outside of zoned deeryards of two companies. Harvest revenue is total returns from all entries within 50 years with the first entry at year 0; standing value is the stumpage value. “IGSR” represents the irregular group shelterwood with reserves system.



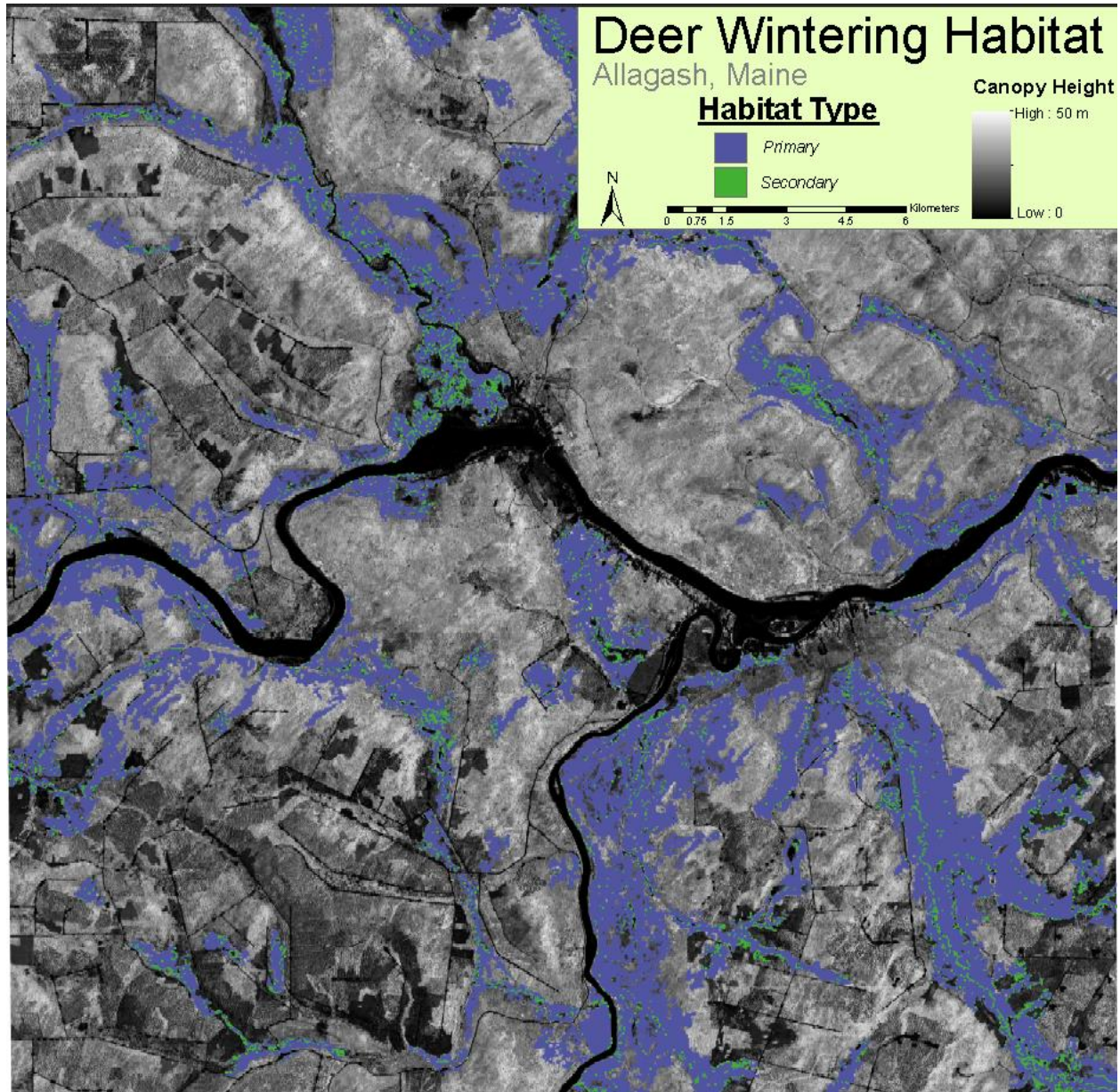
**Figure 33.** Difference in revenue per hectare between “business as usual” management scenarios and those applied within zoned deeryards of two companies. Positive values indicate greater revenue outside deeryards; negative indicates greater revenue inside. Harvest revenue is total returns from all entries within 50 years with the first entry at year 0; standing value is the stumpage value of standing timber at the end of the 50-year simulation. “IGSR” represents the irregular group shelterwood with reserves system.



## Mapping Areas for Lidar-based Habitat Quality Models



**Figure 34.** The study area extent for the LiDAR derived habitat mapping objective.



**Figure 35.** Preliminary analysis from LiDAR data of deer wintering habitat, using information for Allagash Township, Maine.

## Future Plans:

- Acquisition of aerial deer survey data to fill temporal and spatial gaps in the current dataset.
- Finalization of the Phase 1 expert-derived habitat model.
- Expansion of the Phase 1 model to the Phase 2 model to include a solar gain variable (or correlate).
- Development of the deer-derived habitat model.
- Finalization of the expansion of habitat definitions derived from Landsat imagery.
- Development of risk maps for DWAs in the face of spruce budworm, using LANDIS-II.
- Expansion of the economic cost estimates using landscape-level information.

## Acknowledgements:

We gratefully acknowledge the assistance and cooperation of CFRU landowners, including J.D. Irving, Weyerhaeuser, Downeast Lakes Land Trust, Appalachian Mountain Club, Seven Islands, Katahdin Forest Management, Penobscot Experimental Forest, and others. We thank Elias Ayrey at the University of Maine for significant time analyzing LiDAR data and building deer habitat models. Significant collaboration for this project is with Maine Department of Inland Fisheries and Wildlife.



*This single-tree selection stand exemplifies conditions that could potentially serve as shelter for deer in adverse weather conditions.*

*Photo: K. Bothwell*



# APPENDIX

## CFRU Products Delivered During 2017

Photo: B. Roth



# CFRU Publications

## Refereed Journal Publications:

- Bose, A. K., A. R. Weiskittel, R. G. Wagner. 2017. Occurrence, pattern of change, and factors associated with American beech-dominance in stands of the northeastern USA forest. *Forest Ecology and Management* 392: 202-212.
- Bose, A. K., A. Weiskittel, and R. G. Wagner. 2017. A three decade assessment of climate-associated changes in forest composition across the north-eastern USA. *Journal of Applied Ecology* 54(6): 1592-1604.
- Bose, A. K., R. G. Wagner, B. Roth, and A. Weiskittel. 2018. Influence of browsing and overstory on American beech and sugar maple regeneration nine years following understory herbicide release in central Maine. *New Forests* 49(1): 67-85.
- Castle, M., A. Weiskittel, R. Wagner, M. Duvey, J. Frank, and G. Pelletier. 2017. Variation in stem form and risk of four commercially important hardwood species in the Acadian Forest: Implications for potential sawlog volume and tree classification systems. *Canadian Journal of Forest Research*. 47(11): 1457-1467.
- Hiesl, P., M.S. Crandall, A.R. Weiskittel, and A.R. Kizha. 2017. Assessing alternative silvicultural prescriptions for mid-rotation, unthinned, spruce-fir stands in Maine. *Forests* 8 (370): 1:15
- Koirala, A., A. R. Kizha., and S. De Urioste-Stone. 2017. Policy recommendation from stakeholders to improve Maine's forest trucking enterprises: A qualitative research approach. *Forests*. 8(11): 434 doi:10.3390/f8110434.
- Koirala, A., A. R. Kizha, and B. E. Roth. 2017. Perceiving major problems and potential resolutions in forest products transportation by trucks and trailers. *European Journal of Forest Engineering*. 3(1):23-34.
- Koirala, A., A. R. Kizha, C. F. Dehoop, P. Hiesl, S. Gauthum, H.-S. Han, D. Abbas, and S. Bick. *In review*. Where have we reached? Scientific literatures in secondary forest products transportation from 2000 to 2015. Sustainable energy (under review).

## Research Reports & Conference Papers/Posters:

- Bothwell, K., E. Simons-Legaard, M. S. Crandall, and A. Roth. Using Landsat to Define Deer Wintering Areas in Maine. Cooperative Fish and Wildlife Research Unit Annual Coordinating Committee Meeting, March 2017, Orono ME. Poster.
- Koirala, A., A. R. Kizha., and S. De Urioste-Stone. Improving Maine's forest trucking enterprises: A qualitative approach. 40<sup>th</sup> Annual Meeting of the Council on Forest Engineering, July 30 to August 2, 2017, Bangor, ME.

Koirala A., A. R. Kizha., and B. E. Roth. Forest trucking industry in Maine: A review on challenges and resolutions. DEMO International Conference. September 2016. Vancouver, BC, Canada.

Parkhill, N. S., J. M. Tebbenkamp, S. Dunham, D. J. Harrison, and E. J. Blomberg. Effects of forest structure on nest site selection by spruce grouse across 2 scales. The Wildlife Society, October 2016, Raleigh, NC. Poster.

Parkhill, N. S., J. M. Tebbenkamp, S. Dunham, D. J. Harrison, and E. J. Blomberg. Effects of forest structure on nest site selection by spruce grouse across 2 scales. Maine Cooperative Fish and Wildlife Research Unit Annual Meeting, March 2017, Orono, ME. Poster.

Rahimzadeh-Bajgiran, P., A. Weiskittel, D. Kneeshaw, and D. A. MacLean. A multi-index Landsat-derived model for spruce budworm defoliation detection and quantification: Examples of past and current outbreaks (1970s and 2000s). ASPRS-Pecora Memorial Remote Sensing Symposium, November 2017, Sioux Falls, SD.

Tebbenkamp, J. M., E. J. Blomberg, D. J. Harrison, and R. L. Holberton. Is autumnal display associated with territorial defense or mate prospecting? A case study with spruce grouse. The Wildlife Society, October 2016 Raleigh, NC. Poster.

## **Theses:**

Bothwell, K. N. 2017. Economic and Spatial Impacts of a Wildlife Habitat Policy on Forest Management. M.S. thesis, University of Maine, Orono. 98 p.

Castle, M. 2017. Evaluating the Influence of Stem Form and Vigor on Product Potential, Growth, and Survival for Northern Commercial Hardwood Species. M. S. thesis, University of Maine, Orono. 85 p.

Koirala, A. 2017. Forest trucking industry in Maine: Opportunities and challenges. Masters in Forestry. University of Maine. 120 p.

## **Webinars:**

Bose, A. K. Exploring Silvicultural Strategies for New England: American beech. University of Vermont. February 15<sup>th</sup>, 2017.

## **Presentations/Workshops/Meetings/Field Tours:**

- Blomberg, E., S. Fraver, S. Morano, M. Thompson, T. Peterson. Bat Ecology in Maine Commercial Forests: Information Synthesis, Future Research Needs, and Pilot Data Collection. CFRU Spring Advisory Committee Meeting, April 2017, Orono, ME.
- Bose, A. K., A. R. Weiskittel, and R. G. Wagner. Stand archetypes, and management of American beech stands. CFRU Fall Advisory Committee Meeting, October 2016, Orono, ME.
- Bose, A. K., Weiskittel, A. and Wagner, R.G. 2017. Beech dynamics, stand archetypes, and management in the Northeast. Tenth Annual Meeting of the Center for Advanced Forestry Systems, May 2017. Portland, OR.
- Bothwell, K., M. S. Crandall, and A. Roth. Economic Impacts of Wildlife Regulations on Forest Management: The Opportunity Cost of Managing Deer Wintering Areas. New England Society of American Foresters Annual Meeting, March 2017, Bangor ME.
- Bothwell, K., M. S. Crandall, and A. Roth. Economic Impacts of Wildlife Regulations on Forest Management: The Opportunity Cost of Managing Deer Wintering Areas. CFRU Spring Advisory Committee Meeting, April 2017, Orono, ME.
- Kenefic, L., S. Fraver, A. Weiskittel, J.-C. Ruel, and A. White. Old Growth Characteristics of Northern White-Cedar Stands. CFRU Winter Advisory Committee Meeting, January 2017, Orono, ME.
- Kizha., A. R. Evaluating the opportunities and challenges of Maine's forest products trucking enterprises. Forest Bioproducts Research Experience, August 2017, Orono, ME.
- Kizha., A. R. Developing Management Guideline for the Forest Products Trucking Industry in Maine. Forest Resource Association Maine forum, December 2016, Brewer, ME.
- Kizha., A. R. Preliminary Results: Trucking Study, Maine. CFRU Fall Advisory Committee Meeting, October 2016, Orono, ME.
- Kizha., A. R. Challenges faced by the Secondary Forest Products Transportation in Maine. Forest Bioproducts Research Experience, July 2016, Orono, ME.
- Morano, S., P. Pekins, and F. Servello. Moose Density and Forest Regeneration Relationships in Maine. CFRU Spring Advisory Committee Meeting, April 2017, Orono, ME.
- Rahimzadeh-Bajgiran, P., A. R. Weiskittel, D. Kneeshaw, and D. A. MacLean. A model for spruce budworm defoliation detection and quantification using Landsat imagery. SFR-UMaine/MSG/NASA planning workshop, November 2016, Portland, ME.
- Rolek, B. D. Harrison, C. Loftin, and P. Bohall Wood. Effects of Forest Management Practices in Acadian Conifer Forests on Forest Bird Communities, with Emphasis on Species of Conservation Priority. CFRU Spring Advisory Committee Meeting, April 2017, Orono, ME.

Roth, B., C. Lachance, R. Wagner, and J. Benjamin. The Effects of Mechanized Harvesting Operations on Residual Stand Condition. CFRU Winter Advisory Committee Meeting, January 2017, Orono, ME.

Roth, B.E. The Cooperative Forestry Research Unit: Forest engineering, from where we've been, to where we're going. 40<sup>th</sup> Annual Council on Forest Engineering Meeting, July 31st 2017, Bangor, ME.

Wesley, N., L. Kenefic, S. Fraver, A. Weiskittel, J.-C. Ruel, and A. White. Old Growth Characteristics of Northern White-Cedar Stands. CFRU Winter Advisory Committee Meeting, January 2017, Orono, ME.





*Photo: R. Wishart*