Cooperative Forestry Research Unit

2018 Annual Report

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Jenna M. Zukswert (MSc), 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 32 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. The CFRU is housed within the Center for Research on Sustainable Forests at the University of Maine.

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Front Page Photo

Logging road in northern Maine. Photo by Harikrishnan Soman.

Credits

Final layout by Jenna Zukswert. Individual sections were written by authors as indicated. Image credit 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) 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). We use both metric and English units in this report. Please consult any of the conversion tables that are available on the internet if you need assistance.

Photo: J. Zukswert.

2018 CFRU Highlights

- CFRU membership decreased slightly in Fiscal Year 2017–18, but acres managed remains stable with nearly 8.2 million acres managed by 32 cooperating members. A slight decrease in funding was in part attributed to a delay in contributions from the State (see page 15).

- CFRU continued to leverage a wide variety of funding sources to support cooperating member research priorities. For every $1 contributed by CFRU's largest members, an additional $14.30 was leveraged from other sources (see page 15).

- In June, the CFRU hosted scientists from across North America and Europe who presented a technical workshop and field tour entitled "Long-Term Site Productivity Research: Lessons from Other Regions and Opportunities for Maine." This two-day event drew 50 participants each day (see page 22).

- In response to requests by members to increase outreach efforts, the CFRU launched a new communications initiative to more frequently share research results. This initiative produced a new webinar series as well as the more frequent dissemination of 1–2 page Research Updates, summarizing CFRU research results in an easy-to-read format (see page 22).

Silviculture & Productivity Research

- Obtained in an effort to better understand northern white-cedar lowlands and thereby improve silvicultural recommendations, pre-harvest measurements at the Penobscot Experimental Forest suggest that these forests have high volumes of dead wood, high water tables, and white-cedar that originates from both seed and layers (see page 28).

- An evaluation of the effects of four different prescriptions on soil compaction and the cost of implementing Best Management Practices (BMPs) to reduce soil damage suggest that the cost of BMP implementation (between $10 and $52 PMH^{-3}) depends on machine maneuverability and the extent of area covered by the BMP (see page 32).

- Two sites in the Maine's Adaptive Silviculture Network were harvested this year (one in T16 R8 owned by Irving Woodlands, LLC, and the other in T13 R15 owned by Seven Islands Land Company). Three more installations were established as well: Stetsontown Township owned by Wagner Forest Management, Thorndike Township owned by Weyerhaeuser Company, and Massabesic Experimental Forest owned by the US Forest Service (see page 35).

- Soil samples collected for a study of long-term effects of whole-tree harvesting and residue management at the Weymouth Point Study Area in 2017 were analyzed for nutrient content in 2018. Ecosystem carbon and nutrient budget work is ongoing. Other preliminary results suggest that dead wood debris is three times greater in the unharvested watershed than in the clearcut watershed (see page 38).

Growth & Yield Modeling Research

- Repeat measurements were made on hardwood trees on both the Penobscot Experimental Forest Rehabilitation Study and the Silvicultural Intensity and Species Composition experiment. These data, along with data from forest inventories with repeat measurements of tree attributes in Maine, New Brunswick, and Nova Scotia, will be used to develop growth and mortality response functions for common hardwood species (see page 46).

- Incorporation of Sentinel-2 satellite derived variables into models that predict tree volume per hectare using biomass growth index (BGI) improves the accuracy of these models, increasing out-of-bag r^2 values by 10–12%. Site Index models were also improved with the incorporation of Sentinel-2 derived variables, but not to the same extent (see page 49).

- Data from the 2017–18 spruce budworm second instar larvae (L2) survey suggest that overwintering larvae levels in Maine remain very low, with 32 larvae found in 13 sample locations and no larvae found in 242 of 255 locations (see page 54).

- To acquire LiDAR data for the remaining areas of Maine that were not obtained this year due to a variety of unforeseen issues, a spring 2019 flight is planned. Final LiDAR products should be completed and provided to stakeholders by the end of 2019 (see page 57).

Wildlife Habitat Research

- Preliminary results of a long-term effort (1989–2019) to study the effects of landscape configuration changes on American marten populations indicate that the catch rate in spring 2018 was lower than it has been during the past seven field seasons, and that each of the five martens monitored this season were detected in over 40 locations (see page 62).

- Preliminary data from a study investigating the use of breeding habitat for Bicknell's thrush in Maine's commercial forestlands suggests that Bicknell's thrush is using lower elevation habitat (see page 69).

- The first full year of large-scale surveys that use trail cameras to detect carnivores was completed, which involved deploying three cameras at each of 120 sites in 15 distinct study areas throughout the state for a minimum of two weeks each (see page 73).

- Two deer wintering area habitat models were produced using management guidelines from the Maine Department of Inland Fisheries and Wildlife, one of the models also including basking habitat within 250 m. Deer wintering areas for which we have the most recent occupancy information had the lowest proportion of high-quality wintering habitat (see page 79).

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Chair’s Report

As last year was described as a year of challenges for the CFRU, I like to think that 2018 was a year of stabilization for our research cooperative. Early in the fiscal year, we were fortunate to hire two very qualified individuals to fill vacancies in the CFRU’s administration. Additionally, we were finally able to appoint Dr. Brian Roth as the CFRU’s Program Leader after serving in that role on an interim basis since September 2016.

Amidst this transition, it is a credit to the continued support of the membership, the skill of the researchers, and the diligence of the staff that the CFRU was able to continue to conduct quality research. This report highlights the progress of 12 separate CFRU-funded research projects in our core interest areas of Silviculture & Productivity, Wildlife Management, and Growth & Yield Modeling. It is a diverse mix of studies and projects reflecting the interests of our diverse membership. I am confident that there are several studies that you will find of interest.

As mentioned in last year’s annual report, the Executive Committee participated in the University’s review of the Center for Research on Sustainable Forests. This enabled us to provide our perspective on the CFRU’s role within the CRSF and the University as a whole. This process led to separate discussions with the Vice President of Research, the Dean of the College of Natural Sciences, Forestry, and Agriculture, the Director of the School of Forest Resources and the Director of CRSF concerning support of the CFRU. While these discussions will continue in 2019, we are grateful for the increased financial support that was supplied this year by both Vice President Varahramyan and Dean Servello.

Looking forward to 2019, the membership and the CFRU staff will be developing a new prospectus to guide our efforts for the next 5 years. I look forward to working with members and staff as we strive to develop this strategic plan and pursue the continued excellence of the CFRU.

Sincerely,

Gordon Gamble
CFRU Executive Committee Chair

Program Leader's Report

The year 2018 has continued to bring change to Maine's forest community as well as the CFRU. Perhaps you have noticed an updated CFRU logo on the front cover of this report? It has been 14 years since the previous update and almost 50 years since its original creation by Dr. Maxwell McCormack. The new look retains all the symbolic features found in previous designs but has now been modernized. This is symbolic of the many new challenges facing our forest industry these days as CFRU members employ new technologies and applications to address long-standing problems.

For example, CFRU research projects now use LiDAR to map streams and wet areas, update decades-old soil surveys, quantify timber inventories, and predict the quality and distribution of wildlife habitat. CFRU researchers also use high-resolution imagery from satellites, airplanes, and UAVs to identify tree species biomass, forest types, disturbance history, and foliage losses to damaging agents such as the spruce budworm. By employing machine learning algorithms that are combined with the power of super computers, we are producing statewide high-resolution georeferenced maps of the aforementioned attributes. These detailed maps provide landowners and managers near real-time data to visualize and quantify changes, problems, and opportunities for the resources they manage, thereby reducing the uncertainty of "surprise forestry" that we are all so familiar with.

It is understandable that along with these new tools, there comes an increased need for assistance in understanding and implementing new technology and research for managers and foresters. In response, the CFRU has reallocated resources and added a full-time Research and Communications Coordinator position to our staff. Jenna Zukswert was hired at the end of 2017 and has done and amazing job developing communications products that are rapid to digest and easy to absorb for today's busy forestry professionals. In addition to standard reporting, workshops and field tours, CFRU members have access to easy-to-read research results papers, one hour-webinars, and on-site presentations by research scientists.

Other new initiatives are the implementation of a regional Adaptive Silviculture Network (MASN) (see page 35) and consideration for CFRU expansion to a regional cooperative that would include members from New York, Vermont, and New Hampshire. These major initiatives will better position the CFRU to respond to problems that will be facing forestland owners and managers in the future in the areas of forest sustainability, adaptation, and resilience, among others. Regional expansion will bring opportunities to broaden our research findings, leveraging a larger pool of funding sources led by a wider group of collaborating scientists.

Meanwhile at the University of Maine, I am pleased to report that as an outcome of the recent review of the Center for Research on Sustainable Forestry (CRSF) and support from CFRU members, my reclassification from Acting Director to Program Leader has become effective. Additionally, the Vice President for Research and Dean of the Graduate School (Kody Varahramyan) and the Dean of the College of Natural Sciences, Forestry, and Agriculture (Fred Servello) have offered $70,000 in joint support for the CFRU in FY18-19. This is in the form of a stipend, tuition, and half of the health insurance costs for two graduate students along with wages for two undergraduate students working on CFRU projects. The undergraduate support will be facilitated through the Center for Undergraduate Research (CUGR). The University continues to evaluate the present organizational alignment of the CFRU and CRSF with respect to providing stable institutional support for both units, while ensuring effective synergy between these units and other university and external partners.

In closing, I feel that I am extremely fortunate to have the continued support of CFRU membership along with the guidance of the CFRU Executive Committee in navigating the uncertainty we have faced over the past two years. Above all, I would like to thank my highly qualified staff of Leslee Noyes (Administrative Specialist) and Jenna Zukswert (Research and Communications Coordinator) for their ideas, dedication, hard work, and persistence in delivering the CFRU mission to our members this year. I'm looking forward to 2019 and will be continuing with efforts to increase the value we deliver to our membership now and into the future.

Sincerely,

Brian E. Roth, PhD
CFRU Program Leader

1975 2004 2018

Membership

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

WOOD PROCESSORS:
Sappi North America

CORPORATE / INDIVIDUAL MEMBERS:
Huber Engineered Woods, LLC
Forest Society of Maine
LandVest
David B. Field
Acadia Forestry, LLC

ADVISORY COMMITTEE:

Chair:
Gordon Gamble: *Wagner Forest Management*

Vice Chair:
Ian Prior: *Seven Islands Land Company*

Financial Officer:
Greg Adams: *Irving Woodlands, LLC*

Member-at-Large:
Kenny Fergusson: *Huber Resources Corp. [Fallen Timber, LLC; Sylvan Timberlands, LLC; North Woods ME Timberlands, LLC; St. John Timber, LLC; Solifor Timberland, Inc.]*

Members:
Kyle Burdick: *Baskahegan Company*
Tom Charles: *Maine Bureau of Parks and Lands*
Frank Cuff: *Weyerhaeuser Company*
David Dow: *Prentiss and Carlisle Company, Inc.*
Elizabeth Farrell: *BBC Land, LLC*
Alec Giffen: *New England Forestry Foundation*
Scott Joachim: *Katahdin Forest Management, LLC*
Eugene Mahar: *LandVest* [*Frontier Forest, LLC; Clayton Lake Woodlands Holding, LLC; EMC Holdings, LLC, Mosquito, LLC, The Tall Timber Trust]*
Brittany Mauricette: *Downeast Lakes Land Trust*
Jacob Metzler: *Forest Society of Maine*
Dan Pelletier: *Huber Engineered Woods, LLC*
Jim Robbins, Jr.: *Robbins Lumber Company*
Matthew Sampson: *The Forestland Group, LLC*
Nancy Sferra: *The Nature Conservancy*
Eben Sypitkowski: *Baxter State Park*
Steve Tatko: *Appalachian Mountain Club*
Nathaniel Vir: *Sappi North America*

Research Team

Staff

- **Brian Roth** (PhD), CFRU Program Leader
- **Leslee Canty-Noyes** (MIS), Administrative Specialist
- **Jenna Zukswert** (MSc), Research & Communications Coordinator
- **Aaron Weiskittel** (PhD), Center for Research on Sustainable Forests (CRSF) Director
- **Meg Fergusson**, CRSF Outreach and Communication Specialist

Brian Roth and Aaron Weiskittel attend a workshop in Baltimore, MD. Photo: CRSF.

Project Scientists

- **Karin Bothwell** (MS), School of Forest Resources, University of Maine
- **Russell Briggs** (PhD), State University of New York – Environmental Science and Forestry
- **John Campbell** (PhD), Northern Research Station, U.S. Forest Service
- **Mindy Crandall** (PhD), School of Forest Resources, University of Maine
- **Ivan Fernandez** (PhD), School of Forest Resources, University of Maine
- **Shawn Fraver** (PhD), School of Forest Resources, University of Maine
- **Hamish Greig** (PhD), School of Biology and Ecology, University of Maine
- **Anthony Guay** (MS), The Wheatland Lab, University of Maine
- **Daniel Harrison** (PhD), Department of Wildlife, Fisheries, and Conservation Biology, University of Maine
- **Daniel Hayes** (PhD), School of Forest Resources, University of Maine
- **Chris Hennigar** (PhD), University of New Brunswick
- **Keith Kanoti** (MS), University Forests Office, University of Maine
- **Laura Kenefic** (PhD), Northern Research Station, U.S. Forest Service
- **Anil Raj Kizha.** (PhD), School of Forest Resources, University of Maine
- **Christian Kuehne** (PhD), School of Forest Resources, University of Maine
- **Kasey Legaard** (PhD), School of Forest Resources, University of Maine
- **Adrienne Leppold** (PhD), Maine Department of Inland Fisheries and Wildlife
- **John Lloyd** (PhD), Vermont Center for Ecostudies
- **Joshua Puhlick** (PhD), School of Forest Resources, University of Maine
- **Parinaz Rahimzadeh** (PhD), School of Forest Resources, University of Maine
- **Amber Roth** (PhD), School of Forest Resources and Department of Wildlife, Fisheries, and Conservation Biology, University of Maine
- **Erin Simons-Legaard** (PhD), School of Forest Resources, University of Maine
- **C. T. (Tat) Smith** (PhD), Department of Geography & Planning, University of Toronto
- **Inge Stupak** (PhD), Department of Geosciences and Natural Resource Management, University of Copenhagen
- **Dan Walters** (MS), U.S. Geological Survey
- **Jay Wason** (PhD), School of Forest Resources, University of Maine
- **Joseph Young**, Maine Office of GIS

Graduate Students

- **Jeanette Allogio** (MS student advised by Dr. Fraver) Northern white-cedar regeneration
- **James Alt** (MF student, UMaine): Northern white-cedar silviculture
- **Bruna Barusco** (MSc student advised by Dr. Stupak): Whole-tree harvesting at Weymouth Point
- **John (Jack) Chappen** (MF student, UMaine): Northern white-cedar silviculture
- **Bryn Evans** (PhD student advised by Dr. Mortelliti): Carnivore detection
- **Kirstin Fagan** (PhD student advised by Dr. Harrison): Marten population dynamics
- **Agnė Grigaitė** (MSc student advised by Dr. Stupak): Whole-tree harvesting at Weymouth Point
- **Christopher Preece** (MFC student advised by Dr. Smith): Whole-tree harvesting at Weymouth Point
- **Adriana Rezai-Stevens** (MFC student advised by Dr. Smith): Whole-tree harvesting at Weymouth Point
- **Harikrishnan Soman** (MS student advised by Dr. Kizha.): Effects of harvesting on soil compaction
- **Kaitlyn Wilson** (MS student advised by Dr. Amber Roth): Bicknell's thrush habitat
- **Tyler Woollard** (MS student advised by Dr. Harrison): Marten population dynamics

Undergraduate Students

- **Griffin Archambault** (BS student, UMaine, CUGR): Carnivore detection, Marten population dynamics
- **Jamie Behan** (BS student, UMaine): Northern white-cedar silviculture
- **Robert Brightingham** (BS student, UMaine): Carnivore detection
- **Michael Buyaskas** (BS student, UMaine, CUGR): Carnivore detection, Marten population dynamics
- **Cassandra Carroll** (BS student, UMaine): Deer wintering area
- **Noah Coogan** (BS student, UMaine): L2 survey
- **Rose Crispin** (BS student, UMaine): Carnivore detection (volunteer)
- **Aaron Davenport** (BS student, UMaine): Bicknell's thrush habitat
- **Aashish Dhungana** (BS student, UMaine): Northern white-cedar silviculture
- **Casey Dumont** (BS student, UMaine): Whole-tree harvesting at Weymouth Point
- **Jack Ferrara** (BS student, UMaine): Hardwood growth and yield
- **David Holmberg** (BS student, UMaine): Northern white-cedar silviculture
- **Corey Kotfila** (BS student, UMaine): Northern white-cedar silviculture
- **Robert (Bobby) Lemieux** (BS student, UMaine): Northern white-cedar silviculture
- **Noel Lienert** (BS student, UMaine): Effects of harvesting on soil compaction
- **Aaron Malone** (BS student, UMaine): Northern white-cedar silviculture
- **Evan Nahor** (BS student, UMaine): Effects of harvesting on soil compaction
- **Emma Payne** (BS student, Cornell University): Hardwood growth and yield
- **Natalia Perez** (BS student, UMaine): Marten population dynamics
- **Stephanie Ross** (BS student, UMaine): Carnivore detection
- **Michael Shaw** (BS student, UMaine): Carnivore detection (volunteer)
- **Joe'l Yurkanin** (BS student, UMaine): Carnivore detection


Left: Bryn Evans (L) and visiting scholar Sara Tironi (R) pose by a trail camera. Photo: B. Evans. Right: Aashish Dhungana and Andrew Richley in the field. Photo: J. Wason.



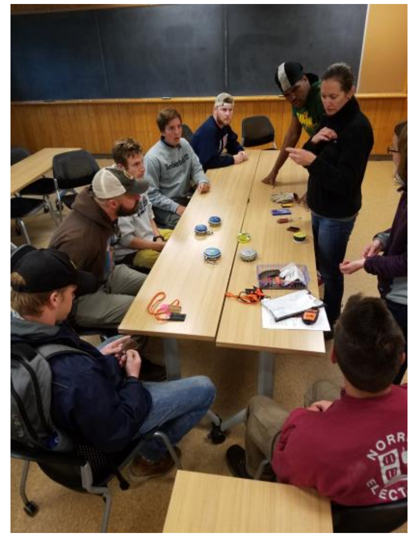
Left: Soren Donisvitch (L) and Shane Miller (R) collect data at the Commercial Thinning Research Network site at Harlow Road. Center: David Höglund uses a Hitman ST-300 to measure acoustic velocity of a standing tree. Right: Kathrin Bauer obtains a tree core. Photos: J. Zukswert.



Left: Tat Smith (R) shows Inge Stupak (center) and Agnė Grigaitė (L) an example of B horizon soil at Weymouth Point. Photo: J. Zukswert. Center: Harikrishnan Soman, Anil Kizha., Kevaughan Smith, and Neil Thompson at the MASN site on Irving Woodlands, LLC property. Photo: B. Roth. Right: Tyler Woollard holds an American marten. Photo: G. Archambault.

CFRU Summer Field Crew

- **Kathrin Bauer** (BS student, Rottenburg University of Applied Forest Sciences, Germany): International exchange internship with a focus on wildlife management
- **Jacob Burgess** (BS student, University of Maine): Maine's Adaptive Silviculture Network
- **Soren Donisvitch** (BS student, University of Maine): Commercial Thinning Research Network
- **David Höglund** (BS student, Swedish University of Agricultural Sciences, Umeå, Sweden): Commercial Thinning Research Network
- **Ethan Jacobs** (BS student, University of Maine): Maine's Adaptive Silviculture Network
- **Shane Miller** (BS student, UMaine): Commercial Thinning Research Network
- **Kevaughan Smith** (BS student, University of Maine Fort Kent): Maine's Adaptive Silviculture Network
- **Jacob Watson** (BS student, University of Maine): Maine's Adaptive Silviculture Network



Kate Locke trains the CFRU field crew. Photo: B. Roth.

Technical Assistance

- **Kyle Arvisais** (MF): Northern white-cedar silviculture
- **Alex Barnes**: Bicknell's thrush habitat
- **Heather Brinson**: Whole-tree harvesting at Weymouth Point
- **Matthew Dickinson**: Maine's Adaptive Silviculture Network
- **Kathryn (Kate) Gerndt** (MS): Northern white-cedar silviculture
- **Richard (Rich) Hoppe**: Deer wintering area
- **Katharine (Kate) Locke** (MF): Maine's Adaptive Silviculture Network
- **Emma Nelson**: Silvicultural Intensity and Species Composition (SIComp) study
- **Robert Nelson**: Silvicultural Intensity and Species Composition (SIComp) study
- **Logan Parker**: Maine's Adaptive Silviculture Network
- **Andrew Richley** (MF): Northern white-cedar silviculture
- **William (Bill) Thomas**: Whole-tree harvesting at Weymouth Point, Maine's Adaptive Silviculture Network

Shawn Fraver teaches Bill Thomas how to collect tree cores in preparation for field work at Weymouth Point. Photo: J. Zukswert.

CFRU Summer Field Crew 2018.
From left to right: Jacob Burgess, Jenna Zukswert, Kate Locke, David Höglund, Soren Donisvitch, Jacob Watson, Ethan Jacobs, Kevaughan Smith, Brian Roth, Shane Miller.

Financial Report

Brian Roth
CFRU Program Leader

Thirty-two members representing 8.19 million acres of Maine's forestland contributed $463,714 to support the CFRU this year (Table 1). These member contributions will be used to support research activities during Fiscal Year 2018–19. The amount of acreage owned by our Landowner/Manager members increased by 107,448 acres (1.3%) which was largely due to **Solifor Timberlands, Inc.** joining the CFRU. This property was formerly known as **Ste-Aurelie Timberlands**. We welcome Solifor, which is managed by Huber Resources, to the CFRU. Other notable changes included the inclusion of **The Tall Timber Trust** to **Clayton Lake Woodlands Holding, LLC** under the same ownership and managed by LandVest, and the transfer of **Snowshoe Timberlands, LLC** to **Fallen Timber, LLC**. Tons of wood products produced by wood processor members has remained stable and **Sappi North America** continues to be a strong partner. **ReEnergy Holdings, LLC** continues to struggle financially and has dropped its membership from the CFRU. **James W. Sewall Company** has been acquired by a private investment firm, **Treadwell Franklin Infrastructure Capital, LLC**, who has decided not to continue membership in the CFRU.

Overall, CFRU member contributions are slightly down from last year (a $3,639 or 0.8% decrease) relative to FY 2016–17. While some of this decrease was due to the changes described above, as of the time of writing this report, the **Maine Bureau of Parks and Lands (MBPL)** contribution has not been received nor is included in this report, despite a signature by the Governor releasing the funds. This holdup is due to difficulties in transferring the funds between the State and the University of Maine (UMaine) accounts receivable. We hope to have these two years of contributions in hand by early 2019. The State of Maine and MBPL has continued to be very supportive to the CFRU and we appreciate their continued engagement. 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 Project Scientists were successful at leveraging an additional $191,060 in extramural grants to support CFRU research projects. This amount does not include around $1 million dollars in leveraged funding for the final phase of the LiDAR acquisition from Federal and local sources and $37,190 out of $60,000 from the **National Science Foundation** as part of CFRU's membership in the national Center for Advanced Forestry Systems (CAFS). CAFS is supporting CFRU research on understanding and modeling competition effects on tree growth and stand development across varying forest types, which is led by Drs**. Joshua J. Puhlick** and **Christian Kuehne**. These external grants made up 22% of CFRU total income this year (Figure 1). In addition to extramural sources, UMaine provided $126,681 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 $100,271. Therefore, UMaine provided an additional $226,952 or 26% of total funding. In total, about 47% ($418,012) 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, LLC, Wagner Forest Management, BBC Land, LLC, Weyerhaeuser Company,** and **Prentiss and Carlisle Company, Inc.**) this year, $6.57 was received from other CFRU member contributions, $3.53 was contributed by external grants through CFRU scientists, and $4.19 was received from UMaine in direct and indirect contributions, for a total leveraging of $14.30 for every $1 contributed by CFRU's largest members.

Continued sound fiscal management by CFRU scientists and staff resulted in spending $58,723 (10.8%) less than the $543,343 that was approved by the Advisory Committee for this fiscal year (Table 2). Some of the remaining funds had been allocated but not spent towards a salary increase for the Program Leader, which was delayed. There were considerable cost savings from the Weymouth Point project through soil chemistry work performed at **Dr. Russ Briggs's** laboratory at SUNY-ESF. **Dr. Hamish Greig** (funded for the 2018-19 fiscal year) requested an early expenditure of $6,378 to fund a graduate student for the summer. **Dr. Daniel Harrison** requested that his unspent remaining funds of $13,482, be carried forward to the next fiscal year, as did **Dr. Parinaz Rahimzadeh**, who requested $1,458 be carried forward on the site productivity mapping project. All other projects came in at or near budget.

CFRU research expenses by category this year included 39% on five Silviculture & Productivity projects, 22% on three Growth & Yield Modeling projects, and 39% on five Wildlife Habitat projects (Figure 2).

Foresters attending the CFRU Fall Field Tour in September 2018 on Irving Woodlands, LLC property in northern Maine. Photo: J. Zukswert.

Table 1. CFRU member contributions received FY 2017–18 (for allocation in 2018–19).

CFRU Member	FY17-18		FY18-19		Changes Acres/tons	Assessed Amount	Received as of 10/02/2018	% Receieved
FOREST LANDOWNERS / MANAGERS:								
Irving Woodlands, LLC	1,255,000	acres	1,255,000	acres	0	$68,804	$68,804	100.0%
Wagner Forest Management	1,026,885	acres	1,024,145	acres	-2,740	$57,077	$57,077	100.0%
BBC Land, LLC	971,298	acres	971,297	acres	-1	$54,320	$54,320	100.0%
Weyerhaeuser Company	841,009	acres	838,624	acres	-2,385	$47,249	$47,249	100.0%
Prentiss and Carlisle Company, Inc.	751,972	acres	760,660	acres	8,688	$43,093	$43,093	100.0%
Seven Islands Land Company	746,791	acres	746,791	acres	0	$42,354	$42,354	100.0%
Clayton Lake Woodlands Holding, LLC	489,056	acres	784,492	acres	295,436	$44,363	$44,363	100.0%
Maine Bureau of Parks and Lands	427,000	acres	431,000	acres	4,000	$25,170		0.0%
Katahdin Forest Management, LLC	299,000	acres	300,159	acres	1,159	$17,529	$17,529	100.0%
The Tall Timber Trust	295,436	acres		acres	-295,436	$0		
The Nature Conservancy	158,723	acres	158,723	acres	0	$9,269	$9,269	100.0%
Snowshoe Timberlands, LLC	137,720	acres		acres	-137,720	$0		
Fallen Timber, LLC			127,880	acres	127,880	$7,468	$7,468	100.0%
Baskahegan Company	118,118	acres	118,118	acres	0	$6,898	$6,898	100.0%
Sylvan Timberlands, LLC	101,416	acres	94,546	acres	-6,870	$5,521	$5,521	100.0%
Sandy Gray Forest, LLC	100,016	acres	100,015	acres	-1	$5,841	$5,841	100.0%
North Woods Maine, LLC	31,403	acres	27,236	acres	-4,167	$1,591	$1,591	100.0%
The Forestland Group, LLC	13,069	acres	13,069	acres	0	$763	$1,000	100.0%
Appalachian Mountain Club	69,534	acres	69,534	acres	0	$4,061	$4,061	100.0%
Frontier Forest, LLC	53,338	acres	53,338	acres	0	$3,115	$3,115	100.0%
Downeast Lakes Land Trust	55,678	acres	55,930	acres	252	$3,266	$3,266	100.0%
EMC Holdings, LLC	40,470	acres	40,470	acres	0	$2,363	$2,363	100.0%
Baxter State Park, SFMA	29,537	acres	29,537	acres	0	$1,725	$1,725	100.0%
Robbins Lumber Company	26,786	acres	26,786	acres	0	$1,564	$1,564	100.0%
Solifor Timberland Inc.			119,353	acres	119,353	$6,970	$6,970	100.0%
St. John Timber, LLC	24,617	acres	24,617	acres	0	$1,438	$1,438	100.0%
Mosquito, LLC	16,222	acres	16,222	acres	0	$947	$1,000	105.6%
New England Forestry Foundation	2,852	acres	2,852	acres	0	$167	$1,000	600.4%
TOTAL	8,082,946	acres	8,190,394	acres	107,448	$462,928	$438,879	94.8%
WOOD PROCESSORS:								
Sappi North America	1,850,400	tons	1,850,400	tons	0	$22,435	$22,435	100.0%
TOTAL	1,850,400	tons	1,850,400	tons	0	$22,435	$22,435	100.0%
CORPORATE and INDIVIDUAL MEMBERS:								
ReEnergy Holdings, LLC	1	static	1	static		$5,000		0.0%
James W. Sewall Company	1	static	1	static		$5,000		0.0%
Huber Engineered Woods, LLC	1	static	1	static		$1,000	$1,000	100.0%
Forest Society of Maine	1	static	1	static		$1,000	$1,000	100.0%
LandVest	1	static	1	static		$200	$200	100.0%
David B. Field	1	static	1	static		$100	$100	100.0%
Acadia Forestry, LLC	1	static	1	static		$100	$100	100.0%
TOTAL						$12,400	$2,400	19.4%
GRAND TOTAL (32 members):						$497,763	$463,714	93.2%

* The Tall Timber Trust now under Clayton Lake Woodlands Holding, LLC

Contribution Received
Contribution Pending
New Member
Member Withdrew

Table 2. CFRU expenses incurred during FY 2017–18.

PROJECT	Project Number	Principal Investigator	Approved Amount	Total Spent Year End	Balance Remaining	% Balance Remaining
Total Administration			$250,428.00	$224,015.74	$26,412.26	10.5%
Administration	5250201	B. Roth	$250,428.00	$224,015.74	$26,412.26	10.5%
Research Projects				0		
Silviculture and Productivity:			$115,964.00	$100,397.28	$15,566.72	13.4%
Long-term Impacts of Whole Tree Harvesting: Weymouth Point Study	5250247	Smith	$51,567.00	$38,408.58	$13,158.42	25.5%
Lowland Northern White Cedar	5250249	Kenefic	$8,184.00	$8,215.03	-$31.03	-0.4%
Maine's Adaptive SilvicultureNetwork (MASN)	5250246	B. Roth	$44,017.00	$41,639.74	$2,377.26	5.4%
Eval Timber Harvest Operations on Soils	5250248	Kizha	$2,646.00	$2,583.93	$62.07	2.3%
Spruce Budworm L2 Sampling		B. Roth	$9,550.00	$9,550.00	$0.00	0.0%
Growth & Yield Modeling			$58,245.22	$56,673.85	$1,571.37	2.7%
Maine Statewide Light Detection and Ranging (LiDAR) Data Acquisition Project *		B. Roth	$13,400.00	$13,400.00	$0.00	0.0%
Development Approches for Hardwood	5250251	Puhlick	$16,635.00	$16,521.62	$113.38	0.7%
***Dynamic Site Productivity Mapping	5250250	Rahimzadeh	$28,210.22	$26,752.23	$1,457.99	5.2%
Wildlife Habitat:			$120,706.58	$99,813.86	$15,172.73	12.6%
Bicknells Thrush	5250252	A. Roth	$33,556.00	$32,481.52	$1,074.48	3.2%
Large Scale Monitoring of Carnivores	5250253	Mortelliti	$6,632.00	$6,691.75	-$59.75	-0.9%
Landscape-level Evaluation of Deer Wintering Habitat in Northern Maine	5250244	Crandall	$40,040.00	$40,022.80	$17.20	0.0%
***Response of Marten Population 30 years Later	5250254	Harrison	$34,100.00	$20,617.79	$13,482.21	39.5%
**Quantifying the ecological and economic outcomes of alternative riparian management strategies	5250255	Greig	$6,378.58	$5,719.99	$658.59	10.3%
Total			**$545,343.80**	**$480,900.73**	**$58,723.08**	**10.8%**
Control Account		**Roth**	**$971,287.97**			
			Begin Balance			
Fleet Account	5250238	Roth	$8,334.30		$25,127.29	
CAFS 1 @ 10%	5209981 20 5406022	Weistkittel	$60,000.00		$0.00	$0.00
CAFS 2 @10%	5209981 20 5406022	Weistkittel	$240,000.00			$0.00

Note: * This completes the $50,000 that was allocated for completion of the Statewide LiDAR Acquisition.

** Funds advanced to support early start with Grad Student.

*** Remaining Funds to be carried forward to next FY

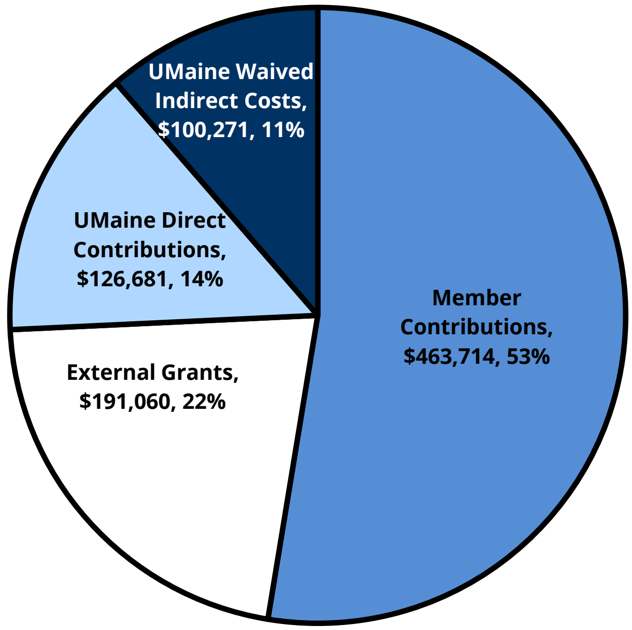


Figure 1. CFRU income sources FY 2017–18.

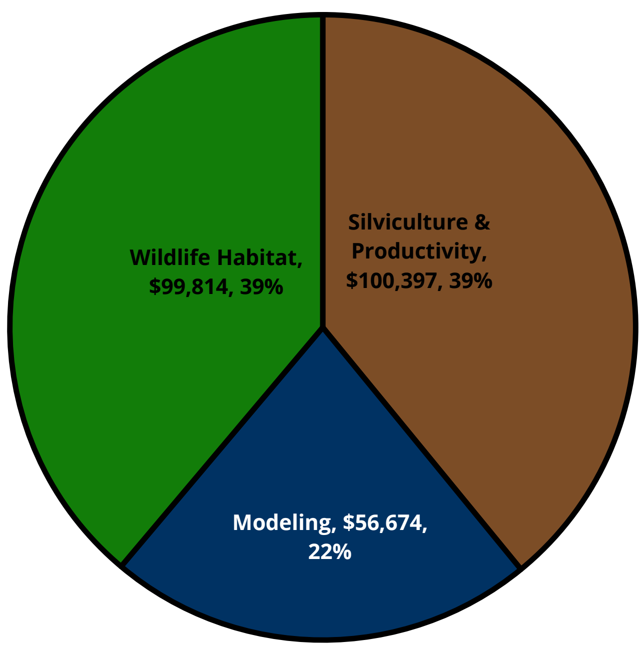


Figure 2. CFRU research expenses FY 2017–18.

Activities

Advisory Committee

The CFRU is guided by our member organizations through an Advisory Committee. The CFRU Advisory Committee elects officers for the Executive Committee for two-year terms in the positions of Chairperson, Vice Chairperson, Member-at-Large, and Financial Officer. The Vice Chairperson serves as Chairperson after one term, and the past Chairperson moves to the position of Financial Officer for one term. Due to the retirement of **Eric Dumond** (**ReEnergy Holdings, LLC**) and his resignation as Chairperson in the fall of 2016, the current executive is in the second year of a three-year term. **Gordon Gamble** (**Wagner Forest Management**) is Chairperson, the Vice Chairperson is **Ian Prior** (**Seven Islands Land Company**), **Greg Adams** (**Irving Woodlands, LLC**) is the Financial Officer and **Kenny Fergusson** (**Huber Resources**) is the Member-at-Large. The Advisory Committee will hold an election in the fall of 2019 to select the incoming Vice Chairperson and Member-at-Large.

The Advisory Committee holds business meetings three times a year. The first business meeting of FY 2017–18 was held on October 25, 2017 at the University of Maine Fort Kent, during which Dr. Brian Roth introduced new Research & Communications Coordinator **Jenna Zukswert** as well as the new Irving Woodlands, LLC Professor of Forestry at the University of Maine Fort Kent, **Dr. Neil Thompson**. The 2017 Fall Field Tour was intended to coincide with this meeting, but was canceled due to low registration, logistical difficulties, and adverse weather conditions expected. At the second Advisory Committee meeting, held on January 24, 2018 at the Wells Conference Center at the University of Maine, six pre-proposals for new research were presented to the Advisory Committee following an online pre-screening process, during which three additional pre-proposals were retracted by principal investigators following feedback and ranking by cooperators. Of these, all six were approved to advance to the full proposal stage and were presented at the April 11th Advisory Committee meeting. Visitors from the U.S. Forest Service **John Coulston**, **Maria Janowiak**, and **Christopher Woodall** gave presentations at this meeting as well. Five projects were approved for funding to begin on October 1, 2018. Look for updates on these projects in future CFRU presentations, publications, and annual reports.

Cooperators

CFRU membership decreased slightly in 2017–18, but this did not lead to a decrease in acres managed (Table 1). In fact, it lead to a slight increase, largely due to **Solifor Timberlands, Inc.** (managed by **Huber Resources**) joining the CFRU. Welcome to the CFRU, Solifor Timberlands! A few transfers occurred, during which **The Tall Timber Trust** became included in **Clayton Lake Woodlands Holding, LLC** (managed by **LandVest)** and **Snowshoe Timberlands, LLC** was transferred to **Fallen Timber, LLC** managed by **Huber Resources**). Both **ReEnergy Holdings, LLC** and **James W. Sewall Company** have decided not to continue their membership in the CFRU. As a result of these additions, transfers, and cancellations, the CFRU membership consisted of 32 cooperators at the end of the 2017–18 fiscal year.

Personnel

Following a recommendation to the University of Maine **Vice President for Research (VPR) Dr. Kody Varahramyan** and a review of the CRSF by the VPR's office, **Dr. Brian Roth**'s position as **CFRU Program Leader**, as well as **Dr. Aaron Weiskittel**'s position as **Director** of the **Center for Research on Sustainable Forests (CRSF)** became permanent. In December, **Jenna Zukswert** was hired as the CFRU **Research & Communications Coordinator**, in response to cooperators' request to have the CFRU increase outreach efforts and more frequently communicate research findings. Jenna focuses on communications geared toward CFRU members, while **Meg Fergusson**, whose role has become **Outreach and Communication Specialist** for the CRSF, focuses on communication about CRSF and CFRU initiatives to the public. **Cindy Smith** stepped down as **Administrative Specialist** in November, and in January, the CFRU hired **Leslee Canty-Noyes** to fill this role. Leslee's position is shared with the CRSF, as she takes care of accounts for both the CRSF and CFRU. We will miss Cindy and appreciate all that she has done for the CFRU, but welcome Jenna and Leslee to the team!

Students

The CFRU continues to contribute to the development of students, with eight graduate students directly working on CFRU-funded projects for their theses and dissertations. Four of these students have projects related to wildlife management; these include **Kaitlyn Wilson** (MS, advised by **Dr. Amber Roth**) investigating Bicknell's thrush habitat, **Bryn Evans** (PhD, advised by **Dr. Alessio Mortelliti**) evaluating methods for monitoring large carnivores using trail cameras, and **Kirstin Fagan** (PhD) and **Tyler Woollard** (MS), advised **Dr. Daniel Harrison** and investigating responses of American marten populations to land use change. **Harikrishnan Soman** (MS), advised by **Dr. Anil Raj Kizha.**, is quantifying the effects of timber harvesting on soil on sites in the Maine's Adaptive Silviculture Network. And through the University of Toronto's Masters in Forest Conservation (MFC) program, **Adriana Rezai-Stevens** (advised by **Dr. Tat Smith**), is evaluating the belowground effects of whole-tree harvesting at Weymouth Point, thirty years following harvesting. From the University of Copenhagen, students **Bruna Barusco** (MSc) and **Agnė Grigaitė** (MSc), advised by **Dr. Inge Stupak**, will also be working on the Weymouth Point project, teaming up to work on the carbon modeling aspect. They started this work in August 2018 with a trip to visit Weymouth Point.

In December 2017, **Christopher Preece** defended his MFC thesis at the University of Toronto. Advised by **Dr. Tat Smith**, he investigated aboveground effects of whole-tree harvesting at Weymouth Point. We wish Chris the best in his future endeavors!

This summer, the CFRU had eight undergraduates on our summer field crew. While most students were from the **University of Maine**, with one from the **University of Maine Fort Kent**, we did have one student from **Umeå, Sweden** and another student from **Baden-Württemberg, Germany**. Half of these students collected baseline data for the new Maine's Adaptive Silviculture Network, while the others collected inventory measurements at all 15 Commercial Thinning Research Network sites.

Many other students were involved in CFRU research this year, as **Center for Undergraduate Research (CUGR)** Honors students, field technicians, or volunteers. Please refer to our Research Team pages for their names and affiliated projects.

2018 Communications Initiatives

With the hiring of a full-time Research & Communications Coordinator came a wave of new communications initiatives. **Jenna Zukswert** started by updating the CFRU's informative poster and brochure, and then produced a poster and research bulletin both summarizing findings from the Commercial Thinning Research Network. She has since produced and distributed research updates on spruce grouse (prefacing a redistributed research note written by **Stephen Dunham**), spruce budworm monitoring research, and evaluating deer wintering habitat using remote sensing. We intend to produce and distribute five to six research updates per year.

We have also started a new webinar series, which is open to the public. The first webinar was held in February 2018, with presentations by **Allison Kanoti** of the **Maine Forest Service** and **Rob Johns** of the **Canadian Forest Service** speaking on the topic of spruce budworm and early intervention strategies in New Brunswick. In April, **Dr. Lisa Venier** of the **Canadian Forest Service** and **Dr. Adrienne Leppold** of the **Maine Department of Inland Fisheries and Wildlife** presented on ways in which forest birds are monitored in Maine, including more information about the Maine Bird Atlas project. We intend to host three to four webinars per year.

We also offered on-site workshops and presentations, visiting with **Sappi North America** foresters with the **Wheatland Lab** and with **Wagner Forest Management** foresters in May. Please feel free to reach out if you would like us to coordinate a visit with your organization.

Long-Term Site Productivity Research Workshop

In June, the CFRU hosted a group of international scientists at the University of Maine for a two-day event, open to the public, entitled, "Long-Term Site Productivity Research: Lessons from Other Regions and Opportunities for Maine." On Thursday, June 7th, the event kicked off with an indoor technical workshop during which scientists from around the world presented on long-term site productivity research from their region. Presenting scientists include **Dr. C. T. (Tat) Smith** (University of Toronto), **Dr. Inge Stupak** (University of Copenhagen), **Dr. Cindy Prescott** (University of British Columbia), **Dr. Eric Sucre** (Weyerhaeuser Company, Springfield, Oregon), **Dr. David Morris** (Ontario Ministry of Natural Resources), **Dr. Daniel Kneeshaw** (Université du Québec à Montréal), **Dr. Paul Arp** (University of New Brunswick), **Dr. Brian Roth** (Cooperative Forestry Research Unit), and **Dr. Joshua Puhlick** (University of Maine). Fifty people attended this event.

The second day of this event, on Friday, June 8th, consisted of a field tour at the Maine's Adaptive Silviculture Network (MASN) site in Grand Falls Township, managed by American Forest Management. Presenters included **Dr. Paul Arp**, **Tom Gilbert** (Maine Forest Service), **Anthony Guay** (The Wheatland Lab, University of Maine), **Dr. Anil Raj Kizha.** (University of Maine), **Dr. Joshua Puhlick**, and **Dr. Brian Roth**. Nearly 50 people attended this tour.

Joshua Puhlick teaches tour participants about soil. Photo: J. Zukswert.

Fall Field Tour 2018: Outcome Based Forestry and Long-Term Research

This year, we decoupled the Fall Field Tour from our CFRU Fall Advisory Committee meeting and hosted the 2018 Fall Field Tour on September 14th, 2018. Upon meeting in Ashland, Maine, over 60 attendees explored sites owned and managed by **Irving Woodlands, LLC** in northern Maine. At the first tour site, we listened to an overview of Outcome Based Forestry (OBF) by members of the OBF panel (including **Doug Denico**, **Donald Mansius**, and **David Struble** of the **Maine Forest Service**, and **Dr. Maxwell McCormack** and **Mike Dann**, retired) before hearing more about OBF from participating landowners (**Ked Coffin** representing **Irving Woodlands, LLC**, and **Jason Desjardin** representing **Seven Islands Land Company**). **Dr. Neil Thompson** then presented on his harvest aesthetics research, which he is doing in support of OBF.

The second field tour site was in T16 R8 on the Maine's Adaptive Silviculture Network (MASN) site on **Irving Woodlands, LLC** land. After an introduction to MASN by **Dr. Brian Roth**, **Dr. Anil Raj Kizha.** spoke about his harvest productivity and residual stand damage research, and **Gaetan Pelletier** of the **Northern Hardwoods Research Institute** and **Dr. Maxwell McCormack** spoke on beech management and opportunities in this stand type.

CFRU field tour participants on property of Irving Woodlands, LLC in northern Maine in September. Photo: B. Roth

Center for Advanced Forestry Systems (CAFS)

Aaron Weiskittel

This year saw the completion of the fourth year of Phase II for the University of Maine (UMaine) site under the Center for Advanced Forestry Systems (CAFS). CAFS is funded by the National Science Foundation (NSF) Industry/University Cooperative Research Centers Program (I/UCRC) in partnership with CFRU members. CAFS is a partnership between CFRU members and I/UCRC to support a University of Maine research site for CAFS. CAFS unites ten university forest research programs with forest industry members across the United States to collaborate on solving complex, industry-wide problems at multiple scales. 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.

During the 5-year span of Phase II, the NSF contributes $60,000 per year to the center as long as CFRU members contribute a minimum of $250,000 per year to support the work of the site. This past year of CAFS funding supported two projects led by UMaine (Understanding and Modeling Competition Effects on Tree Growth and Stand Development Across Varying Forest Types and Management Intensities; The Rise of Commercially Less Desirable Species in Maine: Identification, Characterization, and Associated Driving Factors). Two new UMaine projects were recently approved: (1) Modeling the influence of spruce budworm on forest productivity (Cen Chen) and (2) Development of small tree growth and survival equations for the commercially important species in the Acadian Region (Joshua Puhlick). Both are one-year projects to be completed in 2019.

In addition, the CRSF/CFRU organized the annual Industry Advisory Board meeting held in Burlington, Vermont in June. Thirty participants used the day to review and discuss ongoing research, assess new proposals, and consider the future of CAFS after Phase II ends. The meeting was followed by a full-day field trip around Vermont's Northeast Kingdom to visit operations on Weyerhaeuser and state-managed lands, and a tour of the Maple Guild's sugaring operations and syrup facility. The next CAFS meeting will be held in Georgia.

In 2018, UMaine became the CAFS lead site, and Dr. Weiskittel took on the role of Center Director. He will preside over proposal submission efforts for CAFS Phase III in the middle of December. CAFS Phase III would provide another five-years of support from NSF at $50,000 per year. To address NSF concerns from Phase II, bylaws, strategic plan, and technology roadmap have been drafted for CAFS. These documents and others are available online via the CRSF website: https://crsf.umaine.edu/research-2/center-for-advanced-forestry-systems/.

CAFS field tour participants on the field tour in Vermont in June. Photo: M. Fergusson

NC STATE UNIVERSITY

Oregon State UNIVERSITY OSU

PURDUE UNIVERSITY

UF UNIVERSITY of FLORIDA

The University of Georgia

University of Idaho

1865 THE UNIVERSITY OF MAINE

W UNIVERSITY of WASHINGTON

VirginiaTech

Research Project Reports

Weymouth Point Study Area unharvested stand.
Photo: A. Rezai-Stevens.

Silviculture & Productivity

- **Silviculture and Operations in Northern White-Cedar Lowlands: A Pilot Study**
- **Evaluating the Costs and Impacts of Timber Harvesting Operations on Soil Compaction**
- **Maine’s Adaptive Silviculture Network**
- **Long-Term Effects of Whole-Tree Harvesting: The Weymouth Point Study**

MASN site in Grand Falls Township.
Photo: J. Puhlick.

Silviculture and Operations in Northern White-Cedar Lowlands: A Pilot Study

Laura Kenefic[1], Anil Raj Kizha.[2], Shawn Fraver[2], Hamish Greig[2], Amber Roth[2], Jay Wason[2], Keith Kanoti[2]

[1]U.S. Forest Service
[2]University of Maine

Jay Wason holds northern white-cedar layers at the Penobscot Experimental Forest. Photo: L. Kenefic.

Status: Progress Report (Year 1)

Summary:

Northern white-cedar is found in mixed stands and white-cedar-dominated lowlands. Though research over the last decade has addressed management of white-cedar in mixtures, there are still questions about management of lowlands. Such stands are important for commodity production and ecological values. This collaborative and interdisciplinary project is generating new findings related to silviculture, production, and ecology in a regionally important forest type, facilitating effective and active management by CFRU member organizations and others.

Project Objectives:

- Assess change in structure, composition, and stocking resulting from silvicultural treatment in lowland white-cedar.

- Quantify logging damage to residual trees and site impacts (e.g., rutting, compaction, hydrologic changes) from harvest operations.

- Make preliminary recommendations for management of white-cedar lowlands, expanding the scope of the existing Silvicultural Guide (Boulfroy *et al.* 2012).

Approach:

- Conduct operational-scale experiment in which stand structure, composition, quality, and site characteristics are measured pre- and post-harvest in white-cedar-dominated lowlands (≥ 60% of basal area) at four sites, each consisting of a treated stand and a reference (control).

- Establish a network of permanent sample plots and transects to quantify stand composition and structure, tree quality, regeneration density and stocking, dead wood, and microtopography pre- and post-harvest.

- Measure edaphic and hydrologic features such as compaction and depth to water table.

- Apply irregular shelterwood treatment as follows:
    - Establish and release white-cedar regeneration through the creation of small (one to two tree-height) canopy gaps.
    - Favor the growth of the best residual pole- and small-sawtimber white-cedar through crop tree release between gaps (40% removal).
    - Conduct mechanical (brushsaw) post-harvest control of regeneration in a subset of gaps.

- Collect harvest productivity and cost data and quantify damage to residual trees to assess operational impacts and feasibility of partial harvests on low-productivity sites.

Unharvested white-cedar-dominated lowlands can have high basal area (e.g., 250 to 300 ft^2/acre).
Photo: L. Kenefic.

Key Findings/Accomplishments:

- In FY18, pre-harvest measurements were completed on one site (Penobscot Experimental Forest), and harvesting is scheduled for winter 2018–19 using a cut-to-length system. Additional study sites have been identified on cooperator lands (Baskahegan Company and Wagner Forest Management) and were visited to determine suitability for the study in fall 2018. These sites will be inventoried in summer 2019 for harvesting in winter 2019–20 using cut-to-length and whole-tree systems, respectively.

- Findings from the first site indicate that:
  - Volumes of dead wood are high in unharvested white-cedar-dominated lowlands, likely due to slow rates of decay.
  - High water table in white-cedar-dominated lowlands limits tree establishment and growth to elevated microsites such as those from stumps and buried wood (Figure 3).
  - Both seedlings (sexual reproduction from seed) and layers (asexual reproduction from branches that root to the ground) are common on white-cedar-dominated lowlands.
  - Layers can originate from tree branches resting on the ground as well as established seedlings and saplings apparently pressed down by snow and ice loads.
  - Saplings of other species (e.g., balsam fir, alder) often compete with white-cedar in the understory.

- In light of our finding that both layers and seedlings are common in lowland white-cedar stands, we have undertaken an additional study of mode of regeneration. Specifically, co-PI Wason is supervising an undergraduate intern in the Experiential Learning for Multicultural Students program in the development of a key to distinguish layers and seedlings by microscopic cell structure. Seedlings were excavated across belt transects at the first study site for this work.

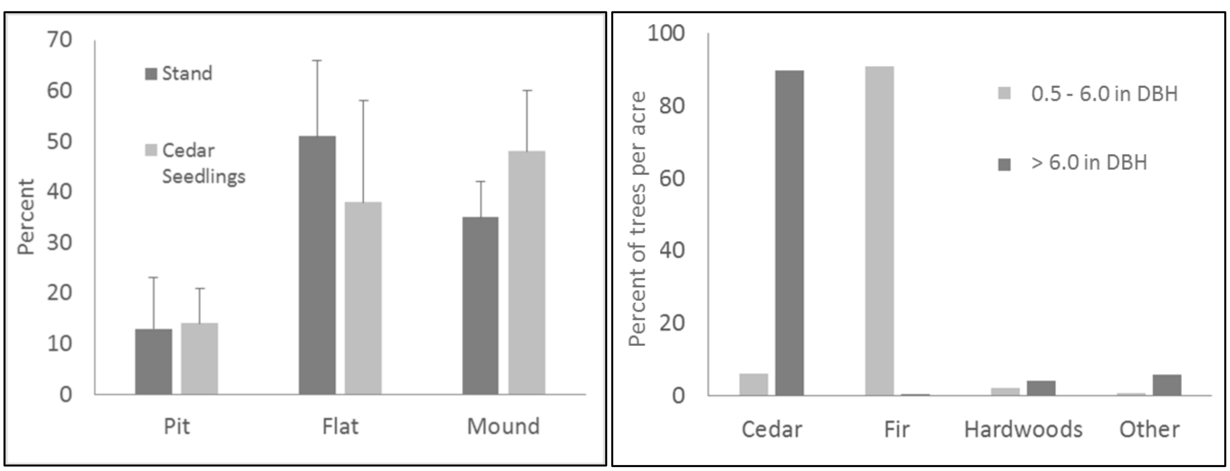


Figure 3. Comparison of percent of cedar seedlings (light gray) in pits, flat areas, and mounds, with the percent of stand area represented by those conditions (left); composition of the Penobscot Experimental Forest study site, expressed as percent of trees per acre (right).

Future Plans:

- Harvest Penobscot Experimental Forest study site: winter 2018–19.
- Post-treatment sampling of harvested stand: summer 2019.
- Pre-treatment sampling of replicate white-cedar stands: summer 2019.
- Harvest replicate stands: winter 2019–20.
- Post-treatment sampling of replicate stands: summer 2020.

References:

Boulfroy, E., E. Forget, P. V. Hofmeyer, L. S. Kenefic, C. Larouche, G. Lessard, J-M. Lussier, F. Pinto, J-C. Ruel, and A. Weiskittel. 2012. Silvicultural guide for northern white-cedar (eastern white cedar). Gen. Tech. Rep. NRS-98. Newtown Square, PA: Dept. of Agric., Forest Service, Northern Research Station. 74 p.

Acknowledgements:

We thank staff of the University of Maine Forests Office, Wagner Forest Management, and Baskahegan Company for their assistance. We also thank the Cooperative Forestry Research Unit; U.S. Forest Service, Northern Research Station; Penobscot Experimental Forest, Research Operating Team; University of Maine, School of Forest Resources; and Maibec for funding.

Kate Gerndt, Andrew Richley, Laura Kenefic, and Jeanette Allogio in the field.
Photo: A. Richley.

Evaluating the Costs and Impacts of Timber Harvesting Operations on Soil Compaction

Anil Raj Kizha.[1], Harikrishnan Soman[1], Brian Roth[2]

[1]University of Maine
[2]Cooperative Forestry Research Unit

Anil Kizha. discusses the project on site with CFRU field crew members. Photo: J. Zukswert.

Status: Progress Report (Year 1)

Summary:

Rising costs of forest operations and decreasing revenue generated from harvesting are becoming critical challenges in forest management throughout the northeastern United States. Along with this, the low markets for comminuted forest residues and stricter policies on environmental protection have prompted utilization of these materials as slash mats on skid trails for minimizing soil disturbances. The aim of this study was to evaluate the cost of different silvicultural treatments and utilization of forest residues generated from a mechanized timber harvesting operation for implementing Best Management Practices (BMPs). The field-based experiment was done in central Maine at one of the CFRU Maine's Adaptive Silvilculture Network (MASN) sites, where four forest stands were managed at varying intensities following silvicultural prescriptions common to the region (partial harvest (PH) and clearcut (CC) treatments). Variables measured included delay-free cycle times of various timber harvesting machines, predictor variables, and stand features. The total cost of PH was higher than that of CC (\$22.94 m^{-3} versus \$14.88 m^{-3}). Of the various operational phases, the costs associated with skidding was the highest and ranged from 52 to 70% of the total cost for PH and CC, respectively. The cost of BMP implementation was estimated to be between \$10 and 52 PMH^{-3}, or \$1.0 and \$3.7 m^{-3}, and was influenced by several factors, including machine maneuverability and the extent of area which demanded BMP implementation. This information on the cost and productivity for timber harvesting operations, along with BMP implementation, will support the development of economic and environmentally sustainable harvesting strategies.

Project Objectives:

- Estimate hourly production rate for each operational phase (an operational phase corresponds to any activity that alters the form or location of the wood), and the operation as a whole for contrasting silvicultural prescriptions.

- Calculate the costs associated with implementing BMPs.

- Determine major factors affecting overall cost and productivity of the harvesting operation.

Approach:

- Conduct a detailed time-motion study.
- Scale logs harvested in the study.
- Perform machine rate calculations.
- Perform BMP implementation cost calculations.

Key Findings/Accomplishments:

- Clearcut operations were found to be economically more feasible than partial harvest operations (Table 3).
- For both clearcut and partial harvests, primary transportation was the costliest component.
- Cost of BMP implementation was found to range between \$1.0 and \$3.7 m^{-3} (Table 4).
- Efficiently laid skid trails can reduce BMP implementation costs to a great extent even if the site is poorly drained.

Table 3. Cost (\$ m^{-3}) and productivity (m^3 PMH^{-1}) of the different phases of the operation for wood handled in the partial harvest (PH) and clearcut (CC) treatments.

Operational Phase	**Cost**						**Productivity**	
	PH I	PH II	Combined PH	CC I	CC II	Combined CC	Combined PH	Combined CC
Felling	1.76	2.65	1.74	1.53	0.74	1.38	101.88	128.72
Skidding[a]	39.76	25.38	15.98	29.58	10.24	7.72	19.07	39.55
Processing	5.96	2.97	3.63	3.69	4.46	3.71	67.41	39.63
Sorting	0.60	0.49	0.63	0.74	0.74	1.11	258.71	146.33
Loading[b]	0.96	0.96	0.96	0.96	0.96	0.96	168.93	168.93
Total	49.04	32.45	22.94	36.50	17.14	14.88		

[a]Cost of skidding includes values for both the skidders used.

[b]Loading cost was the same for both treatments as the piles were combined during sorting to facilitate loading of similar market products.

Table 4. Average time taken to implement Best Management Practices (BMPs) in different silvicultural treatments.

Treatment[a]	BMP Time[b]	Average DFC (mins /turn)	BMP as % of average DFC	BMP Implementation Cost	
				($/PMH)[c]	($ m^{-3}) [d]
PH I	3.8	11.8	32	49.8	3.7
PH II	2.4	7.2	34	51.6	2.0
CC I	1.2	5.1	23	35.7	1.2
CC II	1.1	16.4	7	10.0	1.0

[a]PH is partial harvest and CC is clearcut.

[b]Time (in minutes) for implementing BMP was determined by summing picking up slash time, and handling slash from the skidders' Delay Free Cycle (DFC) time.

[c]Implementation cost calculated as a percentage of the skidders' productive machine hour (PMH) devoted for BMP implementation. The operational cost per PMH was calculated to be $153.87.

[d]BMP Implementation cost calculated in $ m^{-3} based on machine rate calculation

Future Plans:

- Analyze soil compaction and rutting caused during harvesting.

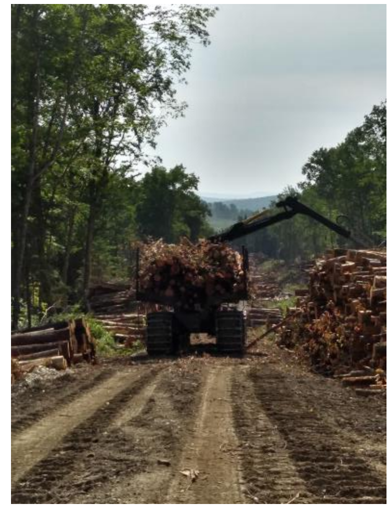
Acknowledgements:

We would like to express our gratitude to Casey Dumont, Ethan Olson, Ethan Jacobs, William Thomas, Marshal Bertrand, and Noah Coogan for assisting in data collection and analysis. Our appreciation goes to Jenna Zukswert (CFRU), Allen Lebrun (American Forest Management), Steve Madden (Madden Timberlands, Inc.) and Randell Madden (Randall Madden Trucking, Inc.) for their cooperation in the operational aspect of the study. We would also like to thank Dr. Ivan J. Fernandez (University of Maine, Orono) for his valuable comments and suggestions.

Maine's Adaptive Silviculture Network (MASN)

Brian Roth[1], Aaron Weiskittel[2], Anil Raj Kizha.[2], Amber Roth[2]

[1]Cooperative Forestry Research Unit
[2]University of Maine



Harvesting at the T16 R8 MASN site. Photo: H. Soman.

Status: Progress Report (Year 2)

Summary:

This is the second year of a five-year project to establish a new region-wide study series: Maine's Adaptive Silviculture Network (MASN). The MASN study will be the backbone for new research in the areas of growth and yield, wildlife habitat, harvest productivity, regeneration dynamics, remote sensing of invetory, forest health, and others. There has been much interest from researchers wishing to take advantage of these study sites on research problems of interest to CFRU membership. In addition to the American Forest Management (AFM) installation established at Grand Falls township (TWP) in the summer of 2017, there have been two additional installations established in 2018: T16 R8 on Irving Woodlands, LLC and T13 R15 on Seven Islands Land Company. Three more installations are laid out and harvests planned for 2019: Stetsontown TWP on Wagner Forest Management, Thorndike TWP on Weyerhaeuser Company, and the Massabesic Experimental Forest of the U.S. Forest Service (USFS) Northern Research Station.

Project Objectives:

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

Approach:

- Working with regional forest managers, identify potential areas with uniform soils, drainage class, topography, stand type, and recent harvest history.
- For each installation, delineate four to seven treatment blocks and randomly assign and implement various operational silvicultural treatments representing the full range of operational harvest conditions found in Maine (e.g., clearcut, overstory removal, crop tree release, first and second entry thinning). A delayed harvest control block will be included.

- Across a grid of permanent sample points on each installation, collect baseline pre- and post-harvest data, including overstory and understory vegetation inventories, forest bird surveys, tree damage assessments, 360-degree photography, high-resolution aerial imagery, and more.

Key Findings/Accomplishments:

- Baseline protocols have been documented and preliminary data collected on forest birds, inventory, understory vegetation, harvest damage, and 360-degree photo documentation.

- In addition to the first installation on AFM at Grand Falls TWP, two installations were established and harvested in 2018: T16 R8 on Irving Woodlands, LLC and T13 R15 on Seven Islands Land Company.

- Three installations are laid out and harvests planned for the Fall/Winter of 2018: Stetsontown on Wagner Forest Management, Thorndike TWP on Weyerhaeuser Company, and the Massabesic Experimental Forest of the USFS Northern Research Station.

- A study on the cost of BMP implementation was completed on the first installation (see study "Evaluating the Costs and Impacts of Timber Harvesting Operations on Soil Compaction" in this report).

- The CFRU 2018 Fall Field Tour included a stop at the T16 R8 installation where the study was introduced and the problems associated with managing diseased beach discussed.

Brian Roth introduces the T16 R8 MASN site to the Fall Field Tour participants in September 2018. Photo: J. Zukswert.

Future Plans:

- In late 2018 and early 2019, the installations in Stetsontown TWP on Wagner Forest Management and Thorndike TWP on Weyerhaeuser Company are scheduled to be harvested.

- NEPA (National Environmental Policy Act) approval is underway on the Massabesic Experimental Forest installation through the USFS.

- We are actively working on site selection for an additional six installations in 2019.

- Harvesting will continue with completion expected on the remaining sites selected this year.

- The Forest Watershed Research Center at the University of New Brunswick is producing high-resolution wet areas maps for MASN installations.

- We will continue hosting field tours and recruiting for new research projects on these sites.

Acknowledgements:

We would like to thank Matt Stedman and Brian Holland of Irving Woodlands, LLC and Jason McLellan of Seven Islands Land Company for their dedication and assistance with the harvesting in 2018.

Anil Kizha. discusses his research to the Long-Term Site Productivity Research field tour participants at the Grand Falls MASN site in June. Photo: B. Roth.

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

Fallen tree in the unharvested watershed at Weymouth Point.
Photo: A. Rezai-Stevens

C.T. (Tat) Smith[1], Russell D. Briggs[2], John L. Campbell[3], Ivan Fernandez[4], Shawn Fraver[4], Brian E. Roth[5], Inge Stupak[6]

[1]University of Toronto
[2]SUNY College of Environmental Science and Forestry (SUNY-ESF)
[3]U.S. Forest Service
[4]University of Maine
[5]Cooperative Forestry Research Unit
[6]University of Copenhagen

Status: Progress Report (Year 3)

Summary:

The Weymouth Point study was initiated in 1979 to determine the effects of whole-tree clearcutting a spruce-fir forest on watershed nutrient cycling and budgets. Fixed-area plots established on two adjacent watersheds (unharvested and clearcut) enable evaluation of long-term effects of harvest residue treatments on tree growth and long-term dynamics in soil and whole ecosystem carbon (C) and nutrient pools. Between 1979 and 2015, 52 permanent study plots were established across three soil drainage classes in the unharvested and clearcut watersheds. Residue treatments applied in 1981 include: whole-tree harvesting (WTH), return of lopped and scattered delimbing residues to the site (LOP), and return of chipped delimbing residues to the site (CHP). Stand density and basal area for plots located in the mature, unharvested reference and harvested watersheds were strongly affected by age and silvicultural treatments, but not by delimbing residue treatments or fertilizer. Ecosystem C and nutrient budget modeling is ongoing.

Project Objectives:

- **Objective 1:** Quantify trends in ecosystem C and nutrient pools 35 years after clearcutting a balsam fir-red spruce forest at Weymouth Point Study Area (WPSA).
- **Objective 2:** Compare 35-year ecosystem C pool dynamics with C dynamics predicted by an
-

- IPCC-relevant forest C budget model (CBM-CFS3 is proposed).
- **Objective 3**: Inform development of criteria and indicators of sustainable forest management (SFM) in forest policy and certification systems adopted for balsam fir-red spruce forests in northern New England.

Approach:

Objective 1:

- Measure all trees over 5 cm diameter at breast height (DBH) on 52 permanent study plots (this was done in 2016, and a complete tree audit was completed in 2017 to verify those results).
    - Measure saplings (< 5 cm DBH) in a 1-m^2 subplot on each plot.
    - Use allometric equations to estimate aboveground biomass.
    - Measure individual tree species' dimensions (DBH and height).
    - Estimate aboveground biomass of trees (kg/tree) and plots (Mg/ha) using equations developed by Smith *et al.* (1986) for balsam fir and red spruce and Young *et al.* (1980) for other species.
    - Measure effects of treatments (WTH, LOP, CHP) 35 years after harvest (WTH and SOH).
    - Measure effects of fertilization (FERT) and precommercial thinning (PCT) on standing biomass 35 years following harvest were measured.

- Inventory fine and coarse woody debris (FWD and CWD), stumps, and snags in 25, 20 × 20-m permanent study plots.
    - Analyze the effect of treatment (WTH, LOP, CHP) on FWD and CWD as well as an interaction with drainage class on the 25, 20 × 20-m permanent study plots established on the paired watersheds.

- Collect forest floor samples on 49 permanent study plots; dry and prepare for lab analysis to determine forest floor C in 2016 to compare with measurements after harvesting in 1981.

- Excavate and process subsamples from depth increments in 25, 0.5 m^2 quantitative soil pits; document soil properties (horizon depth, color) in 25 morphological soil pits (one of each per permanent study plot).
    - Determine depth to seasonal and permanent wetness in morphological soil pits.
    - Estimate rock volumes and fine earth fragment mass in quantitative pit samples.
    - Measure pH, Walkley-Black C, total C and soil nutrients (total N, Bray-P and exchangeable K, Ca and Mg) from quantitative pit samples.

- Use the mass of each nutrient (N, P, K, Mg and Ca) contained in the forest floor in 1980 prior to harvesting (quantified by C. T. Smith) and current mass to determine if changes in nutrient pools relate to tree growth after 35 years.
    - Analyze effect of treatment (WTH, LOP, CHP) on nutrient pools (N, P, K, Mg, and Ca).

- Quantify C in standing dead wood (snags and stumps) and downed dead wood (coarse woody

- debris and fine woody debris) of the unharvested forest (REF) and for different harvesting residue treatments: whole-tree harvesting (WTH), return of lopped and scattered delimbing residues to the site (LOP), and return of chipped delimbing residues to the site (CHP).

Objective 2:

- Compare empirical 35-year ecosystem C pools with C pools predicted by the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3).

Objective 3:

- Convene workshops designed to inform development of criteria and indicators of sustainable forest management (SFM) in forest policy and certification systems adopted for balsam fir-red spruce forests in northern New England.

Key Findings/Accomplishments:

- Forest floor measurements in 2016 indicate significant decomposition (ranging from 67-76% of original mass) during the 35-year period from 1981–2016: 112 to 35 Mg/ha or loss of 77 Mg/ha (69%) for WTH; 169 to 55 Mg/ha or loss of 114 Mg/ha (67%) for LOP; 176 to 43 Mg/ha or loss of 133 Mg/ha (76%) for CHP (Figure 4).

- Soil samples collected in the 2017 field season were processed at the University of Maine and analyzed for pH, Walkley-Black C, total C and N, Bray-P and exchangeable Ca, Mg and K at SUNY-ESF.

- Concentrations of total C and N appear to be somewhat higher in harvested watershed soils (WTH, LOP and CHP treatments) than reference watershed soils (REF) at 0–10 and 25–50 cm depths, but less Bray-P and exchangeable Ca (Figure 5).

- Carbon was estimated in standing dead wood (snags and stumps) and downed dead wood (coarse woody debris and fine woody debris) of the unharvested forest (REF) and for different harvesting residue treatments: whole-tree harvesting (WTH), return of lopped and scattered delimbing residues to the site (LOP) and return of chipped delimbing residues to the site (CHP) using methods of Ducey and Fraver (2018), Harmon *et al.* (2011) and Woodall and Monleon (2010). Preliminary results shows that dead woody debris in the unharvested forest is about three times that observed in harvested watershed treatments (Figure 6).

- Two MSc students from the University of Copenhagen, Bruna Barusco and Agnė Grigaitė, are working under the supervision of Drs. Inge Stupak and Tat Smith to complete the second objective of the Weymouth Point project: to compare measurement-based estimates of 35-year forest ecosystem C pools with C dynamics predicted by the CBM-CFS3 model.

- A workshop was arranged at the University of Maine at Orono on June 7th and 8th, 2018 titled "Long-Term Site Productivity Research: Lessons from Other Regions and Opportunities for Maine". See: https://umaine.edu/cfru/event/long-term-site-productivity-research-lessons-regions-opportunities-maine/

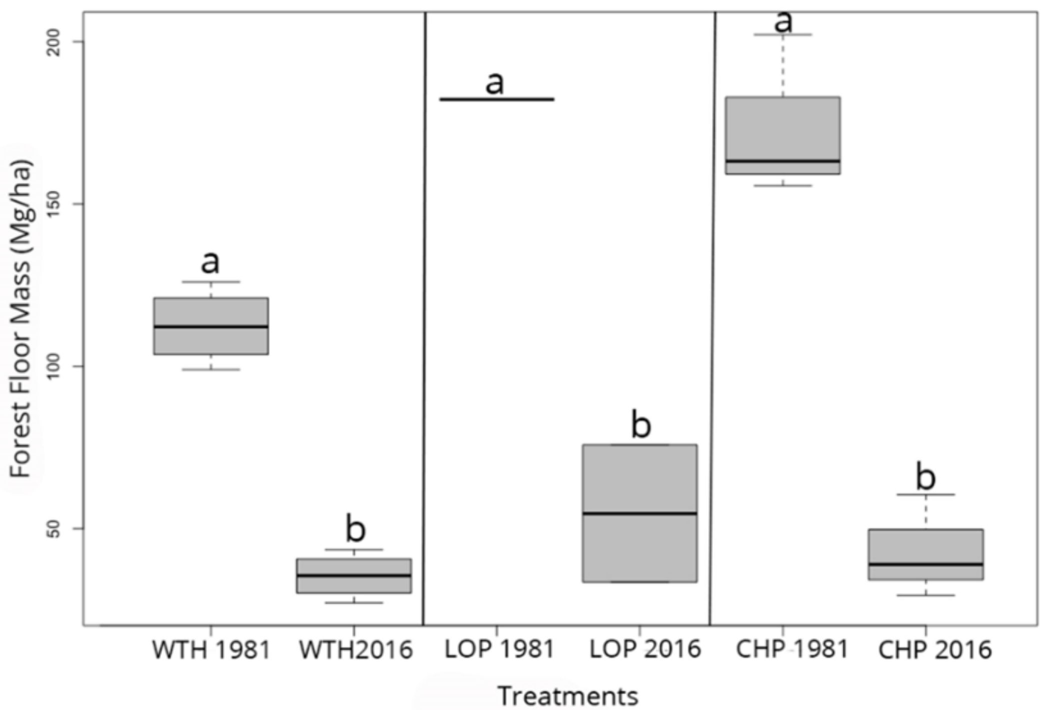


Figure 4. Mass of forest floor, un-merchantable tree biomass and delimbing residues (Mg/ha) in 1981 immediately after treatment and in 2016. The black line represents the mean, and the gray box represents 50% of the data with the whiskers representing the minimum and maximum data points. Different letters for each treatment indicates significant mass loss from 1981–2016. Treatments include: whole-tree harvesting (WTH); return of lopped and scattered delimbing residues to the site (LOP); and return of chipped delimbing residues to the site (CHP).

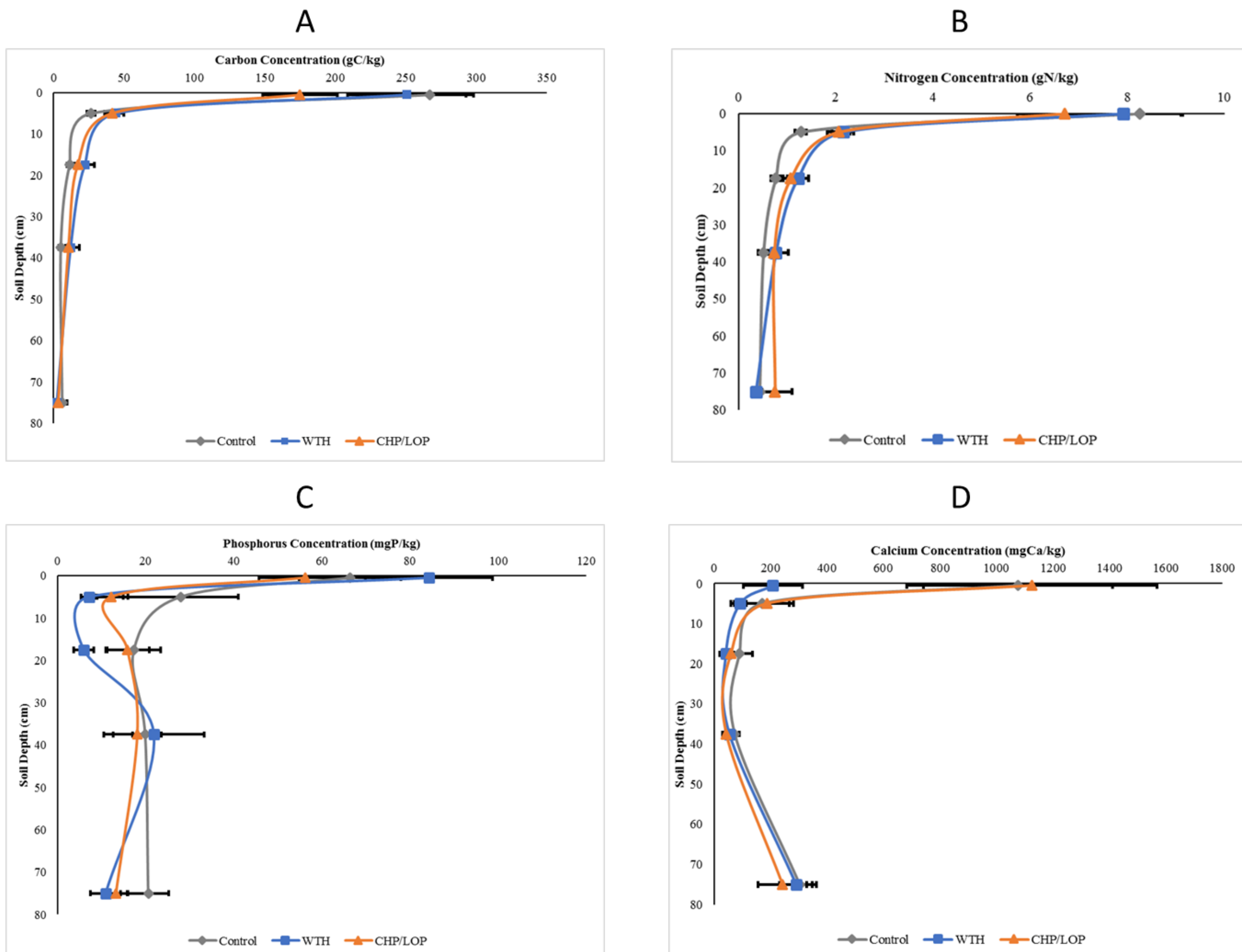


Figure 5. Concentrations of total C (A) and N (B), Bray-P (C) and exchangeable Ca (D) in Weymouth Point soils excavated from 0.5-m^2 quantitative pits. Means for treatments are plotted at excavated layer mid-points for OEB, 0–10, 10–25, 25–50 and 50–100-cm (hard pan) depths. Treatments include: unharvested forest (REF); whole-tree harvesting (WTH); return of lopped and scattered delimbing residues to the site (LOP); and return of chipped delimbing residues to the site (CHP).

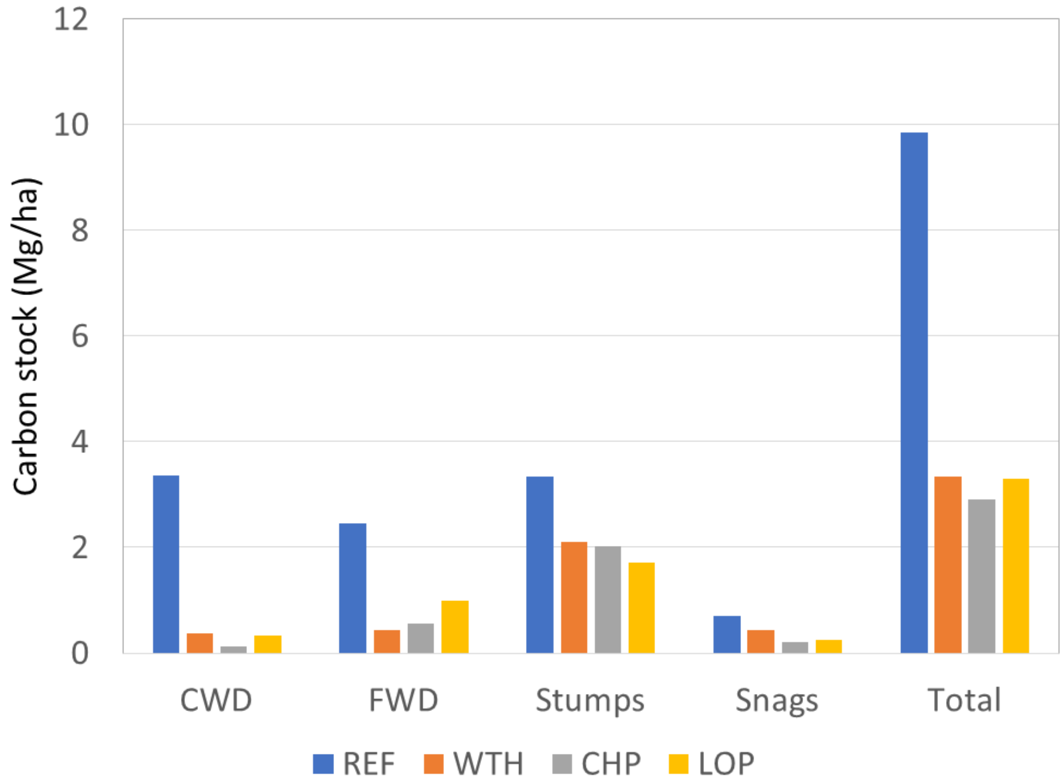


Figure 6. Mean C stock of standing dead wood (snags and stump) and downed dead wood (coarse woody debris (CWD) and fine woody debris (FWD)) in 2016 for the unharvested reference forest (REF) and the different residue treatments: whole-tree harvesting (WTH), and delimbing with residues chipped and spread (CHP), and delimbing with residues lopped and scattered (LOP) (preliminary results).

Future Plans:

- Complete analysis of data from chemical analyses of soil subsamples collected from 25, 0.5-m^2 quantitative soil pits and 25 morphological soil pits.

- Complete data analysis of standing and downed dead wood to determine differences in dead wood pools among the unharvested reference watershed (REF) and residue treatments (WTH, LOP, CHP).

- Analyze tree biomass samples for C, N, P, K, Ca, and Mg to enable precise estimates of above-ground nutrient pools.

- Run the CBM-CFS3 model to compare measured and estimated above- and belowground tree biomass, dead wood, and soil C pool dynamics with model-predicted values.

- Identify opportunities for workshops designed to inform development of criteria and indicators of sustainable forest management (SFM) in forest policy and certification systems adopted for balsam fir-red spruce forests in northern New England.

References:

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Harmon, M.E., C. W. Woodall, B. Fasth, J. Sexton, and M. Yatkov. Differences between standing and downed dead tree wood density reduction factors: A comparison across decay classes and trees species. U.S. Forest Service Research Paper NRS-15.

Woodall, C. W., and V. J. Monleon. 2010. Estimating the quadratic mean diameters of fine woody debris in forests of the United States. Forest Ecology and Management 260: 1088–1093.

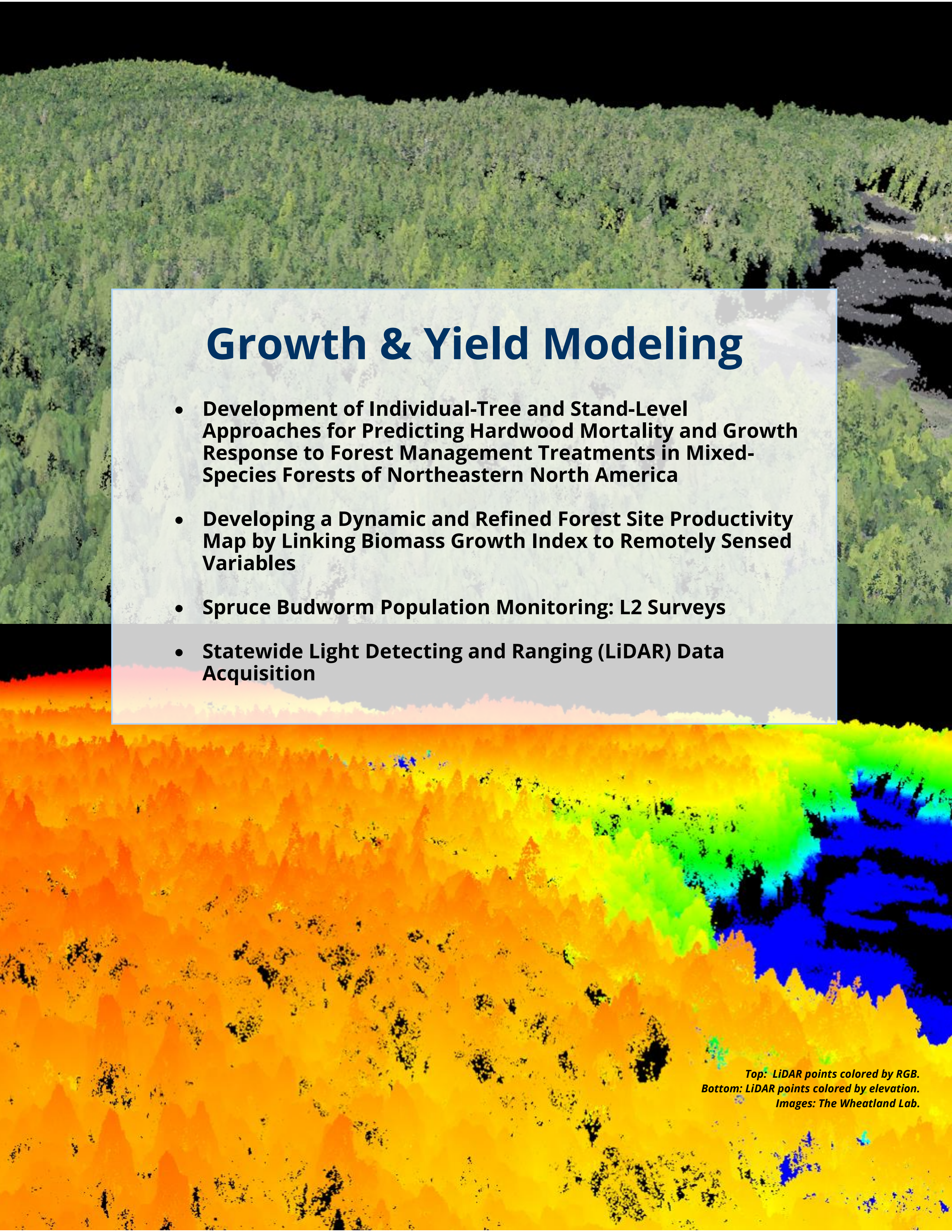
Acknowledgements:

Sincere thanks to Katahdin Forest Management, LLC and specifically Marcia McKeague and Dave Wilson for all that they have contributed to the Weymouth Point study since 1979.

Field visit to Weymouth Point on August 22, 2018 to acquaint University of Toronto MFC student Adriana Rezai-Stevens and University of Copenhagen MSc students Agnė Grigaitė and Bruna Barusco and supervisor Dr. Inge Stupak with the research plots and experimental design and colleagues involved in the project since 1979. From left to right: Agnė Grigaitė, Brian Roth, Adriana Rezai-Stevens, Tat Smith, Bruna Barusco, Maxwell McCormack (in back), Inge Stupak, Jenna Zukswert.

Growth & Yield Modeling

- Development of Individual-Tree and Stand-Level Approaches for Predicting Hardwood Mortality and Growth Response to Forest Management Treatments in Mixed-Species Forests of Northeastern North America
- Developing a Dynamic and Refined Forest Site Productivity Map by Linking Biomass Growth Index to Remotely Sensed Variables
- Spruce Budworm Population Monitoring: L2 Surveys
- Statewide Light Detecting and Ranging (LiDAR) Data Acquisition



Top: LiDAR points colored by RGB.
Bottom: LiDAR points colored by elevation.
Images: The Wheatland Lab.

Development of Individual-Tree and Stand-Level Approaches for Predicting Hardwood Mortality and Growth Response to Forest Management Treatments in Mixed-Species Forests of Northeastern North America

Joshua Puhlick assessing hardwood growth and yield on the Silvicultural Intensity and Species Composition (SIComp) experiment. Photo: J. Ferrara.

Joshua J. Puhlick, Christian Kuehne

University of Maine

Status: Progress Report (Year 1)

Summary:

In Year 1 of this two-year project, we acquired data from existing forest inventories with repeat measurements of tree attributes in Maine, New Brunswick, and Nova Scotia. We also conducted repeat measurements of crop trees on the Penobscot Experimental Forest Rehabilitation Study and the Silvicultural Intensity and Species Composition experiment. These data sources will be used to develop growth and mortality response functions for common hardwood species of northeastern North America to account for treatment effects after various forest management activities.

Project Objectives:

- Compile and standardize data from existing tree-ring chronologies and forest inventories with repeat measurements of tree attributes in the Northeast.
- Develop growth and mortality response functions for common hardwood species of the Northeast to account for treatment effects after various forest management activities.
- Compare performance of derived sub-models of growth and mortality after forest management treatments to current predictions in the Northeast and Acadian variants of the Forest Vegetation Simulator (FVS-NE and FVS-ACD, respectively).
- Incorporate potential growth and mortality treatment response functions into FVS-ACD.

Approach:

- Acquire and standardize repeated tree measurement data and tree-ring chronologies from studies across the Acadian Forest.

- Develop and evaluate growth response models, consisting of baseline models for most common hardwood species in the Acadian region (for annual diameter increment, height increment, height-to-crown base increment, and individual tree mortality), as well as thinning-response functions.

Key Findings/Accomplishments:

- In Year 1 of the project, we acquired data from existing forest inventories with repeat measurements of tree attributes in Maine, New Brunswick, and Nova Scotia. This involved meeting and signing data agreements with colleagues at the Northern Hardwoods Research Institute in Edmundston, New Brunswick (Gaetan Pelletier) and the University of New Brunswick in Fredericton (Chris Hennigar). Forest inventory data from the Penobscot Experimental Forest in central Maine were acquired from the U.S. Forest Service. We also requested forest inventory data from colleagues in Québec (Steve Bédard, Ministère des Forêts, de la Faune et des Parcs).

- In addition to data acquisition, we also conducted repeat measurements of crop trees on the Penobscot Experimental Forest Rehabilitation Study (during the summer and fall of 2017) and the Silvicultural Intensity and Species Composition experiment (late fall 2017 and early spring 2018). The Rehabilitation Study measurements were used to evaluate crop tree growth and quality in cutover mixed-wood stands after rehabilitation treatments. A manuscript with the results of this analysis were published in a peer-reviewed journal. The measurements from both studies will be used to develop tree growth and yield models for early successional hardwood and mixed-wood stands.

Future Plans:

- The plans for Year 2 of the project include developing growth and mortality response functions for common hardwood species, which will improve the prediction of stand and tree-level growth and mortality in FVS-ACD.

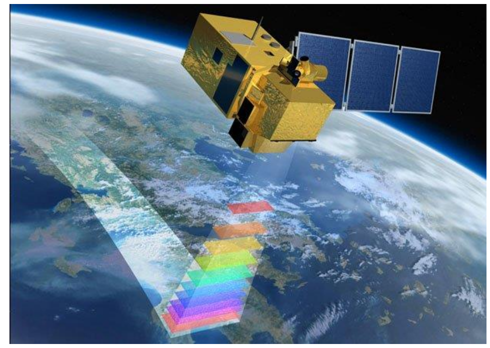
- We will also work with the U.S. Forest Service to incorporate the hardwood growth and mortality modifiers into the online version of FVS-ACD.

Acknowledgements:

We thank the Gaetan Pelletier (Northern Hardwoods Research Institute) and Chris Hennigar (University of New Brunswick) for meeting with us and discussing the details of the project.

Christian Kuehne assessing paper birch crop tree quality on the Penobscot Experimental Forest Rehabilitation Study.
Photo: J. Puhlick.

Developing a Dynamic and Refined Forest Site Productivity Map by Linking Biomass Growth Index to Remotely Sensed Variables



Model of a Sentinel-2 satellite.
Image from https://eos.com/sentinel-2/

Parinaz Rahimzadeh[1], Aaron Weiskittel[1], Chris Hennigar[2]

[1]*University of Maine*

[2]*University of New Brunswick*

Status: Progress Report (Year 1)

Summary:

Forest potential productivity is an important measure for sustainable forest planning and management. However, its quantification has always been a challenging task, particularly on a regional scale. Due to the essential need for a fine-resolution region-wide map of forest productivity for effective large-scale forestry planning and management, a novel productivity model, biomass growth index (BGI), was suggested by Hennigar *et al*. (2016) for the Acadian region. The model explains only 53% of the variation in plot aboveground biomass growth partly because of poor soils data resolution and incomplete stand development history in the model. Based on the strong potential for the improvement of this model by incorporation of techniques using remote sensing (RS) data, several newly-launched Sentinel-2 satellite derived variables were selected for the analysis. Twenty-one Sentinel-2 derived variables including nine single spectral bands and 12 spectral vegetation indices (SVIs) with a combination of other variables were used to predict tree volume/ha (GTV), height, and the Site Index (SI20). Initial model runs showed a 10 to 12 % increase in out of bag (OOB) r^2 when Sentinel-2 variables were included in the prediction of total volume in combination with BGI. Site Index was not predicted with the same accuracy as GTV, but it is still promising.

Project Objectives:

- The overall goal was to incorporate remote sensing data into the BGI model (Hennigar *et al*. 2016) and present a more accurate BGI model for Maine and New Brunswick. Specific objectives are:
    - Estimate various spectral vegetation indices (SVIs) from Sentinel-2 satellite imagery for Maine and New Brunswick .
    - Evaluate the performance of SVIs using plot inventory data.
    - Normalize SVI data layers by land cover/land use, history of previous and current forest disturbances, and forest composition data.
    - Develop a model based on the combination of Sentinel-2 derived SVIs and site factors, improving the existing BGI model for the regions with higher uncertainty, and provide a more accurate, high-resolution BGI map (BGI v.2)

Approach:

- Several attempts have been made to map forest productivity using satellite derived SVIs alone or in combination with other environmental variables to address the needs for regional near-real time data (Waring *et al*. 2006). Several SVIs like normalized difference vegetation index (NDVI) and enhanced vegetation index (EVI) have been suggested to estimate forest biophysical variables such as leaf area index (LAI) and productivity (Pfeifer *et al.* 2012). Sentinel-2 imagery has spectral bands in red-edge (RE) regions that were not available in previous multi-spectral satellites like Landsat. These spectral bands are more efficient in detecting forest biophysical attributes such as leaf chlorophyll content, LAI, and fractional vegetation cover (Delegido *et al.* 2011, Rahimzadeh-Bajgiran *et al.* 2012).

- In this project based on previous research, 21 Sentinel-2 satellite derived variables were selected for the analysis. Sentinel-2 derived variables, in combination with other variables, were used to predict tree volume/ha (GTV) and height. LiDAR-derived forest inventory predictions (total volume/ha and height) on a 20 × 20-m point feature grid were intersected with the nine spectral bands and 12 vegetation indices from the Sentinel-2 images (July and September 2017) to obtain Sentinel-2 data for each LiDAR point.

- The resulting 20 × 20-m point layer was intersected with the New Brunswick Crown forest management polygon layer, which contained photo-interpreted species composition, treatment history, and year of treatment, and allowed us to determine species percentages, stand age and management type (i.e., planted, precommercial thinning(PCT), and clearcut regeneration) for each point. Total volume/ha and height were modeled by Random Forests (Breiman 2001) using species composition, age, and management type (Mgmt), BGI, and Sentinel-2 spectral bands and indices. Figure 7 shows our study site and data used for model development. Only stands that were > 1 acre were used in each Random Forest model (7,400 stands total).

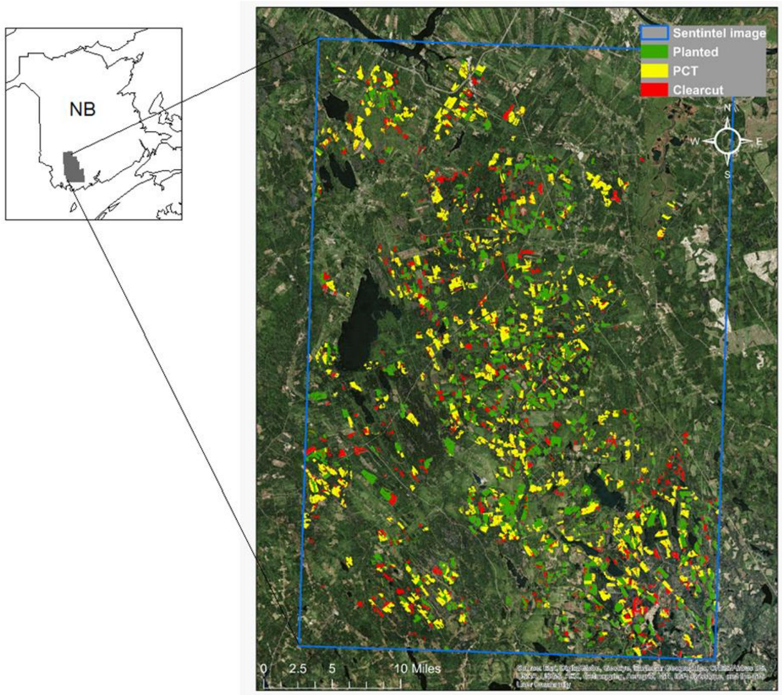


Figure 7. Location and the extent of the study area used for model development (map of Sentinel-2 image coverage and the corresponding stands data used for model development). PCT: precommercial thinning.

Key Findings/Accomplishments:

- Prediction of GTV using species composition, age, Mgmt., BGI, and Sentinel-2 spectral bands and indices:
    - Model runs showed a 10–12 % increase in out of bag (OOB) r^2 when Sentinel-2 data was included in the prediction of total volume (Table 5). Prediction of stand-level volume based on age, species composition, management type, and BGI yielded an OOB r^2 of 68%, whereas the addition of the Sentinel-2 data increased the OOB r^2 to 80%. Additionally, dropping species composition as a predictor variable did not significantly affect the OOB r^2 (80% vs. 78%). In all cases, band 2 (green) was the strongest predictor variable, even outperforming age as a predictor of GTV.
    - After reviewing the correlation matrix of the bands and indices (Figure 8), all bands and indices with the exception of green and near infrared (NIR) bands and Sentinel-2 rededge position index (S2REP) and Normalized Difference Vegetation Index 45 (NDVI45) were dropped from the model as they did not contribute significantly to model performance. Results for height prediction incorporating Sentinal-2 data were similar to those obtained for GTV.
    - Removing age and management variables and running the model on only BGI, three Sentinel-2 derived variables (green and near infrared (NIR) bands and Sentinel-2 red-edge position index (S2REP)) yielded an OOB r^2 of 62%.

- Prediction of GTV using only Sentinel-2 best bands and indices:
    - Prediction of total volume (GTV), with spectral bands and indices performed the best when two single bands (green and NIR) and two SVIs (S2REP and NDVI45) were used.
    - Prediction of GTV using only the best bands and indices and BGI resulted in an out of bag r^2 of 62.5%. Removing BGI reduced the out of bag r^2 to 59.3%. BGI does not seem to have considerable effects on predicting GTV (Table 5).

- Prediction of Site Index (SI20) with species composition, age, Mgmt., BGI, and Sentinel-2 spectral variables:
    - SI20 was not predicted with the same accuracy as GTV but still promising (e.g., SI20~Age, Mgmt, BGI, July Sentinel-2 (green, NIR, S2REP and NDVI45) and species: OOB r^2 = 69.7).
    - This part is still in progress, and the final results will be presented in the final report.

Table 5. Results of total volume/ha (GTV) prediction by Random Forests using species composition, age, Mgmt., BGI and Sentinel-2 spectral bands and indices. OOB = out of bag, and RMSE = root mean squared error.

Response	Predictor variables	OOB r^2	RMSE
Total volume/ha	Age, Species, Mgmt., BGI	68%	24.8
	Age, Species, Mgmt., BGI, July Sentinel-2	80%	19.7
	Age, Species, Mgmt., BGI, Sept. Sentinel-2	80%	19.7
	Age, Mgmt., BGI, July Sentinel-2	78%	20.7
	Age, Mgmt., BGI, July Sentinel-2 (green, NIR, S2REP, NDVI45)	77%	20.9
	All July Sentinel-2 bands and indices	65%	25.6
	July Sentinel-2 (green, NIR, S2REP, NDVI45)	59.3%	26.1

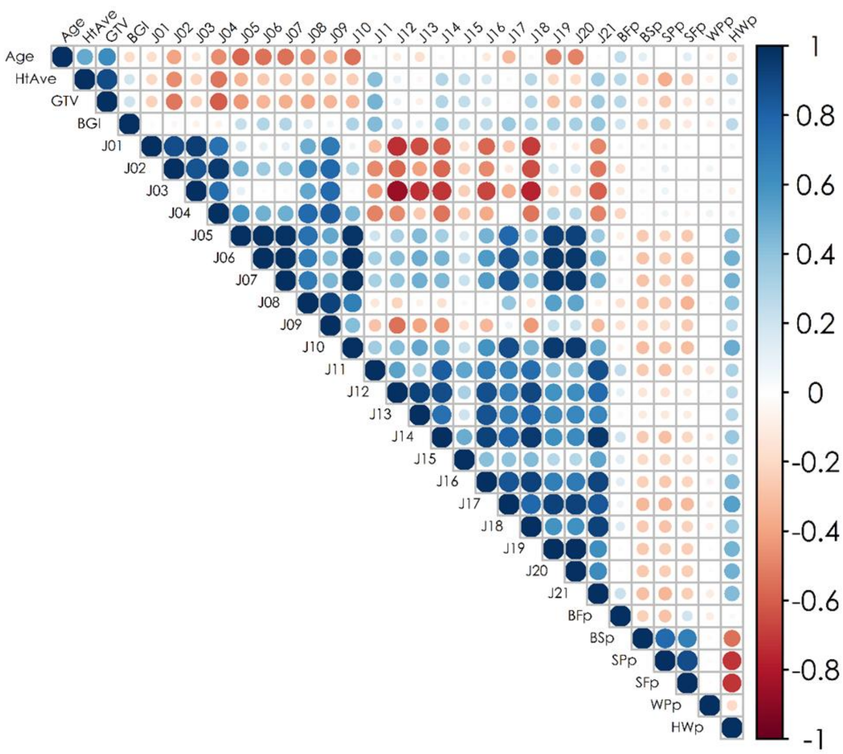


Figure 8. Correlation matrix for Sentinel-2 bands and indices (GTV = gross total volume, BFp = % balsam fir, BSp = % black spruce, SPp = % spruce, SFp = % spruce-fir, WPp = % white pine, HWp = % hardwood).

Future Plans:

- Species composition, age, Mgmt., BGI, and Sentinel-2 spectral bands and indices were also applied to predict Site Index (SI20). This part is still in progress and the preliminary results are not presented here.

- Mosaic of the best Sentinel-2 single bands and SVIs are currently being produced for all of Maine and New Brunswick to produce improved forest potential productivity map product (BGI v.2)

References:

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Aerial view of Baxter State Park in Maine, part of the Acadian region.
Photo: The Wheatland Lab

Spruce Budworm Population Monitoring: L2 Surveys

Brian Roth[1], Erin Simons-Legaard[2], Kasey Legaard[2]

[1]Cooperative Forestry Research Unit
[2]University of Maine

Rob Johns (R) gives a tour of the Canadian Forest Service's L2 processing facility in New Brunswick. Photo: B. Roth.

Status: Progress Report (Year 2)

Summary:

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

Project Objectives:

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

Approach:

- Collect one branch sample per each of three trees co-located with pheromone traps during the fall and winter. Locations are selected in areas where pheromone trap catches had been high, modeling predicted at-risk stands, or previous samples had been collected (Figure 9).
- Collected branch samples are transported to the Canadian Forest Service Insect Laboratory in Fredericton, NB for processing, with data and maps shared annually on the Healthy Forest Partnership website: http://www.healthyforestpartnership.ca/en/research/what-where-and-when/

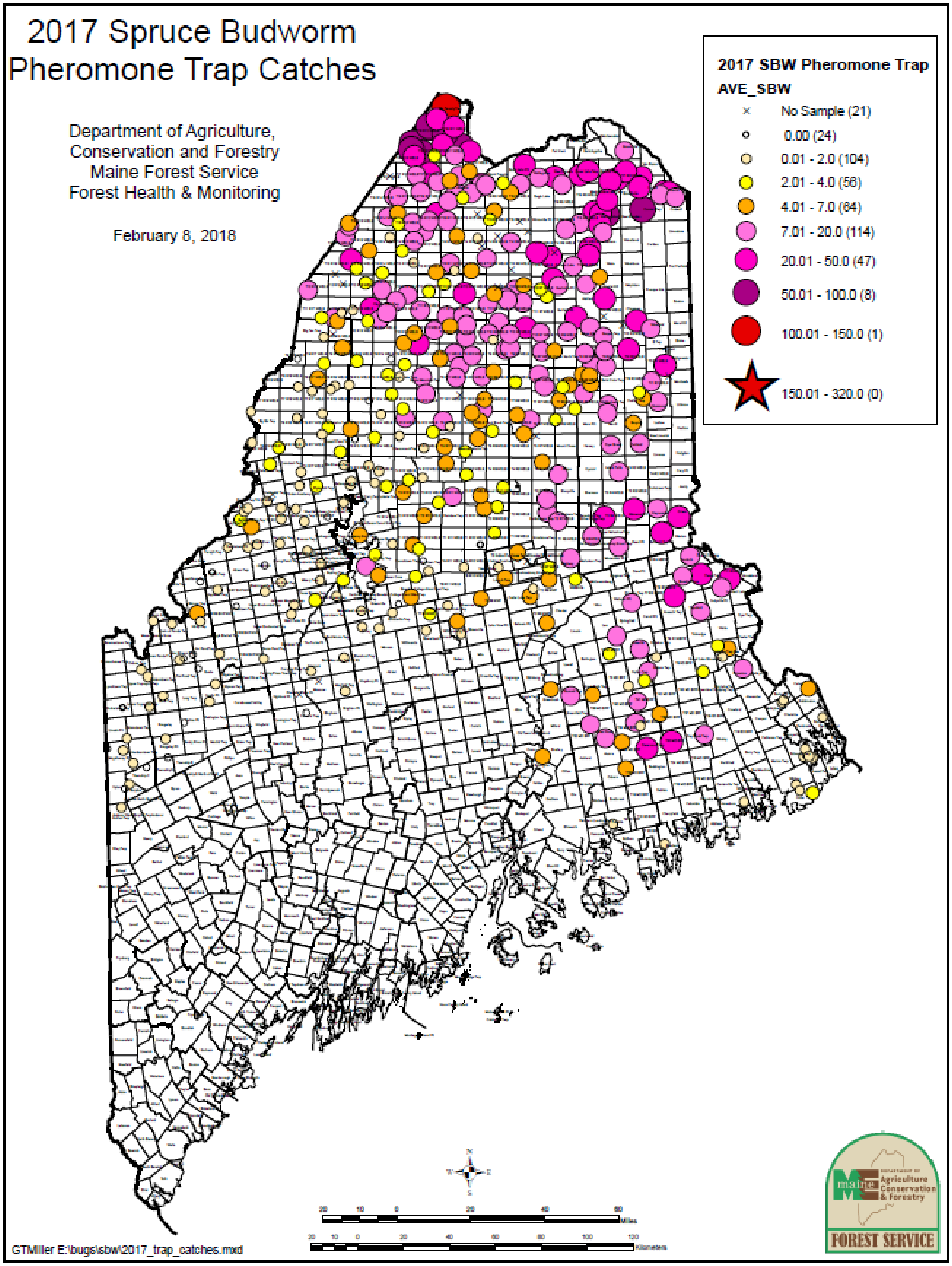

Figure 9. 2017 distribution of spruce budworm pheromone traps and trap catches across Maine.

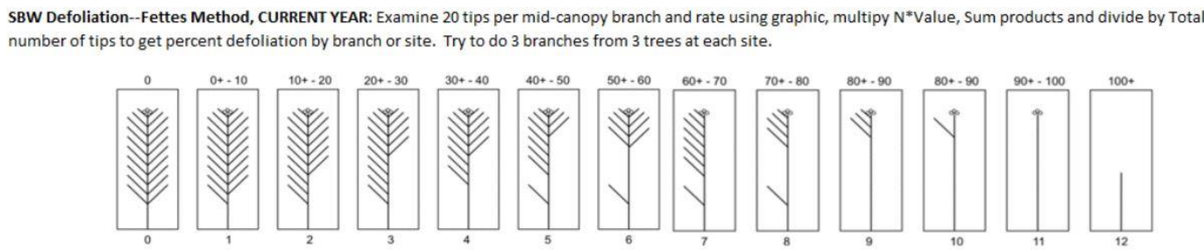

Figure 10. Diagram of the Fettes method for quantifying current year defoliation. This method will be used to collect defoliation data on all L2-survey branch samples collected in 2018.

Key Findings/Accomplishments:

- Data from the winter of 2017–18 indicate that there continue to be very low levels of SBW overwintering larvae in northern Maine.

- 2017–18 L2 samples from Maine yielded a total of 32 larvae across 13 sample locations. No larvae were recovered at 242 of the 255 sites sampled.

- A limited aerial survey in late 2017 in northern Maine did not identify any areas where defoliation was evident.

Future Plans:

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

- In the 2018–19 season, we will quantify current-year defoliation on branch samples in the lab using the Fettes method (Figure 10).

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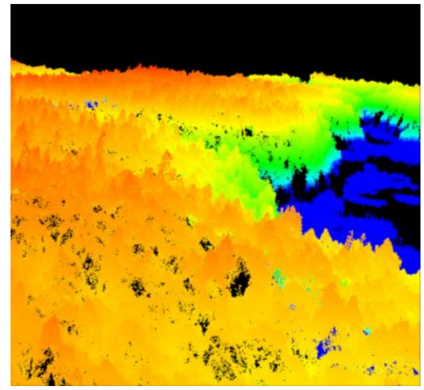
Acknowledgements:

We would like to thank the Canadian Forest Service, Maine Forest Service, Irving Woodlands, LLC, Weyerhaeuser Company, Seven Islands Land Company, LandVest, Huber Resources, Baxter State Park, and Noah Coogan.

Statewide Light Detection and Ranging (LiDAR) Data Acquisition

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

[1]Cooperative Forestry Research Unit
[2]Maine Office of GIS & the Maine GeoLibrary Board
[3]U.S. Geological Survey



LiDAR points colored by elevation. Image: The Wheatland Lab.

Status: Final Report (Year 5)

Summary:

Light detection and ranging (LiDAR) is a remote sensing technology that uses pulses of light to generate a three-dimensional map of objects that reflect the light. These 3-D point clouds can be combined with ground truth data from field plots to generate algorithms that predict forest metrics such as merchantable volume, basal area, canopy height, stem density, etc., on a raster basis across the landscape. Combined with Geographic Information Systems (GIS), forest managers have the ability to make accurate, large-scale assessments of forest resources across the landscape. The goal of this project is to assemble a complete statewide base LiDAR dataset. This dataset will lay the groundwork for future high-resolution statewide mapping projects such as wet areas, soils, and wildlife habitat.

Project Objectives:

- The overall objective of this project is to leverage CFRU contributions with that of other private, state, and federal funding sources to acquire a statewide LiDAR dataset that can be used for forest inventory along with statewide mapping of wet areas, soils, and wildlife habitat.

Approach:

- Solicit large landowners, communities, and other stakeholders in the unorganized territories to partner on LiDAR acquisition projects.

- Through the Maine GeoLibrary Board, actively pursue legislation to establish a Geospatial Data Reserve Fund that will match outside funding sources with State funds on a 1:1 basis.

- Partner with the U.S. Geological Survey (USGS), Natural Resources Conservation Service (NRCS), Federal Emergency Management Agency (FEMA), and other agencies to cost share LiDAR acquisition projects.

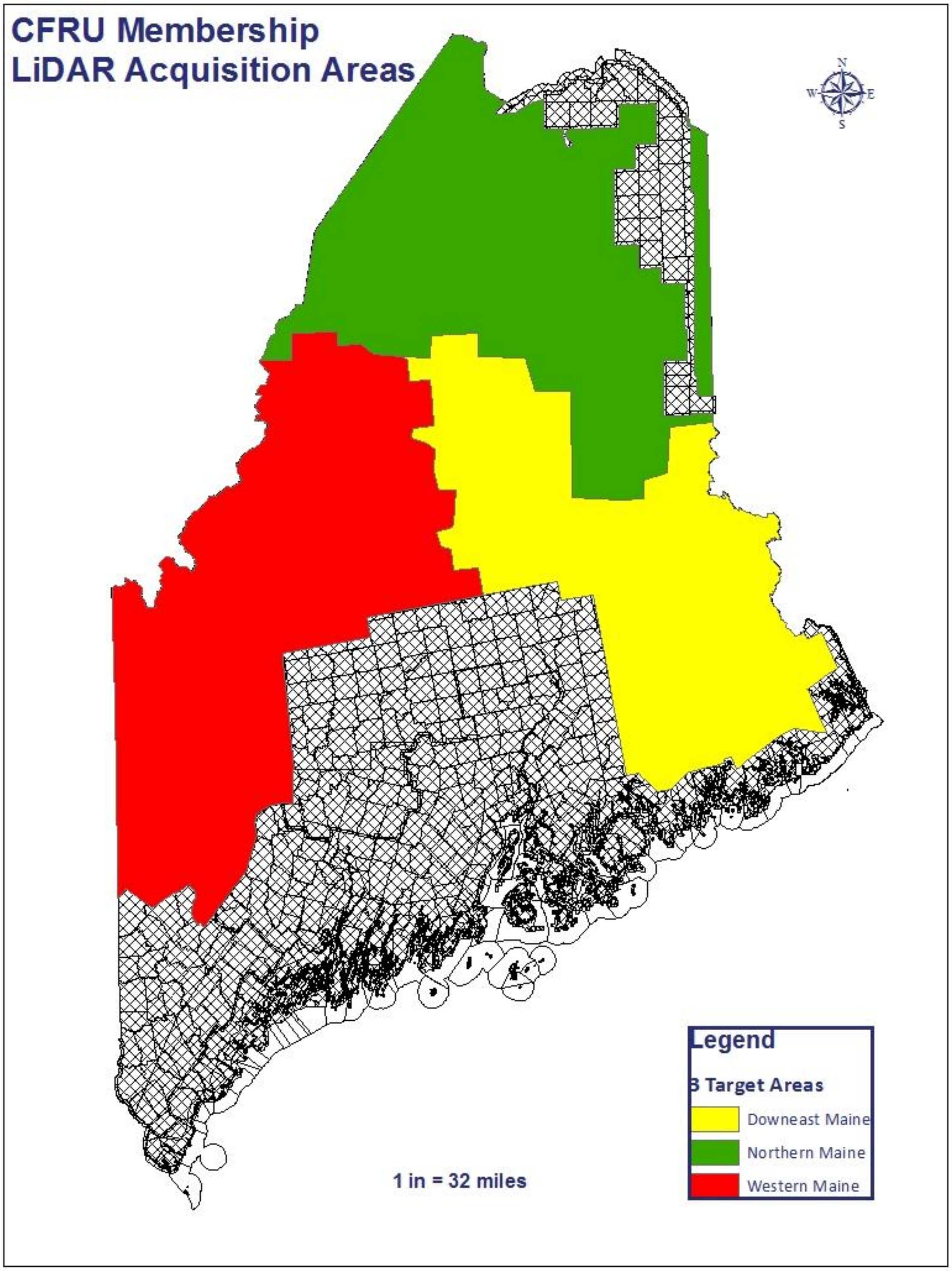


Figure 11. Three-year acquisition plan to complete LiDAR coverage for the entire state of Maine. The area in green was nearly completed in 2018 with some follow-up planned for the spring of 2019. Total funding for the final acquisition is in excess of $1.2 million with CFRU funding leveraging $500,000 from the USGS and $125,000 from the Maine Department of Transportation, among other sources.

Key Findings/Accomplishments:

- 2018 was the third and final phase of the acquisition.
- There were approximately 6,000 square miles of new acquisition to USGS QL2 specifications and an additional 1,000 square miles covering areas with previously acquired LiDAR (Figure 11).
- Sensor problems, a short window of optimum data acquisition in the spring, and early snows in the fall of 2018 unfortunately prevented full data acquisition.

Future Plans:

- A spring 2019 flight is planned to acquire the remaining area of interest (AOI) not acquired in 2018.
- Final products should be complete and provided to stakeholders by the end of 2019, pending final acquisition and data quality control/assurance.
- LiDAR products will be the inputs for a new CFRU research project by Dr. Daniel Hayes on efficient methodology for predicting Enhanced Forest Inventory.
- Plans are underway to update statewide wet area maps at high resolution, which will also inform digital soil mapping efforts.

Quantum Spatial LiDAR acquisition airplane at Bangor International Airport on May 26th, 2017. From left to right: Joseph Young (MEGIS), Brian Roth (CFRU), Steve West (Seven Islands Land Co.), Bob Bistrais (MEGIS), David Sandilands (Wheatland Geospatial Lab).

Acknowledgements:

We would like to acknowledge the following collaborators for making this statewide initiative possible: The Maine Office of GIS and the GeoLibrary Board, U.S. Geological Society, U.S. Department of Agriculture, Quantum Spatial, Weyerhaeuser Company, Baxter State Park, Maine Bureau of Parks and Land, Maine Department of Transportation, Maine Center for Disease Control, Clayton Lake Woodland Holdings, Seven Islands Land Company, LandVest, The Nature Conservancy, and King Pine Wind, LLC.

Wildlife Habitat

- **Responses of Marten Populations to 30 Years of Habitat Change in Commercially Managed Landscapes of Northern Maine**
- **Bicknell's Thrush Distribution and Habitat Use on Commercial Forests in Maine**
- **Development of Large-Scale Optimal Monitoring Protocols for Carnivores**
- **Landscape-Level Evaluation of Deer Wintering Habitat in Northern Maine**

Two martens near a bait station. Trail camera photo: B. Evans.

Responses of Marten Populations to 30 Years of Habitat Change in Commercially Managed Landscapes of Northern Maine

American marten in a trap. Photo: K. Fagan.

Daniel Harrison, Erin Simons-Legaard, Kirstin Fagan, Tyler Woollard

University of Maine

Status: Progress Report (Year 1)

Summary:

Since the enactment of the Maine Forest Practices Act, it is unclear to what degree forest-dependent wildlife have responded to the resulting patterns of landscape composition and connectivity. Previous CFRU-funded research on American marten, an area- and fragmentation-sensitive forest carnivore, demonstrated the utility of martens as an effective umbrella species for 71% of vertebrate species in Maine. Based on species occurrence models that were based on previous radio telemetry projects with martens funded by the CFRU, we predicted a widespread loss of marten habitat coincident with decreasing extent and increased fragmentation of suitable habitat patches during 1970–2007. Marten are a highly sought furbearer, and understanding more recent changes in habitat supply for martens is needed to ensure that marten harvests are sustainable and to ensure that managed landscapes continue to support viable marten populations. Thus, the goal of our project is to assess the cumulative effects of changes in habitat composition and landscape configuration on martens from 1989–2019 by documenting and comparing multi-scalar habitat associations and densities of resident marten over time. We are replicating systematic live-trapping and radio-tracking protocols conducted during previous studies during 1989–97. Preliminary results indicate that, despite consistent spatial and temporal trapping effort, our 2018 spring catch rate was lower than experienced during seven prior field seasons conducted in the same area. We monitored 5 resident martens in 2018 and obtained > 40 locations on each. Further analyses will integrate data from our 2018–19 field seasons with prior studies, will compare the patterns of habitat selection and spatial use of resident martens, and will test and develop new models for predicting marten occurrence in contemporary landscapes.

Project Objectives:

- Our goal is to contribute to management planning for viable wildlife populations in the commercial timberlands of Maine by evaluating stand- and landscape-scale habitat associations for American marten in north-central Maine over the past 30 years.

- Specifically, we seek to enhance understanding of the effects of cumulative habitat changes, which will inform future habitat and harvest management for marten in landscapes where shifting regulations, land ownership patterns, and fiber markets have drastically altered landscape composition and structure since the enactment of the Maine Forest Practices Act.

- To accomplish this goal, our objectives include the following:
    - Resurvey commercially managed lands bordering the western boundary of Baxter State Park for marten by replicating leaf-on season trapping protocols established from 1989–97 (Katnik 1992, Payer 1999).
    - Radio-collar and track marten captured during May–July of 2018 and 2019 to estimate home range boundaries and determine habitat use within territories.
    - Develop a detailed map documenting stand composition, harvest histories, and harvest intensities across the landscape.
    - Compare patterns of stand- and landscape-scale habitat associations, spatial occurrence, and density of resident marten across all years of study. Develop predictive occurrence models based on data collected from 2018–19 and compare performance and reliability with previous models developed from data collected from 1989–97 (Katnik 1992, Payer 1999).

Approach:

- We established trap lines on commercially managed lands in T4 R11 and T5 R11 WELS. We checked baited live traps to capture resident martens for 10 trap nights at each location during May through early July. Metrics of trapping effort, including effective surveyed area, trap density, and total trap nights, were consistent with prior studies of marten in the same area (Figure 12).

- Captured martens were sexed, weighed, evaluated for evidence of lactation; we also extracted a first premolar for age estimation (results pending). Marten equipped with VHF transmitters were relocated throughout the leaf-on season via triangulation. We produced 95% minimum convex polygon home ranges for individual marten using estimated locations from telemetry data.

- We are in the process of mapping the 200 km^2 landscape (72 mi^2) based on habitat currencies relevant to martens. We will create binary maps of suitable and unsuitable habitat based on published findings that martens strongly select for stands with trees > 35 ft (11 m), basal area of trees > 80 ft^2/acre (18 m^2/ha), and winter canopy closure > 50% (Payer and Harrison 2003, 2004; Fuller and Harrison 2011).

- We will assign site-specific attributes, including stand characteristics and edge effects, to each marten capture, recapture, and relocation. We will evaluate stand-scale habitat associations for marten in our study area by evaluating used versus available habitat within individual home ranges. Selection indices calculated based on new data (2018–19) will be compared with those derived from prior data (1989–97).

- We will predict marten occurrence patterns across the current landscape based on the application of previously developed models based on data collected from 1994–97 (Hepinstall *et al.* in prep). Model outcomes will be compared with the spatial distribution of martens observed during 2018–19. We will build new models based on the stand harvesting histories, residual stockings, and canopy closure in the current landscape.

Key Findings/Accomplishments:

- We established 292 trap sites throughout T4 R11 and T5 R11 WELS. Based on sex-specific home range estimates from prior studies (Katnik 1992, Payer 1999, Hearn 2007), our trapping scheme resulted in effective surveyed areas of 179.4 km^2 and 153.7 km^2 for male and female marten, respectively. The spring 2018 trapping session (17 May–4 July) consisted of 2,954 trap nights and yielded 12 captures and recaptures, including 9 individual marten (7 males, 2 females). Despite consistent spatial and temporal trapping effort, our catch rate (0.4 captures per 100 trap nights) was substantially lower than observed during seven prior field seasons conducted in the same area (Figure 13).

- We affixed radiocollars to seven captured marten, two of which dispersed from the study area in late May. We attempted to locate each of the five remaining marten daily during the leaf-on season via ground-based telemetry (date of initial capture through 29 September), with locations of individual marten separated by a minimum of 12 hours to ensure spatial and temporal independence (Katnik *et al.* 1994, Phillips 1994, Payer 1999). We obtained an average of 45 relocations per animal, with location times distributed around the clock. Field testing with hidden radiotransmitters resulted in a mean angular error of 3.2º (standard deviation (SD) = 2.4) and a mean location error of 58.9 m (SD = 24.3). These error metrics were used to estimate confidence ellipses associated with individual locations.

- Consistent with prior marten research in the area, locations with confidence ellipses < 4.4 ha (99.6% of locations collected in 2018) were used to calculate 95% minimum convex polygon (MCP) home ranges. The smallest marten home range we observed in 2018, associated with male marten #111, was 0.43 m^2 which is 38.6% smaller than any male marten home range observed in our study area from 1989–94 (Hearn 2009). The largest home range we observed this year, associated with male marten #005, was 17.04 m^2 which is 54.9% larger than any male marten home range observed in our study area from 1989–94 (Hearn 2009).

- Despite comparatively lower trapping effort during fall (e.g., 102 total trap nights during fall versus 364 during spring), our fall capture success rate (14.7 captures per 100 trap nights) was an order of magnitude larger than our spring capture success rate among comparable trap sites (0.5 captures per 100 trap nights). This difference likely reflects the influx of juvenile animals known to disperse from Baxter State Park during this period (Phillips 1994), emphasizing the importance of surveying the density and spatial distribution of resident marten during May and June and avoiding surveys during other times of the year when non-resident animals represent the preponderance of captures.

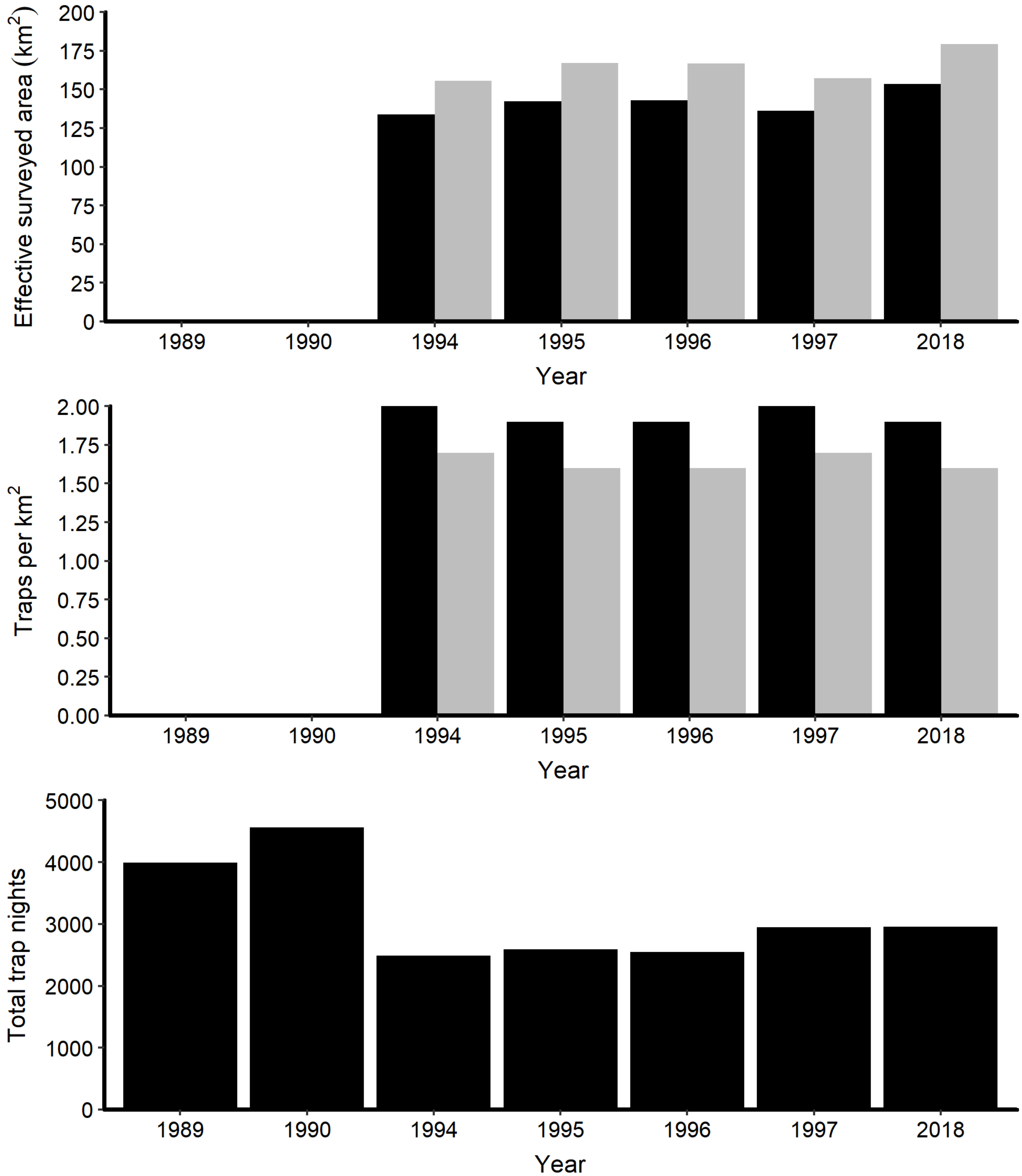


Figure 12. Overview of effort for spring trapping sessions (approximately 15 May–4 July) targeting American marten in T4 R11 and T5 R11 WELS during eight field seasons from 1989–2018. We present sex-specific effective surveyed areas (km^2), sex-specific trap densities ($traps/km^2$), and total trap nights. Effective surveyed areas and trap densities are pending for 1989–90. Surveyed areas and trap densities are displayed for females (black) and males (gray).

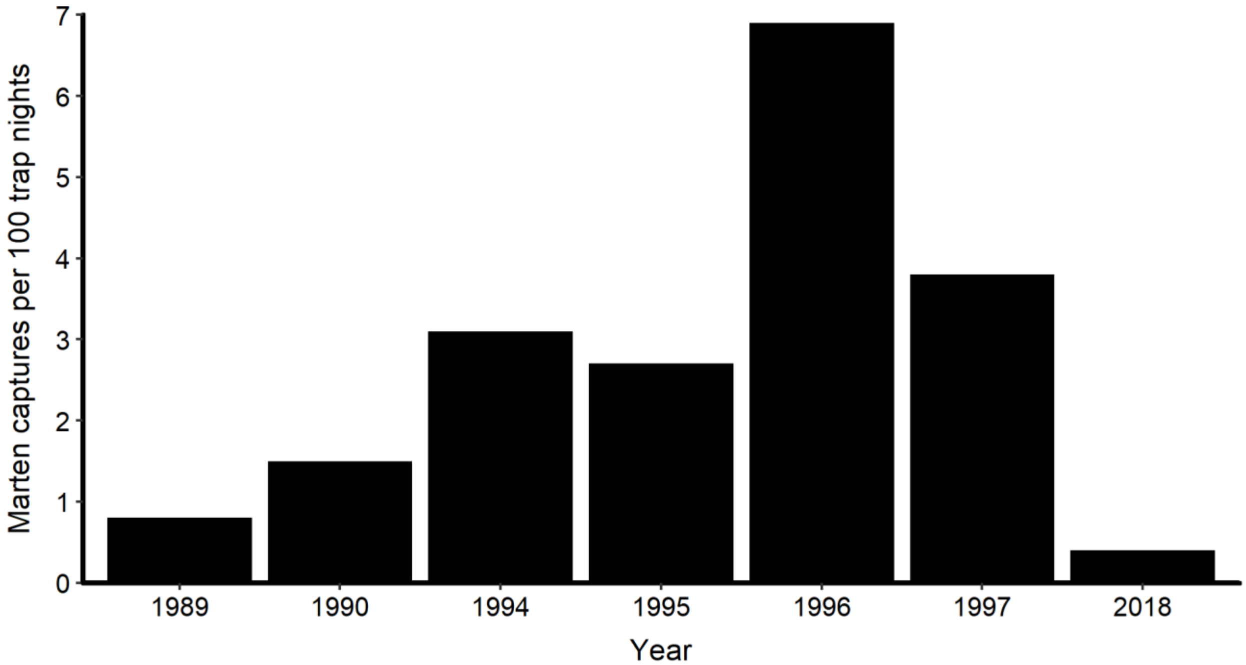


Figure 13. Capture success (marten captures per 100 trap nights) for spring trapping sessions (approximately 15 May–4 July) targeting American marten in T4 R11 and T5 R11 WELS during eight field seasons from 1989–2018.

a) Kirstin Fagan with marten captured June 2018. b) Tyler Woollard tracking a marten near the Telos Checkpoint. c) Graduate students at the Telos field camp. Students from the Harrison Lab have studied forest carnivores and other species in the North Maine Woods from this field station for over 30 years. d) Dr. Daniel Harrison (PI) and graduate students with American marten captured May 2018 in north-central Maine. Photos: G. Archambault, K. Fagan, T. Woollard, and J. Tebbenkamp.

Future Plans:

- Age estimates and ultimate fates of study animals are pending at this time. Estimated ages via cementum analysis are pending results from Matson's Laboratory (Manhattan, MT). Fates of individual animals are pending results of routine carcass collection during fall furbearer trapping season by the Maine Department of Inland Fisheries and Wildlife. These data will help inform analyses of age-specific habitat associations and survival.

- We will repeat our trapping and radio-tracking protocols during May–October of 2019. Combined with data collected during 2018, these contemporary data provide the opportunity for comparisons with historical data.

- Comprehensive analyses will be structured around the PhD and MS programs for K. Fagan and T. Woollard, respectively. Anticipated topics include the following: changes in stand- and landscape-scale resource selection over time and across related studies in Maine; influence of edge effects on stand-scale occurrence; influence of landscape resistance on occurrence; estimation of population density over time using spatially-explicit capture histories integrated with telemetry data; demographic analyses of resident marten compared with fall captures and harvested marten across time.

References:

Fuller, A. K., and D. J. Harrison. 2011. A landscape planning initiative for northern Maine using area-sensitive umbrella species: Evaluating baseline conditions and effects of alternative management scenarios and silvicultural portfolios on future timber harvest volumes, standing forest inventory, and marten and lynx habitat supply on The Nature Conservancy's St. John Lands in northern Maine. Report to the Maine Chapter of the Nature Conservancy.

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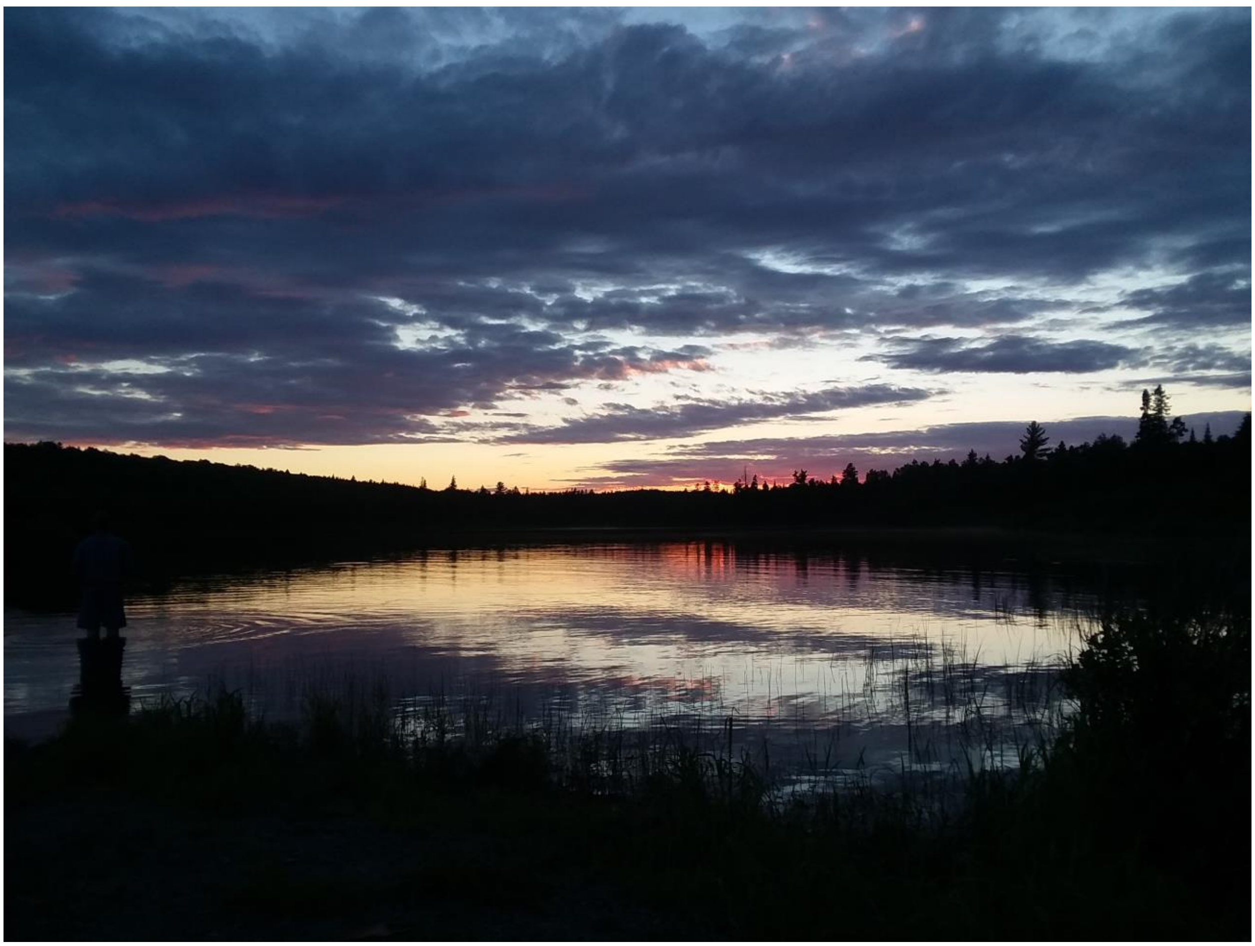
Phillips, D. M. 1994. Social and spatial characteristics and dispersal of marten in a forest preserve and industrial forest. Thesis, University of Maine, Orono.

Acknowledgements:

We thank the Cooperative Forestry Research Unit for funding this project. We would also like to acknowledge Aaron Pelletier (Pelletier Brothers, Inc.), Scott Joachim (Katahdin Forest Management, LLC), Steve Dunham (Baxter State Park), Scott McLellan (Maine Department of Inland Fisheries and Wildlife), and all the folks at the Telos Checkpoint (North Maine Woods, Inc.). Thank you to Crown Prince, Inc., King Oscar, Inc., and Anne Beerits (Nervous Nellie's Jams and Jellies) for their generous donations of sardines and raspberry jam, respectively, which were used as baits for capturing martens at ~300 trap sites.



Nesowadnehunk Lake: one of the places the field crew would go to relax when not conducting field work. Photo: K. Fagan.

Bicknell's Thrush Distribution and Habitat Use on Commercial Forests in Maine

Amber Roth[1], Adrienne Leppold[2], John Lloyd[3], Kaitlyn Wilson[1]

[1]University of Maine
[2]Maine Department of Inland Fisheries and Wildlife
[3]Vermont Center for Ecostudies

Tagged male Bicknell's thrush. Photo: A. Roth.

Status: Progress Report (Year 1)

Summary:

Bicknell's thrush (BITH) is a range-restricted habitat specialist occurring in balsam fir-dominated montane forests that have been recently disturbed and are undergoing successional growth. The species traditionally occurs at elevations above 800 m in the U.S., but if suitable habitat is available, BITH can occur at lower elevations. The potential for suitable habitat at lower elevations exists in Maine because of the state's unique distribution of tree communities and due to changes in forest structure and composition brought about by forestry practices. By means of telemetry, resource selection functions, and LiDAR, we aim to understand the use of breeding habitat for BITH in commercial forestlands in Maine. The research will produce a description of BITH use of commercially managed fir-spruce forests in Maine. Furthermore, the research will contribute to the development of Maine-specific forest BMPs to provide high-quality breeding habitat for BITH while meeting commercial forest landowner objectives.

Project Objectives:

- Identify forest structure characteristics associated with breeding habitat selection by Bicknell's thrush on commercial forestlands in Maine at multiple scales, both above and below the traditional elevation threshold for the species.

- Identify novel, LiDAR-derived forest structure estimates that explain Bicknell's thrush habitat selection.

- Obtain or re-create forest management records to describe the management history that has resulted in the occupied breeding habitat.

Approach:

- Radio-mark and track Bicknell's thrush at two study sites (a harvested landscape and a non-harvested landscape) during 2018 and 2019 breeding seasons to investigate habitat use.
- Quantify habitat using LiDAR-derived estimates of forest structure.
- Compare LiDAR-derived forest structure characteristics at locations used by individuals to those at available locations, using resource selection functions to identify habitat selection at multiple scales.

Key Findings/Accomplishments:

- We radio-marked 20 Bicknell's thrush (male = 18, female = 2) during 2018.
- We successfully tracked 11 individuals (6 in the harvested landscape, 5 in the non-harvested landscape) and collected 35–45 locations per bird (Figure 14).
- Preliminary data suggest that the species is using lower elevation habitat in commercial forests in Maine.
- Following analysis of habitat use, we will be able to recommend management practices to land managers to conserve breeding habitat for Bicknell's thrush on commercial forests in Maine.

Kaitlyn Wilson tracks Bicknell's thrush in a young balsam fir stand at Kibby Mountain. Photo: A. Fish.

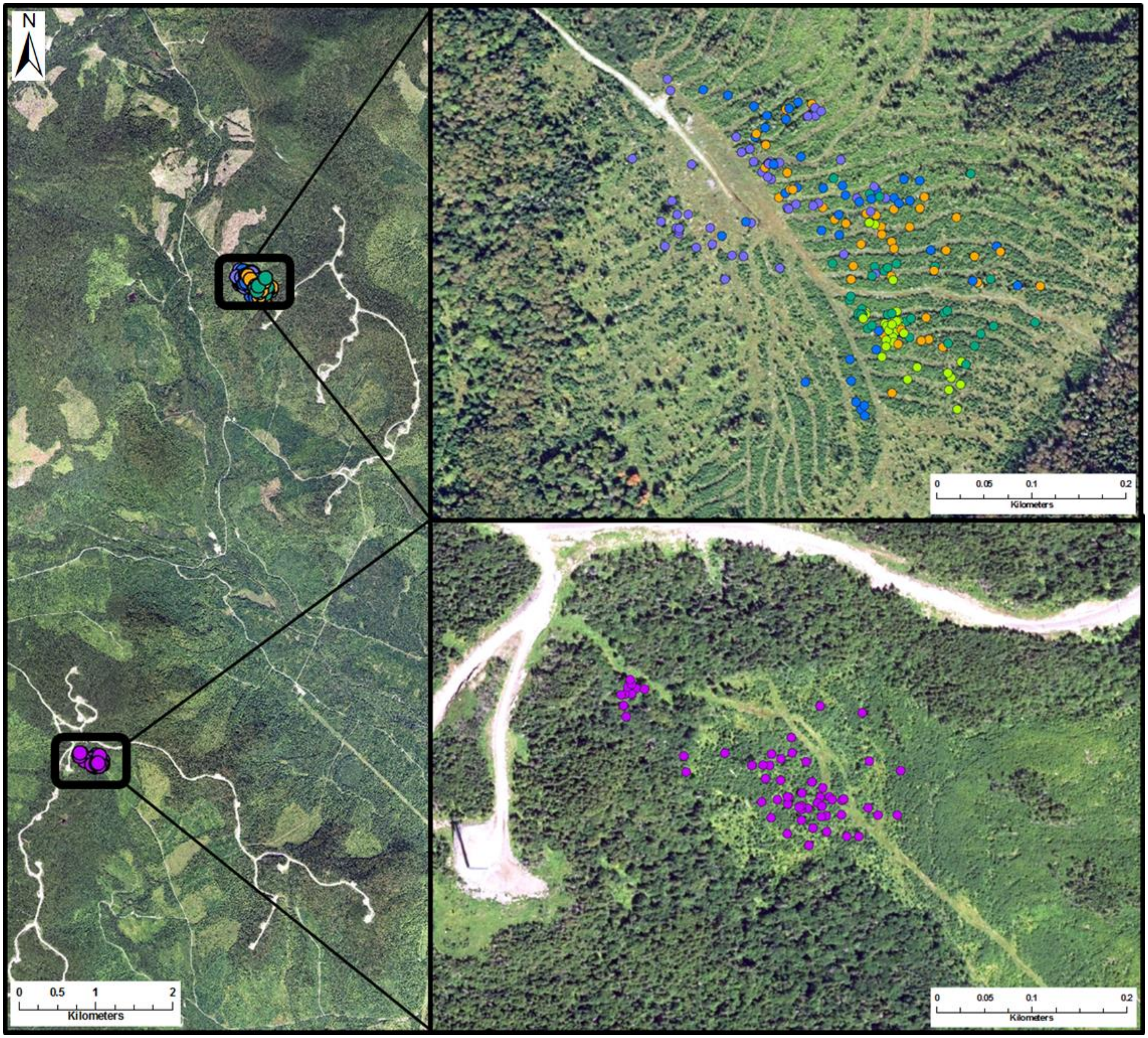


Figure 14. Bicknell's thrush locations at Kibby Mountain (harvested landscape) during the 2018 breeding season. Each color represents an individual bird that was tracked throughout the breeding season.

Future Plans:

- Complete analysis of 2018 data.
- Investigate the use of archival GPS tags for the 2019 breeding season.
- Capture and radio-mark 20 Bicknell's thrush during the 2019 breeding season.
- Obtain inventory data for both study sites from our collaborators to ground truth LiDAR models.
- Gather Bicknell's thrush survey data collected using the Mountain Bird Watch protocol from partners in Maine.

Acknowledgements:

We would like to acknowledge Weyerhaeuser and the U.S. Navy for access to their lands. Specifically, thank you to Henning Stabins and Ian Trefy. We gratefully acknowledge Elias Ayrey for his assistance with LiDAR modeling. Additionally, we acknowledge Wilson's graduate advisory committee members, Adrienne Leppold, Erik Blomberg, and Dan Hayes, for their continued input and support for this project. We are very grateful to the CFRU office staff, Leslee Canty-Noyes, Jenna Zukswert, and Brian Roth, for their support and assistance prior to and during the 2018 field season. We gratefully acknowledge CFRU, Maine Agricultural and Forest Experiment Station, and The Nature Conservancy for providing funding for this research. Finally, we acknowledge NextEra Energy, Vermont Center for Ecostudies, and TRC Environmental Corporation for providing Bicknell's thrush survey data.

Development of Large-Scale Optimal Monitoring Protocols for Carnivores

Alessio Mortelliti, Bryn Evans

University of Maine

Status: Progress Report (Year 1)

Evans sets up a trail camera
Photo: H. Haverkamp

Summary:

This is a multi-year, collaborative research project between the University of Maine, the Maine Department of Inland Fisheries and Wildlife, and the Cooperative Forestry Research Unit. We began with a pilot season during winter 2017 to test configurations of trail cameras to detect multiple carnivore species, followed by a summer of large-scale surveys. Year 1 of the CFRU project from October 2017 to September 2018 encompassed the first full-scale winter surveys, as well as the second summer season expanding into new regions and revisiting a subset of prior sites. We also cataloged the camera trap data by species observed in each image for the first year of surveys, and conducted preliminary occupancy models indicating interesting trends for top priority species and that the robust study design will provide valuable information to managers and researchers interested in how forestry practices and wild carnivore population dynamics interact.

Project Objectives:

- Understand the current patterns of presence for diverse carnivore species native to Maine.
- Investigate relationships among different species, and between species and landscape features. This will be achieved by conducting a multiple year, multiple season study following a balanced study design. Survey effort will span across different levels of timber harvest in northern Maine (which are known to influence population parameters for carnivores, e.g., Simons 2009), as well as the configuration of harvest types and multiple geographic locations.
- Assess the efficacy of trail cameras to monitor carnivore species long-term. This will include explicitly addressing trade-offs between different aspects of study design (number of stations deployed, length of deployment, etc.) and how these affect the precision of estimates and the power to detect changes in population status for different species.

Approach:

- We are using motion-triggered trail cameras, an increasingly popular and cost-effective tool to research cryptic wildlife species (Burton *et al.* 2015).

- Our survey locations were selected for carnivores throughout northern Maine using a balanced study design, including different degrees of timber harvest and landscape features (Figure 15).

- We are taking a multi-step approac. First, we assessed the ideal number and spacing of baited trail camera units to detect carnivores, particularly cryptic and difficult to detect species such as marten, fisher and coyote. Over this year and into the next years of the project, we are expanding surveys using this station design across much of northern Maine.

- Our analytical approaches will use occupancy models (MacKenzie *et al.* 2017) to explore relationships between both detection probability and occupancy patterns for carnivore species individually, in relation to other species, and over time and space.

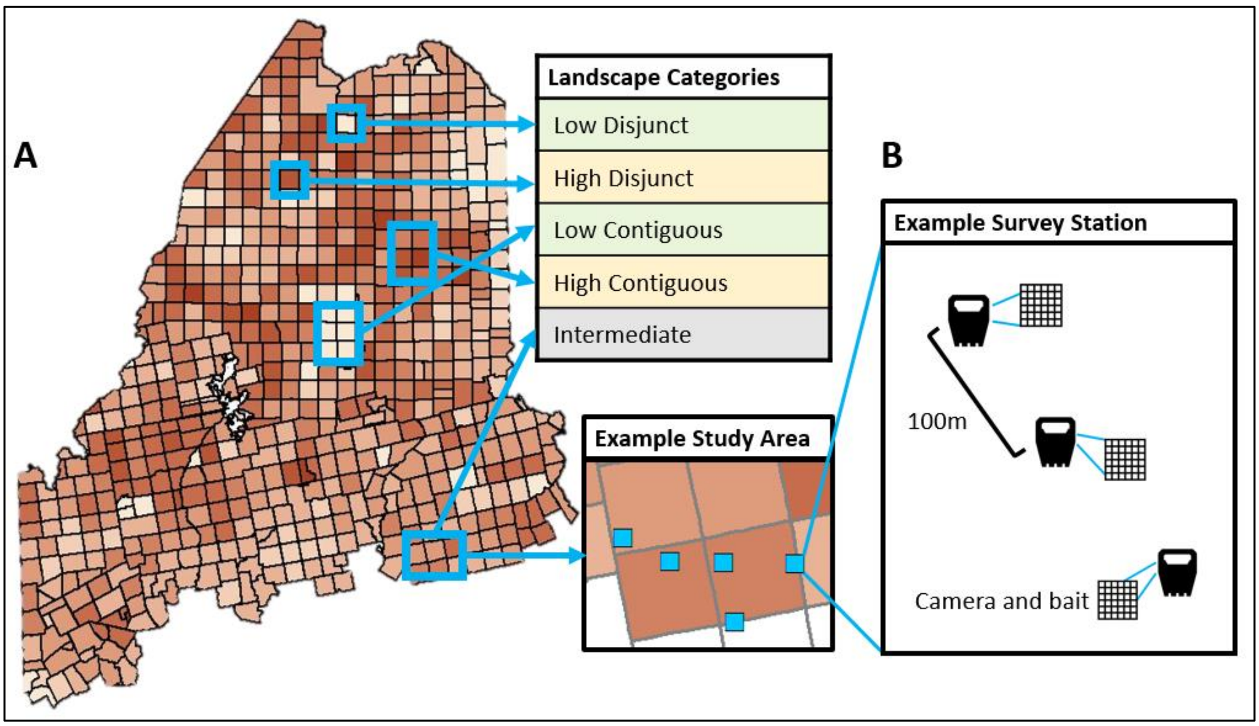


Figure 15. A) Study design incorporating overall timber harvest at the township scale (low, intermediate, and high) and the landscape configuration (disjunct and contiguous), as well as balancing survey effort geographically (north to south, not shown). B) Configuration of three motion triggered trail cameras, spaced 100 m apart and each facing beaver meat bait attached to a tree and scent lure (as established during our pilot season).

Key Findings/Accomplishments:

- From our pilot season, we selected the optimal arrangement and spacing of trail cameras using multi-method analyses in program Presence (Hines *et al.* 2006, Nichols *et al.* 2008). We selected an array of three cameras, with bait and lure, spaced 100 m apart to most effectively collect information on elusive carnivores in Maine, prioritizing marten, fisher, and coyote.

- During our first full year of large-scale surveys, we surveyed 120 sites in both summer and in winter, in 15 distinct study areas, for a minimum of two weeks each. From these data, we have conducted preliminary analyses on detection rates (Figure 16), as well as an initial exploration of occupancy status and between-season fluctuations using the multi-season modeling approach in R package ‘unmarked’ (MacKenzie *et al.* 2003, Fiske and Chandler 2011).

- Prior to our second summer field season, we selected sites representative of the first year study design components to be “permanent” survey locations, to allow analyses of trends over the four year project, as well as sites in new study areas to expand our geographic coverage and include areas of intermediate timber harvest.

- From June to October 2018, we surveyed 40 permanent sites and 48 new sites for a minimum of three weeks each. Sampling fewer points in a season allowed for the longer survey period, which will enable a comparison of the overall benefit of addition weeks per survey. Table 6 summarizes our survey effort over either completed or planned for the first two years of the project. Figure 17 shows the geographic distribution of survey sites.

Table 6. Balanced study design to date, including north and south, timber harvest amount, and landscape configuration.

<table>
<tr><th rowspan="2">Region</th><th rowspan="2">Timber Harvest</th><th rowspan="2">Landscape</th><th rowspan="2">Stations 2017–18</th><th colspan="2">Stations 2018–19*</th></tr>
<tr><th>Permanent</th><th>New</th></tr>
<tr><td rowspan="6">North</td><td rowspan="2">Low harvest</td><td>Disjunct</td><td>13</td><td>5</td><td></td></tr>
<tr><td>Contiguous</td><td>17</td><td>5</td><td></td></tr>
<tr><td rowspan="2">High harvest</td><td>Disjunct</td><td>13</td><td>5</td><td></td></tr>
<tr><td>Contiguous</td><td>17</td><td>5</td><td></td></tr>
<tr><td rowspan="2">Intermediate</td><td>Low harvest surrounding</td><td></td><td></td><td>12</td></tr>
<tr><td>High harvest surrounding</td><td></td><td></td><td>13</td></tr>
<tr><td rowspan="6">South</td><td rowspan="2">Low harvest</td><td>Disjunct</td><td>16</td><td>5</td><td></td></tr>
<tr><td>Contiguous</td><td>17</td><td>5</td><td></td></tr>
<tr><td rowspan="2">High harvest</td><td>Disjunct</td><td>14</td><td>5</td><td></td></tr>
<tr><td>Contiguous</td><td>14</td><td>5</td><td></td></tr>
<tr><td rowspan="2">Intermediate</td><td>Low harvest surrounding</td><td></td><td></td><td>11</td></tr>
<tr><td>High harvest surrounding</td><td></td><td></td><td>12</td></tr>
<tr><td colspan="6">* Anticipated for upcoming winter 2019 season</td></tr>
</table>

Figure 16. Naïve detection results for six species of carnivores in Maine, from summer and winter camera stations in 2017–18. Use of bait and lure, and an array of three trail cameras, increased detection probability for marten, fisher, and coyote as seen during our pilot season. Bobcat, lynx, and bear were detected at higher levels as we expanded geographically and included summer surveys.

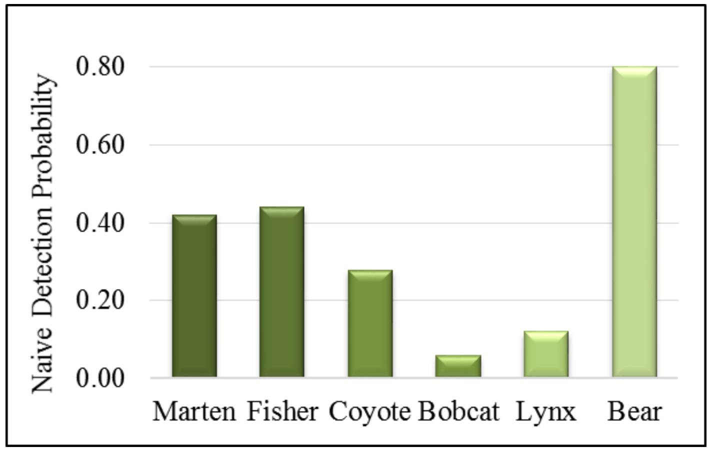
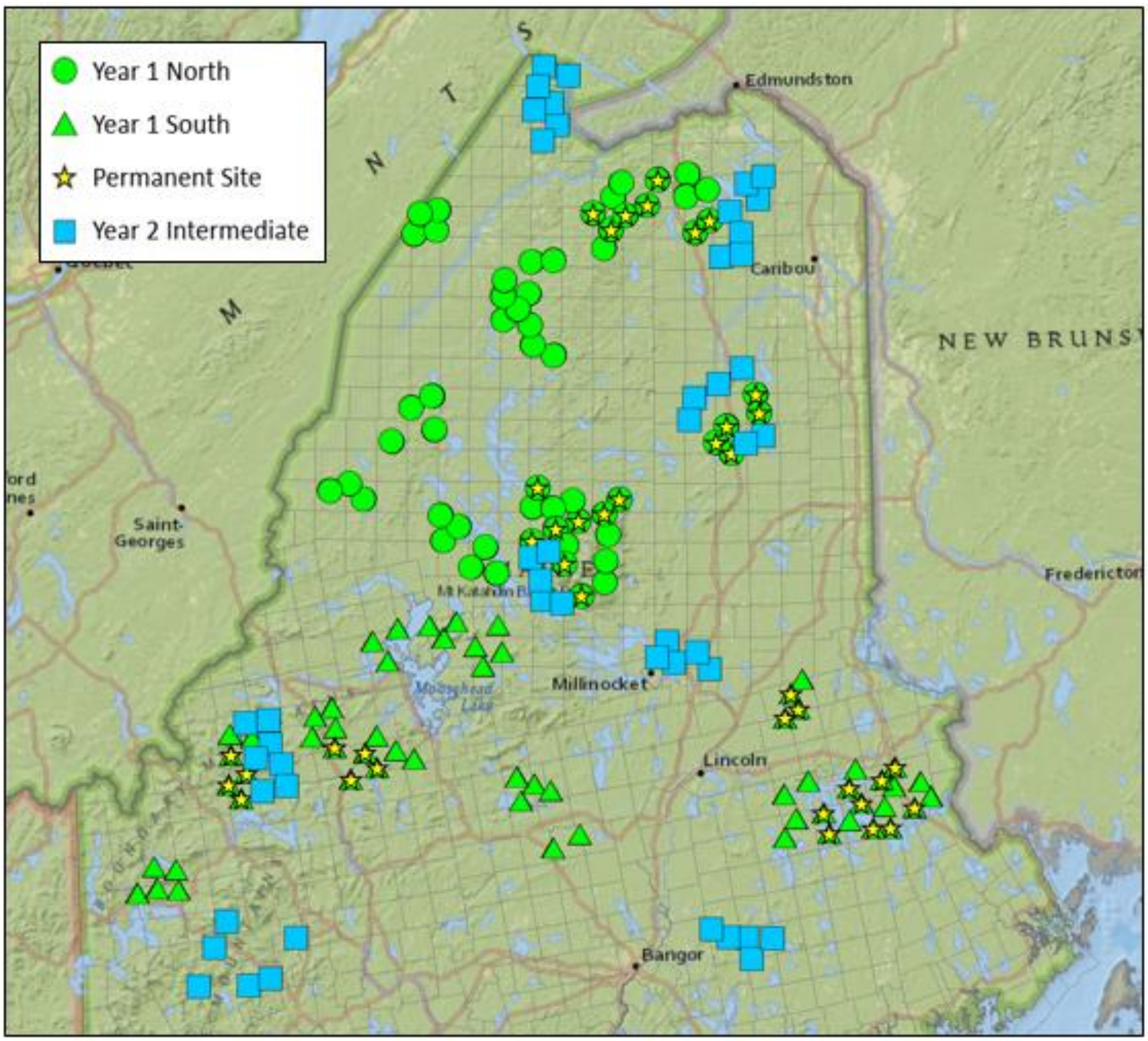


Figure 17. Study areas and survey points completed during summer and winter of the first full year (Year 1) and expected to be completed over winter 2019 (Year 2).



Summer trail camera success: Resting lynx

Winter visitor: Fisher feeding on bait

Summer field work, a stroll through the park. (Bobby Brightingham and Rose Crispin)

Winter field work is ALSO a stroll through the park! (Meg Gilmartin)

Images: Bryn Evans

Future Plans:

- Year 2 of the CFRU project funds will include our second full-scale winter survey and our third summer survey period.

- From January to April 2019, we (Bryn Evans, Bill Thomas, Alessio Mortelliti) will revisit 88 sites and collect a minimum of three weeks of data at each.

- Following the winter field season, we will incorporate the second full year of surveys into our multi-season models, as well as focus on analyzing patterns of multiple coexisting carnivore species (particularly marten and fisher) using the multi-species adaptations for occupancy models (Rota *et al.* 2016)

- From June to September 2019, we will conduct a third summer of surveys, revisiting our subset of permanent sites as well as visiting new sites to ensure balanced survey effort across landscape variables.

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Burton, A. C., E. Neilson, D. Moreira, A. Ladle, R. Steenweg, J. T. Fisher, E. Bayne, and S. Boutin. 2015. Wildlife camera trapping: a review and recommendations for linking surveys to ecological processes. Journal of Applied Ecology 52: 675–68.

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Rota, C. T., M. A. R. Ferreira, R. W. Kays, T. D. Forrester, E. L. Kalies, W. J. McShea, A. W. Parsons, and J. J. Millspaugh. 2016. A multispecies occupancy model for two or more interacting species. Methods in Ecology and Evolution 7(10): 1164–73.

Simons, E. M. 2009. Influences of past and future forest management on the spatiotemporal dynamics of habitat supply for Canada lynx and American martens in northern Maine. Dissertation, University of Maine, Orono.

Acknowledgements:

We very much appreciate all the assistance from Brian Roth, who provided essential early introductions and contact details for many of the collaborating CFRU landowners! Both Jenna Zukswert and Leslee Canty-Noyes continue to provide amazing support throughout our CFRU collaboration. Also, a big thank you to Holland Haverkamp and Elysa Catalina for documenting our work in progress!

Landscape-Level Evaluation of Deer Wintering Habitat in Northern Maine

Mindy S. Crandall[1], Amber Roth[1], Erin Simons-Legaard[1], Anthony Guay[1] Karin Bothwell[1], Daniel Hayes[1], Brian Roth[2]

[1]University of Maine
[2]Cooperative Forestry Research Unit

Spruce-fir canopy in deer wintering area. Photo: K. Bothwell.

Status: Final Report

Summary:

The goal of this project was to expand current wildlife habitat, forest management, and landscape dynamics knowledge in a novel way, bridging previous work and newly available spatial data to contribute information that will help *reduce landowner uncertainty and achieve better habitat results in deer wintering areas*. To date, we have completed a region-wide analysis to identify areas that currently exhibit the characteristics of white-tailed deer wintering habitat and a quantitative evaluation of that habitat's distribution. Results confirmed that the original zones effectively protected patches of softwood-dominated forest from intensive timber harvests; many patches of potential wintering habitat persist across northern Maine and tend to be aggregated on the landscape. Specific deer wintering area boundaries were digitized from aerial surveys conducted during winter in 1957–2015 across northern Maine. We developed two deer habitat quality models, one using the Maine Department of Inland Fisheries and Wildlife's deer wintering areas management guidelines for primary and secondary winter shelter and the second also includes basking habitat within 250 m of the winter shelter. Historically occupied deer wintering areas continue to have a high proportion of high-quality wintering habitat. The deer wintering areas for which we have the most recent occupancy information (1990s in Maine, 2000s–2010s in New Brunswick) had the lowest proportion of high-quality wintering habitat, suggesting that deer may be selecting these deer wintering areas, at least in part, for other reasons.

Project Objectives:

- Quantify the quality and distribution of deer wintering habitat at broad and fine scales.
- Compile spatial and temporal maps of deer occupancy for Maine across ownerships and agencies using best knowledge available over the past 40 years.

- Expand and standardize recent Landsat habitat evaluation maps to cover northern Maine.

- Scale up the estimation of opportunity costs associated with habitat management for deer.

- Develop two predictive spatially explicit habitat quality models (HQMs) from digital elevation models (DEMs), Enhanced Forest Inventory (EFI) metrics derived from LiDAR, traditional forest inventories, and expert observer opinion.

- Develop ecological based habitat models using winter occupancy of deer as quality indicator.

- Map the existing distribution of deer wintering habitat quality on a landscape level using a combination of available 3-D LiDAR and Landsat imagery.

- Assess landscape-level risk of spruce budworm induced tree mortality in deer wintering habitat in northern Maine as expected during the next outbreak.

Approach:

- *Deer wintering area maps* were generated by digitizing hand-drawn maps from aerial deer wintering area surveys conducted by Maine Inland Fisheries and Wildlife. Other deer wintering area survey information from J.D. Irving was also acquired. Differences in survey methodology prevented combining these spatial data into a single digital layer (GIS map).

- *Expanded habitat quantity map development* utilized a newly-available dataset of forest disturbance and high-resolution predictions of tree species percent biomass to generate a refined map of potential deer wintering habitat spanning 10 million acres (Figure 18).

- *Habitat quality models* were developed from EFI data from LiDAR, state guidelines for deer wintering habitat, and deer occupancy information. The study area for this effort is restricted to areas with access to EFI as well as historical occupancy information in five study site clusters in northern Maine and western New Brunswick (Figure 18).

- *Landscape simulations and accounting for disturbance risk*: Risk of mortality by spruce budworm and the impacts on deer habitat areas will be assessed using LANDIS-II.

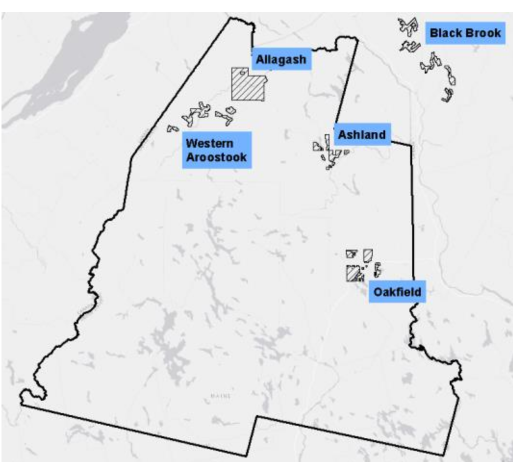


Figure 18. Project study area, including 10 million-acre area (bold black outline) used for expanded map of potential deer wintering habitat and five study site clusters in northern Maine and western New Brunswick (black hatched areas) that were the area of interest for the deer wintering habitat quality models.

Key Findings/Accomplishments:

- While deer wintering area management restrictions can result in a financial loss relative to a business-as-usual scenario, this finding is not universal and is highly dependent on landowner objectives and starting stand conditions. Further work is needed to expand calculations to a landscape level.

- Deer wintering area boundaries were digitized from aerial surveys conducted during winter in 1957–2015 across northern Maine and western New Brunswick. Deer wintering area occupancy information from Maine was collected in 1957–99 (17 years with data) and 2003–15 (4 years with data) in New Brunswick. No deer surveys were conducted in years when snow conditions were inappropriate for an area. As a result, not all study site clusters were surveyed within a year, and there were many years when no surveys were conducted anywhere in the study area.

- We developed two deer habitat quality models, one using the Maine Inland Fisheries and Wildlife's "Guidelines for Wildlife: Managing Deer Wintering Areas in Northern, Western and Eastern Maine (version 2.4.10)" to map primary and secondary winter shelter and the second also included basking habitat within 250 m of the winter shelter (Figure 19). Contrary to our prediction, the proportion of non-winter deer habitat (i.e., anything other than winter shelter and basking habitat) did not decline since time of deer wintering area occupancy (Figure 19). Historically occupied deer wintering areas continue to have a high proportion of high-quality wintering habitat, both winter shelter and basking habitat. Deer wintering areas occupied in the 1990s (Maine) and 2000–2010s (New Brunswick) suggest that these most recently occupied deer wintering areas have the lowest proportion of high-quality wintering habitat.

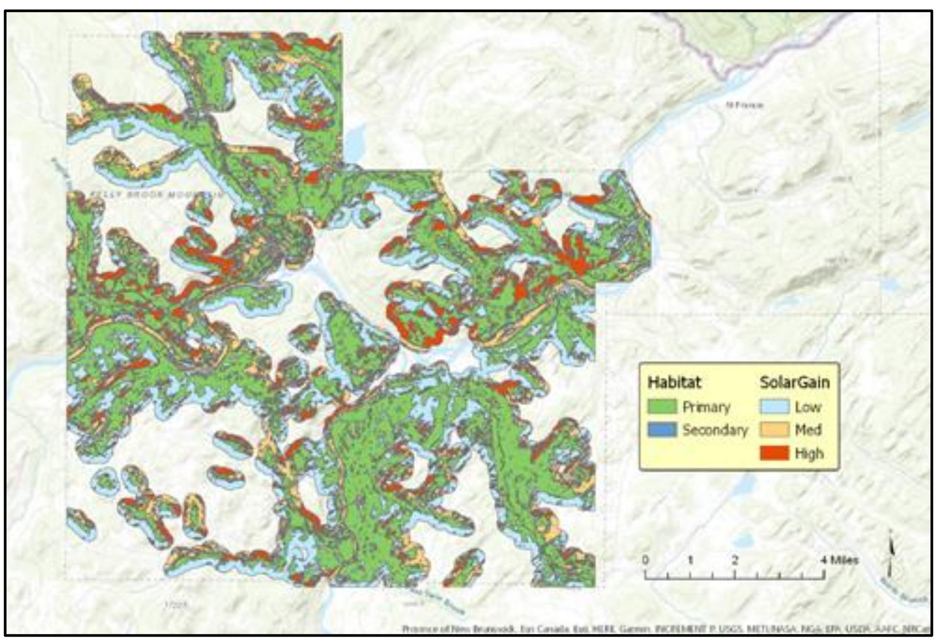


Figure 19. Phase 2 deer habitat quality model for the Allagash, Maine study site cluster. This model includes both winter shelter (primary and secondary winter shelter as defined by the Maine Department of Inland Fisheries and Wildlife guidelines for managing deer wintering areas) and solar gain (or basking habitat) divided into low-, medium-, and high-quality basking habitat.

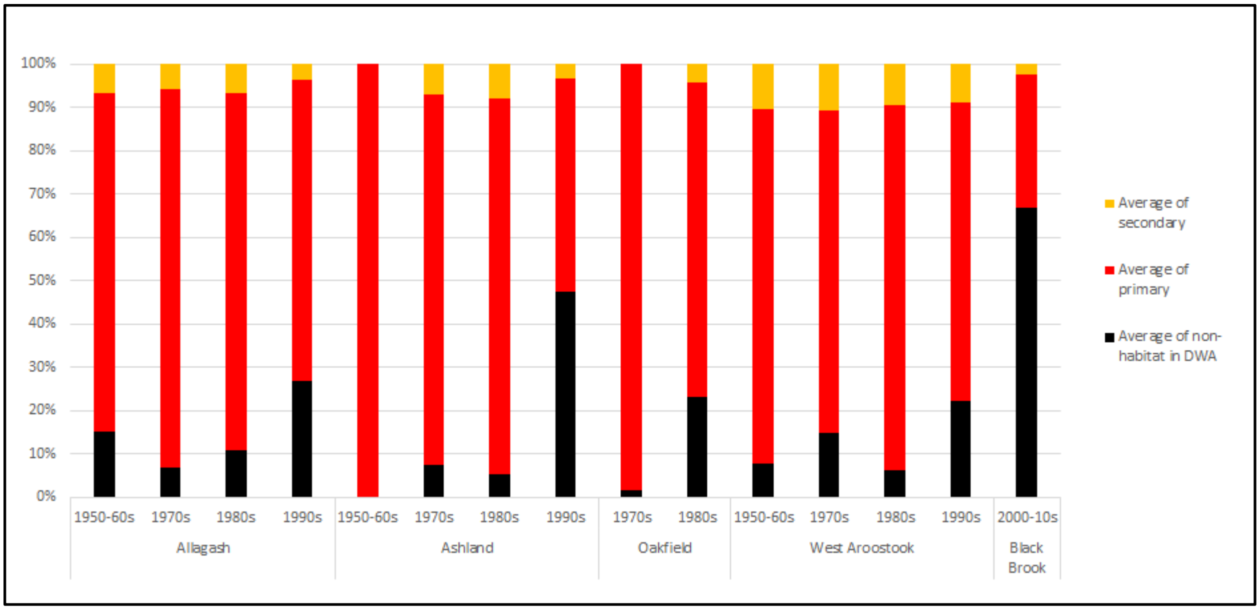


Figure 20. The proportion of primary and secondary winter shelter to non-habitat within deer wintering areas was lowest in the most recent decade of deer surveys for each study site cluster. Note that the years for aerial deer surveys differed by study site cluster due to varying snow conditions.

- We identified four key issues with the deer habitat quality model development that should be addressed in future models. First, our study site clusters were not clipped to deer wintering areas because these areas were being digitized into a GIS concurrently with habitat model development. Second, we modeled canopy cover based on leaf-on LiDAR data but this metric would be more accurately modeled for winter shelter using leaf-off LiDAR data. Third, we assumed that canopy cover was highly correlated with canopy closure which we know is inaccurate. Canopy closure is difficult to measure from LiDAR data, and a procedure has yet to be developed by anyone in the field. Finally, the lack of recent/current deer wintering area occupancy information precluded comparing them to historically occupied deer wintering areas.

- We defined the composition component of deer wintering habitat based on the four most abundant tree species (which were northern white-cedar, balsam fir, red spruce, and black spruce), within the 373 Fish and Wildlife Protection subdistricts (P-FWs) that occurred within our 10 million-acre study area. Average relative abundance within the P-FWs for these species were 22%, 20%, 17%, and 10%, respectively. In combination, the four species represented 69% of the relative abundance of live tree biomass on average; one of the four species was the dominant species in 94% (350 out of the 373) of the P-FWs in our study area.

- In total, 744,875 ha of mature forest (i.e., > 40 years old) had the compositional characteristics associated with P-FWs (Figure 21a). Seventy-nine percent (591,399 ha) of this deer wintering habitat occurred in patches greater than or equal to 10 ha. P-FWs commonly encompassed portions of larger habitat patches (Figure 21b).

- Simulations suggested landscape-scale risk of budworm mortality varied widely by P-FW, and was strongly influenced by the local dominance of host species (Figure 22).

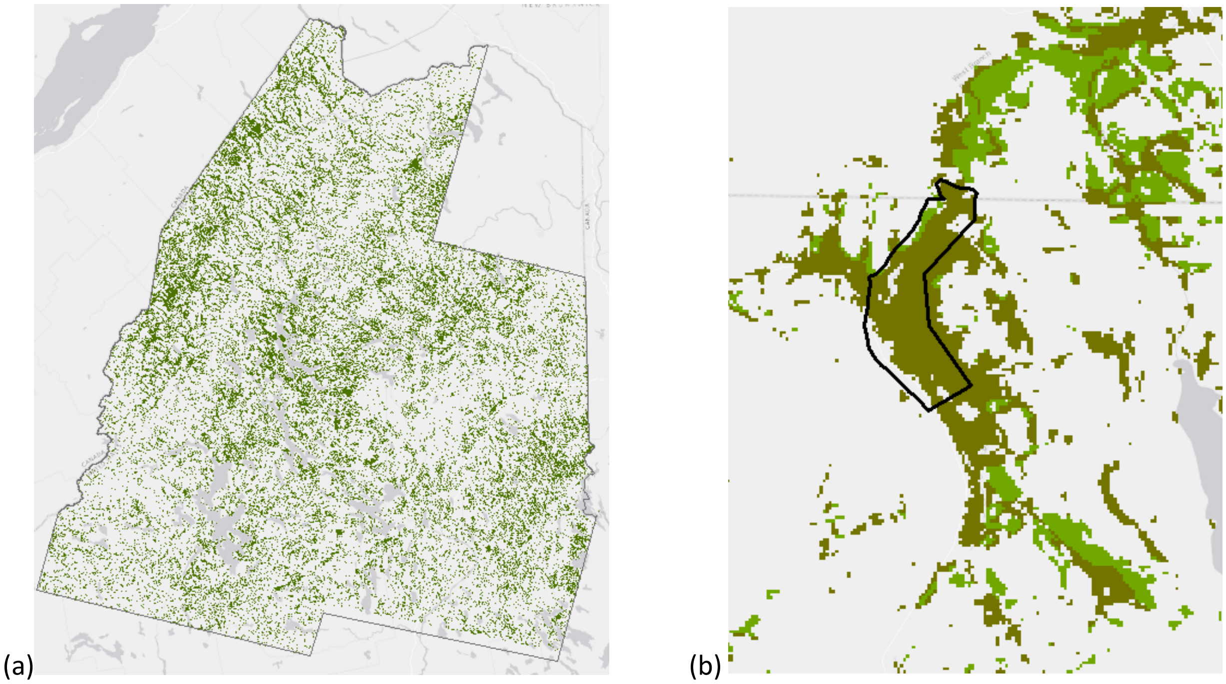


Figure 21. Distribution of deer wintering habitat across our 10 million-acre study area (a). Habitat was identified based on forest maturity (> 40 years old) and relative abundance of the 4 tree species identified as most common in LUPC-designated Fish and Wildlife Protection subdistricts (P-FWs), which were northern white-cedar, balsam fir, red spruce, and black spruce. P-FWs (b; black outline) commonly encompassed portions of large patches of potential deer wintering habitat (dark green) and immature (< 40 years old) habitat (light green).

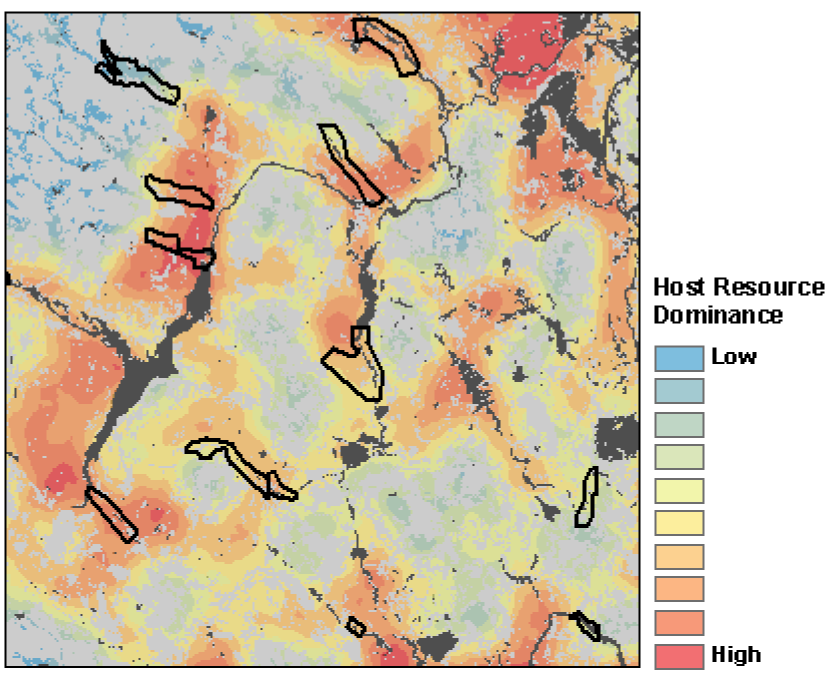


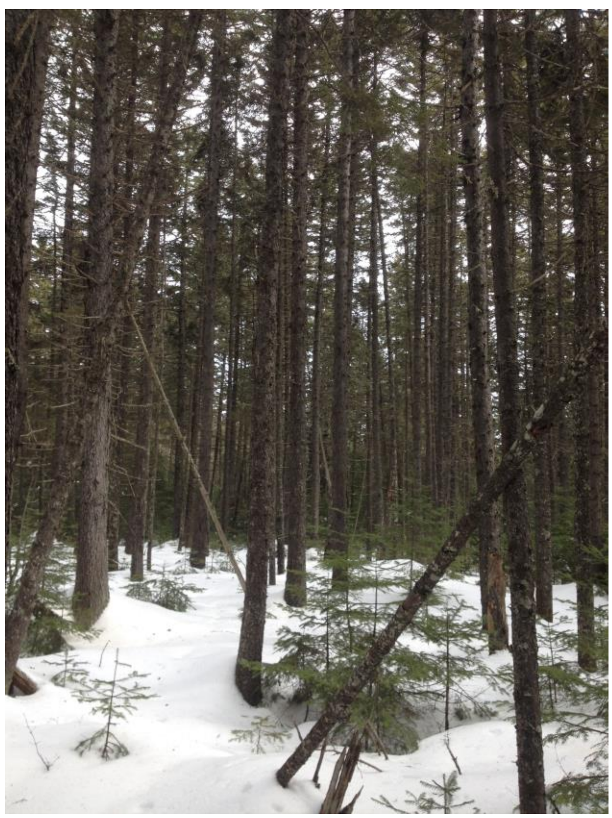
Figure 22. Simulated risk of spruce budworm mortality varied across the study area with dominance of host species.

Future Plans:

- Continue to prepare journal submissions as appropriate.
- Outreach to potential collaborators for a project to extend and refine the mapping work is underway.
- Expanded project being considered for submission next cycle (January 2020).

Acknowledgements:

We gratefully acknowledge the assistance and cooperation of CFRU landowners, including J.D. Irving, Weyerhaeuser Company Downeast Lakes Land Trust, Appalachian Mountain Club, Seven Islands Land Company, Katahdin Forest Management, LLC, and the Penobscot Experimental Forest. LiDAR data was provided by Jon Gilbert and Chris Huston at J.D. Irving. Initial LiDAR analysis was conducted by Elias Ayrey. Deer wintering area boundary digitizing was completed by Karin Bothwell and Cassandra Carroll. Technical assistance was provided by Ryan Robicheau, Kyle Ravana, Nathan Bieber, and Chuck Hulsey at Maine Department of Inland Fisheries and Wildlife. Field data was collected by Rich Hoppe, Chuck Hulsey, and Steve Dunham.



Mature softwood adjacent to areas of regeneration; these conditions could provide shelter to wintering deer through stand development.
Photo: K. Bothwell.

APPENDIX

CFRU Products Delivered During 2017–18

Photo: B. Roth

CFRU Publications and Products
October 2017 – September 2018

Refereed Journal Publications:

Andrews, C., A. Weiskittel, A. W. D'Amato, and E. Simons-Legaard. 2018. Variation in the maximum stand density index and its linkage to climate in mixed species forest of the North American Acadian Regio. Forest Ecology and Management 417: 90–102.

Bose, A. K., A. Weiskittel, C. Kuehne, R. G. Wagner, and E. Turnblom. 2017. Does commercial thinning improve stand-level growth of the three most commercially important softwood forest types in North America? Forest Ecology and Management 409: 683–693.

Castle, M., A. Weiskittel, R. Wagner, M. Ducey, J. Frank, and G. Pelletier. 2018. Evaluating the influence of stem form and damage on individual-tree diameter increment and survival in the Acadian Region: Implications for predicting future value of northern commercial hardwood stands. Canadian Journal of Forest Research 48: 1007–1019.

Frank, J. M. E. Castle, J. A. Westfall, A. R. Weiskittel, D. W. MacFarlane, S. K. Baral, P. J. Radtke, and G. Pelletier. 2018. Variation in occurrence and extent of internal stem decay in standing trees across the eastern US and Canada: Evaluation of alternative modelling approaches and influential factors. Forestry 91: 382–399.

Koirala, A., A. R. Kizha., and S. M. De Urioste-Stone. 2017. Policy recommendation from stakeholders to improve forest products transportation: A qualitative study. Forests 8, 434; doi: 10.3390/f8110434

Kuehne, C., A. Weiskittel, A. Pommerening, and R. G. Wagner. 2018. Evaluation of 10-year temporal and spatial variability in structure and growth across contrasting commercial thinning treatments in spruce-fir forests of northern Maine, USA. Annals of Forest Science 75: 20.

Preece, C., C. T. Smith, B. Roth, R. Briggs, and I. Fernandez. 2018. Long-term effects of harvest residues on spruce-fir site productivity following whole-tree and stem-only harvesting. Forest Ecology and Management. *In prep.*

Puhlick, J. J., C. Kuehne, and L. S. Kenefic. 2018. Crop tree growth response and quality after silvicultural rehabilitation of cutover stands. Canadian Journal of Forest Research; doi: 10.1139/cjfr-2018-0248

Rahimzadeh-Bajgiran, P., A. R. Weiskittel, D. Kneeshaw, and D. A. MacLean. 2018. Detection of annual spruce budworm defoliation and severity classification using Landsat imagery. Forests 9, 357; doi: 10.3390/f906035.

Rolek, B. W., D. J. Harrison, C. S. Loftin, and P. B. Wood. 2018. Regenerating clearcuts combined with postharvest forestry treatments promote habitat for breeding and post-breeding spruce-fir avian assemblages in the Atlantic Northern Forest. Forest Ecology and Management 427: 392–413.

Simons-Legaard, E. M., D. J. Harrison, and K. R. Legaard. 2018. Ineffectiveness of local zoning to reduce regional loss and fragmentation of wintering habitat for white-tailed deer. Forest Ecology and Management 427: 78–85.

Soman H, A. R. Kizha., B. E. Roth. 2018. Impacts of silvicultural prescriptions and implementation of best management practices on timber harvesting costs. International Journal of Forest Engineering. *In press*.

Wesely, N. S. Fraver, L. S. Kenefic, A. R. Weiskittel, J.-C. Ruel, M. E. Thompson, and A. S. White. 2018. Structural attributes of old-growth and partially harvested northern white-cedar stands in northeastern North America. Forests 9, 376; doi: 10.3390/f9070376.

Research Reports & Conference Papers/Posters:

Evans, B. E., C. Mosby, and A. Mortelliti. Large scale monitoring for carnivores in Maine, USA: Assessing linear arrays of multiple trail cameras to increase detection success. International Martes Working Group Symposium, July/August 2018, Ashland, Wisconsin. Poster.

Preece, Chris, C. T. Smith, B. Roth, R. Briggs, and I. Fernandez. 2018. Long-term effects of harvest residues on spruce-fir site productivity following whole-tree and stem-only harvesting. Governing sustainability of bioenergy, biomaterial and bioproduct supply chains from forest and agricultural landscapes. April 2018, Copenhagen, Denmark. Poster.

Preece, Chris, C. T. Smith, B. Roth, R. Briggs, and I. Fernandez. 2018. Long-term effects of harvest residues on spruce-fir site productivity following whole-tree and stem-only harvesting. North American Forest Soils Conference – International Symposium on Forest Soils, June 2018, Québec City, Québec. Poster.

Rezai-Stevens, A., C. T. Smith, B. Roth, R. Briggs, and I. Fernandez. 2018. Long-term effects of whole-tree harvesting and residue management on spruce-fir soil quality in central Maine. North American Forest Soils Conference – International Symposium on Forest Soils, June 2018, Québec City, Québec. Poster.

Soman, H., E. Nahor, and A. R. Kizha. Evaluating operational cost and residual stand conditions in varying silvicultural prescriptions. 41st Annual Meeting of the Council on Forest Engineering, July 2018, Williamsburg, Virginia.

Theses and Capstone Reports:

Nahor, E. 2018. Residual stand damage: A comparison of silvicultural prescriptions. Capstone paper, University of Maine, Orono.

Preece, C. J. 2018. Long-term effects of harvest residues on spruce-fir forest growth following whole-tree and stem-only harvesting at Weymouth Point. MFC thesis, University of Toronto, Ontario.

Newspapers/Periodicals/Television/Webpages:

Catalina, E. 2018. Carnivores on Camera. UMaine Today Fall/Winter 2018 and online feature with video: umainetoday.umaine.edu/stories/2018/carnivores-on-camera

Other Publications:

Kenefic, L. S., K. M. Gerndt, J. J. Puhlick, and C. Kuehne. 2018. Overstory tree and regeneration data from the "Rehabilitation of cutover mixedwood stands" study at Penobscot Experimental Forest. Fort Collins, CO: Forest Service Research Data Archive. *In review*.

Presentations/Workshops/Meetings/Field Tours:

Castonguay, M., J. Ogilvie, and P. A. Arp. Development of the next generation of wet areas mapping (WAM) for Maine. Long-Term Site Productivity Research: Lessons from Other Regions and Opportunities for Maine (CFRU workshop), June 2018, Orono, Maine.

Johns, R. and E. Owens. 2018. The Spruce Budworm Early Intervention Program in New Brunswick. Presentation to Keeping Maine's Forests Board, September 2018, Bangor, Maine.

Kenefic L., A. Kizha, S. Fraver, A. Roth, K. Kanoti, and D. Rocque. Silviculture and operations in lowland northern white-cedar. US-Canada Cedar Club meeting, May 2018, Québec City, Québec.

Kizha., A. R., B. E. Roth, and H. Soman. Best management practices for varying silvicultural prescriptions: Evaluating the cost and impact of soil protection. 2017 Society of American Foresters Convention, November 2017, Albuquerque, New Mexico.

Kizha., A. R. Harvest productivity, residual stand damage, and soil disturbance. Outcome Based Forestry and Long-Term Research: CFRU Fall Field Tour, September 2018, Irving Woodlands, LLC in Ashland, Maine

Kizha., A. R. Impacts of timber harvesting on site and stand quality. Long-Term Site Productivity Research: Lessons from Other Regions and Opportunities for Maine (CFRU workshop), June 2018, Orono, Maine.

Puhlick, J. J. Crop tree growth response and quality after silvicultural rehabilitation of cutover stands. CFRU Winter Advisory Committee Meeting, January 2018, Orono, Maine.

Puhlick, J. J., C. Kuehne, and L. S. Kenefic. Crop tree growth response and quality after silvicultural rehabilitation of cutover stands. New England Society of American Foresters Winter Meeting, March 2018, Nashua, New Hampshire.

Puhlick, J. J. Opportunities for assessment of long-term site productivity across contrasting sites in Maine. Long-Term Site Productivity Research: Lessons from Other Regions and Opportunities for Maine (CFRU workshop), June 2018, Orono, Maine.

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

Rahimzadeh-Bajgiran, P., A. Weiskittel, D. Kneeshaw, and D. A. Maclean. A multi-index Landsat-derived model for annual spruce budworm defoliation detection and severity classification. CFRU Winter Advisory Committee Meeting, January 2018, Orono, Maine.

Roth, B. E. 2018. Introduction to Maine's Adaptive Silviculture Network. CFRU Fall Field Tour: Outcome Based Forestry and Long-Term Research, September 2018, T16 R8, Maine.

Roth, B. E. MASN and Weymouth Point Project Updates. CFRU Winter Advisory Committee Meeting, January 2018, Orono, Maine.

Roth, B. E., and S. Mathes. 2018. A Review of Recent CFRU Research Projects and Planning for the MASN Installation at Stetsontown. Wagner Forest Management Foresters' Training Day, May 2018, Forks, Maine.

Roth, B. E., C. Lachance, R. Wagner, and J. Benjamin. Influence of severe soil disturbance on crop tree growth and species composition 32 years following harvesting in a Maine spruce-fir stand. New England Society of American Foresters Winter Meeting, March 2018, Nashua, New Hampshire.

Roth, B., J. Puhlick, A. Kizha., T. Gilman, A. Guay, D. Sandilands, and P. Arp. 2018. Long-Term Site Productivity Research: Lessons from Other Regions and Opportunities for Maine Field Tour of AFM MASN Installation. June 8th, 2018 Grand Falls TWP, Maine.

Roth, B. E. The Cooperative Forestry Research Unit and the value of long-term research. Long-Term Site Productivity Research: Lessons from Other Regions and Opportunities for Maine (CFRU workshop), June 2018, Orono, Maine.

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Anil Kizha. and his student Noel Lienert present a poster in the field at the "Long-Term Site Productivity Research: Lessons from Other Regions and Opportunities for Maine" field tour in June.
Photo: B. Roth.

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