CFRU

Cooperative Forestry Research Unit

2016 Annual Report

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Brian E. Roth (Ph.D), 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.

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Front Page Photo

Aerial photo of extensive partial harvesting in Northern Maine taken in October of 2016. Notice the mid-story beech component showing as orange in the hardwood stands – photo courtesy of Dr. Maxwell McCormack.

Credits

Final layout by Pamela Wells of Oakleafs Studio, Old Town, Maine. Individual sections were written by authors as indicated. Photography compliments of CFRU archives, Pamela Wells or as indicated.

A Note About Units

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

2016 CFRU Highlights

- CFRU membership and funding remained relatively stable this year, with 34 member organizations representing half (8.3 million acres) of Maine's commercial forests (See page 11).
- CFRU continued to leverage a wide variety of funding sources to support member research priorities. For every $1 contributed by CFRU's largest members, an additional $19.88 was leveraged from other sources (See page 11).
- CFRU in coordination with the **Maine office of GIS** has leveraged over $1.7 million for the second phase of LiDAR acquisition to be completed in western Maine in the spring of 2017 (See page 43).
- The CFRU hosted a very successful Field Tour on October 29th, 2015 focused on Spruce Budworm. Nearly 100 CFRU members, stakeholders, State and Federal policy makers attended to hear from leading SBW experts from **Quebec, New Brunswick** and **Maine** (See page 16).

Silviculture & Productivity Research

- Results from revisiting a 10 year-old study of **beech control in partially harvested stands** using ground-based herbicides indicates a lasting benefit on understory sugar maple abundance but not height. The lack of a height response to release was most likely due to the effects of browsing and increasing crop tree basal area in the overstory (See page 21).
- A study was completed to identify the **structural characteristics** that are potentially **unique to old-growth northern white-cedar stands**. The volume of advanced-decay coarse woody material and live tree quadratic mean diameter differentiate old-growth from partially harvested stands. The ability to identify old-growth northern white-cedar stands through these characteristics improves successful management of the species (See page 28).
- Findings from a study examining the **effects of mechanized harvesting operations on residual stand conditions** demonstrated that despite severe rutting and soil disturbance at the time of Whole Tree clearcut harvesting at the Weymouth Point Study, there was no negative impact observed on forest composition, structure, or crop tree growth after 32 years. Soil disturbance had no influence on all tree- and stand-level variables examined, including basal area, density, percent hardwood, volume, DBH, and height (See page 32).

Growth & Yield Modeling Research

- The **influence of tree stem form and defects** on potential product recovery, diameter increment, probability of survival, and occurrence of decay in northern hardwood species was modeled. Stem taper, crown ratio, and species were found to be influential factors for predicting the occurrence of internal stem decay. Potential product recovery was significantly lower for trees with multiple sweeps or stems, severe lean, significant forks or those considered to be high risk. Annual diameter growth was 6% lower for high risk trees and the probability of survival was lower for trees with severe lean, and multiple stems or sweeps (See page 38).
- The first phase of a three year plan **to acquire Statewide LiDAR data** has been completed and plans are in place for the second year's data to be acquired in 2017 (See page 43).

- This was the first year of a two year study aimed at identifying the relationships between **Spruce Budworm (SBW) moth abundance, larval density, and mapped forest conditions** for risk assessment during outbreak development. The study will identify forest and landscape features that promote SBW population establishment and growth, and identify areas where immigrant moths are more likely to seed local populations. A total of 241 locations were sampled for pheromone traps and L2/branch density in areas that are representative of the forest conditions, terrain, and environments expected to influence the establishment and growth of local SBW populations (See page 47).
- A new study has begun that uses **Landsat satellite imagery to detect and estimate SBW defoliation severity** on the landscape that is similar to the aerial sketch mapping of the past. Early results indicate potential for the effective detection and classification of areas of defoliation over a four year period on the North Shore in Quebec. This tool would have the advantage of greater accuracy, near real-time availability, and increased cost effectiveness and non-subjective methodology as compared to traditional methods (See page 52).
- **A 20 meter resolution map of predicted site quality** was made for the entire Acadian Forest Region as a function of climate, lithology, soils and topographic features; the products are available on the CFRU website for download: http://www.forusresearch.com/bgi.php (See page 57).

Wildlife Habitat Research

- A total of 57 Spruce Grouse were monitored in the second year of a three year project examining **the link between commercial forest management, forest habitat characteristics and Spruce Grouse population performance.** Preliminary data indicates that nest site selection by adult females was negatively associated with the basal area of live trees at both local (30 m) and patch (forest stand) scales and yet there was a positive relationship with lateral cover at the local scale (See page 61).
- A study of **Northern Long-Eared Bats (NLEB) in Maine** was completed as the NLEB was listed as ESA Threatened in 2015. The study consisted of a literature review focused on bats in northeastern forest ecosystems along with field sampling of bat occupancy to evaluate several detection methods and their efficacy in Maine forests. The NLEB has generalist habitat preferences, some of which may differ in the northeast relative to other portions of the species range. Acoustic surveys may fail to detect the species if detectors are not deployed for a sufficient number of sampling nights (See page 65).
- The **opportunity costs of managing Deer Wintering Areas** (DWAs) was quantified by modeling common silvicultural scenarios from two representative timberland properties. Results were specific to site and the influence of landowner objectives on past management. In one case, there were lower revenues in deeryards due to less stand tending, while in the other case, higher revenues resulted due to a greater commercial species composition (See page 73).
- Over two years, the **effects of moose density on forest regeneration, composition and damage** was investigated in hardwood, mixedwood and conifer stands of varying age and harvest histories. Evidence of damage was higher in hardwood stands and declined with time since harvesting (See page 77).

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CFRU Faculty, Staff and Students repaint the CFRU storage building in May 2016. This building was the first project funded by the CFRU upon its formation in 1975. Photo – Brian Roth.

Chair's Report

CFRU Chair, Gordon Gamble

It is my pleasure to present this 2016 Annual Report from the Cooperative Forestry Research Unit (CFRU). In this report you can find a review of activities of the Cooperative as well as results from a dozen ongoing and completed applied research projects in the areas of Silviculture, Productivity, Growth & Yield, and Wildlife Habitat. I hope you will find as much value in this information as I have.

The summer of 2016 was a period of change for the CFRU, and the Center for Research for Sustainable Forests (CRSF) where it is housed, with the retirement and departure of Director, Dr. Bob Wagner for greener pastures at Purdue University in Illinois. Like any good leader, Bob was instrumental in bringing highly qualified and engaged people into the University of Maine System. Two examples are Drs. Aaron Weiskittel and Brian Roth, both of whom will be key to carrying on the great work that is done by the CFRU. I wish Bob the very best in his new position and I am sure he will excel. With Bob's departure, Dr. Brian Roth assumed a leadership role as CFRU Acting Director while Dr. Aaron Weiskittel is serving as the Acting Director of the CRSF. As the Director of CRSF reports directly to Vice President of Research (VPR) at the University of Maine, the VPR will make the final CFRU appointment at the recommendation of the CFRU Executive Committee pending a review of the CRSF.

The forest industry is experiencing many challenges these days and with the increased uncertainty it is certain that changes will be coming in the years ahead. However, I am confident that with the ongoing efforts of the CFRU to provide relevant knowledge and information of interest to our membership, we will all be in a better position to make informed decisions about how best to manage our forest resource while influencing policy at State and National levels.

Gordon Gamble (Wagner Forest Management)
CFRU Chair

Acting Director's Report

The year 2016 marks the 40th year that the CFRU has been in existence. While it is hard to imagine Maine's forestry community without the rich history of this unique cooperative, I am particularly conscious of the considerable efforts of all who have been involved over the years in bringing the CFRU to where we are today. In August of 2016, after over 18 years leading the CFRU, **Dr. Bob Wagner** moved on to a leadership role with the **Forestry & Natural Resources Department** at **Purdue University** and I assumed the role of **Acting Director**, having served the CFRU since 2011 as the **Associate Director.**

I consider leading this organization to be the greatest honor and privilege of my 25 year career in applied forest research. I am humbled by the trust that the CFRU Executive, Members and University Administration have placed in me as we move through a particularly challenging period of change in the forest sector. Along with their support and guidance, I will continue to work hard to keep the CFRU relevant in supporting the research needs and interests of its membership. It is my goal for the CFRU to remain a national model for stakeholder-driven forest research for the next 40 years and beyond.

I am excited about the opportunity to collaborate with stakeholders, Researchers and Students in providing the information and knowledge that is needed to improve forest management and policy within this state and region. As the CFRU leadership transition continues, I am looking forward to listening to your ideas and concerns about how to best to manage this diverse and extensive forest resource in Maine.

B. E. Roth

Brian E. Roth
CFRU Acting Director

Brian Roth on the Beech Mountain lookout tower on Mount Desert Island, Maine

Membership

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

WOOD PROCESSORS:
SAPPI Fine Paper
UPM Madison Paper

CORPORATE / INDIVIDUAL MEMBERS:
ReEnergy Holdings, LLC
James W. Sewall Company
Huber Engineered Woods, LLC
Forest Society of Maine
LandVest
Field Timberlands

ADVISORY COMMITTEE:

Chair: Eric Dumond
ReEnergy Holdings, LLC

Vice Chair: Gordon Gamble
Wagner Forest Management

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:
Butch Barberi – *UPM Madison Paper*
Kyle Burdick – *Downeast Lakes Land Trust*
John Bryant – *American Forest Management (BBC Land, LLC)*
Tom Charles – *Maine Division of Parks & Lands*
Brian Condon – *The Forestland Group, LLC*
Frank Cuff – *Plum Creek Timber Company, Inc.*
David Daut – *Timbervest, LLC*
Jason Desjardins – *Canopy Timberlands Maine, Inc. (Orion Timberlands, LLC)*
David Dow – *Prentiss and Carlisle Company, Inc.*
Alec Giffen – *New England Forestry Foundation*
Brian Higgs – *Baskahegan Corporation*
Eugene Maher – *LandVest (Frontier Forest, LLC; Clayton Lake Woodlands Holding, LLC; Simorg North Forests, LLC; EMC Holdings, LLC, Mosquito, LLC)*
Kevin McCarthy – *SAPPI Fine Papers*
Marcia McKeague – *Katahdin Forest Management, LLC*
Wil Mercier – *J.W. Sewall Company*
Jacob Metzler – *Forest Society of Maine*
Bill Patterson - *The Nature Conservancy, LLC*
Dan Pelletier – *Huber Engineered Woods, LLC*
Ian Prior – *Seven Islands Land Company*
Jim Robbins, Jr. – *Robbins Lumber Company*
Eben Sypitkowski – *Baxter State Park*
Steve Tatko – *Appalachian Mountain Club*

Research Team

CFRU Summer Crew

Staff

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

Cooperating Scientists

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

Project Scientists

Lee Allen, PhD, ProFOR Consulting
Arun Bose, PhD, University of Maine
Jeff Benjamin, PhD, Bangor Christian Schools
Mindy Crandall, PhD, University of Maine
Erik Blomberg, PhD, University of Maine
Jereme Frank, MS, University of Maine
Shawn Fraver, PhD, University of Maine
Chris Hennigar, PhD, University of New Brunswick
Laura Kenefic, PhD, USDA U.S. Forest Service, Northern Research Station
Daniel Kneeshaw, PhD, University of Quebec at Montreal
Christian Kuehne, PhD, University of Maine
Erin Simons-Legaard, PhD, University of Maine
Kasey Legaard, MS, University of Maine
David MacLean, PhD, University of New Brunswick
Sabrina Morano, PhD, University of Maine
Peter Pekins, PhD, University of New Hampshire
Gaetan Pelletier, University of Moncton
Amber Roth, PhD, University of Maine
Fred Servello, PhD, University of Maine
Daniel Walters, US Geological Survey
Joseph Young, Maine Office of GIS

Graduate Students

Mark Castle (MS student – Weiskittel) – Hardwood stem form & vigor
Todd Douglass (MF student - Crandall)
Cody Lachance (MS student – Wagner/B.Roth) – Mechanized harvesting conditions
Sean Lamb (MSc student – Hennigar) – Growth and yield
Joel Tebbenkamp (PhD student – Harrison) – Spruce grouse habitat
Karin Bothwell (MS student – Crandall/A.Roth) – Impacts of wildlife habitat regulations
Nathan Wesley (MS student – Kenefic/Fraver) – Old growth cedar

Financial Report

Brian Roth,
CFRU Acting Director

Thirty-four members representing 8.26 million acres of Maine's forestland contributed $498,490 to support the CFRU this year (**Table 1**). These member contributions will be used to support research activities during FY 2016-17. The amount of acreage by our Landowner/Manager members decreased by 59,917 acres (0.7%) following land sales and purchases this year. A significant addition this year was welcoming **Sandy Gray Forest, LLC** as a new landowner member with the CFRU. Sandy Gray Forest, LLC will be managed by Huber Resources Corporation and we look forward to having them as a member of the CFRU. Tons of wood products produced by wood processor members decreased slightly (46,800 tons or 2.1%) relative to last year, and we are concerned about the stability of membership in this class given market pressures on the pulp and paper industry. Overall, CFRU member contributions remained stable (a $9,749 or 1.9% decrease) relative to FY 2014-15. We thank all of our members for their continued financial and in-kind contributions, as well as the trust in the CFRU and UMaine that these contributions represent.

In addition to member financial contributions, CFRU Cooperating and Project Scientists were successful at leveraging an additional $376,155 in extramural grants to support CFRU research projects. This amount does not include $1,740,646 in leveraged funding for LiDAR acquisition from Federal and local sources and $60,000 from the **National Science Foundation** as part of CFRU's membership in the national **Center for Advanced Forestry Systems (CAFS)**, which is supporting the Commercial Thinning Research Network and Growth & Yield modeling projects. These external grants made up 32% of CFRU total income this year (Fig. 1). In addition to extramural sources, UMaine provided $141,348 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 $173,494. Therefore, UMaine provided an additional $314,842 or 27% of total funding. In total, about 68% ($690,997) of all CFRU funding came from external sources or from direct and indirect support from UMaine.

As a result, for every $1 contributed on average by CFRU's five largest members (**Irving Woodlands, Wagner Forest Management, BBC Land, Plum Creek Timber Company,** and **Prentiss & Carlisle**) this year, $7.17 was received from other CFRU member contributions, $6.92 was contributed by external grants through CFRU scientists, and $5.79 was received from UMaine in direct and indirect contributions; for a ***total leveraging of $19.88 for every $1 contributed by CFRU's largest members***.

Continued sound fiscal management by CFRU scientists and staff resulted in spending $5,201 (1.0%) less than the $508,780 that was approved by the Advisory Committee for this fiscal year (**Table 2**). All projects came in at or near budget. The approved request from **Dr. Bob Wagner** to spend the FY14-15 research project surplus of $33,220 towards the purchase of replacement vehicles in the CFRU Fleet was carried out with the purchase of two new vehicles and the sale of two older models. The earlier request for $10,000 from the CFRU control account to 'seed' the CFRU fleet account was not needed.

CFRU research expenses by category this year included 31% on four silviculture & productivity projects, 38% on five growth & yield modeling projects, and 31% on four wildlife habitat projects (**Figure 2**).

Table 1. CFRU member contributions received FY 2015-16 (for allocation during FY 2016-17).

CFRU Member	FY15-16		FY16-17		Changes Acres/tons	Assessed Amount	Received as of 09/19/2016
FOREST LANDOWNERS / MANAGERS:							
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
TOTAL	**8,256,580**	**acres**	**8,196,663**	**acres**	**-59,917**	**$465,437**	**$462,690**
WOOD PROCESSORS:							
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
TOTAL	**2,186,400**	**tons**	**2,139,600**	**tons**	**-46,800**	**$27,173**	**$23,500**
CORPORATE and INDIVIDUAL MEMBERS:							
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
TOTAL						**$12,300**	**$12,300**
GRAND TOTAL (34 members):						**$504,910**	**$498,490**

Table 2. CFRU expenses incurred during FY 2015-16.

PROJECT	Principal Investigator	Approved Amount	Amount Spent To-Date	Balance Remaining	% Balance Remaining
Total Administration		$204,875.00	$204,291.40	$583.60	0.3%
Administration	Roth	$204,875.00	$204,291.40	$583.60	0.3%
Research Projects					
Silviculture and Productivity:		$97,153.00	$94,752.01	$2,400.99	2.5%
CTRN Commercial Thinning Research Network: Continued Measurements and New Opportunities	Roth	$32,695.00	$31,263.52	$1,431.48	4.4%
The Effects of Mechanized Harvesting Operations on Residual Stand Condition	Roth	$33,043.00	$32,986.51	$56.49	0.2%
Identifying Attributes that Distinguish Old-and Second-Growth Northern White-Cedar Stands for Forest Management and Planning	Weiskittel	$12,000.00	$11,267.31	$732.69	6.1%
Strategies for rehabilitating beech-dominated stands	Roth	$19,415.00	$19,234.67	$180.33	0.9%
Growth & Yield Modeling		$114,418.00	$112,749.75	$1,668.25	1.5%
Assessing the Influence of Tree Form and Damage	Weiskittel	$24,191.00	$24,010.05	$180.95	0.7%
Linking Site Quality to Tree Growth and Survival in the Acadian Forest	Weiskittel	$27,759.00	$27,759.00	$0.00	0.0%
Maine Statewide Light Detection and Ranging (LiDAR) Data Acquisition Project		$10,000.00	$10,000.00	$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	$36,094.00	$34,519.79	$1,574.21	4.4%
Development an application of early detection and monitoring of SBW defoliation using remote sensing	Rahimzadeh & Weiskittel	$16,374.00	$16,460.91	-$86.91	-0.5%
Wildlife Habitat:		$92,334.00	$91,785.96	$548.04	0.6%
Populations Dynamics Spruce Grouse	Harrison	$29,829.00	$29,321.66	$507.34	1.7%
Moose Density and Forest Regeneration Relationships in Maine	Pekins	$21,890.00	$21,976.81	-$86.81	-0.4%
Bat Ecology in Commercial Forests	Blomberg	$23,455.00	$23,424.24	$30.76	0.1%
Economic Impacts of Wildlife Regulations on Forest Management and Industry	Crandall	$17,160.00	$17,063.25	$96.75	0.6%
Total		**$508,780.00**	**$503,579.12**	**$5,200.88**	**1.0%**

Dan Kneeshaw (UQAM) discusses Spruce Budworm and stand dynamics on the 2015 CFRU Fall Field Tour - photo Brian Roth

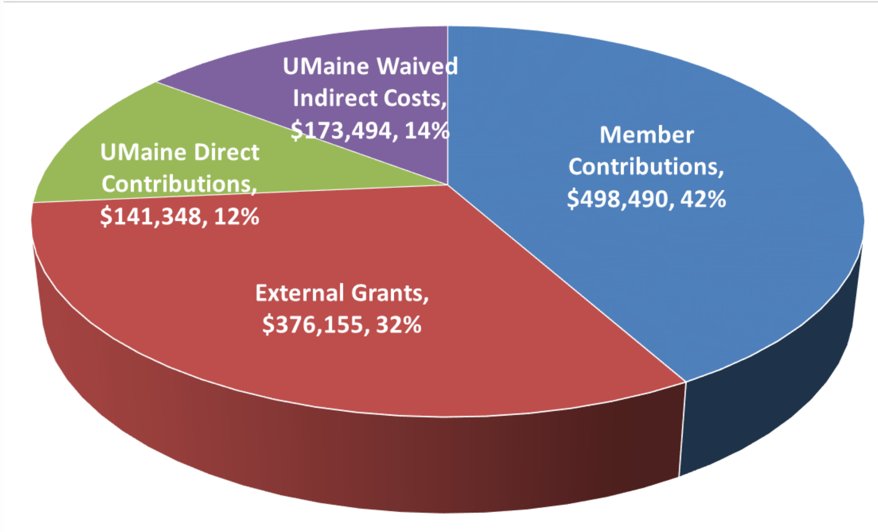


Figure 1. CFRU income sources FY 2015-16.

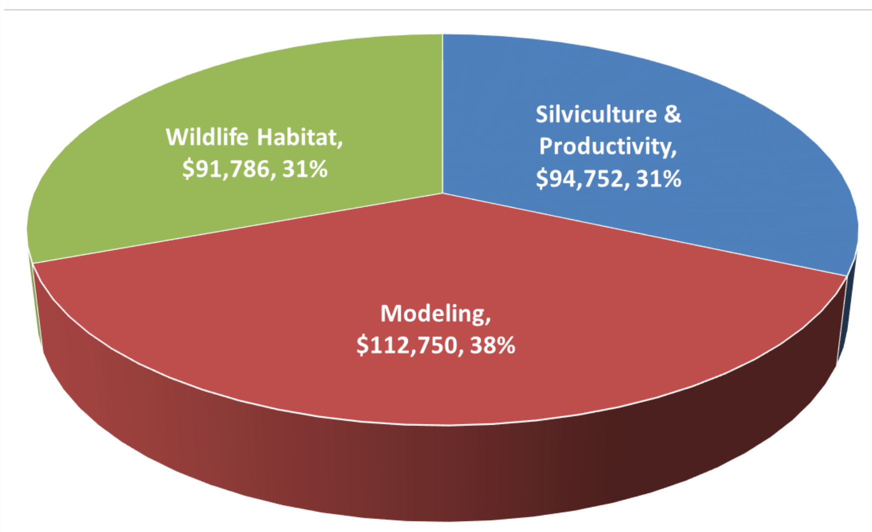


Figure 2. CFRU research expenses FY 2015-16.

Activities

Advisory Committee

Rich Hoppe on the 2015 CFRU Fall Field Tour. Photo - Brian Roth

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. 2016 was a period of change on the CFRU Executive. This marked the first year of a two year term for **Eric Dumond (ReEnergy Holdings, LLC)** as Chairperson, **Gordon Gamble (Wagner Forest Management)** as Vice Chairperson, **Kenny Fergusson (Huber Resources)** as Member-at-Large and **Greg Adams (JD Irving Ltd.)** as Financial Officer. However, due to Eric's retirement from ReEnergy Holdings, he resigned his position in the fall of 2016. As per CFRU by-laws, the Vice Chairperson assumes the Chairperson position immediately. This left a vacancy at Vice Chairperson and **Ian Prior (Seven Islands Land Company)** was elected. To maintain the officer term schedule in even years, it was decided that this current executive serve a 3 year term and then return to the current 2 year term schedule with elections in the Fall of 2018.

The Advisory Committee meets three times a year for business meetings. The first business meeting of FY 2015-16 was held on October 28, 2015 at the **Shiretown Inn & Suites** in **Houlton, ME** where the new CFRU Vehicle Fleet account was discussed and launched. At the second meeting, held on January 20, 2016 at UMaine, in celebration of CFRU's 40th Anniversary, Wagner presented cooperators with a special edition anniversary hat. Ten pre-proposals were presented to the Advisory Committee. Of these, five were approved to advance to the full proposal stage and were presented at the April 20th, 2016 business meeting. All five projects were approved for funding to begin on October 1, 2016. Look for updates on these projects in future CFRU presentations, publications and annual reports. In addition to the business meetings, a special CFRU Executive Committee meeting was held on September 14th, 2016 where the CFRU leadership transition was discussed.

Cooperators

CFRU membership continued to be remarkably stable in 2015-16 with one new member and only a slight loss in acres managed due to land sales (Table 1). **Sandy Gray Forest, LLC** joined as a Landowner member and is represented by Huber Resources. Welcome to the CFRU!

Personnel

Drs. Arun Bose and **Christian Kuehne** continue work on CFRU projects as Post-Docs with the support of CAFS. Arun is working on forest regeneration patterns while Christian is using the CTRN dataset to develop thinning modifiers for existing growth and yield models. **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** has assumed leadership duties as the **Acting Director**. Brian will report to **Dr.**

Aaron Weiskittel, who will serve 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. Carole Kim, that these appointments become permanent. This decision is being delayed by a pending review of the CRSF by the VPR's office.

2015 Fall Field Tour

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

Students

The CFRU continues to contribute to the development of students, with four graduate students completing degrees funded by CFRU projects this year. **Brian Rolek** has completed his PhD on the forest birds project and **Steve Dunham** has completed his MS degree on a Spruce Grouse project, both under the direction of **Dr. Dan Harrison**. In addition, **Cody Lachance** has completed his MS project focusing on stand conditions following mechanized harvesting with the supervision of **Drs. Bob Wagner and Brian Roth. Nathan Wesely** has finished a MS degree examining the characteristics of old-growth cedar under the guidance of **Drs. Laura Kenefic** (USFS) and **Shawn Fraver**. We wish Brian, Steve, Cody and Nathan all the best in their new endeavors following graduate school.

There are currently five graduate students working on CFRU funded projects**: Joel Tebbenkamp** (Ph.D., Spruce Grouse) is co-advised by Drs. **Erik Blomberg** and **Dan Harrison. Dr. Aaron Weiskittel** is supervising **Mark Castle** (MS, Hardwood Stem form Growth & Yield). **Todd Douglass** (MF, hardwood stem form) is working with Drs. Aaron Weiskittel and **Mindy Crandall**. **Sean Lamb** (MSc., managed stand growth and yield models) is working with Dr. **Chris Hennigar** at the **University of New Brunswick**. **Karin Bothwell** (MS, impacts of wildlife habitat regulations) is working under the supervision of Drs. Mindy Crandall and **Amber Roth**. In addition, almost two dozen undergraduate students were hired as research technicians for CFRU projects during the summer of 2016 including one foreign forestry student, **Anton Nilsson**, from the **Swedish University of Agricultural Sciences**.

Ted Shina, Huber Resources Corporation Senior Operations Forester at 2015 Summer Crew Safety Training Session. Photo - Brian Roth

Center for Advanced Forestry Systems (CAFS)

Aaron Weiskittel and Bob Wagner

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. With the completion of Phase I, the Maine CAFS site has entered Phase II of the I/UCRC as a result of a successful NSF proposal led by Bob Wagner and Aaron Weiskittel. In Phase II, NSF will provide $60,000 per year for 5 years if CFRU members contribute a minimum of $350,000 per year. Phase 1 of CAFS contributed $70,000 per year to the **University of Maine** since CFRU members contributed a minimum of $300,000 per year to support the work of the site. The intent of the 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.

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.

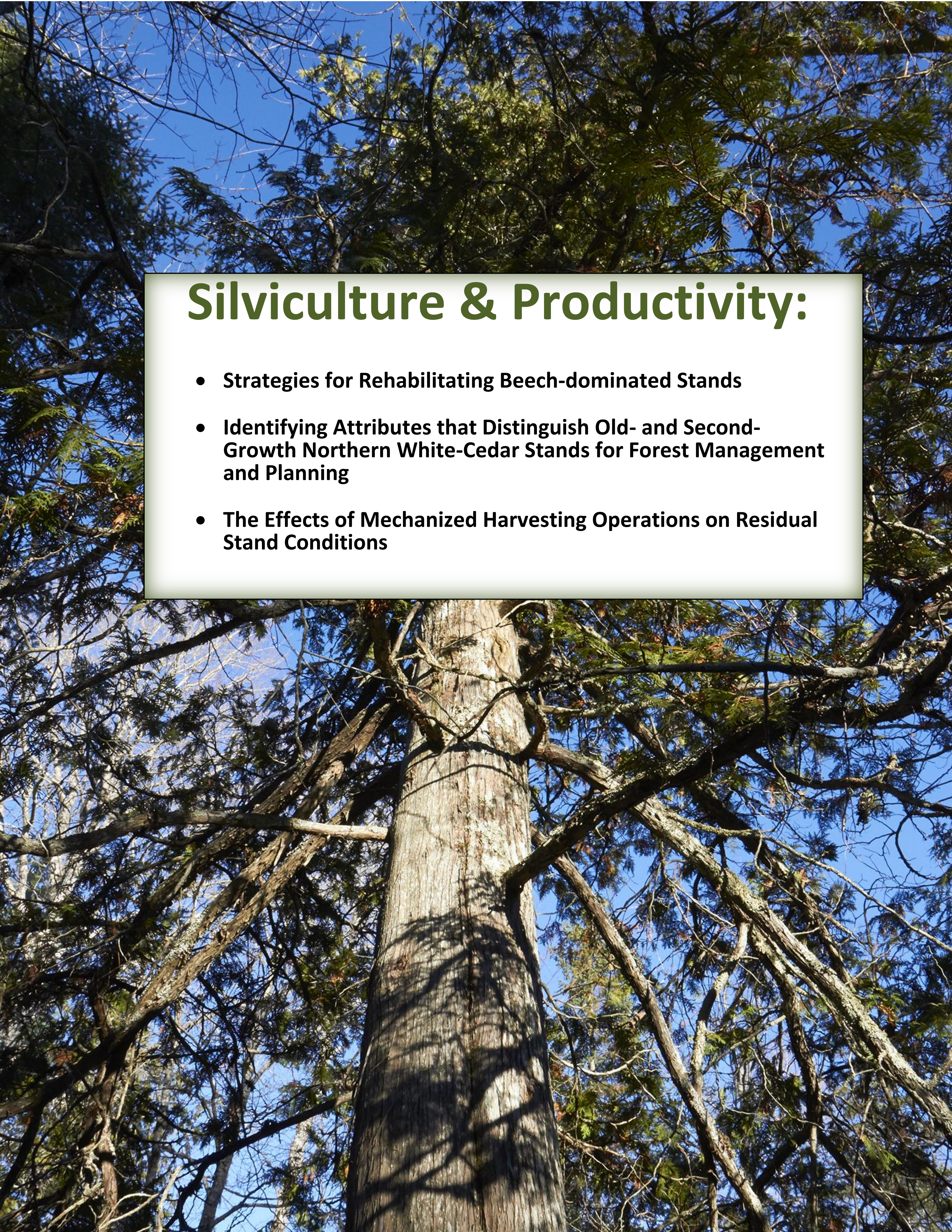
One new CAFS project was funded this year (16.65). This two-year project is a NSF Fundamental Research Project in partnership with Virginia Tech and the University of Washington aimed at understanding and modeling competition effects on tree growth and stand development across varying forest types and management intensities. There are also two existing CAFS projects in their first year (15.59 & 15.64). Project 15.59 supports Post-Doc Dr. Arun Bose's research on the classification, projection, and financial impact of beech-dominated understories in mid-rotation stands in the northeast. Project 15.64 supports Post-Doc Dr. Christian Kuehne's research on the impact of commercial thinning on the growth response and upper diameter distribution potential of commercial forest stands.

CFRU staff and several Advisory Committee members represented the Maine CAFS site at the Ninth Annual CAFS Industrial Advisory Board (IAB) Meeting held May 26-28, 2016 in Pensacola Beach, Florida. 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.

CAFS Partner Institutions

- NC State University
- Oregon State University
- Purdue University
- Auburn University
- The University of Georgia
- University of Idaho
- The University of Maine
- University of Washington
- Virginia Tech

Common Yellow-throated Warbler - Photo Pamela Wells



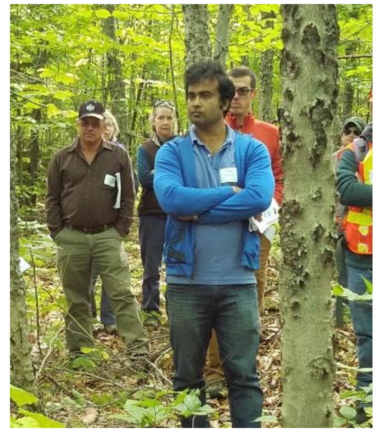
Silviculture & Productivity:

- **Strategies for Rehabilitating Beech-dominated Stands**
- **Identifying Attributes that Distinguish Old- and Second-Growth Northern White-Cedar Stands for Forest Management and Planning**
- **The Effects of Mechanized Harvesting Operations on Residual Stand Conditions**

Strategies for Rehabilitating Beech-dominated Stands

Robert Wagner[2], Aaron Weiskittel[1], Arun Bose[1], Brian Roth[1], and Gaetan Pelletier[3]

[1]School of Forest Resources, University of Maine, ME, USA
[2]Purdue University, IN, USA
[3]University of Moncton, NB, Canada



Dr. Arun Bose with diseased beech

Progress Report, Year 1

Summary:

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

Project Objectives:

- Determine whether the understory beech control treatments that were applied in 2006 as part of the CFRU beech control study (Nelson and Wagner 2011, 2014) maintained a sugar maple-dominated understory 10 years after treatment.

- Quantify the extent of the beech problem across forest land areas of Maine.

- Classify beech-dominated stands based on their species composition, productivity, and silvicultural difficulty and project future stand conditions for the derived stand classifications.

- Assess the financial value of a range of silvicultural interventions applied to the range of derived stand classifications to determine the viability of developing cost-effective silvicultural treatments for reducing beech to shift the composition to higher-value tree species.

Approach:

- In August 2006, a 3 X 4 factorial combination of glyphosate herbicide and surfactant concentrations were tested. These factors included glyphosate rates of 0.56, 1.12, and 1.68 kg ha^{-1} and surfactant concentrations of 0.0, 0.25, 0.5, and 1.0% ($v\ v^{-1}$) plus a non-treated control.

- In November 2015, all treatment units (13 treatments at 3 sites) were measured for regeneration species, dbh, height and browsing status. Overstory trees were assessed using an English 10 basal area factor variable-radius plot.

- Regeneration abundance (absolute and relative) and height were modelled as a function of species (sugar maple, beech, other hardwoods and softwoods), glyphosate rate, surfactant, overstory basal area and browsing classes (heavy, moderate and light).

- US Forest Service Forest Inventory and Analysis (FIA) data was used to understand the extent of beech issue in Maine as well as three other states of the northeastern USA (New Hampshire, New York and Vermont). We considered all FIA plots that had at least one individual of American beech to identify the extent of the beech presence.

- Plots with at least one beech were classified/grouped using the hierarchical cluster analysis to identify the beech-dominated forestland areas. The occurrence of different stand types where beech was presence was modelled as a function of time (past 16 years) as well as a function of key biotic and abiotic factors.

Key Findings / Accomplishments:

- Successful sugar maple release, as documented three years after herbicide treatment, was sustained through year nine.

- Glyphosate rate increased the abundance of sugar maple regeneration, but not height. In contrast, the abundance and height of beech regeneration were all significantly decreased with increasing glyphosate rate. However, post-release browsing and an increased overstory basal area reduced the sugar maple height.

- Our results indicated that glyphosate herbicide can significantly increase the abundance of sugar maple regeneration, however, subsequent browsing combined with the negative influence of the residual overstory in shelterwood stands can reduce the overall benefit of these treatments. Therefore, in addition to herbicide treatment, a post treatment overstory removal and browse control measures may be needed to promote sugar maple regeneration over beech in northern hardwood stands.

- In Maine, 36% of the total forestland area currently (2011-2015) has beech present. Based on the understory, midstory and overstory characteristics, we identified four distinct stand types where beech was present: i) beech-dominated, ii) commercial hardwood-dominated, iii) other hardwood dominated, and iv) softwood dominated.

- Among these four stand types, the beech-dominated type currently occupies 9.0% of the total forestland areas of Maine and has increased by ~1% over the past 16 years.

- Increasing mean annual precipitation and overstory basal area were positively associated with the probability of occurrence of the beech-dominated stand type. However, the same effects had a negative association on the probability of occurrence 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.

- Overall, the findings highlight the extent of the diseased beech issue and the factors that promoting the dominance of beech across the forested landscape of northeastern USA. This knowledge is important for understanding the large-scale changes in forest composition in the northeastern USA, the implications for management decisions in these stand types.

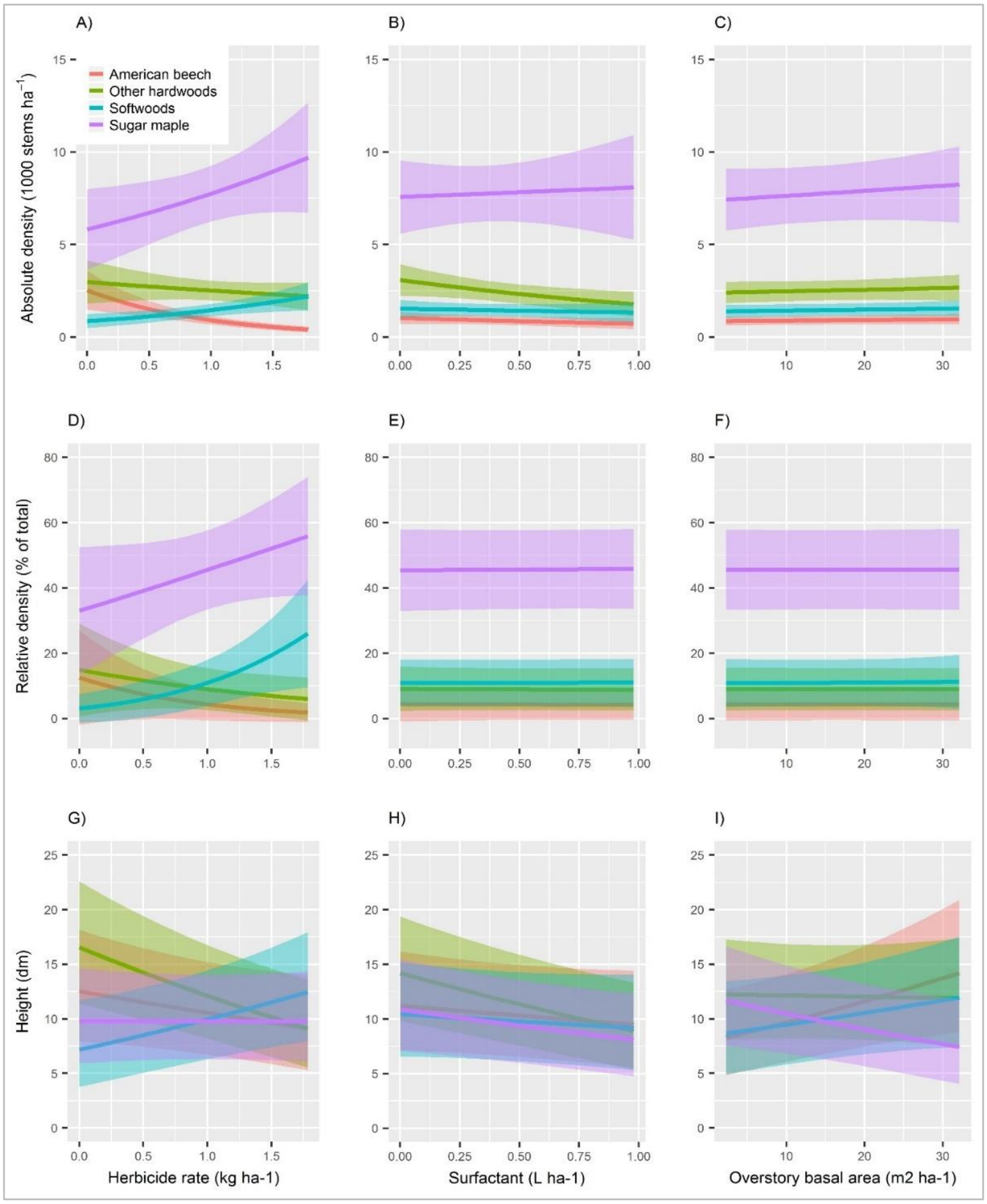


Figure 3. Predicted regeneration absolute density, relative density and height with 95% confidence interval as a function of herbicide rate, surfactant concentration, and overstory basal area for heavily browsed regeneration.

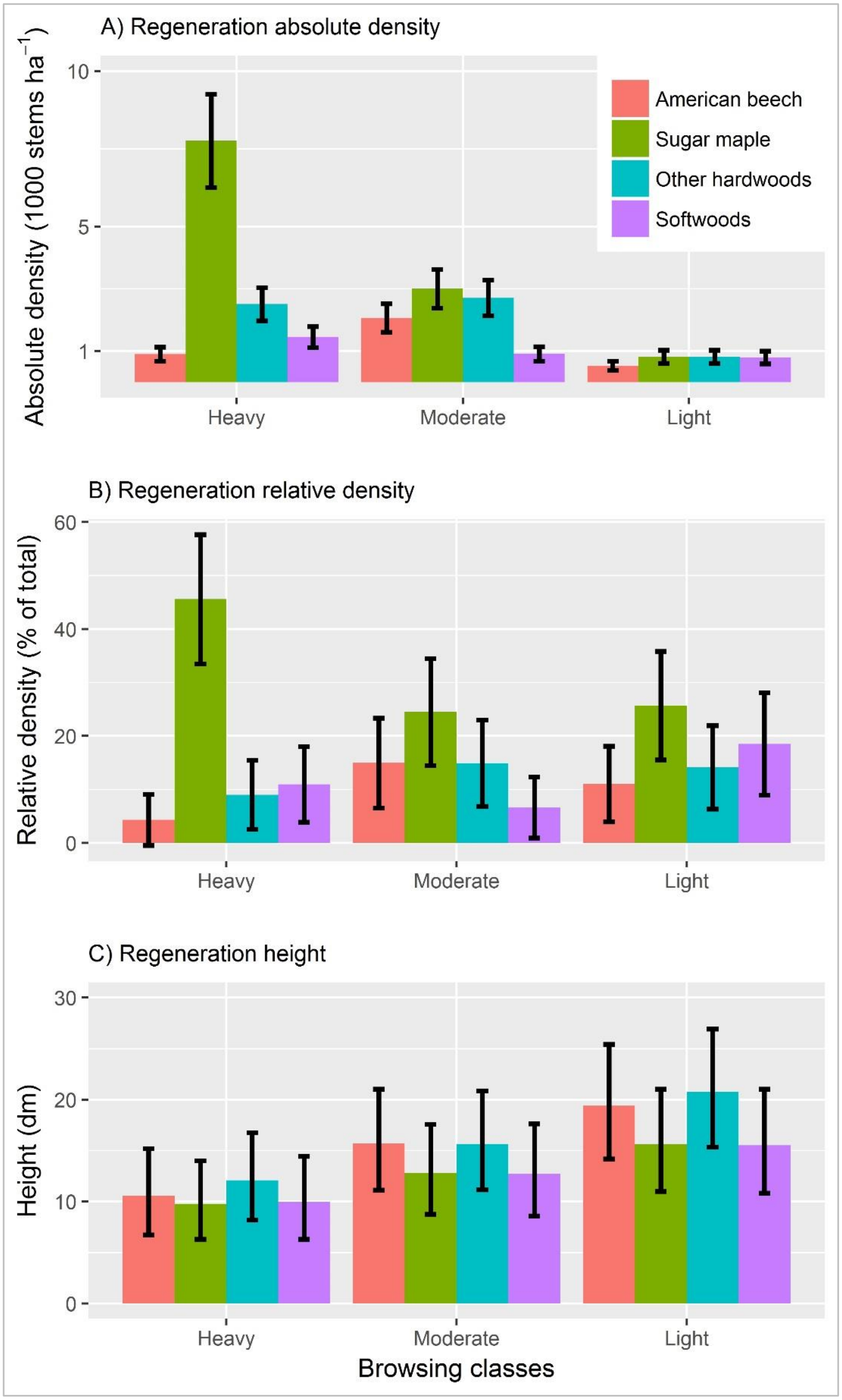


Figure 4.Predicted regeneration absolute density, relative density, and height of four tree species for three browsing damage classes (mean ± 95% confidence).

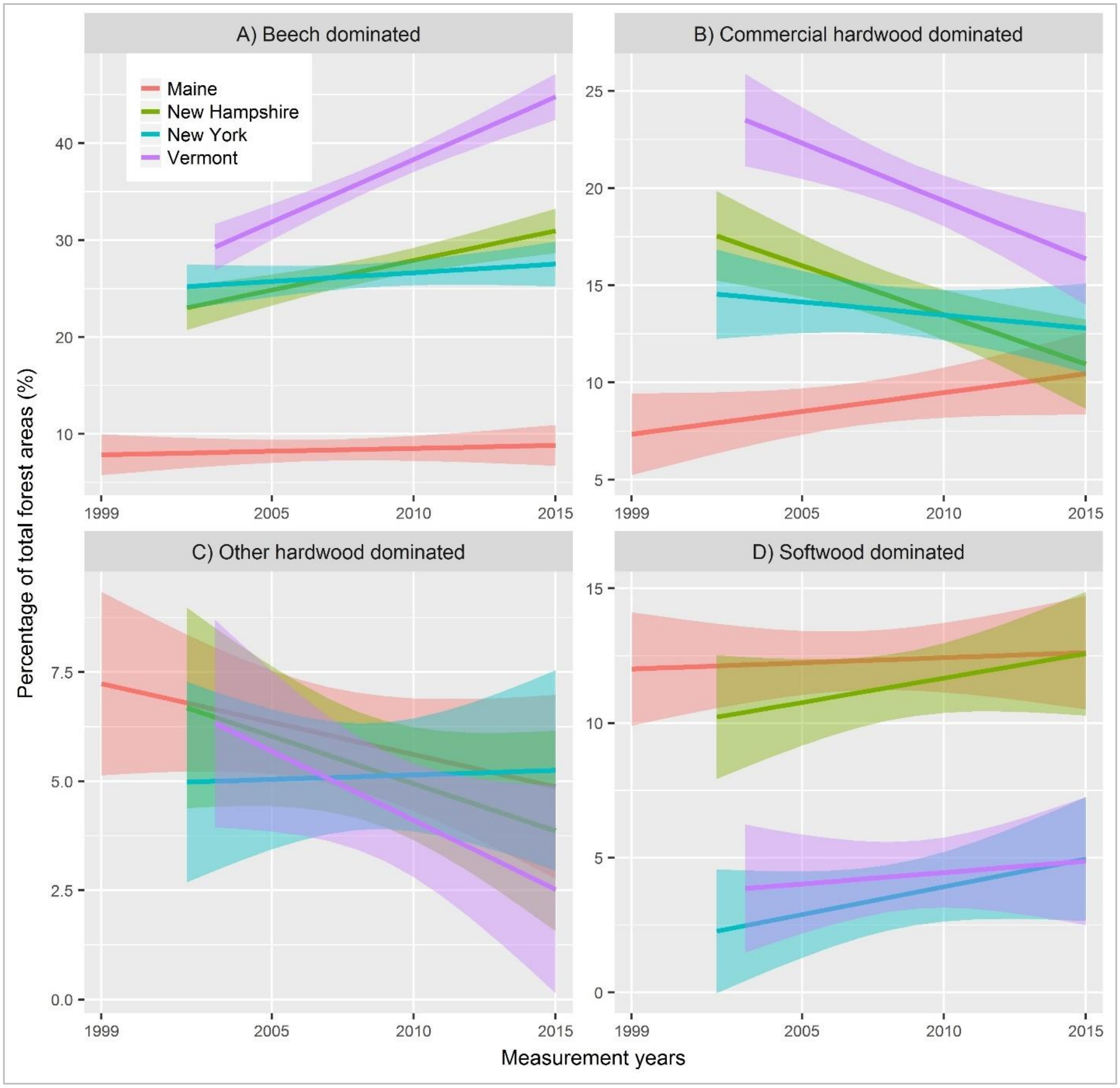


Figure 5. Predicted changes in occupation (% of total forest area in the region) with 95% confidence intervals for the four stand types over the past 16 years for four northeastern states of USA.

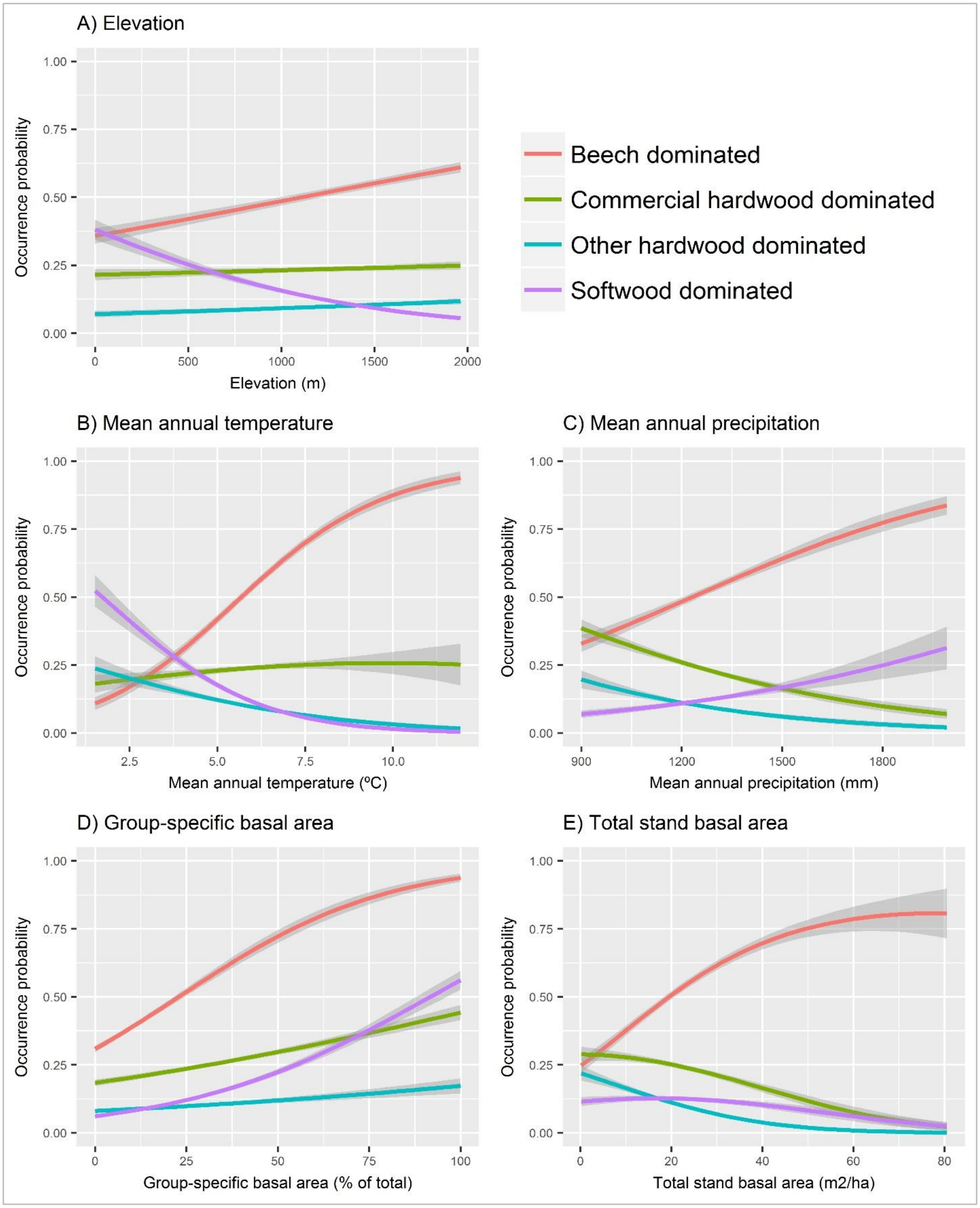


Figure 6. Predicted occurrence probability with 95% confidence intervals of the four stand types in the four northeastern states by gradients of A) elevation (m), B) mean annual temperature for the period of 1980-2015 (°C), C) total mean annual precipitation for the period of 1980-2015 (mm), D) conspecific overstory basal area (% of total) of each stand type, and E) total stand overstory basal area (m^2 ha^{-1}).

Future Plans:

- In Year-2, The FVS-ACD will be used to project the future conditions of the derived four stand types 50-100 years into the future using a factorial combination of various levels of overstory and understory basal area (0, 33, 66, and 100%) removal. Model outputs such as relative abundance of beech at various size classes, stand volume, and regeneration density will be analyzed in terms of mean and the variance.

- We will also collaborate with forest managers in northern Maine to identify representative examples of the four identified stand types that provide the highest value opportunity for rehabilitation. We will then develop potential operational silvicultural strategies for treating these stands. We will use qualitative methods to determine general recommendations in agreement with our findings.

Acknowledgements:

We are thankful to Rob and Emma-Grace Nelson for their outstanding technical support in relocating and re-measuring the experimental plots used in this study. Funding for this work was provided by the National Science Foundation (NSF), Center for Advanced Forestry Systems (CAFS) and the Cooperative Forest Research Unit (CFRU), at the University of Maine.

2016 CFRU Fall Field Tour to Seven Islands Land Company operational understory beech control. Photo – Brian Roth

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

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

[1] U.S. Forest Service, Northern Research Station
[2] University of Maine

Status: Final Report

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

Summary:

Forestry practitioners are confronted with challenges when managing northern white-cedar, including the recognition of old-growth characteristics and the differentiation between old-growth and partially harvested stands, particularly in the context of Forest Stewardship Council (FSC-US) certification. To identify the structural characteristics potentially unique to old-growth northern white-cedar stands, we compared detailed forest inventories from 16 old-growth stands and 17 partially harvested stands in Maine and New Brunswick. Using a generalized linear mixed-model approach, two significant predictors were identified that differentiate old-growth from partially harvested stands: the volume of advanced-decay coarse woody material (logs in decay classes 4 and 5 using a 5-decay-class system) and live tree quadratic mean diameter. Our research shows that these two measures can be used, in combination, to identify old-growth northern white-cedar stands, and it improves our understanding of old-growth characteristics in this forest type, aiding in its successful management.

Project Objectives:

- Quantify the compositional and structural attributes of old-growth and partially-harvested northern white-cedar-dominated stands.
- Identify which attributes best differentiate old-growth from partially-harvested stands.
- Develop management guidelines for old-growth characteristics of northern white-cedar stands under FSC-US certification guidelines.

Approach:

- Identified 16 old-growth stands and 17 associated partially-harvested stands by communicating with collaborators, exploring geodatabases, and visiting sites.
- Established randomly located fixed-area plots (0.1 ha) and woody debris transects (120 m total) at each site to measure and calculate stand structural and compositional variables commonly used in forest management, including live and dead tree basal area (BA; $ft^2\ ac^{-1}$), number of

trees per acre (TPA), quadratic mean diameter of live and dead trees (QMD; inches), BA and TPA of live and dead large trees (≥ 16 inches DBH), and volume of coarse woody material by decay class ($ft^3\ ac^{-1}$).

- Evaluated the set of potential predictors using variable-selection methods available in the random forest (VSURF package in R) to identify the most meaningful subset for inclusion in the predictive model.
- Applied a generalized linear mixed-modeling approach using old-growth vs. partial-harvest status as a binary response variable.
- The model was refined by iteratively excluding insignificant predictor variables in a stepwise procedure until only significant predictors remained, and a model of best fit was identified based on the Akaike information criterion (AIC) score and area under the curve (AUC).

Key Findings / Accomplishments:

- Two significant predictors, in combination, were identified that differentiate old-growth from partially-harvested northern white-cedar stands: volume of advanced-decay coarse woody material (logs in decay classes 4 and 5 using a 5-decay-class system) and live tree quadratic mean diameter (QMD).
- We developed a predictive equation to calculate the probability of a northern white-cedar stand having old-growth characteristics for application in forest management and planning (Eq. 1). That is, for a given stand of unknown status (old-growth vs. partially-harvested), volumes of advanced-decay coarse woody material (CWM_{ADV}, $ft^3\ ac^{-1}$) and QMD can be entered into this equation to yield the probability of that stand having old-growth characteristics.
- We note that this equation (Eq. 1) does not predict old-growth status per se, but the probability-threshold that a stand has old-growth characteristics. The user must choose the acceptable level of certainty in advance.
- The approach we have taken is not limited to deciding whether a stand is old-growth or not; it can also be applied to examine old-growth features of managed stands and thus to help inform silvicultural prescriptions.

Figure 7. Old-growth northern white-cedar swamp at Big Reed Forest Preserve, Maine (left) and Irving Woodlands cedar training and field tour of old-growth northern white-cedar stand in Deboullie Ecoreserve, Maine. Photos - Nathan Wesely

Equation 1.- ***Predictive equation for estimating the probability a stand has old-growth (OG) structural characteristics based on volume of advanced decay coarse woody material (CWM_{ADV}; $ft^3\ ac^{-1}$) and quadratic mean diameter (QMD; inches).***

$$Probability\ of\ OG\ characteristics = \frac{2.72^{[-10.44+0.004(CWM_{ADV})+0.75(QMD)]}}{1+2.72^{[-10.44+0.004(CWM_{ADV})+.75(QMD)]}}$$

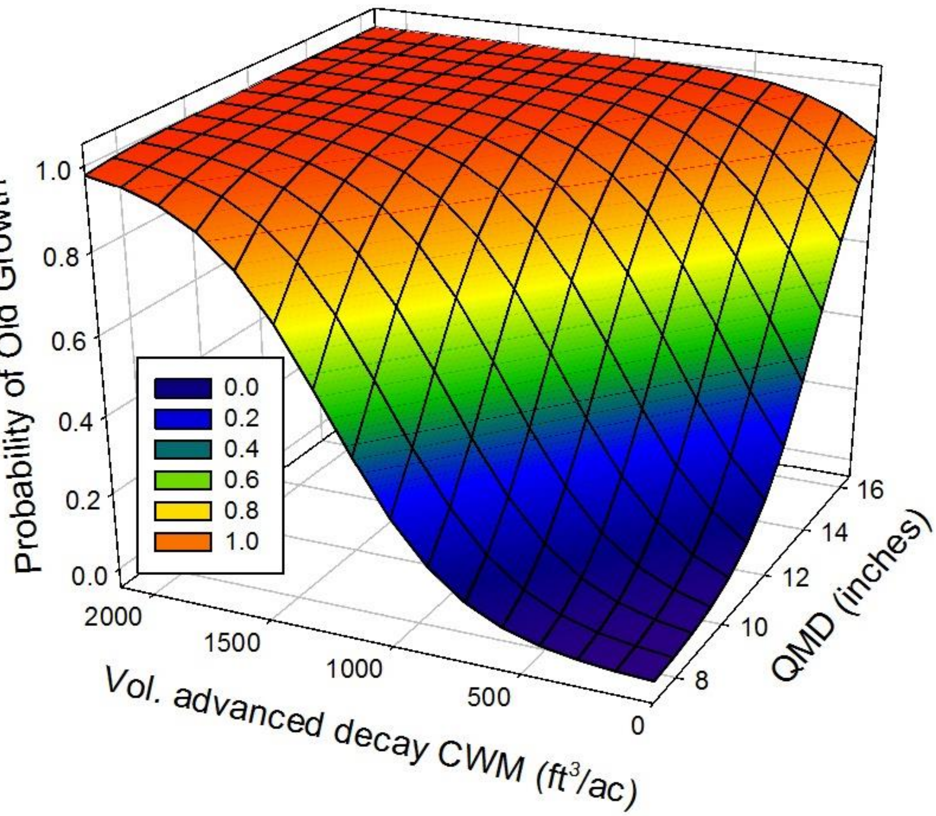


Figure 7. Three-dimensional representation showing probability of old-growth as a function of volume of advanced-decay coarse woody material (CWM_{ADV}) and quadratic mean tree diameter (QMD). As values of either one or both increase, so does the probability that a given stand can be classified as having old-growth characteristics.

Future Plans:

- Publish a *Practitioner's Field Guide* to aid in recognizing old-growth characteristics in northern white-cedar stands for application in forest management and planning. (In preparation.)
- Publish a peer-reviewed journal article based on the findings from this work. Targeted journal: *Forest Ecology and Management*. (In preparation.)
- Further develop guidelines for ecologically based forestry in cedar stands, building upon the recently published *Silvicultural Guide for Northern White-Cedar* (Boulfroy et al. 2012).

References:

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

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

Acknowledgements:

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

Towards the Cribworks rapids below the Telos bridge on the West branch of the Penobscot River. Photo – Brian Roth

The Effects of Mechanized Harvesting Operations on Residual Stand Conditions

Cody Lachance, Robert G. Wagner and Brian E. Roth

University of Maine

Status: Final Report

Summary:

We examined the effects of whole-tree (WT) and cut-to-length (CTL) harvesting systems on residual stand and soil disturbance in Maine spruce-fir stands using two long-term CFRU study sites. The first (Austin Pond Study), quantified stem, root, and crown damage following commercial thinning (CT). The treatments were three levels of relative density reduction (33, 50, and 66%) in stands that had pre-commercial thinning (PCT) and no-PCT (Hiesl 2015). Greater tree densities (i.e. no-PCT) combined with WT harvesting increased the probability of residual stem damage (86%). Stem and root damage increased with removals above 33% while trees closer to harvest trails were more likely to have stem and root damage in addition to the severity of such wounds.

The second study (Weymouth Point), quantified current stand composition and growth 32 years following WT clearcut harvesting using soil disturbance transects established at the time of harvest (Martin 1988). Despite severe soil rutting and mineral soil exposure at the time of harvest, we were unable to detect any differences in subsequent forest composition, structure, or crop tree growth. Soil disturbance had no influence on tree- and stand-level variables, including basal area, density, percent hardwood, volume, DBH, and height. Historic annual radial growth rates between two contrasting subsets of balsam-fir crop trees that had grown on the most and least disturbed soil conditions did not differ.

Project Objectives:

The goal of this study was to increase understanding about the effects of logging disturbance on Maine spruce-fir stands. The specific objectives were to:

- Investigate the effects of initial stand density, level of commercial thinning (CT) removal, and distance from trail on residual stem damage following commercial thinning operations in spruce-fir stands that had previously received pre-commercial thinning (PCT) or no-PCT.

- Investigate the influence of soil disturbance on stand and tree productivity in a spruce-fir forest 32 years following clearcut harvesting using a WT harvesting system. We used two long-term experiments to address these objectives.

Approach:

- In the first study, an experiment in west-central Maine (Austin Pond Study) was used to quantify stem, root, and crown damage following commercial thinning (CT) at 33, 50, and 66% levels of relative density reduction in stands that had previously received pre-commercial thinning (PCT) or no-PCT.

- Stem, root, and crown damage was assessed on all trees with visible residual stem damage and stem wounds were further classified by their size and height.

- In the second study, a long-term experiment in northern Maine (Weymouth Point Study) was used to quantify stand composition and growth 32 years after a WT harvest clearcut.

- We compared soil disturbance measurements from 100 random 25 meter transects, established at the time of harvest with crop tree growth, stand composition, basal area, and individual crop tree growth.

- Annual radial growth rates measured in cores from a subset of balsam fir crop trees that had grown on the most and least disturbed soil conditions were compared.

Figure 8. Austin Pond PCT stand with CTL harvest system (left) and no-PCT stand with WT harvest system (right).

Photos – Patrick Hiesl and Brian Roth

Figure 9. Koehring feller-forwarder operating at the Weymouth Point Study site in 1981. Photo - Wayne Martin.

Key Findings / Accomplishments:

- Higher initial stand densities associated with no-PCT and WT harvesting increased the probability of machine-to-tree or tree-to-tree contact and resulted in 86% more trees with residual stem damage than CTL harvesting in PCT stands.

- CT removal levels above 33% resulted in higher rates of stem and root damage.

- Trees closer to harvest trails had a higher probability of stem and root damage, along with a tendency for more severe wounds.

- Despite severe soil rutting and mineral soil exposure at the time of harvest at Weymouth Point, there were no differences in subsequent forest composition, structure, or growth after 32 years.

- While some types of soil disturbance may not be harmful to crop tree growth, more research is needed examining the long-term impacts, especially on poorly drained soils.

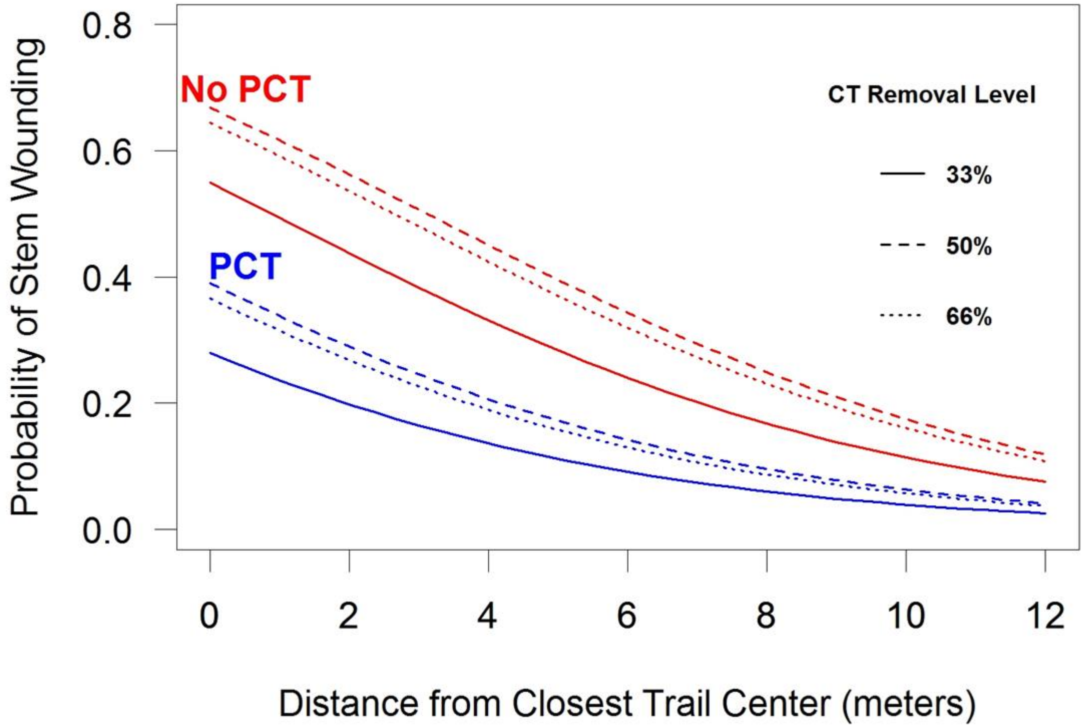


Figure 10. Effect of PCT (and harvest system), thinning removal intensity and distance from trail on probability of stem wounding from Commercial thinning operations at the Austin Pond Study.

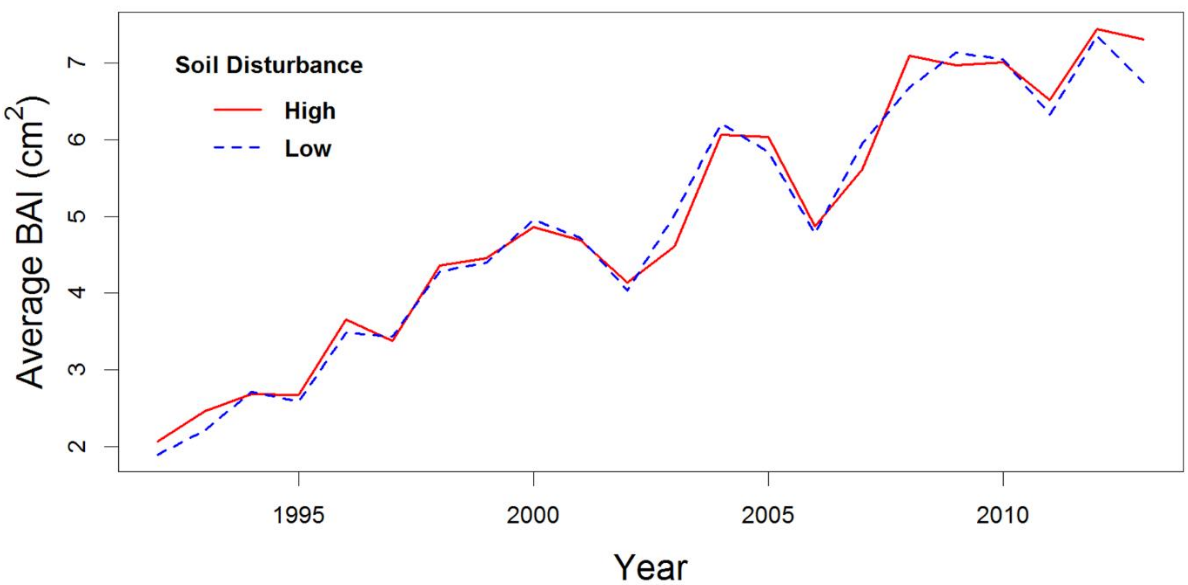


Figure 11. Balsam-fir individual crop tree basal area growth over time on contrasting soil disturbance classes. Inter-annual variation is due to climate variability.

Future Plans:

- Soil compaction studies are planned for Maine's Adaptive Silviculture Experiment Network (MASEN)

- More research is needed examining the long-term impacts of soil disturbance, especially on poorly drained soils.

References:

Hiesl, P., Benjamin, J. G., and B.E. Roth. 2015. Evaluating harvest costs and profit of commercial thinnings in softwood stands in west-central Maine : A case study. The Forestry Chronicle. 91(2): 1–11.

Martin, C. W. 1988. Soil Disturbance by Logging in New England - Review and Management Recommendations. Northern Journal of Applied Forestry. 5: 30–34.

Acknowledgements:

We acknowledge Plum Creek Timber Company and Katahdin Forest Management for providing access to the study sites and altering their harvest schedules to accommodate this research project. Special thanks to Wayne Martin for providing the detailed raw measurements, photos and descriptions of the initial soil disturbance classifications at the Weymouth Point study.

Figure 12. The Weymouth Point Study following harvesting in 1981. Photo – CFRU archives

Growth & Yield Modeling:

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

- **Maine Statewide Light Detection and Ranging (LiDAR) data acquisition.**

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

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

- **Acadian Forest Site Productivity Model**

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

Aaron Weiskittel, Jereme Frank, and Mark Castle

University of Maine

Status: Final Report

Nick Baser with a yellow birch. Photo – Brian Roth

Summary:

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

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

Project Objectives:

- Assess variation in stem form and damage across several prominent northern commercial hardwood species.
- Quantify the influence of stem form and damage on potential sawlog volume recovery, diameter increment, and probability of survival of standing hardwood trees.
- Evaluate efficacy of current tree classification systems and propose a revised classification framework that could be used for hardwood management in the Northeast.

- Use destructively sampled trees to (1) examine the influence of commonly measured tree metrics such as size, taper, risk class, and crown ratio on a tree's susceptibility to decay, and (2) assess whether decay varies between species.

Approach:

- Measurements on standing hardwood and softwood trees were taken from permanent plots across the following locations: Austin Pond, Holt Research Forest, Kingman Farms, Penobscot Experimental Forest, and Scientific Forest Management Area.
- Model the occurrence of defects and percentage of potential saw log volume as a function of tree size, form, risk and stand conditions (figures 13 – 15).
- Quantify the influence of stem form, risk, and stand conditions on individual tree diameter increment and mortality predictions.
- Selection of a tree classification system that adequately assesses stem form and vigor based on results of aforementioned quantitative analyses.
- Destructive sampling trees of varying risk and form classes for key species to assess rot.

Key Findings / Accomplishments:

- Potential sawlog recovery was significantly lower for trees that demonstrated excessive sweep or lean, multiple stems, significant forks, or severe/extensive damage.

- Annual diameter increment growth was 6% lower for trees considered to be high risk.

- Trees demonstrating either lean, sweep, or multiple stems had lower probabilities of survival compared to trees of ideal form.

- Key predictors of decay occurrence included taper, crown ratio, risk class, and species.

- Risk class improved classification rate of internal stem decay occurrence by 5 %.

- Stem quality classifications could add substantial value to standard forest inventories.

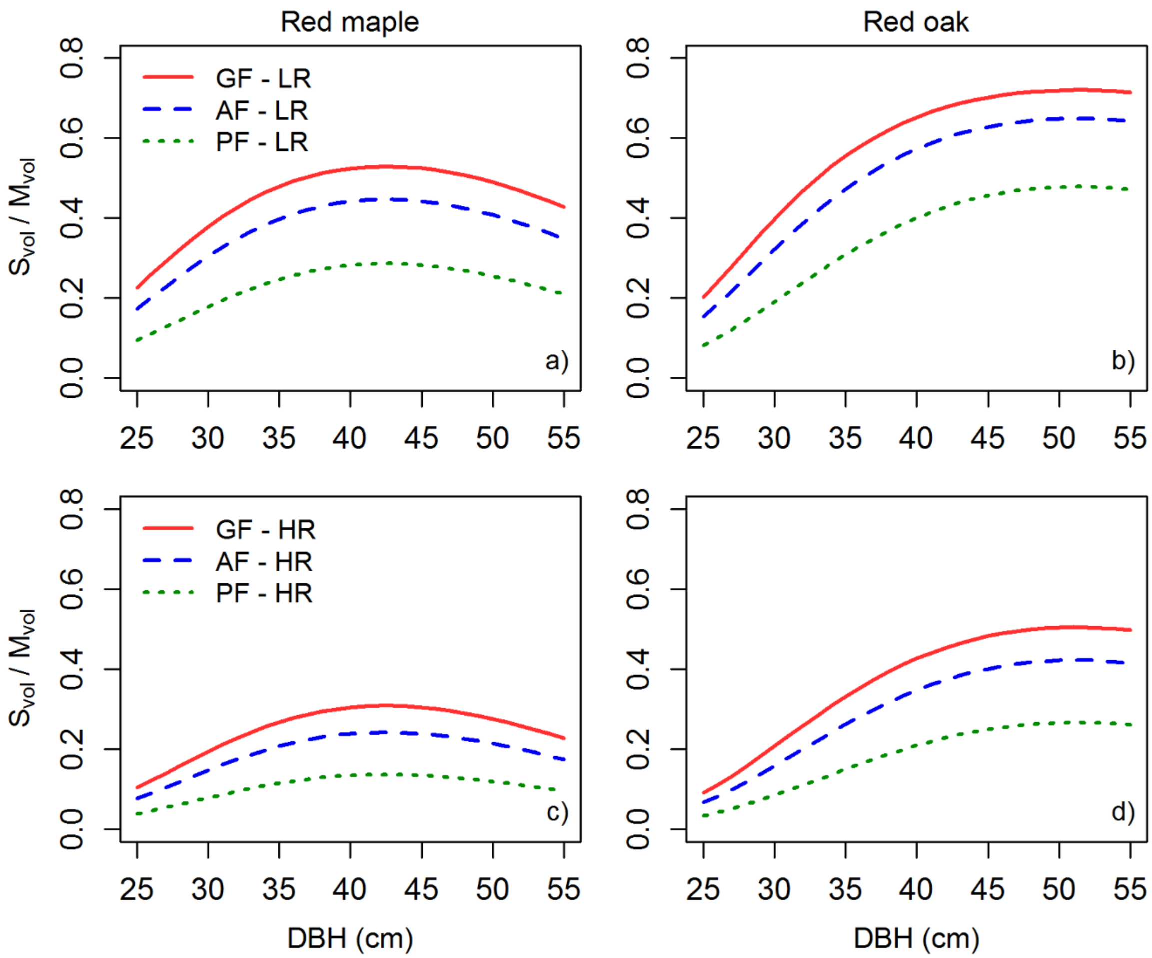


Figure 13. Predictions of the proportion of sawlog volume to merchantable volume (Svol/Mvol) in an individual tree stem across DBH, form (AF, GF, PF), and risk classes (LR and HR) for red maple (a and c) and red oak (b and d). AF, GF and PF correspond to acceptable form (tree with multiple stems, sweep,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

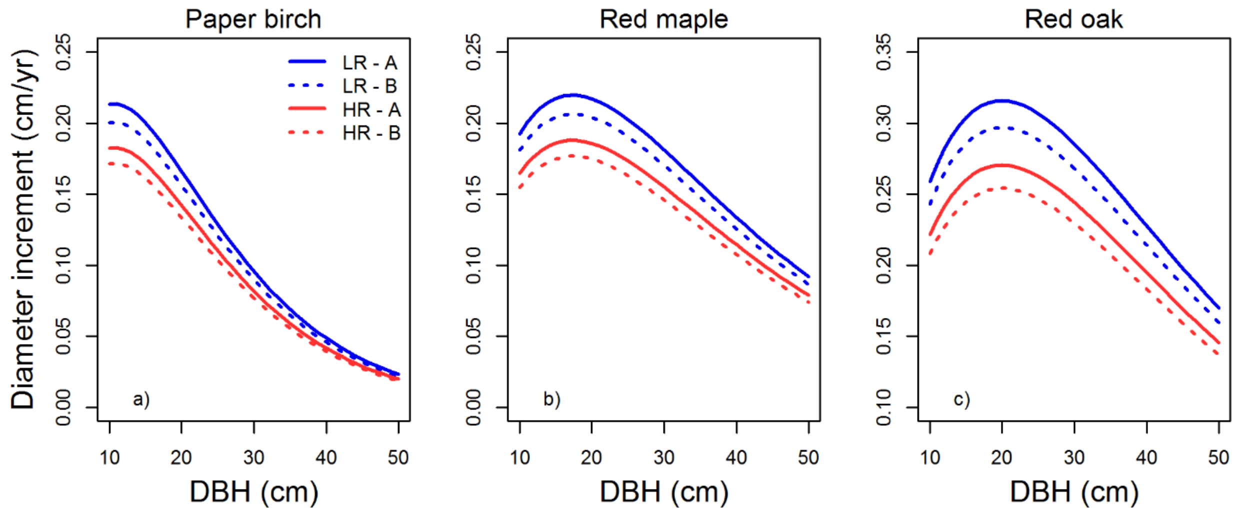


Figure 14. Predictions of annual diameter increment across DBH, form (A, B), risk class (LR, HR) for paper birch (a), red maple (b) and red oak (c). Form class A corresponds to trees with single straight stems or those with significant forks on the lower portion of their bole and form class B corresponds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

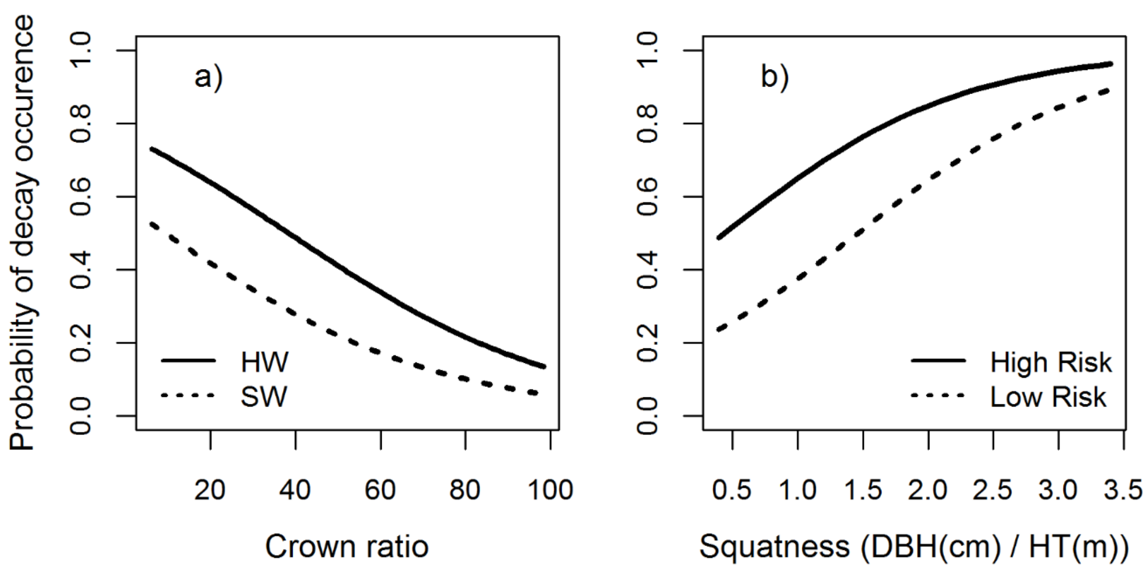


Figure 15. Predictions of the probability of decay occurrence across crown ratio (a), evergreeness (hardwood or softwood, a), squatness(b), and risk class (b).

Future Plans:

- Implement form and risk protocols in statewide forest inventory and use subsequent data to further refine models.
- Incorporate resultant equations and modifiers into FVS – ACD.

References:

Pelletier, G., D. Landry, M. Girouard, M. Mercure, A. Jarret, M. Cyr, and P. H. Poirtras. 2013. *A tree classification system for New Brunswick*. Northern Hardwoods Research Institute, Edmundston, New Brunswick. 53 p.

Acknowledgements:

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

Lunch on 2016 CFRU Fall Field Tour in T11 R7 WELS. Photo – Brian Roth

Maine Statewide Light Detection and Ranging (LiDAR) Data Acquisition

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

[1] Maine Office of GIS
[2] University of Maine
[3] US Geology Survey

Status: progress report, year 4 of 5

Left to Right: Joe Young, Brian Roth, Steve West, ?, and David Sandilands with Quantum Spatial LiDAR acquisition plane in Bangor, ME. Photo – Brian Roth

Summary:

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

Project Objectives:

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

Approach:

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

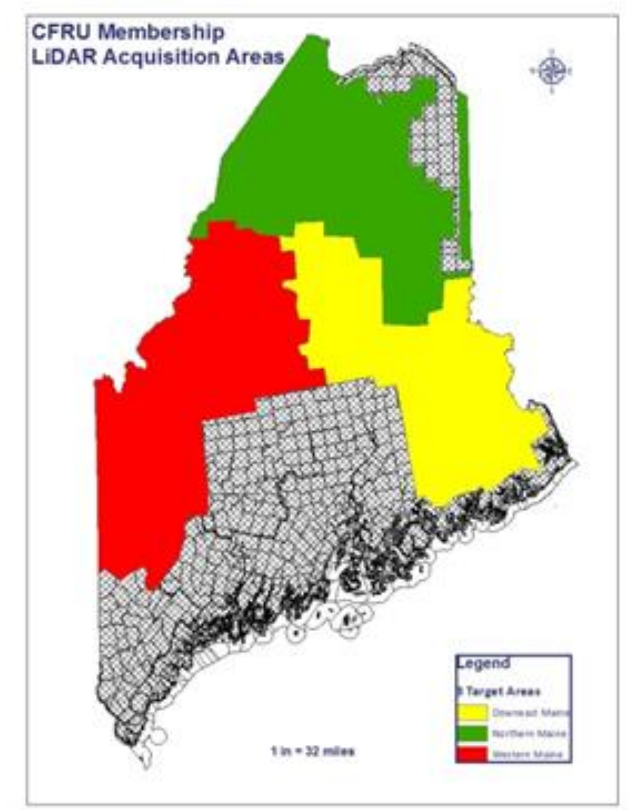
- Partially met goal of acquiring the Western Maine Segment of a three step proposal to acquired LiDAR in all of the Unorganized Territories of Maine. The three areas of interest are shown in figure 16.

- A pilot trial using new technology (Single Photon LiDAR) was flown in the spring of 2016 across the Baxter State Park SFMA.

- Weyerhaeuser (Plum Creek Timberlands), the Nature Conservancy, Maine Bureau of Public Lands, participated in the 2016 acquisition.

- A 2017 acquisition was planned and application for funding was submitted to the USGS for consideration. It received approval and is scheduled for acquisition in the spring of 2017 shown in figure 17.

- FEMA and the USGS have initiated two acquisitions in addition to the dark blue area (8,743sq. mi.) shown in figure 17.



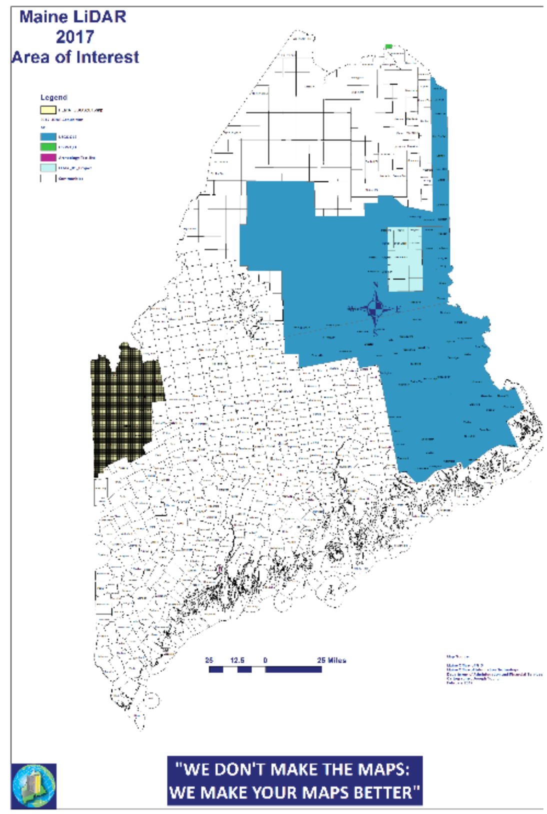


Figure 16. Proposed LiDAR acquisition schedule for Maine (2016- 2018).

Figure 17. 2LiDAR acquisitions scheduled for 2017.

Future Plans:

- Develop models to predict Enhanced Forest Inventory (EFI) metrics from LiDAR data.
- Update statewide Depth to Water Table maps at high resolution.
- Demonstration and training of easy to use tools for managing EFI products.

Acknowledgements:

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

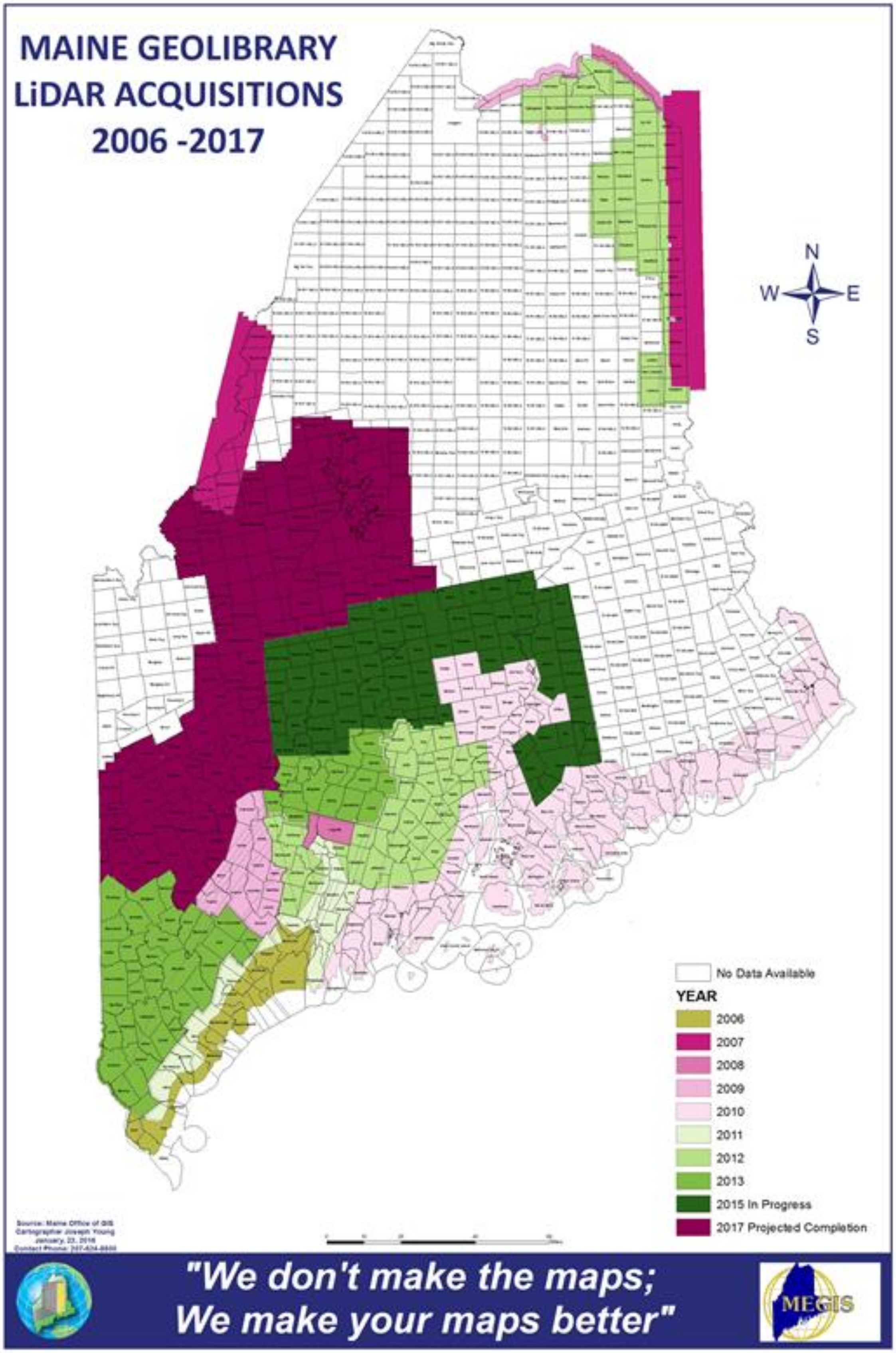


Figure 18. Current status of available LiDAR data.

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

Erin M. Simons-Legaard[1], Kasey R. Legaard[1], and Brian E. Roth[1]

[1] *University of Maine*

Status: Progress Report, Year 1

Summary:

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

Project Objectives:

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

Approach:

- Pheromone trapping was coordinated with MFS and cooperating landowners during the summers of 2015 and 2016 (Figure 1). Guidance was provided to address sampling gaps and deficiencies based on the 2014 trap distribution (figure 19).

- We selected a subset of pheromone trap locations for repeat sampling of L2 larval abundance (winters 2015-16), with locations stratified by mapped risk class. L2 sampling followed established procedures (mid-crown branch samples from 3 host trees per sample location), and samples were processed by the Canadian Forest Service Insect Laboratory in Fredericton, NB.

- We will evaluate hypothesized associations between early establishment of budworm populations and forest/environmental covariates by modeling moth and next-generation L2 abundance and population trends using modern nonparametric regression algorithms (e.g., classification and regression trees, support vector machines). Covariates will include local and immigrant moth abundance, mapped forest conditions at multiple scales, terrain attributes, weather data, and vegetation data collected at L2 sample locations. Vegetation data will include standard measures of forest characteristics, collected by a CFRU field crew (Summer 2016).

- Ultimately, we will produce wall-to-wall maps of predicted budworm moth and L2 abundance.

Key Findings / Accomplishments:

- Based on a preliminary compilation of data, pheromone traps were deployed by collaborators at 424 locations in Summer 2016 (figure 19), including 411 locations previously sampled in 2015 and 13 that were either re-located to reduce spatial redundancy, placed to fill sampling gaps, or moved to high priority stands.

- Moth abundance was generally depressed in 2016 relative to previous years (figure 19). Preliminary analysis indicated some degree of regional variability in the magnitude of change over previous years, although much of the variability in moth catch from since 2014 appears to be associated with local processes.

- In Summer 2016, vegetation sampling was conducted at a broadly distributed set of 48 trap locations at which moth and L2 abundance had been measured in 2015 (figure 20). At each location, standing vegetation was measured over a set of four 1/20th ac subplots, sampling a 1 ac area roughly corresponding to a group of four pixels in maps of forest and terrain attributes.

- L2 surveys were expanded to include a subset of 241 trap locations in Winter 2015 (figure 20).

- Larvae were found at only 14 locations and at nearly uniform low abundance (~1 L2 per branch).

- Once combined with a winter 2016 L2 survey, we will have 3 years of both moth and L2 abundance at roughly 100 sample locations (2014-2016), with 2016 vegetation measurements collected at roughly one half of those.

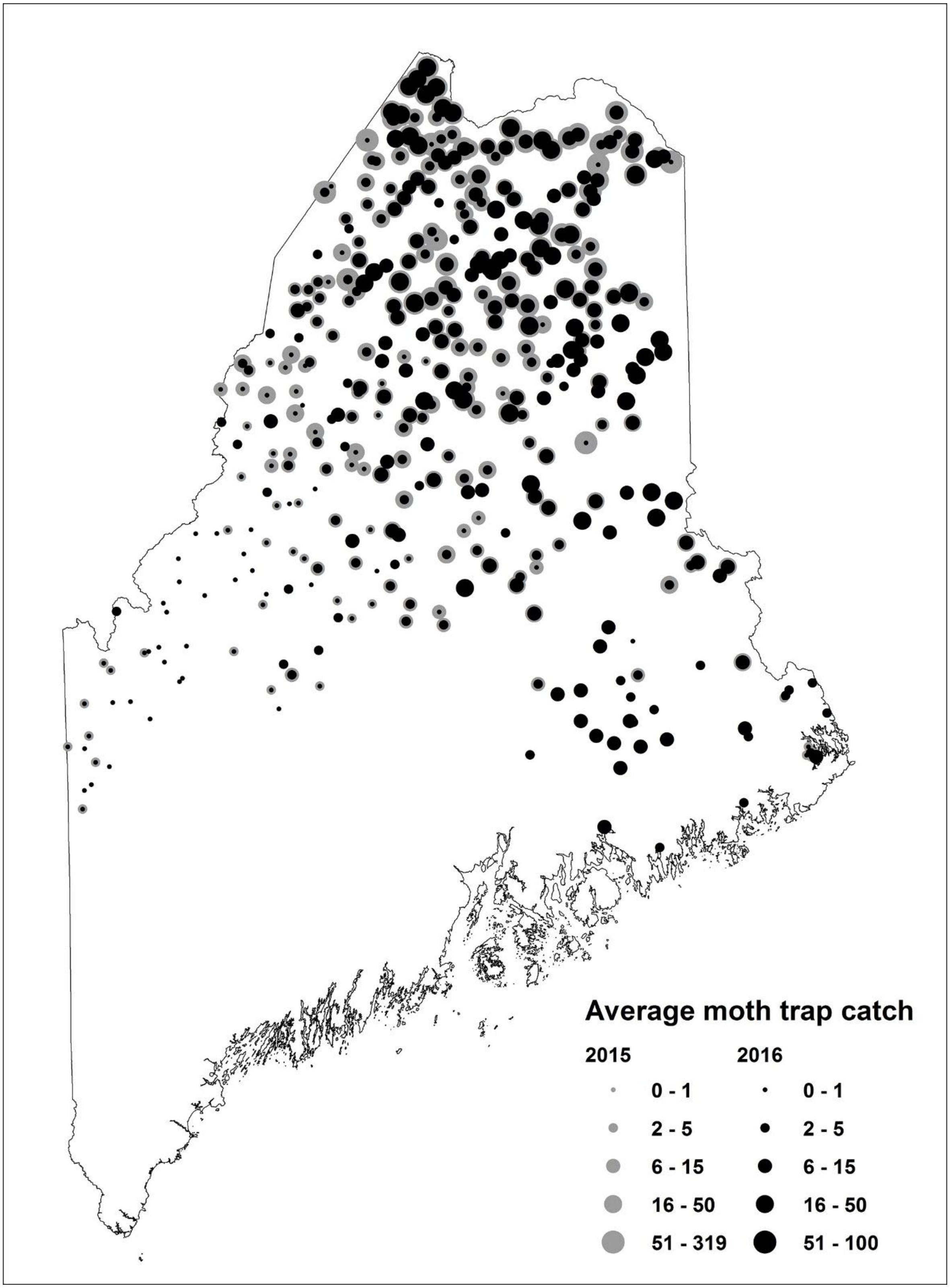


Figure 19. Comparison of average trap catch of spruce budworm moths in 2015 (gray circles) and 2016 (black circles).

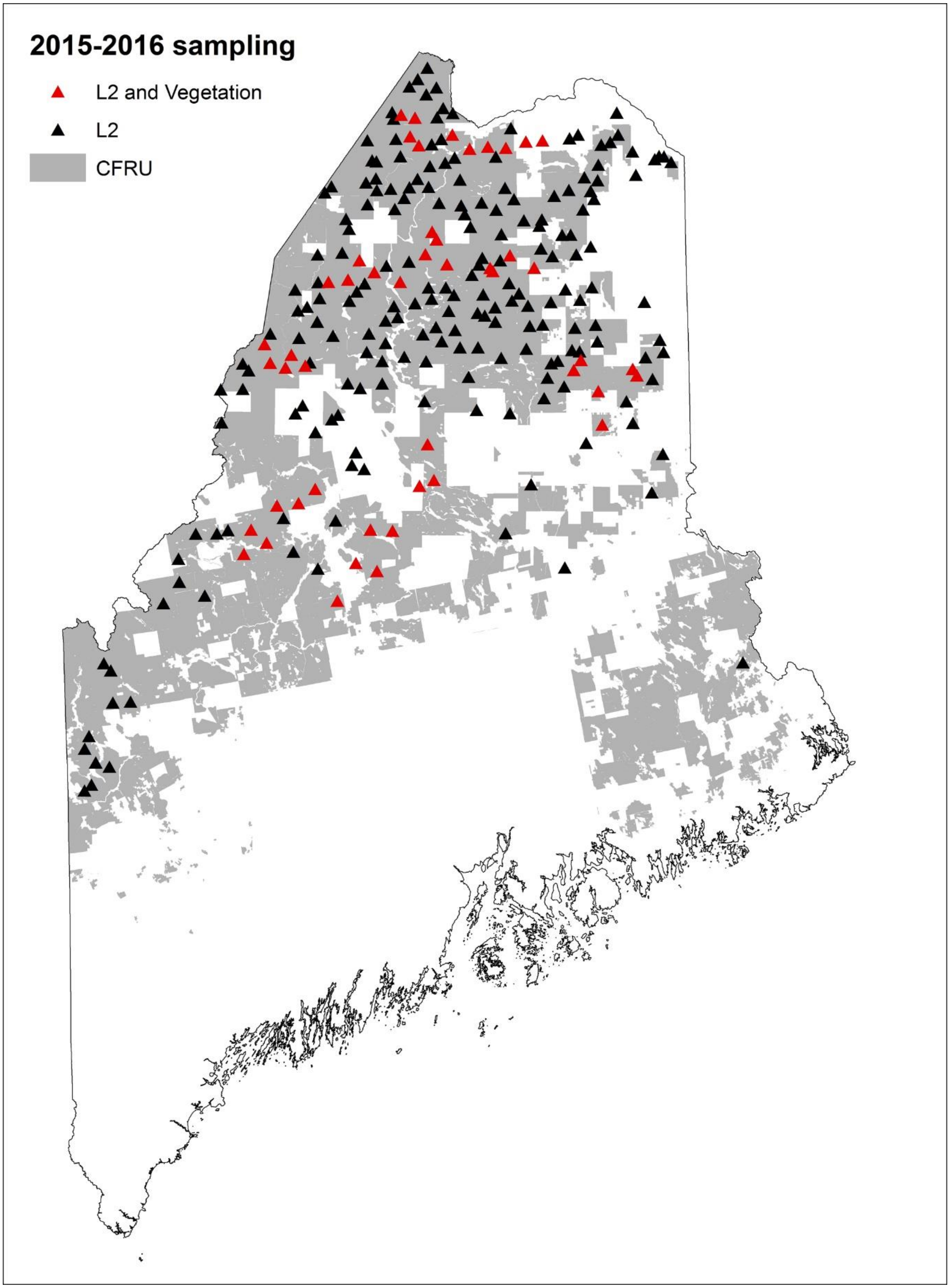


Figure 20. Distribution of expanded L2 sampling in Winter 2015 (black triangles) and vegetation sampling at trap/L2 locations in Summer 2016 (red triangles).

Future Plans:

- Winter 2015 L2 survey locations will be resurveyed in Winter 2016, with plans to continue surveys in subsequent years.

- Summer 2016 pheromone trap locations will be resampled in Summer 2017.

- Maps of moth abundance will be generated using 2014-2017 trap outcomes and compared to identify regions of sustained or increasing population levels.

- 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.

- We are currently awaiting a decision on additional funding to support a statewide expansion of forest vegetation and budworm vulnerability maps (proposal submitted to the Evaluation Monitoring component of the USFS Forest Health Monitoring Program, FY2017). If awarded, this would enable an expansion of moth and L2 modeling across additional CFRU acreage for which vegetation and vulnerability maps are currently unavailable.

Acknowledgements:

We would like to thank Baxter State Park, Huber Engineered Woods, Irving Woodlands, Landvest, Orion Timberlands, Plum Creek Timber Company, and Seven Islands Land Company for collecting moth and L2 samples. We would also like to thank American Forest, Appalachian Mountain Club, Baskahegan Corporation, Forest Society of Maine, Katahdin Forest Management, North Maine Woods, Penobscot Nation, Prentiss and Carlisle Company, and Wagner Forest Management for collecting moth samples. Special thanks to Dave Struble and Allison Kanoti at the Maine Forest Service for all their efforts and support. We would also like to acknowledge our student field crew, Austin Bragdon and Matt McCausland.

Spruce Budworm pheromone traps. Photo – Kenny Fergusson, Huber Resources Corporation

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

Parinaz Rahimzadeh[1], Aaron Weiskittel[1], Daniel Kneeshaw[2] and David MacLean[3]

[1] University of Maine
[2] UQAM, Quebec
[3] UNB, New Brunswick

Left to Right: Allison Kanoti, Pierre Therrien, Parinaz Rahimzadeh. Photo – Brian Roth

Status: progress report, year 1

Summary:

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

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 for Maine.

- Test and verify the developed model using available field data and geospatial maps of active SBW defoliation areas in southern Quebec and 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 such as enhanced vegetation index (EVI), green chlorophyll index (Chlgreen), greenness normalized difference vegetation index (GNDVI), normalized difference moisture index (NDMI), normalized burn ratio1 (NBR1) and 2 (NBR2) to be 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). (fig. 21a) and vegetation phenology information derived from Landsat imagery (fig. 21b).

- 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%), Light (5-35%), Moderate (36-70%), Heavy (70-100%).

- Random Forest (RF) 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.

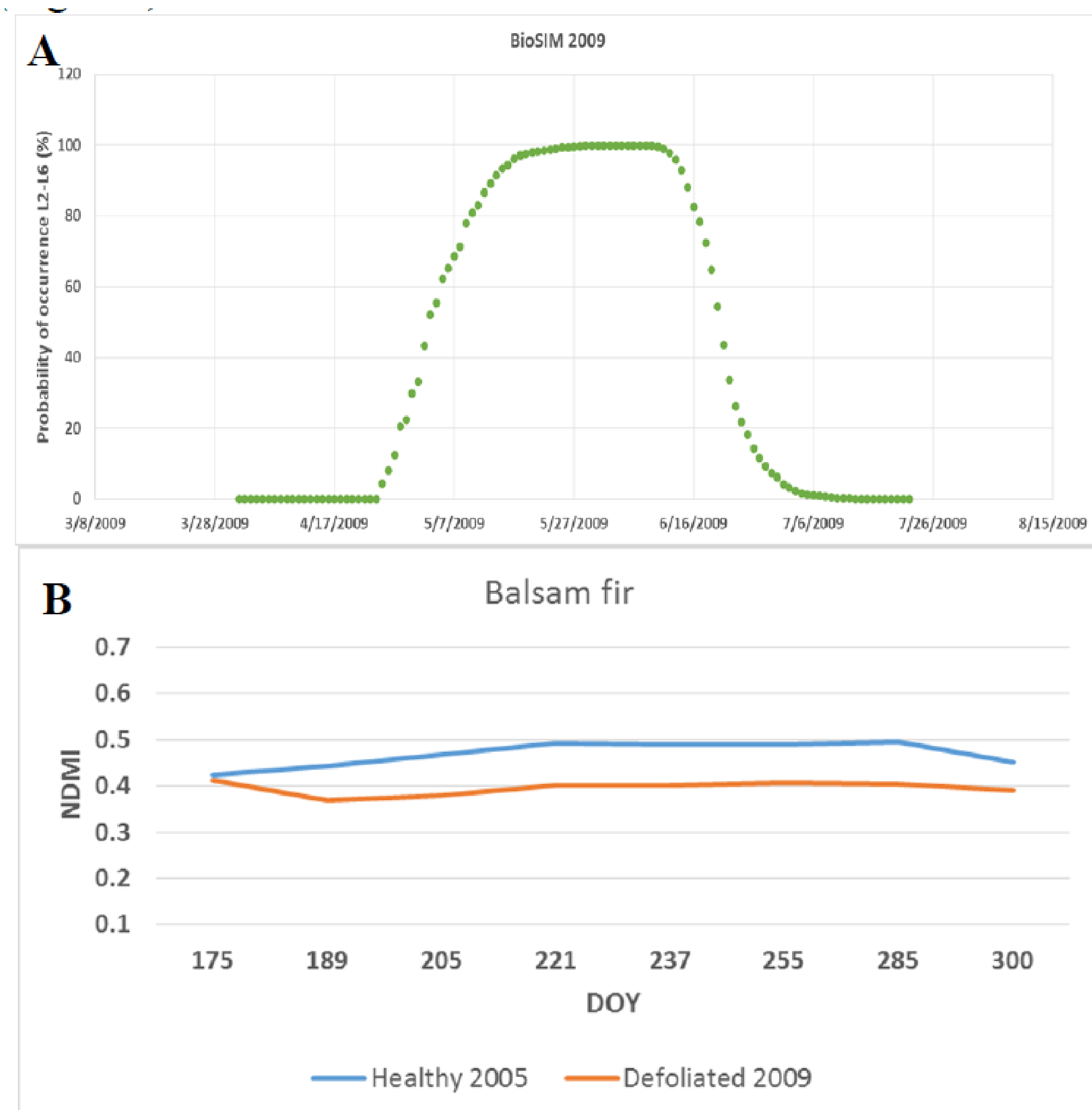


Figure 21. A) SBW probability of occurrence for a balsam fir forest stand in North Shore region in QC simulated by BioSIM model for spring and summer 2009. B) Change in foliage water content in a balsam fir forest stand before and after defoliation using NDMI (DOY: Day of the year).

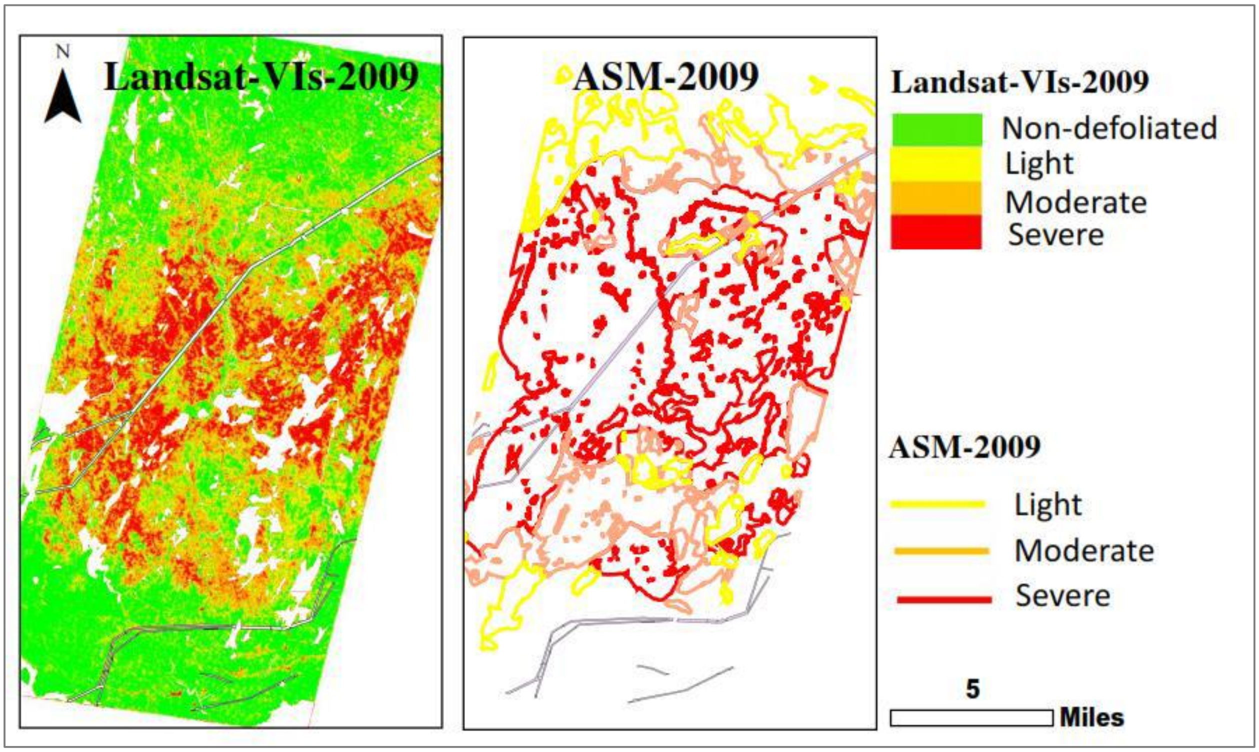


Figure 22. Left: SBW defoliation severity map derived from Landsat NDMI, EVI and NDVI using RF model; Right: Aerial sketch map of SBW defoliation severity for North Shore-QC.

Key Accomplishments:

- Landsat imagery can be used successfully for annual SBW defoliation detection and severity classification. 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 (tables 3 & 4).

- The lower accuracy to detect and classify low-medium intensity defoliation might not be related to the method, rather to the subjectivity of ASM. Incorporation of field data other than AMS can improve severity classification accuracy.

Table 3. Performance of a single index or combination of vegetation indices to detect defoliation using the Random Forest model.

Class	EVI	NDVI	Chlgreen	GNDVI	NDMI	NBR1	NBR2	EVI, NDMI	EVI,NDVI, NDMI	EVI,NDVI, NDMI, NBR
Defoliated	85%	87%	80%	84%	90%	89%	86%	94%	95%	94%
Non-defoliated	62%	56%	39%	48%	76%	74%	58%	78%	78%	80%
OOB error rate	20.5%	20.5%	30%	24.5%	14%	14.5%	21%	10%	9%	9%

Table 4. Performance of a single index or combination of vegetation indices to classify Spruce Budworm defoliation severity using the Random Forest model.

CLASS	EVI	NDVI	NDMI	NBR	EVI,NDMI	EVI,NDVI,NDMI	EVI,NDVI,NDMI,NBR
Non-defoliated	62%	56%	76%	74%	78%	77%	80%
Light	39%	46%	39%	49%	56%	60%	58%
Moderate	33%	45%	43%	46%	51%	52%	56%
Severe	49%	53%	67%	60%	72%	77%	76%
OOB error rate	54%	50%	43%	42%	35.5%	33.5%	32%

Future Plans:

- The results and figures will be finalized and a manuscript will be prepared based on findings of this project to be submitted to a scientific journal.

- The developed model seems to be a sound tool for SBW defoliation detection and classification. The model has potential for improvement to be able to more accurately classify defoliation severity by using recent satellite sensors and better calibration of the model using field data other than ASM. This will be our follow-up research plan.

Acadian Forest Site Productivity Model

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

[1] FORUS Research
[2] University of Maine
[3] ProFOR Consulting

Dr. Chris Hennigar

Status: Final Report, Year 2

Summary:

A detailed report on development and evaluation of a biomass growth index (BGI) for the Acadian forest region was presented in the 2015 CFRU annual report in year one of this project. In addition, pdf wall maps (figure 23) and raster files containing biomass growth index predictions for Maine, Nova Scotia, New Brunswick, and PEI were made available for download from www.forusresearch.com/bgi.php. BGI explained 0-30% of spruce-fir site index variability depending on dataset, and showed similar predictive performance (± 5%) when compared to existing land productivity classifications.

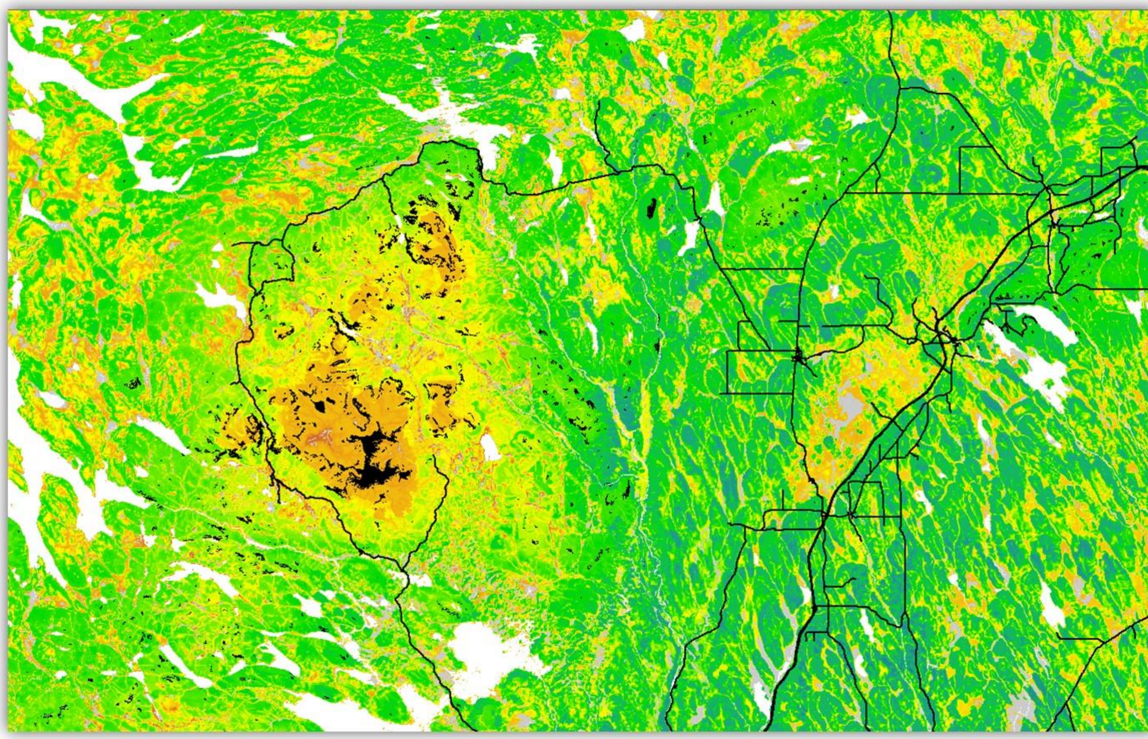


Figure 23. Biomass Growth Index map of Mount Katahdin and surroundings in Maine.

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

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

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

2016 Summer CFRU Field Crew: (left to right) Ethan Hill, Devan Hilton, Garth Dixon, Anton Nilsson, Sean Ducker, Zac Ragot. Photo – Brian Roth.

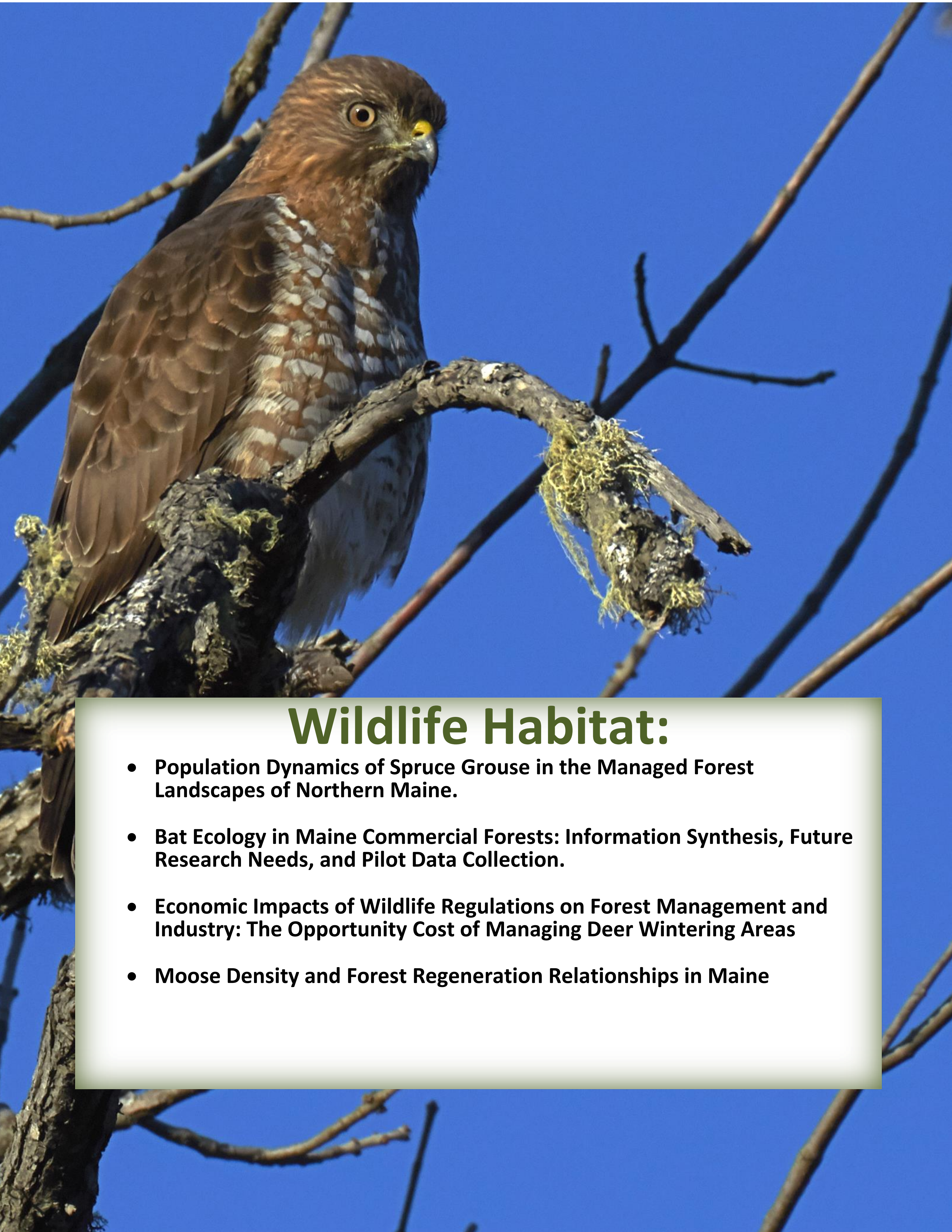
The 2015 CFRU report was improved in 2016 and published (Hennigar *et al.* 2017). The maps and raster files made available in 2015 were not updated in 2016, as no significant model improvements were possible. In 2016, BGI was identified as a significant predictor of tree height in New Brunswick for planted,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

Future site mapping work should explore the possible use of LiDAR-derived metrics and satellite-derived metrics as higher resolution site response variables and as independent site predictor variables.

Acknowledgements:

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

Dr. Lee Allen stands in a soil pit while describing site productivity to a group of foresters in Maine. Photo – Brian Roth



Wildlife Habitat:

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

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

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

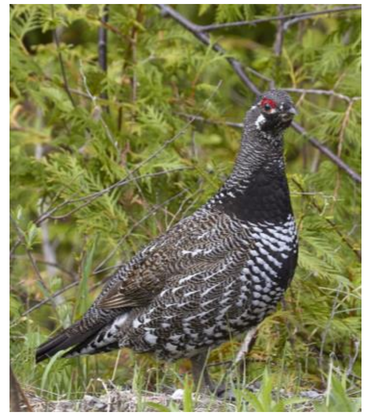
- **Moose Density and Forest Regeneration Relationships in Maine**

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 2



Spruce Grouse - Photo Pamela Wells

Summary:

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

Project Objectives:

Our overall goal for this work is to understand how spruce grouse meet the competing demands of reproduction and survival in order to provide a comprehensive assessment of the link between commercial forest management, forest habitat characteristics, and population performance in northern Maine (figure 24). Our specific objectives are to:

- Objective 1: Estimate demographic rates (adult survival for males and females, nest success, and brood success) of spruce grouse using a combination of radio-telemetry and capture-mark-recapture methods.
- Objective 2: Evaluate resource selection by spruce grouse across multiple scales (e.g. sub-stand scale: understory composition, canopy cover, tree basal area; stand-scale: time since harvest and type of commercial and pre-commercial treatments; landscape-scale: amount and configuration of habitat types/treatments) during important life phases (e.g. nesting, brood rearing, and seasonal dispersal) and determine the influence of selection decisions on demographic rates.
- 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:

- Capture and radio-mark female and male spruce grouse (figure 25).
- Monitor survival and reproductive activities (nesting, brood rearing) of radio-marked birds.
- Measure characteristics of forest structure and composition (e.g. basal area, visual obstruction) at use and random locations.
- Use appropriate data analysis methods to link forest characteristics to spruce grouse habitat use (resource selection functions), demographics (mark-recapture analyses) and population dynamics (stage-based population models).

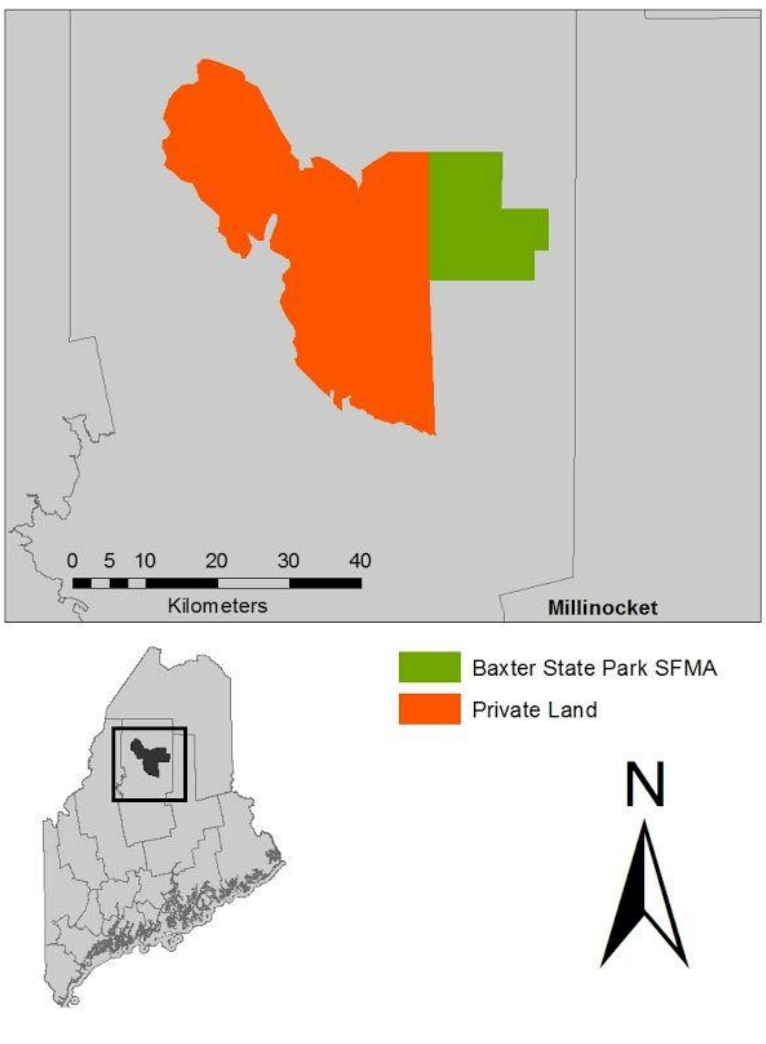


Figure 24. Location and extent of the study area in Piscataquis County, Maine

Figure 25. Radio-marking and measuring female spruce grouse. Photo - Taylor Hannah

Key Findings / Accomplishments:

- Monitored 57 spruce grouse in 2016, including 40 (19 female, 21 male) that were captured and radio-marked during 2016. Documented 16 mortalities.
- Collected ~ 650 locations from radio-marked individuals during the breeding season (spring) through autumn.
- Located 7 spruce grouse nests and monitored 13 broods during 2016.
- Documented 86% apparent nest success (hatched 1 or more eggs) and 62% apparent brood success (fledged 1 or more chicks).
- Measured forest structure and composition at 228 plot locations.
- Conducted preliminary nest site selection analyses using nests found during 2012 – 2015 (n = 26).
- Observed a negative relation between the probability of nest site selection and basal area of live trees at both local (30 m) and patch (forest stand) scales (figure 26) and a positive relation between nest site selection and lateral cover at the local (30 m) scale (figure 27).

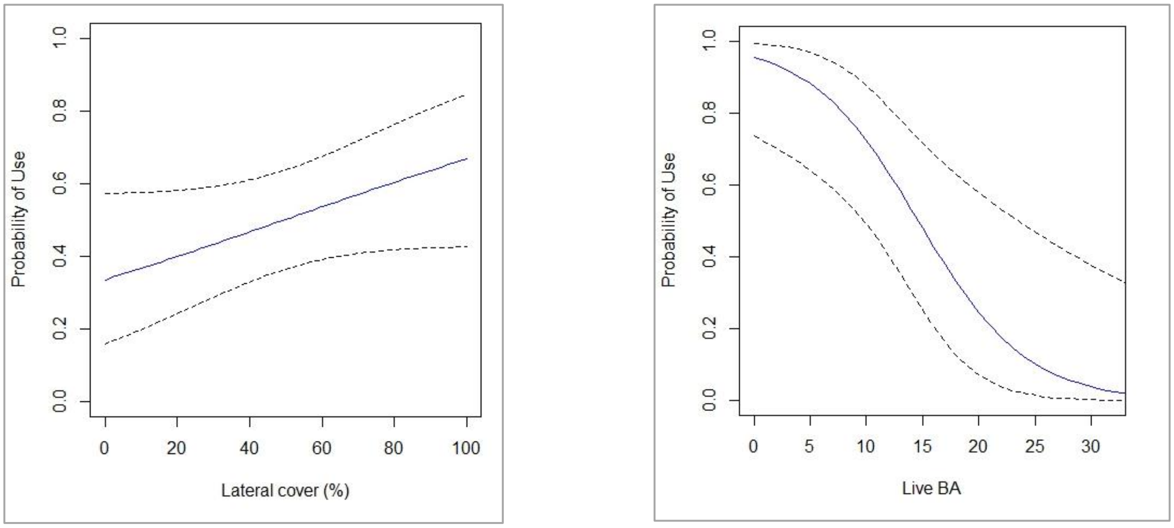


Figure 26. Left: Predicted probability of use relative to basal area of live trees for nest sites selected by female spruce grouse in Piscataquis County, Maine between 2012 – 2015 at the a) local (30 m) and Right: patch (forest stand) scales. Dashed lines represent 95% confidence intervals.

Future Plans:

- Continue to capture and radio-mark grouse to increase sample size.
- Collect one additional season of reproductive, habitat use, and behavioral data.
- Complete habitat selection and demographic analyses.

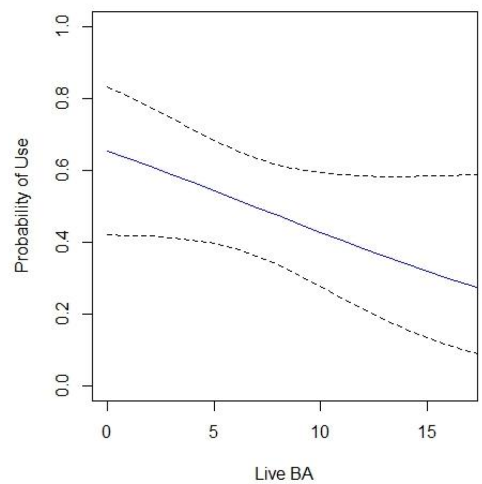


Figure 27. Predicted probability of use relative to lateral cover (%) for nest sites selected by female spruce grouse in Piscataquis County, Maine between 2012 – 2015 at the local (30 m) scale. Dashed lines represent 95% confidence intervals.

Acknowledgements:

We appreciate the participation of Katahdin Forest Management LLC for providing unrestricted use of their lands during this ongoing study and to Katahdin Forest Management LLC for altering their harvesting schedules to accommodate our study design. Additionally, personnel associated with Baxter State Park, particularly Jensen Bissell and Jean Hoekwater were helpful with logistics and accommodating to our study. This project received additional financial support from the Maine Outdoor Heritage Fund and the Maine Department of Inland Fisheries and Wildlife. We thank Brad Allen, Kelsey Sullivan, Jeff Beach, and Jeff Spencer from MDIFW for their collaboration on the project. Finally, the staff of the North Maine Woods at the Telos checkpoint and Larry Pelletier of Gerald Pelletier Inc. has been very accommodating to our field crews at the CFRU's Telos Camp.

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

Dr. Erik Blomberg[1], Dr. Shawn Fraver[1], Dr. Sabrina Morano[1], Michael Thompson[2], and Trevor Peterson[3]

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[2]Penobscot Environmental Consulting, Inc.
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Status: Final Report

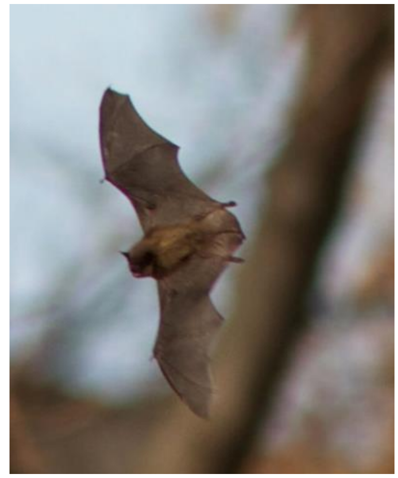

Photo – Maine Audubon

Summary:

The conservation challenges facing cave-hibernating bats in North America are unprecedented, after a fungal disease commonly known as White Nose Syndrome has decimated populations. This has led to regulatory policies at state and federal levels with potential to affect forest management. Of particular concern are Northern Long-Eared Bats, which were listed as ESA Threatened in 2015. We reviewed literature on bats in forest ecosystems and focused on issues germane to bats in the northeast. We also sampled bat occupancy to evaluate several detection methods and assess acoustic survey efficacy in Maine forests. We found that Northern Long-Eared Bats have generalist habitat preferences, some of which may differ in the northeast relative to other portions of the species range. In Maine, Northern Long-Eared bats are now uncommon but remain widely dispersed. Acoustic surveys may fail to detect the species if detectors are not deployed for a sufficient number of sampling nights.

Project Objectives:

- **Objective 1:** Provide a review of the current literature on habitat relationships, geographic ranges, population dynamics, behavior, and natural history of bats that inhabit Eastern forests, focusing on the current state of knowledge for Northern Long-Eared Bats (NLEB) and other bats commonly found in managed forests. Place the review in the context of relevance to Maine commercial forests.

- **Objective 2:** Identify priority research needs and provide recommendations for future data collection to inform forest management decisions related to NLEB and other forest bat species.

- **Objective 3:** Conduct a pilot study to evaluate acoustic monitoring methods for bat detection in Maine forests. This will include pilot acoustic sampling using fixed-point detectors, and an evaluation of handheld acoustic detecting devices for surveying bat presence in forest systems.

Approach:

Literature Review (Objectives 1 and 2):

- We conducted a literature review of the current state of knowledge on the ecology of bats in commercial forests by searching the primary literature. We used various online search platforms (e.g., Google Scholar, Web of Science), and we also relied heavily on citations provided in the US Fish and Wildlife Service listing decision for NLEB and other gray literature.

- We focused our review on issues of relevance to conservation of bats in Maine's forests, including general bat habitat relationships, geographic ranges, population dynamics, behavior, and natural history. (Objective 1)

- We have summarized habitat characteristics for NLEB based on range-wide literature, and highlighted values specific to northeastern forests, and point out where characteristics in the northeast may deviate from those elsewhere. We provide examples in this report and will subsequently publish our findings in a peer-reviewed manuscript.

Comparison of stationary and handheld detectors (Objective 3).

- We used Anabat SM2 stationary acoustic detectors to sample bat occupancy in the Penobscot Experimental Forest (PEF) located in Bradley, Maine.

- We deployed detectors in four different site types: open sites characterized by wetlands or large forest openings, closed canopy sites with mature forest typical of NLEB habitat. Detectors were moved to new sites once every 7 days.

- We enlisted the help of volunteers to field-test handheld, tablet-based acoustic detectors. These detectors consisted of an ultrasonic microphone and iPad tablet. We compare results from volunteer testing with those obtained from traditional stationary detectors (figure 28).

Figure 28. Traditional Anabat SM2 stationary acoustic detector.

- We analyzed all call recordings using Kaleidoscope Pro software to identify recordings to species, and used hand vetting with the assistance of expert opinion to vet potential NLEB calls.

Evaluating detection rates when sampling bats using stationary detectors (Objective 3)

- We used single season occupancy models (MacKenzie 2006) implemented in the 'unmarked' package of Program R to evaluate the probability of detecting bat species presence (p) during a single survey night using a stationary acoustic detectors. We then used these values to estimate the number of survey nights required to conclusively determine that a species or group was present or absent from a site.

- We used our data from the PEF for *Myotis* bats in general; however we had too few detections of NLEB to conduct a similar analysis for only that species. So, we obtained data from the Maine Department of Transportation, who conducted acoustic surveys during the summer of 2015 at roadside sites throughout Maine, to conduct a similar assessment for NLEB specifically.

- We estimated the probability of conclusively determining bat presence from nightly detection probabilities as 1-(1-p)^n, where p is the single night detection rate, and n is the number of survey nights.

Key Findings / Accomplishments:

Key findings of literature review:

- Available literature for NLEB are typically more abundant outside of the Northeast, particularly in the southern Appalachians and Midwest. For example, we found only 5 published studies of NLEB summer roosting habitat that were conducted in the northeast, including New Hampshire (Sasse and Pekins 1996), New Brunswick (Broders and Forbes 2004), Quebec (Fabianek et al. 2015), Nova Scotia (Garroway and Broders 2008), and Newfoundland (Park and Borders 2012). Key findings of these studies are summarized in Table 5. The majority of work on NLEB habitat requirements in the northeast has been conducted in Canada.

- Although they are forest specialists, NLEB exhibit a fair degree of flexibility in use of specific habitat characteristics (Table 1). For example, studies reported that mean DBH of roost trees used by NLEB ranged from 18 cm in Arkansas (Perry and Thill 2007) to 65 cm in Michigan (Foster and Kurta 1999). These ranges of values are likely affected by local-scale availability, however, and bat preference for particular tree characteristics may be obscured by lack of availability in certain systems.

- NLEB are also regularly found to use a wide variety of tree species within a single system. More than 6 species of trees are commonly reported within single studies, including both deciduous and conifer species and live trees (commonly with deformities) and snags.

- When comparing bat studies from the northeaster US and Canada to those from elsewhere in the species range, some similarities and differences are apparent. For example, DBH of trees used as summer roosts by NLEB in the northeast are generally similar to those used elsewhere, however NLEB in the northeast have been found in some studies to use a greater proportion of dead snags, and generally use trees that are shorter in height, compared to elsewhere (figure 29).

Table 5. Summary of available literature for NLEB.

Trait	Females	Males	Location	Study
Roosting behavior	Multiple individuals	Single individuals	New Brunswick	Broders and Forbes 2004
	Average group 10.8 (SD= 2.6)	NA	White Mts, NH	Sasse and Pekins 1996
	Average group 8 (range 1 to 28)	NA	Newfoundland	Park and Broders 2012
Roost tree characteristics	Shade-tolerant hardwoods, intermediate decay stage, large cracks or cavities.	Coniferous species (Red Spruce), intermediate decay stage, under loose bark, DBH <20cm	New Brunswick	Broders and Forbes 2004
	98% hardwoods, 66% snags in intermediate decay stage, average DBH 40.9cm. Diameter and height greater than available nearby. Live roost trees average 30.9 cm DBH, also larger than available trees.		White Mts, NH	Sasse and Pekins 1996
	50% softwood species, >85% snags; selected trees with greater DBH; and selected trees with higher and less variable ambient temperatures	NA	Newfoundland	Park and Broders 2012
	40% softwood, 53% snags; Average DBH 43 cm (SD= 17cm)	NA	Nova Scotia	Garroway and Broaders 2008
Roost site characteristics	Mature stands dominated by shade-tolerant hardwoods	Conifer stands or conifer-dominated mixed wood stands	New Brunswick	Broders and Forbes 2004
	80% canopy cover hardwood stands; greater hardwood basal area and greater number of snags within roosting area		White Mts, NH	Sasse and Pekins 1996
	Greater canopy cover	NA	Newfoundland	Park and Broders 2012
	52% canopy cover for lactating, 75% for non-lactating females; conifer trees dominant	NA	Nova Scotia	Garroway and Broaders 2008
Distance between roost sites	457 m (SD=329)	158 m (SD=127)	New Brunswick	Broders et al. 2006
	Bats moved often between roosts only 17% used continuously		White Mts, NH	Sasse and Pekins 1996

Minimum roosting area[1]	8.6 ha (SD=9.2)	1.4 ha (SD=1.4)	New Brunswick	Broders et al. 2006
Foraging activity[2]	Greater activity at water sites (lakes) compared with terrestrial. Among terrestrial sites, greater activity detected along forested trails, over disturbed sites, clear cuts and edges. Greater activity detected above canopy layer.		New Brunswick	Broders et al. 2006
Minimum foraging area[2]	46.2 ha (SD=44.4)	13.5 ha (SD=8.3)	New Brunswick	Broders et al. 2006
Foraging distance	2,000 m	500 m	New Brunswick	Broders et al. 2006
	602 m (60 -1719m)		White Mts, NH	Sasse and Pekins 1996
Mean parturition date	20-Jul	-	New Brunswick	Broders et al. 2006
	2-Jul	-	White Mts, NH	Sasse and Pekins 1996
	7-Jul	-	Newfoundland	Parks and Brodes 2012

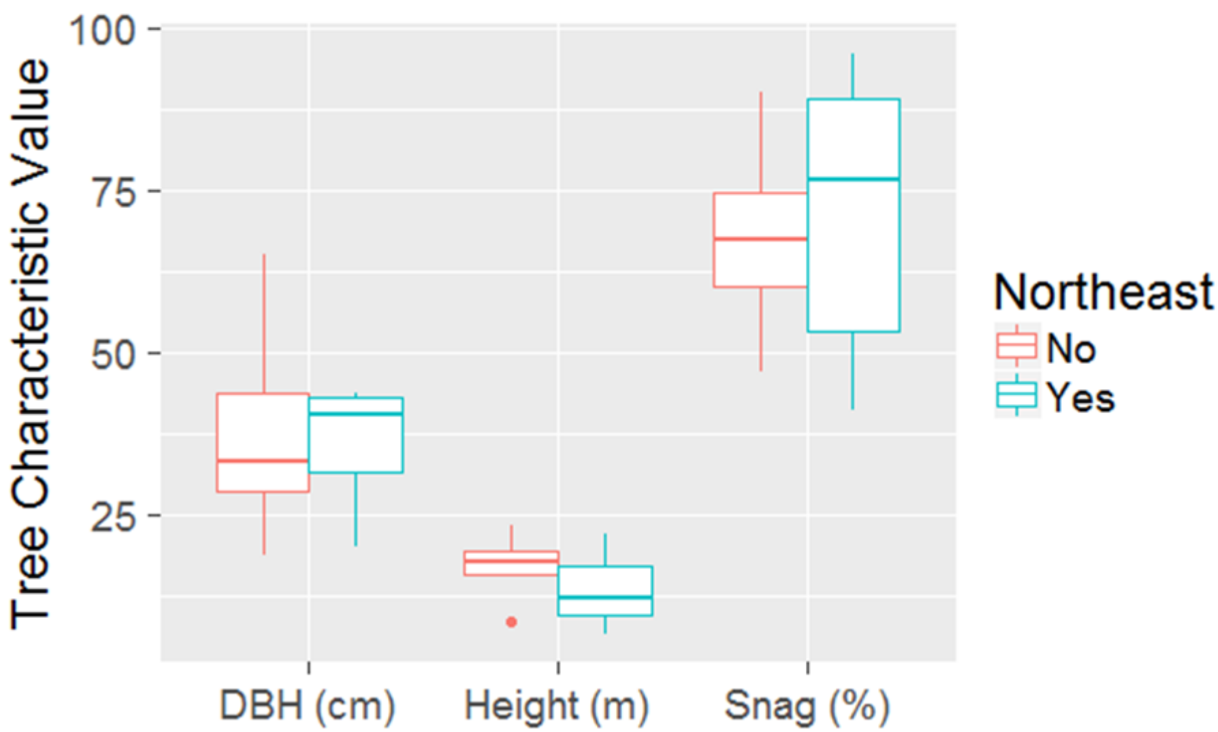

Figure 29. DBH of trees used as summer roosts by NLEB in the northeast.

- Methods for conducting bat surveys include mist-netting, roost surveys, and acoustic monitoring, each with its own limitations. Availability of acoustic survey call libraries and methods for data processing are rapidly evolving, and our review summarizes the current state-of-the-art. Active acoustic survey methods using smartphones and tablets that can be applied by non-scientists are also evolving and our work addresses the utility of these approaches.

- Much of the work that has been done on NLEB occurred prior to the outbreak of white-nose syndrome. Changes in bat density post-WNS may affect habitat relationships, however future research that requires capture of NLEB (e.g. for radio-telemetry) may be challenging because of the low densities of bats and difficulty of capture following population declines.

- Substantial potential exists to use bat acoustic sampling for better-understanding bat-habitat relationships at multiple scales, and to evaluate the relationship between forest structure and practices on the present distributions of species of concern.

Descriptive results from stationary and handheld detectors:

- We detected NLEB at only 3 of 46 sampled sites in the PEF, for a naive occupancy rate of 6.5% of sites. In contrast, Little Brown Bats were detected at 19 of 46 sites (41%). We identified calls from all of Maine's 8 bat species at the PEF (figure 29).

- *Myotis* bats in the PEF were more likely to be detected in areas with both high and low tree densities, compared to sites with intermediate stocking of trees. This variability is likely due to differences in foraging guilds among *Myotis* species.

- We recruited 16 volunteers and to assist us with field-evaluation of handheld tablet-based detectors, and they conducted 53 hours of surveys. These volunteers collected bats during 92% of surveys, whereas they visually observed bats during 55% of surveys. Volunteers reported that tablet detectors were easy to use after a training session, and they recorded acoustic files of similar quality to commonly-used stationary detectors.

- Observers using handheld detectors were generally unlikely to detect *Myotis* species, and were more likely to detect migratory tree bats and Big Brown Bats. However, handheld tablet detectors and stationary detectors produced comparable proportions of calls for each species, except that tablet detectors failed to detect the most uncommon species, including NLEB (figure 30).

- For most bat monitoring applications in commercial forests, stationary detectors are likely to be best-suited to monitoring objectives. However, tablet-based detectors have potential as a more general tool for foresters or biologists to identify hotspots of bat activity using active surveys, and they also are well-suited for mobile vehicle-based surveys.

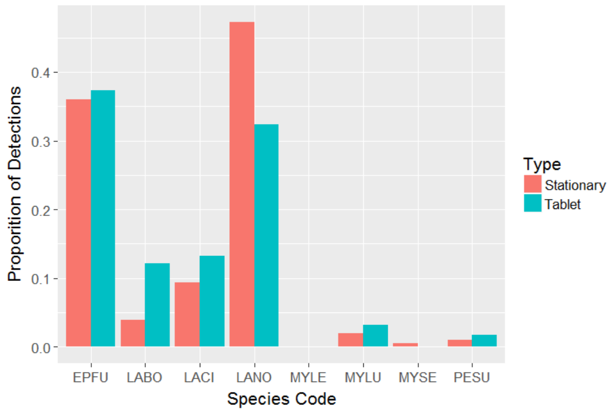

Figure 30. Comparison of stationary versus handheld bat detectors.

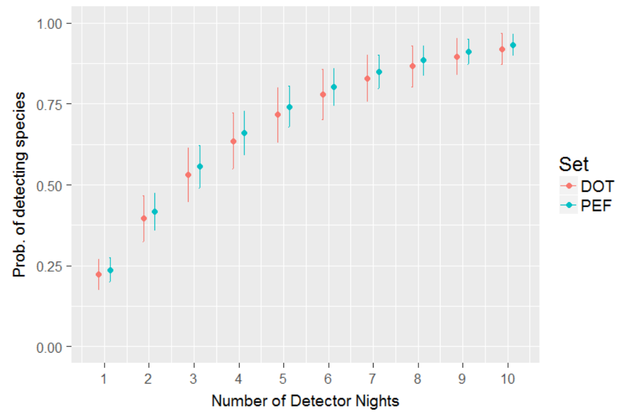

Figure 31. The probability of detection versus number of nights surveyed.

Results of data analyses:

- The nightly detection probability of *Myotis* bats at the PEF was 0.23. This implies it would take >10 nights of acoustic surveys to conclusively determine that a site was occupied by a *Myotis* bat species (figure 31).

- Based on data from Maine DOT, the nightly detection probability of NLEB was 0.22, which produced a nearly identical detection curve to that of all *Myotis* bats from the PEF (figure 31).

- If presence/absence surveys for bat species of concern are required, such as for Section 7 consultations with the US Fish and Wildlife Service or for certification programs, these results provide multiple lines of evidence that at least 10 nights of acoustic surveys are required to definitively declare a species absent.

- These results also suggest that naïve occupancy estimates based on short-term surveys, which do not account for imperfect detection, may regularly underestimate the current distribution of NLEB and other bat species of concern.

Future Plans:

- We are currently drafting a manuscript for publication that summarizes our literature review, gives an overview of current state and federal policies, our interpretation of relevance to Maine forest practices, and priorities for future research. We plan to submit this paper to the Maine Policy Review.

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Acknowledgements:

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

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

Karen N. Bothwell, Mindy S. Crandall, and Amber M. Roth

University of Maine

Status: Final Report

White-tailed deer. Photo - Pamela Wells

Summary:

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

Project Objectives:

- Provide CFRU members with an estimate of the economic impact on forestry of a major wildlife-related regulation, using DWA zoning as a case study.
- Estimate the opportunity cost of current management in DWAs compared to "business as usual" timber management.
- Model management activities designed to better support deer population viability.
- Estimate the costs and benefits of alternative wildlife habitat management.

- Lay the foundation for developing a flexible, market-based model that can be used to quantify the economic impact of a wide range of policies and regulations that influence forest management, wood supplies, and markets.

Approach:

- Working with collaborators, described current activities typically undertaken in DWAs on their lands.

- Using growth and yield software, modeled existing stands under current DWA and "business as usual" management regimes.

- Compared the economic estimates for DWA systems to business as usual.

Accomplishments:

- Compiled interview responses from foresters and biologists managing DWAs, integrating their approaches to management into subsequent growth and yield modeling.

- Modeled common silvicultural scenarios using inventory data from two representative timberland properties, "Company A" and "Company B." Company A practiced typical commercial forest management for timber production, whereas Company B managed primarily for conservation and wildlife habitat priorities. The two companies served as examples of common management paradigms in Maine.

- Converted wood product output of simulated harvests to financial returns using the 2015 Maine Stumpage Price Report.

- Total per-hectare stumpage harvested from DWAs on each property, combined with the stumpage value of standing trees at the end of a 50-year time horizon, was compared to revenues from similar, but presumably more intensive, harvests outside of DWAs. The monetary difference is the opportunity cost of harvesting inside a DWA rather than on unregulated areas of the property.

Key Findings:

- Because of the difference in species composition between the two properties and variations in initial stand metrics, our models resulted in one company's experiencing an economic loss due to restrictions on harvests within DWAs, whereas another gained an economic advantage there despite the lower intensity harvests of those scenarios (table 6, figure 32). The discrepancy in opportunity cost patterns between the two companies allows us to conclude that stand characteristics and landowner objectives influencing past management have a strong impact on current value.

- For Company A, the historically industrially managed land, higher returns came from harvests outside of DWAs across all silvicultural systems. The lower value found within DWAs is likely related to their lower average quadratic mean diameter (QMD) and higher average trees per hectare (TPH), indicating a lower level of merchantability.

- The lower merchantability within DWAs may be due to a lack of intermediate treatments. Longer rotations necessary inside DWAs and uncertainty regarding harvest approval sometimes deter landowners from investments, and any thinnings must be light to maintain a high percentage of canopy closure.

- For Company B, greater revenue was realized from harvests inside DWAs because of species composition. Outside DWAs, American beech (*Fagus grandifolia*) was a major component, whereas red spruce (*Picea rubens*) was found more often inside DWAs. There was more value from harvests within DWAs because they contained a greater proportion of trees with higher stumpage prices.

- Silvicultural systems such as the irregular group shelterwood with reserves have the potential to achieve comparable revenues to more common systems while maintaining necessary habitat.

- With this baseline economic information, we can conclude that implementation of a policy for provisioning wildlife habitat need not be an insurmountable obstacle to private landowners or timber companies seeking reasonable returns from harvests.

- Clear standards that are understandable in terms of both the habitat characteristics and the stand features using common forest inventory metrics would facilitate development and execution of appropriate silvicultural prescriptions.

- The regulatory goal should be to develop an approach where the benefits we receive from deer are the same or greater than the costs we must bear to support their numbers.

Table 6. Economic returns per hectare of modeled management scenarios inside and outside of zoned deeryards. 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. All amounts are discounted at 4% to Year 0 dollars.

Silvicultural system	Management scenario	Harvest revenue		Standing Value		Total	
		Company A	Company B	Company A	Company B	Company A	Company B
Shelterwood	Regular	$ 1,681.53	$ 1,787.89	$ 300.37	$ 525.32	$ 1,981.90	$ 2,313.20
	Deeryard	$ 685.05	$ 1,843.21	$ 525.55	$ 526.26	$ 1,210.59	$ 2,369.47
Clear cut	Regular	$ 1,903.92	$ 1,911.06	$ 258.42	$ 276.12	$ 2,162.34	$ 2,187.18
	Deeryard	$ 1,699.58	$ 3,236.95	$ 248.62	$ 333.32	$ 1,948.20	$ 3,570.27
Single tree selection	Regular	$ 311.78	$ 505.20	$ 612.41	$ 616.69	$ 924.19	$ 1,121.88
	Deeryard	$ 83.18	$ 249.93	$ 589.17	$ 1,092.91	$ 672.35	$ 1,342.84
Group selection	Regular	$ 994.72	$ 976.32	$ 399.12	$ 420.70	$ 1,393.84	$ 1,397.02
	Deeryard	$ 355.44	$ 839.99	$ 493.69	$ 810.94	$ 849.13	$ 1,650.93
Diameter limit	Regular	$ 1,525.78	$ 1,295.75	$ 654.95	$ 436.75	$ 2,180.73	$ 1,732.50
	Deeryard	-	-	-	-	-	-
Irregular group shelterwood	Small gap	$ 631.68	$ 1,207.80	$ 369.15	$ 658.05	$ 1,000.82	$ 1,865.84
	Large gap	$ 1,263.36	$ 2,415.60	$ 109.58	$ 156.68	$ 1,372.94	$ 2,572.27

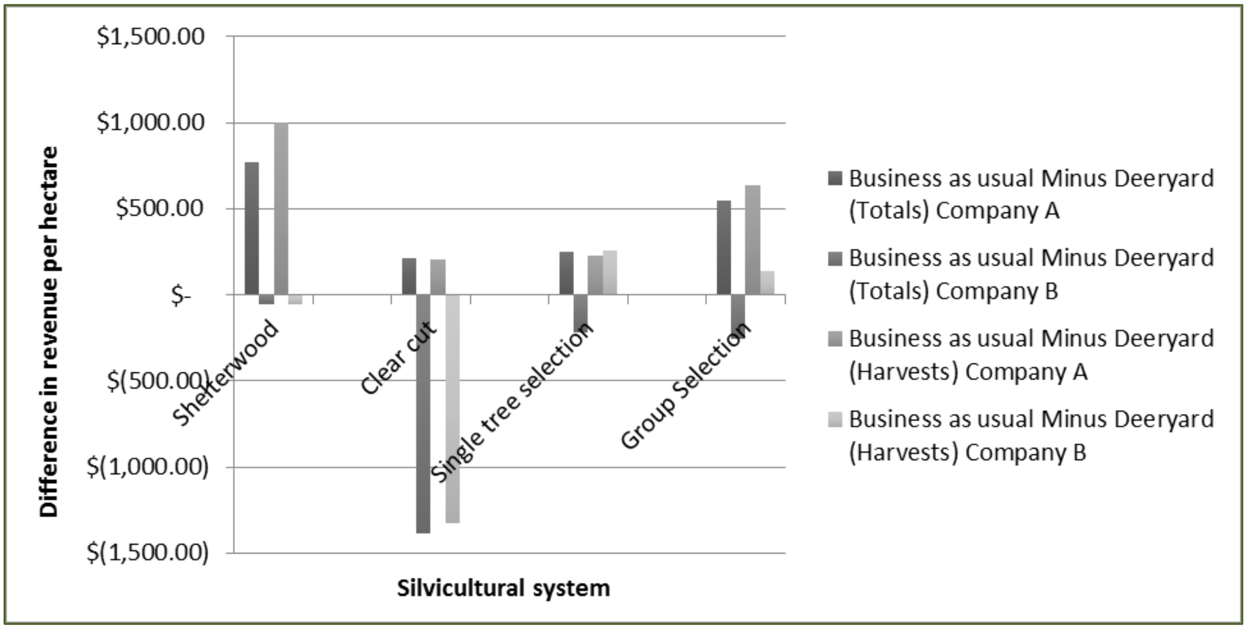

Figure 32. Opportunity cost per hectare, or difference in revenue, between "business as usual" management scenarios and those applied within zoned deeryards for the four silvicultural systems that are used in both contexts. "Harvests" is based only on revenues from harvests that occurred in the 50 year simulation; "Totals" includes those harvest revenues and the standing value at 50 years.

Future Plans:

- Development of management regimes and stands modeled here will be used as key inputs into a landscape-level model of forest composition and management in the state. This larger modeling effort will enable analysis of changes in wood supply (e.g. due to spruce budworm mortality) and harvest intensity and their impact on availability of deer wintering habitat across northern Maine.

Acknowledgements:

Thank you to CFRU cooperators and MDIFW biologists who agreed to be interviewed, tour their properties, and contribute data to this project. Dr. Robert S. Seymour for the use of his FVS merchandising key and to Dr. Laura Kenefic and Keith Kanoti for access to forest inventory data.

Moose Density and Forest Regeneration Relationships in Maine

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Status: Final Report, Year 2

Moose in Maine. Photo - Sue Aygarn

Summary:

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

Project Objectives:

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

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

- conduct a standard forest inventory within 10-15 stands >30 years old with known silvicultural history to assess composition and quality in older stands subjected to moose browsing, and

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

Approach:

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

- A stem was considered to have severe damage if they were broomed or contained multiple forks above breast height (Andreozzi *et al.* 2014). Trees with less severe damage were expected to recover during future growth. A fully stocked stand at 80 years (average density for undisturbed stand) was assumed if a minimum of 40%-60% of plots contained a dominant commercial stem with no severe damage (Leak *et al.*1987, Andreozzi *et al.* 2014).

- To evaluate relative height between age classes and further assess browse impact, we estimated the proportion of plots which contained a dominant commercial stem >3 m with no severe damage; >3 m in height is the threshold above the typical browsing height for moose.

- Older stands (>30 years) were measured with a standard forest inventory using a 20-factor prism where the dbh of sample trees was measured to calculate basal area. Sample trees were assessed for commercial quality with the New Brunswick classification protocol (Pelletier *et al.* 2013) that assigns form (F1-8) and vigor (R1-4) ratings from observed tree characteristics.

Key Findings/Accomplishments:

- During spring 2015 we met with land managers and identified a subset of forest stands which met the criteria for forest type, harvest category, and stand age for the milacre sample plots (Objective 1). We also identified the location of 19 older stands with known harvest history (≥30 years old, Objective 2). Forest stands were located across multiple land management properties in northwestern Maine, Greenville, and Katahdin Iron Works, extending north to Baker Lake and North of Baxter State Park (figure 33).

- We stratified sampling across forest stands to best meet our harvest, forest type, and age class objectives (Objective 1). In total, we sampled 15,686 milacre plots within 145 younger stands, 80-120 plots per stand (table 7). We measured 192 forest inventory plots within 19 older stands, (1 plot/5 acres, 4-20 plots/stand).

- The dominant stem in the majority of milacre plots (>93%) was a commercial species regardless of stand age, harvest practice, or forest type. The most common commercial species were red maple, balsam fir, red spruce, and sugar maple (figure 34), which represented >65% of all dominant stems. Likewise, commercial stems dominated the older stands with balsam fir, red spruce, sugar and red maple, white spruce, and yellow and paper birch (figure 35) representing >80% of stems.

- The majority (79-88%) of stems in the younger aged stands (5-20 year) had no severe damage (table 9) across forest type and harvest type. Rates of severe damage decreased from 21% to

12% with increasing age in clearcut stands (table 3). Severe damage rates were lower and more consistent (14-18%) across age classes in the partial harvest stands; in both harvest groups the majority of plots contained a dominant commercial stem with no severe damage. Most damage was either moderate or light in severity and stems are expected to recover.

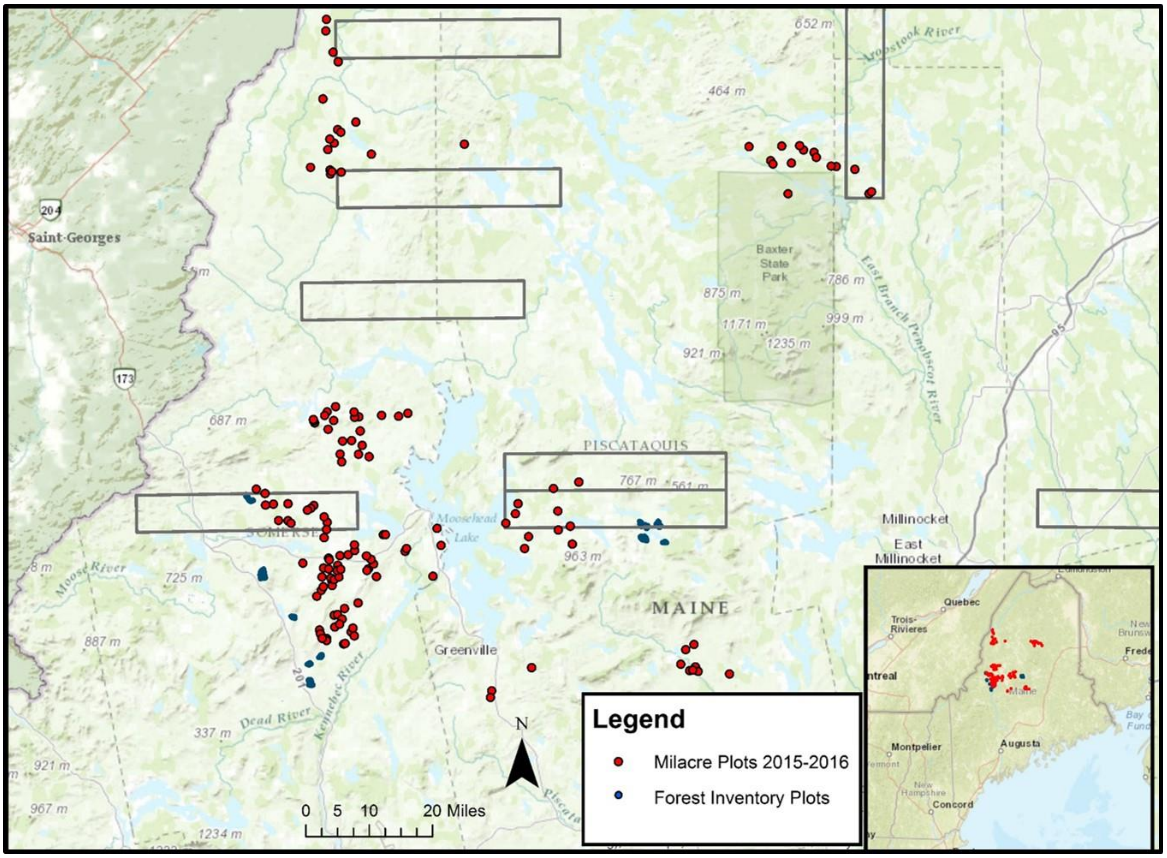

Figure 33. The location of forest stands sampled during summer of 2015 and 2016 using milacre plots (5-20 years old) or a standard forest inventory (>30 year old stands) during the summer of 2015 and 2016. Grey boxes indicate areas where MDIFW have conducted aerial moose surveys.

- The number of dominant commercial stands above 3 m which contained no severe damage increased with stand age (table 3). Clearcut stands showed the greatest increase through time, with 74% of plots containing stems >3m with no severe damage by the 16-20 year age class. This increase was 64% in partial harvest stands by the 16-20 year age class.

- Relative to forest type, hardwood stands had the most severe damage; albeit, severe damage occurred in <25% of plots in any combination of harvest type and age class. At 15-20 years, >80% of partial harvest plots and >85% of clearcut plots had no severe damage (figure 36).

- An acceptable stocking rate (40-60% stems without severe damage) occurred in the 3 forest types and both harvest regimes at 16-20 years (figure 36).

- The majority (~97%) of trees in the >30 year old plots were commercial species, undamaged (96%; table 9), and of Form 1 or 2 (83%; table 8) and vigor R1 or R2 (97%; table 8). Also 61% of stems had the highest combined rating (F1-R1), indicating that stands had high commercial value relative to these criteria (table 8).

Table 7. Proportion of stems in each category, separated by Harvest Type and Cover Type sampled during summer of 2015 and 2016. All plots combined from all stands, one tree sampled per plot, 15686 trees/plots sampled over 145 stands. We attempted to sample 120 plots per stand however stands had between 150 and 54 plots, with an average of 108 (SD =18). Mixed wood stands were the most common on the landscape, softwood and hardwood stands which met our criteria were more difficult to locate, and this is evident in our sample sizes.

	Hardwood						Mixed						Softwood						Total
	Clear Cut			Partial Harvest			Clear Cut			Partial Harvest			Clear Cut			Partial Harvest			
Age Class	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
Com Stem Present	0.95	0.95	0.96	0.98	0.98	0.97	0.94	0.98	0.97	0.97	0.98	0.98	0.89	0.93	0.97	0.96	0.99	0.96	**0.97**
No Commercial Stem	0.05	0.05	0.04	0.02	0.02	0.03	0.06	0.02	0.03	0.03	0.02	0.02	0.11	0.07	0.03	0.04	0.01	0.04	**0.03**
Com Stem Dominant	0.93	0.92	0.96	0.92	0.95	0.95	0.97	0.95	0.96	0.93	0.96	0.95	0.96	0.98	1.00	0.90	0.98	0.99	**0.95**
Non-Com. Stem Dominant	0.07	0.08	0.04	0.08	0.05	0.05	0.03	0.05	0.04	0.07	0.04	0.05	0.04	0.02	0.00	0.10	0.02	0.01	**0.05**
No Damage on Com. Stem	0.31	0.28	0.45	0.46	0.33	0.43	0.53	0.53	0.46	0.54	0.52	0.62	0.64	0.79	0.84	0.68	0.73	0.81	**0.53**
Damage 1.5m - 3m																			
Broom	0.05	0.04	0.01	0.04	0.07	0.04	0.03	0.02	0.05	0.02	0.04	0.02	0.02	0.02	0.01	0.04	0.02	0.00	**0.03**
Light Crook (<30°)	0.06	0.11	0.17	0.11	0.06	0.07	0.03	0.13	0.12	0.06	0.05	0.04	0.02	0.02	0.03	0.02	0.03	0.03	**0.07**
Moderate Crook (30° – 60°)	0.04	0.03	0.04	0.03	0.04	0.03	0.01	0.02	0.03	0.02	0.02	0.03	0.00	0.00	0.01	0.01	0.01	0.01	**0.02**
Severe Crook (> 60°)	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	**0.00**
Fork	0.14	0.15	0.05	0.09	0.12	0.13	0.07	0.07	0.09	0.08	0.11	0.07	0.03	0.02	0.02	0.05	0.05	0.02	**0.08**
No Damage ABH	0.36	0.34	0.23	0.24	0.37	0.26	0.26	0.20	0.23	0.25	0.24	0.20	0.18	0.08	0.06	0.15	0.13	0.09	**0.23**
Damage Below 1.5m																			
Broom	0.05	0.05	0.01	0.03	0.05	0.03	0.03	0.03	0.04	0.04	0.03	0.02	0.06	0.04	0.00	0.07	0.03	0.00	**0.03**
Light Crook (<30°)	0.17	0.15	0.11	0.13	0.06	0.07	0.09	0.12	0.13	0.10	0.08	0.06	0.03	0.02	0.04	0.04	0.03	0.06	**0.09**
Moderate Crook (30° – 60°)	0.04	0.06	0.03	0.03	0.03	0.04	0.04	0.05	0.03	0.05	0.03	0.02	0.01	0.01	0.01	0.03	0.03	0.01	**0.03**
Severe Crook (> 60°)	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	**0.01**
Fork	0.20	0.16	0.05	0.12	0.11	0.11	0.14	0.11	0.09	0.10	0.13	0.09	0.10	0.04	0.02	0.07	0.06	0.02	**0.10**
No Damage BBH	0.17	0.24	0.30	0.20	0.39	0.28	0.10	0.13	0.20	0.12	0.18	0.17	0.05	0.04	0.05	0.07	0.09	0.05	**0.17**
Bark Stripping on stem	0.02	0.05	0.14	0.03	0.04	0.05	0.01	0.03	0.12	0.03	0.05	0.04	0.01	0.01	0.02	0.02	0.04	0.02	**0.04**
Browse on stem	0.47	0.42	0.34	0.23	0.25	0.30	0.25	0.36	0.39	0.29	0.30	0.14	0.25	0.15	0.08	0.23	0.20	0.10	**0.27**
Browse in Plot	0.73	0.80	0.66	0.53	0.84	0.65	0.55	0.65	0.75	0.60	0.64	0.41	0.35	0.34	0.31	0.51	0.43	0.24	**0.58**
Bark Stripping in Plot	0.08	0.09	0.13	0.05	0.09	0.08	0.02	0.07	0.12	0.04	0.08	0.07	0.00	0.02	0.02	0.04	0.03	0.01	**0.06**
Moose Pellets in Plot	0.04	0.15	0.21	0.12	0.10	0.05	0.06	0.17	0.17	0.17	0.09	0.12	0.13	0.25	0.25	0.17	0.08	0.08	**0.12**
Total Number Plots	641	878	719	1023	1017	720	1021	992	807	1404	1655	1240	613	652	660	607	569	468	**15686**
Total Number of Stands	6	9	6	9	9	7	9	9	8	14	15	12	6	6	6	5	5	4	**145**

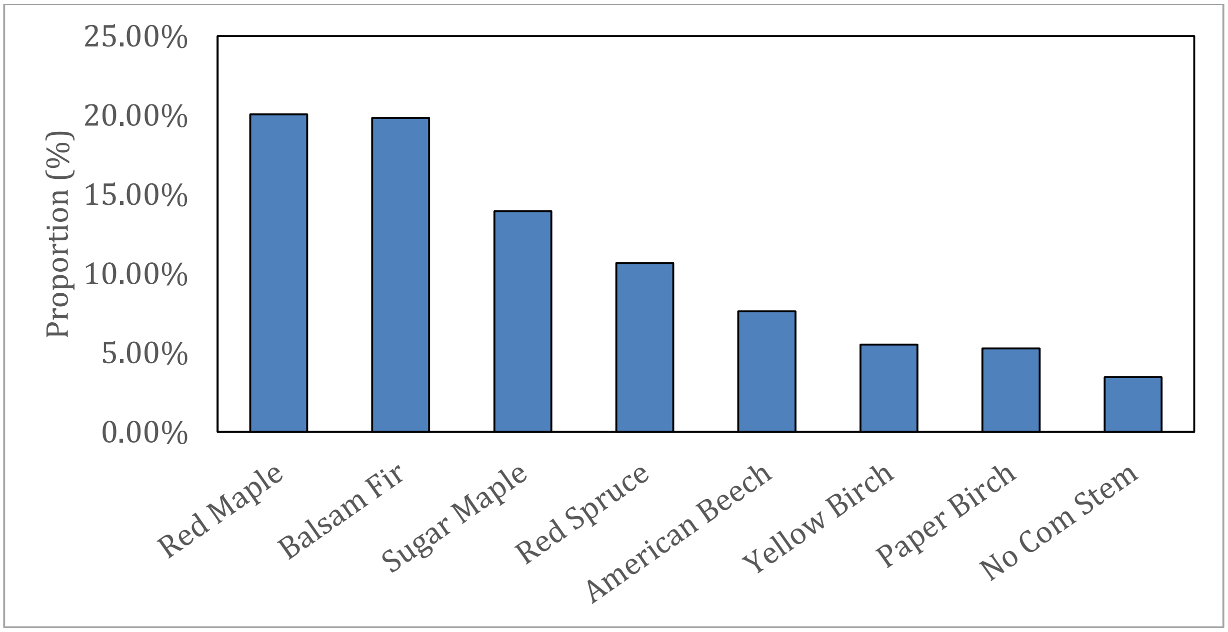

Figure 34. The percent composition of the most common commercial tree species recorded in 15,686 milacre plots measured in 5-20 year-old hardwood, softwood, and mixed wood stands in Maine. Only 3% of plots did not contain a commercial stem. Results are combined across age class and harvest category.

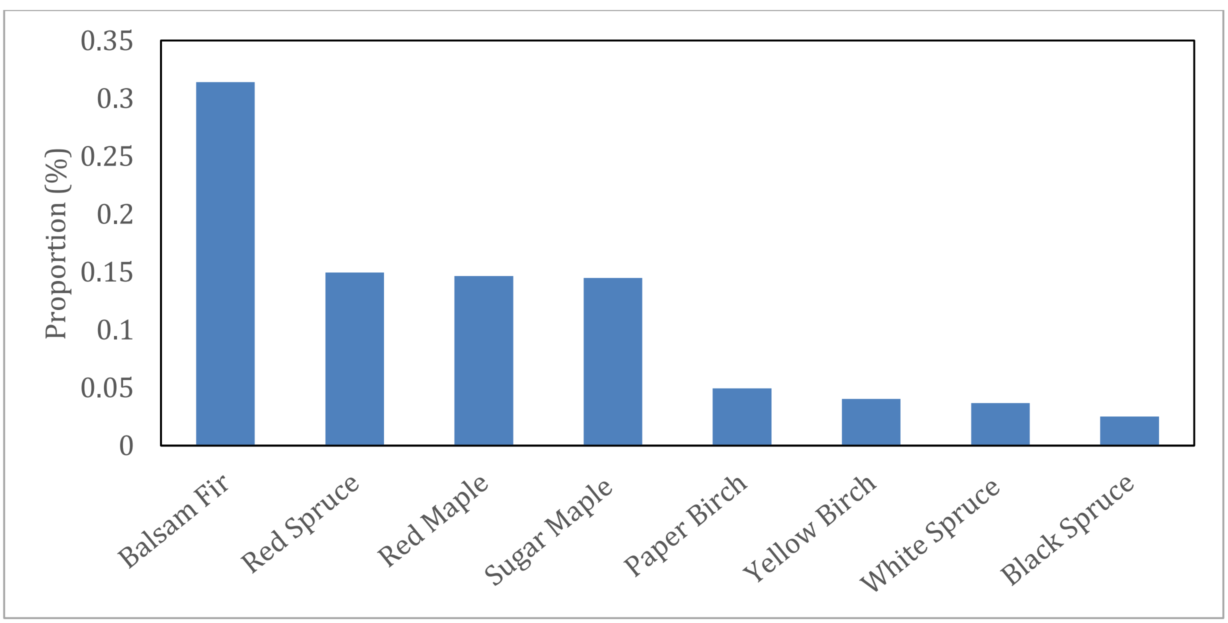

Figure 35. The percent composition of most common commercial (97%) and non-commercial tree species (≥2% total) within 19 forest stands >30 years post-harvest in Maine. Species composition consisted of 55% softwood and 44% hardwood trees sampled. Quality and vigor ratings assigned to sample trees (n = 1712) indicated that the majority were either F1 (73%) or F2 (10%) and R1 (77%) or R2 (20%). Overall, 80% of trees were a combination of F1/2 and R1/2 indicating relatively high commercial value.

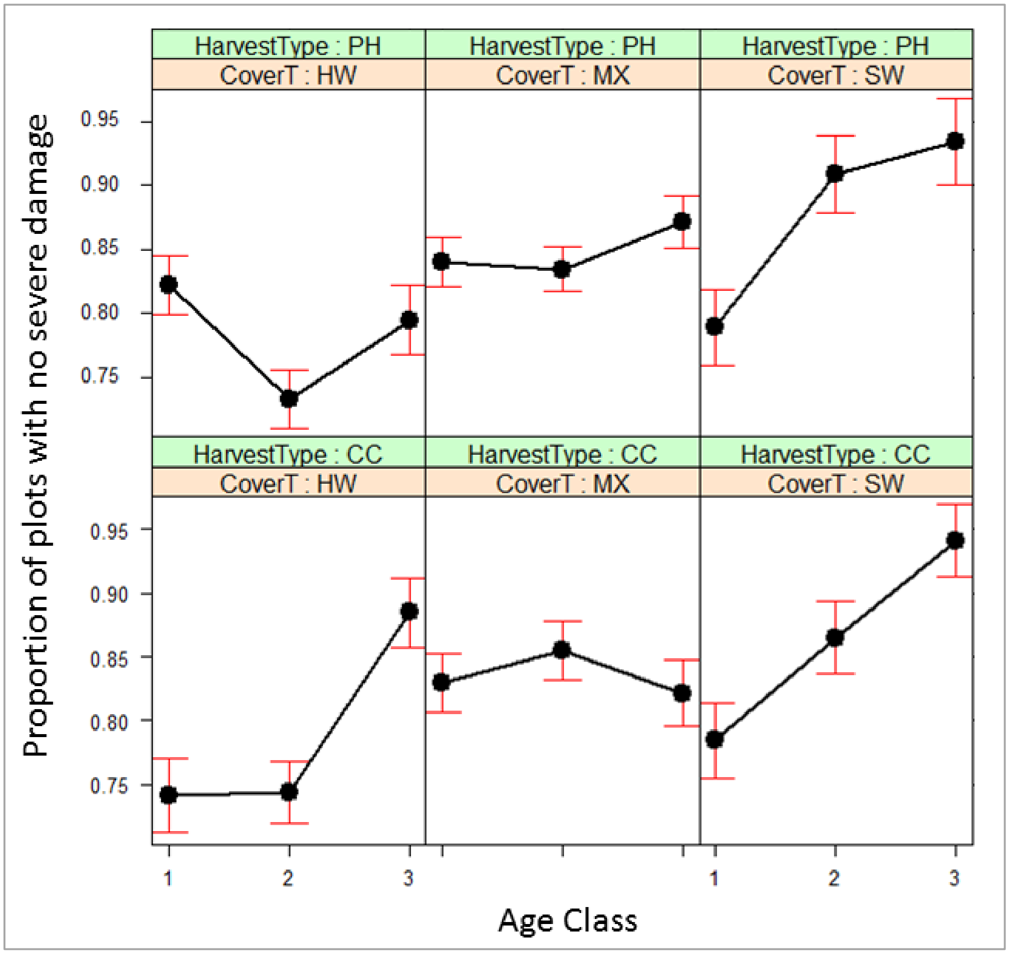

Figure 36. Proportion of milacre plots sampled during summer of 2015 and 2016 which contained a dominant commercial stem with no severe damage. Results are categorized by harvest type (CC-clearcut or PH- partial harvest), forest cover type (HW-hardwood, MX- mixed-wood, SW – softwood) and age class (1) 5-10 years, (2) 11-15 years, (3) 16-20 years since harvest.

Table 8. Proportional distribution of form and vigor ratings as assigned by the New Brunswick classification protocol in older stands (>30 years old). The majority of trees were F1/F2 (83%) or R1/R2 (97%) indicating commercial value; 61% had the highest combined rating (F1-R1).

	Vigor				Total
Form	R1	R2	R3	R4	Form
F1	0.61	0.10	0.01	0.00	0.73
F2	0.05	0.05	0.00	0.00	0.10
F3	0.02	0.00	0.00	0.00	0.03
F4	0.01	0.00	0.00	0.00	0.01
F5	0.01	0.01	0.00	0.00	0.02
F6	0.01	0.02	0.00	0.00	0.03
F7	0.01	0.00	0.00	0.00	0.01
F8	0.04	0.02	0.00	0.00	0.06
Total Vigor	0.77	0.20	0.02	0.01	1.00

Table 9. Proportion of stems in each age class, and standard deviation, which were not classified as having severe damage (broomed or multiple forks above breast height), for milacre plots (5-20 yrs.) and > 30 year old stands forest inventory stands. In older (>30year) stands we identified the proportions of stems sampled with no severe damage. Stems from all forest cover types were combined because of small sample sizes for any one cover type (see table 2) and summarized by harvest category and age class. Letters indicate significant differences (p< 0.05) between classes as identified by tukey pairwise comparison of means.

Harvest Type	Age Class	Proportion of plots/stems with dominant commercial stems with no severe damage			Proportion of plots with dominant commercial stems ≥ 3m with no severe damage		
Clearcut							
	5-10	0.79	(0.41)	a	0.36	(0.48)	a
	11-15	0.82	(0.39)	b	0.46	(0.50)	b
	16-20	0.88	(0.33)	c	0.74	(0.44)	c
Partial Harvest							
	5-10	0.82	(0.38)	a	0.55	(0.50)	a
	11-15	0.82	(0.39)	b	0.63	(0.48)	b
	16-20	0.86	(0.35)	b	0.64	(0.48)	b
Clearcut stands >30 years							
	All Species	0.96					
Clearcut stands >30 years							
	Hardwood	0.92					
	Softwood	1.00					

Future Plans

- This study indicates that severe damage to forest regeneration by moose was limited overall, but where identified, was limited mostly to hardwood stands. We suggest that establishment of permanent plots be limited to hardwood stands, that our measured plots can serve as an initial sample of permanent plots, and that geographic stratification of hardwood plots reflect variable moose density and related moose management strategies.

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Coyote predation on deer in Steuben, ME.

APPENDIX

CFRU Products Delivered During 2016

CFRU Publications

Refereed Journal Publications:

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

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

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

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

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

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

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Research Reports & Conference Papers/Posters:

Anderson, E., E. J. Blomberg, and S. Fraver. Environmental features influencing Myotis bat presence in the Penobscot Experimental Forest, Central Maine. International Bat Research Symposium, Winter Harbor, ME, April 2016. Poster.

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

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

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

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

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

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

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

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

Software/Data:

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

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

Media:

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Max McCormack is presented with the 2016 Austin Wilkins Award in Augusta, ME. Photo – Brian Roth