CFRU

Center for Research on Sustainable Forests

MAINE

COOPERATIVE FORESTRY RESEARCH UNIT

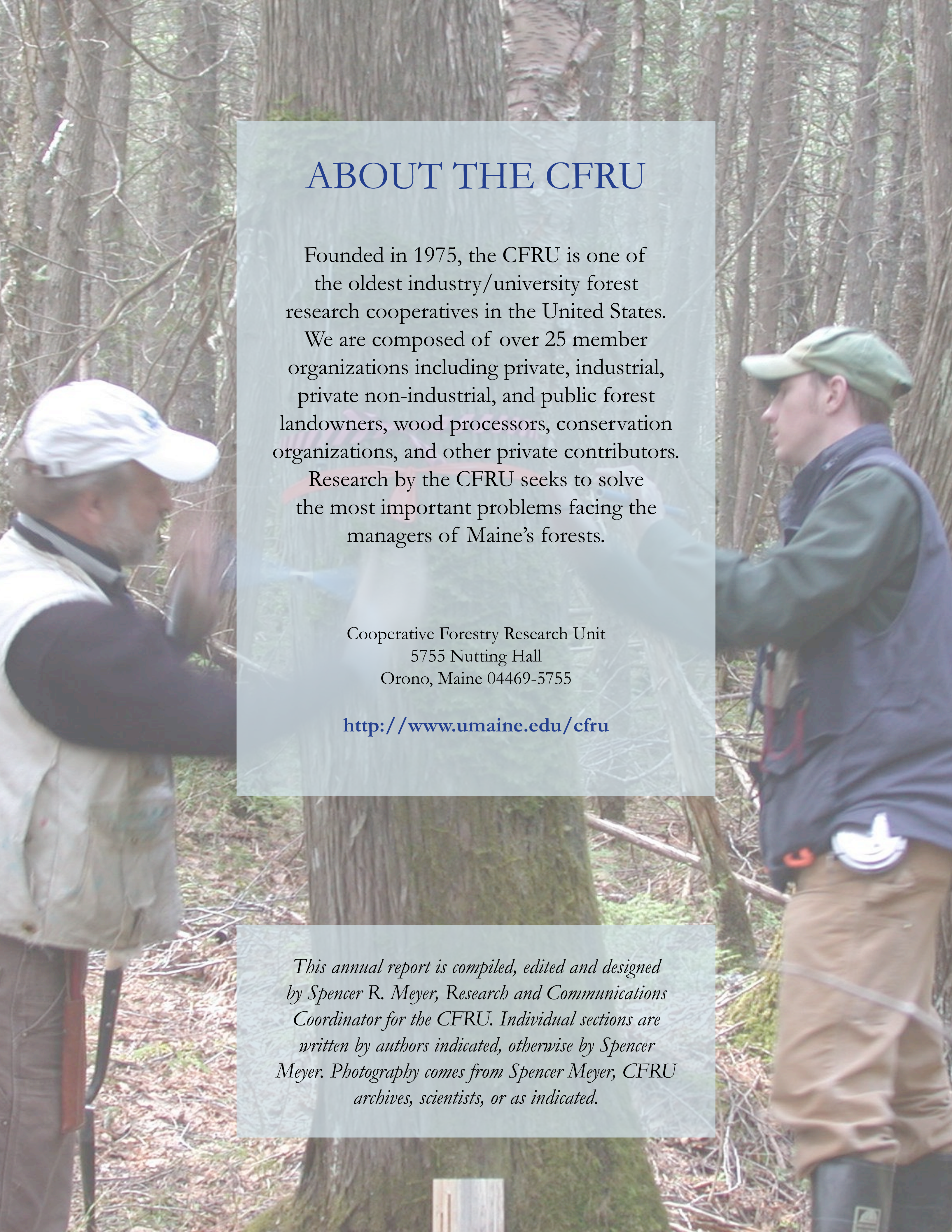
2006 - 2007

Annual Report

COOPERATIVE FORESTRY RESEARCH UNIT ANNUAL REPORT 2006 - 2007

THE UNIVERSITY OF MAINE

Maine Agricultural & Forest Experiment Station
Miscellaneous Report 444



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 over 25 member organizations including private, industrial, private non-industrial, and public forest landowners, wood processors, conservation organizations, and other private contributors. Research by the CFRU seeks to solve the most important problems facing the managers of Maine's forests.

Cooperative Forestry Research Unit
5755 Nutting Hall
Orono, Maine 04469-5755

http://www.umaine.edu/cfru

This annual report is compiled, edited and designed by Spencer R. Meyer, Research and Communications Coordinator for the CFRU. Individual sections are written by authors indicated, otherwise by Spencer Meyer. Photography comes from Spencer Meyer, CFRU archives, scientists, or as indicated.

Contents

Organization

Appendices

It seems like just yesterday we were celebrating 30 years!

Research

Introduction

Since 1975, the Cooperative Forestry Research Unit (CFRU) has been working to improve the stewardship of Maine's forests. This unique partnership between Maine's forest managers and the University of Maine has met a wide range of challenges. First called upon to address the devastating spruce budworm epidemic of the 1970s, CFRU has adapted to an ever-changing forest resource. As Maine's forests have evolved, the unit has kept pace by researching all aspects of forest ecosystems from the sustainability of wood supplies to the effects of forest management on wildlife habitat, water quality, and biodiversity.

With twenty-eight member organizations including private, industrial, private non-industrial, and public forest landowners, wood processors, conservation organizations, and other private contributors, the unit is continually seeking ways to help sustain Maine's tremendous forest resource. CFRU research provides both science-based information about the ecological effects of forestry practices, and tools that improve the efficiency and productivity of forest management.

Just as it has since its inception over 30 years ago, CFRU continues to conduct applied scientific research that contributes to the sustainable management of Maine's forests. Results from a variety of research projects addressing silviculture, wildlife ecology, and biodiversity conservation needs are presented in this report. Regular quarterly meetings, workshops, field tours, and conferences are sponsored by CFRU to rapidly communicate the latest research results. Publications such as, *Results*, research reports, graduate theses, and journal articles are ways we document the findings. Members have immediate access to the latest information, as well as over 30 years of technical publications, through our web page. Technical advice and recommendations to cooperators continue to be benefits of membership and have been a hallmark of our organization since its earliest days. This report documents progress made by the CFRU during fiscal year 2006-2007.

Highlights of CFRU work are proudly displayed in a kiosk in Baxter State Park.

Highlights

ORGANIZATION

- The CFRU kept its cooperatove base strong this year with 7.75 million acres of Maine's forest represented. (see Financial Report).

- New members **Timbervest, LLC** and **Forest Society of Maine** joined the CFRU in 2006 (see Director's Report).

- Total CFRU revenues for 2006-07 reached $454,659 (see Financial Report).

- For every dollar contributed, CFRU scientists leveraged an additional $14.77 (see Financial Report).

- The CFRU research team added Dr. Jeff Benjamin to lead efforts in forest operations research (see Director's Report).

COMMUNICATIONS

- The CFRU visited **Robbins Lumber** in Searsmont, Maine for its annual Fall Field Tour. We toured both mill and land operations at Robbins for a very impressive tour. (see Activities).

- CFRU scientists, staff, and graduate students delivered more than 17 publications and 40 presentations on their latest research results (see Outreach).

- CFRU was part of the All Things Wood Expo for its inaugural year. (see Activities).

RESEARCH

Silviculture

- The second thinnings were conducted on the PCT stands of the Commercial Thinning Research Network (see CTRN).

- Decades of thinning remeasurement data from Maine and eastern Canada were compiled to feed the modelling efforts of Thinning Regimes for Spruce-Fir Stands (see Thinning).

- The second year of the beech managment study was completed and initial results show that over 90% of beech stems can be controlled with a modest application of glyphosate (see Beech Composition).

- A new study looking at ideal forest operations for biomass harvesting while rehabilitating low-value beech stands got underway (see Biomass Harvest)

Wildlife Ecology

- Building on years of CFRU work, Dan Harrison's hare and lynx studies were integrated into Manomet's Biodiversity Scorecard (see Quantifying Biodiversity).

- Based on baseline umbrella species work, remote sensing techniques are now being used to predict the future habitat availablity for forest dwelling species (see Umbrella Species).

Biodiversity Conservation

- Manomet assesses the most cost effective way to track late-successional forest in existing inventories (see Cost Effective).

Membership

MAJOR COOPERATORS

Appalachian Mountain Club
Baskahegan Company
Baxter State Park, Scientific Forest Management Area
Black Bear Forest, Inc.
The Forestland Group, LLC
Frontier Forest, LLC
Huber Resources Corporation
Irving Woodlands, LLC
Katahdin Forest Management, LLC
Maine Bureau of Parks and Lands
Plum Creek Timber Company, Inc.
Prentiss & Carlisle Company, Inc.
Robbins Lumber Company
St. Aurelie Timberlands Company
Sappi Fine Paper
Seven Islands Land Company
The Nature Conservancy
Timbervest, LLC
Wagner Forest Management, Ltd.

OTHER COOPERATORS

Field Timberlands
Finestkind Tree Farms
Forest Society of Maine
Hancock Lumber Company, Inc.
Huber Wood Products
LandVest
Peavey Manufacturing Company
Western Maine Nurseries, Inc.

People

Staff

Robert G. Wagner
Director and
Henry W. Saunders
Professor in Forestry

Spencer R. Meyer
Research and Communications
Coordinator

Michael R. Saunders
Forest Biometrician

Dana M. Smith
Administrative Assistant

Cooperating Scientists

Michael S. Greenwood
Professor of Forest
Ecosystem Science

John M. Hagan
Manomet Center for
Conservation Sciences

Daniel J. Harrison
Professor of Wildlife Ecology

Robert S. Seymour
Curtis Hutchins Professor of
Forest Resources

Project Scientists

Jeffrey G. Benjamin
Assistant Professor of
Forest Operations

William B. Krohn
Leader, Maine Cooperative Fish and
Wildlife Research Unit

Andrew A. Whitman
Manomet Center for
Conservation Sciences

Ethel Wilkerson
Manomet Center for
Conservation Sciences

Jeremy S. Wilson
Irving Chair for
Forest Ecosystem Management

Advisory

Officers

Kenny Fergusson (*Chair*)	Huber Resources
George Motta (*Vice Chair*)	Black Bear Forest, Inc.
Doug Denico (*Financial Officer*)	Plum Creek Timber Company, Inc.
Mike Dann (*Member-at-Large*)	Seven Islands Land Company

Members

Greg Adams	JD Irving, Ltd.
John Brissette	USFS Northern Forest Experiment Station
Tom Charles	Maine Bureau of Parks and Lands
Steve Coleman	Frontier Forest, LLC (LandVest)
Brian Condon	The Forestland Group, LLC
David Dow	Prentiss & Carlisle Company, Inc.
Claude Dufour	Timbervest, LLC (LandVest)
Gordon Gamble	Wagner Forest Management
Laurie McElwain	Baskahegan Company
Jake Metzler	Forest Society of Maine
Ron Lovaglio	Sappi Fine Paper
Marcia McKeague	Katahdin Forest Management
David Publicover	Appalachian Mountain Club
Carol Redelsheimer	Baxter State Park, SFMA
Nancy Sferra	The Nature Conservancy
Paul Van Deusen	National Council for Air & Stream Improvement, Inc. (NCASI)
G. Bruce Wiersma	The University of Maine, Center for Research on Sustainable Forests

Chair's Report

2007 was another productive, vibrant year for the CFRU. Much work was done to improve scientific knowledge of forest management and to disseminate that information to the forestry community. This report is an impressive display of the results. Well done to all.

2007 was also a year of transition year for many people with long term associations with the CFRU. Amongst the many changes **Doug Denico**, **Bill Sylvester**, **Ron Lovaglio**, **Mike Dann**, and **George Motta** all stepped down from their positions with the Advisory Committee. Their knowledge and commitment to research will be hard to replace. New advisory board members for the coming year include **John Bryant**, **Mark Doty**, **Kevin McCarthy**, **Jake Metzler**, and **Kip Nichols**. Their enthusiasm bodes well for our future. We also had a change to our core scientist group with **Mike Saunders** leaving for a post at Purdue while **Jeff Benjamin** joined our team of cooperating scientists which includes **John Hagan**, **Dan Harrison**, and **Bob Seymour**. The slate of member organization was also changed with **Forest Society of Maine** and **Timbervest** joining the CFRU while we lost **Huber Engineered Woods**, **Western Maine Nurseries**, and **Clayton Lake**.

As always, the staff of **Bob Wagner** (Director), **Spencer Meyer** (Research and Communications Coordinator), and **Dana Smith** (Administrative Assistant) have kept the ship on course through all of this turbulence. I cannot place enough praise on them.

The end of 2007 also marks the end of my tenure as chair of this unique organization. Thank you to all that made my term fun and interesting. I am especially grateful to Bob, Spencer, and Dana for organizing everything so well. Their work ensured that the advisory Advisory Committee spent our energy working towards decisions. My fellow advisory board members gave me great latitude as we steered through the meetings. I am stepping down from the position with many happy memories and a feeling of accomplishment (due to the work of others!) and would like to wish John Bryant a brilliant two years as Chair .

Thank you!

Kenny Fergusson

CFRU Advisory Committee Chair

Director's Report

This year saw continued stable membership in CFRU, as well as strong productivity from CFRU researchers as demonstrated by their contributions to this annual report.

We were fortunate to add two new members, **Timbervest, LLC** and **Forest Society of Maine**, to CFRU this year. We welcome them to the program and look forward to new research collaborations during the coming years. This membership gain was balanced with the loss of **Clayton Lake Woodlands** and **J.M. Huber Wood Products** as CFRU members. We thank them for their support over the last few years and wish them the best of luck.

This year saw the close of **Kenny Fergusson's** (**Huber Resources**) two-year term as Chair of the Advisory Committee and **Mike Dann's** (**Seven Islands**) several-year term as Vice Chair and Member-at-Large. We thank Kenny for his tremendous support and leadership over the past several years. We also thank Mike for his many years of valuable contributions to the CFRU and wish him the very best with his new duties at SWOAM.

This turnover of our Executive Committee included the election of **John Bryant** (**Black Bear Forest, Inc.**) as Chair. John replaces incoming Chair, **George Motta** (Black Bear Forest, Inc.) who was not able to serve due to changes within their company. We also welcome **Mark Doty** (**Plum Creek Timber Co.**) as the new Vice Chair, and **Kip Nichols** (Seven Islands) as the new Member-at-Large. We look forward to working with you all over the coming years.

In addition to changes in the Executive Committee, we welcomed **Dr. Jeff Benjamin** (UMaine Assistant Professor of Forest Operations) to the CFRU as a new Cooperating Scientist. We look forward to Jeff's leadership in forest operations research for CFRU.

This year also saw the departure of **Dr. Mike Greenwood** as a Cooperating Scientist who began his phased retirement from UMaine. Mike has been a tremendous contributor to CFRU over many years in the fields of tree improvement and tree physiology. We all wish you the very best in your retirement.

As usual, **Spencer Meyer** (Communications and Research Coordinator) and **Dana Smith** (Administrative Assistant) continued to provide the lion's share of support and coordination that keeps the CFRU functioning flawlessly. My thanks to them for a job well done.

Robert G. Wagner

Robert G. Wagner

CFRU Director

Activities

ADVISORY

During 2006-07 the Advisory met three times as a group. These meetings provide the Advisory members, scientists, staff and students a venue to discuss research ideas, project statuswa and overall operations. The Advisory guides all CFRU activities throughout the year to ensure research is relevant, applicable and of the highest quality.

The October 4, 2006 Advisory meeting, held in the Woolly Room at the University of Maine, included several project updates, a subsequently funded research proposal on beech biomass brought forward by **Dr. Jeff Benjamin**, and a presentation from **Spencer Meyer** and University of Maine System legal staff on data confidentiality for the CFRU. The following day, the CFRU Advisory and many Cooperator employees toured **Robbins Lumber** operations in Searsmont. Details about the excellent field and mill tour are found in the 2005-06 annual report. The October 5, 2007 fall field tour will be highlighted in the 2007-08 annual report. Thanks again, go to **Jim Robbins** and his family for hosting such an impressive event!

On January 24, 2007, the Advisory met at the Buchanan Alumni House in Orono to hear eight new research pre-proposals ranging from a Scorecard to Assess Recreation Impacts on the Landscape (Hagan and Whitman) to Capturing the Value of 30 Years of CFRU Research (Meyer and Wagner). Additionally, Benjamin's forementioned Beech Biomass proposal was funded, **Bob Seymour** presented the results of the White Pine Working Group (formed in April 2006), and Meyer gave an update on the Commercial Thinning Research Network winter harvests.

The April 25, 2007 Advisory meeting, again in the Woolly Room, heard seven full research proposals, five of which were funded for 2007-08. Several project updates were delivered and the 2007-08 budgets were approved. A very important meeting, indeed!

CFRU Advisory meetings allow members to discuss new research ideas and to hear updates on current projects..

TEAM CHANGES

As described in the Chair's Report, we had substantial turnover this year on the Advisory Board. We are sorry to see some dedicated colleagues go but we look forward to working with several new members. As for the research team, we said goodbye to long-standing Cooperating Scientist, **Mike Greenwood** as he retired from the University of Maine. We were also sorry to have CFRU's post-doctoral biometrician, **Michael Saunders** leave us in May 2007 for a faculty post at

Purdue University. However, we are fortunate to have Jeff Benjamin join the team of Cooperating Scientists as he embarks on a forest operations research program that will contribute substantially to the CFRU efforts.

COMMUNICATIONS

CFRU strives to communicate directly with its members through its website, online and print publications, field tours, workshops, group meetings and periodic personal visits. This year CFRU researchers delivered 40 presentations at scientific conferences and workshops and produced 17 articles, including peer-reviewed articles, technical publications, research reports and notes, and other media. These communications target the CFRU, scientific, student, and public audiences but all have the common goal of disseminating the latest results from top-notch CFRU forest research. In an effort to help the public better understand about forst research in Maine, Spencer Meyer exhibited at the All Things Wood Expo in May 2007. This inaugural year of the event was jointly put on by the Center for Research on Sustainable Forests, **Small Woodlot Owners Association of Maine**, **Maine Tree Foundation** and the **Maine Forest Service**. See Outreach in the appendices for a complete list.

CFRU Research and Communications Coordinator, Spencer Meyer, spoke with emembers of the forestry community at the All Things Wood Expo in May 2007.

FIELD OPERATIONS

This year we had a rigorous summer field season from May through August, including silviculture and wildlife crews led by Spencer Meyer and **Ben Gannon**, **Andrew Nelson**, **Shonene Scott**, **Charles "Chuck" Coup** and **Andy Whitman** and **Ethel Wilkerson** at **Manomet**. CFRU friend **Laura Audibert** returned this summer to help Andrew Nelson get post-treatment measurements done on the beech control study. The Commercial Thinning crew assisted the US Forest Service crew of **Rakesh Minocha** again this year. With the thousands of miles of driving along rough roads and hiking over rugged terrain, the worst that happened this summer was a minor scratched eye and a handful of flat tires. Great job, everyone!

STUDENTS

This year, several graduate students in the School of Forest Resources and the Department of Wildlife Ecology made great progress toward their degrees and theses. In **Dan Harrison**'s lab, M.S. student Shonene Scott and Ph.D. students **Erin Simons** and **Kasey Legaard** continued their projects on forest harvesting and wildlife habitat interactions (see Quantifying Biodiversity). Under the guidance of Bob Seymour and **Laura Kenefic**, **Phil Hofmeyer** completed his last field season and is wrapping up his Ph.D. dissertation on cedar silviculture and ecology (see Cedar). M.S. student, Andrew Nelson worked under advising from Bob Wagner to look at spatial patterns in a beech control study (see Beech) and Jeff Benjamin's new M.S. student, Chuck Coup began his program on equipment operations during biomass harvests (see Biomass). Expect great things from this crowd!

The CFRU continues to offer a rewarding summer internship opportunity for undergraduate students interested in natural resources and science. All in all, we had 14 undergraduate students working on everything from counting hare pellets to assessing crown classes of trees. Working hand in hand with many of the graduate students above, these summer interns were exposed to a new world of field research. Without the dedication, attention to detail and rainy smiles of all of them the CFRU would never be able to fulfill its mission.

FOREST RESEARCH COOPERATIVE EXCHANGE

In a unique collaboration the CFRU and the Forest Nutrition Cooperative (FNC) of North Carolina State University (NCSU) and Virginia Tech (VT) got together twice this year. Conceived at the 2006 Society of American Foresters National Convention and Silviculture Instructor's Tour, this coop swap was meant to help each program foster new ideas from what the other has been doing. Though we work in different regions and on different research topics, forest research cooperatives share many of the same challenges and successes.

From July 30 through August 2, 2007, **Lee Allen** and **Tim Albaugh** of NCSU and **Tom Fox** and **Colleen Carlson** of VT came to Maine for a field tour to look at some the recent CFRU research. Tour highlights included the commercial thinning site on **Seven Islands** land in Magalloway Plantation, one of Manomet's headwater stream study in Lincoln Plantation, late successional index work in the Bigelow Preserve, hare and lynx research in the Telos region on **Katahdin Forest Management** land and a tour of **Baxter State Park's Scientific Forest Management Area**. Tom and Lee had both done graduate work in some of these areas in the early 1970s and were impressed with how much the Telos region had grown up since then.

Then from October 15 – 21 , Bob Wagner, Spencer Meyer and graduate student **Matt Olson** visited the FNC down south. First attending an impressive annual meeting of the FNC, meeting forest managers and scientists from all across the south United States and South America and then spending several days on the road touring southern pine trials, we got a dose of what southern, intensive management is all about. The research interests and projects there are surely very different from most of the projects we focus on but the common threads of cooperative efforts were obvious. Bob and Spencer came home with a fresh look at how other coops operate and with some ideas on how to continue to improve on the already successful research of the CFRU. Incidentally, CFRU members Plum Creek Timber Company and Timbervest are also members of FNC.

CFRU and Forest Nutrition Cooperative folks traded field tours: Maine in July and North Corolina and Virginia in October 2007.

Financial Report

Twenty-five members representing 7.75 million acres of Maine's forestland contributed $454,283 in dues to support CFRU this year (Table 1). We added **Timbervest, LLC** (22,589 acres) and **Forest Society of Maine** (1,868 acres) as new members of the CFRU this year. We welcome our new members and thank our other members for their steadfast support.

Sound fiscal management by CFRU project scientists and staff resulted in spending $64,199 (13%) less than $511,362 that was approved by the Advisory Committee (Table 2). All projects came in under or on budget. Inability to find a qualified graduate student for the spruce budworm risk assessment project and a late start for commercial thinning analysis project accounted for most of the under spending this year. These savings were returned to the central account for future use on other CFRU projects.

CFRU spent 63% of its expenditures on research projects and 37% for administration, including staff/scientist salaries and other expenses (meetings, field tours, web maintenance, data bank, travel, computers, safety, phones, printing, and office supplies). Research expenses were divided among seven silviculture projects (33%), two wildlife ecology projects (12%), and six biodiversity conservation projects (55%) (Table 2).

Using contributions from CFRU members, project scientists were able to leverage an additional $367,160 from external sources to support CFRU-sponsored research projects. When added to the $78,899 of in-kind contributions from the University of Maine, total contributions supporting CFRU research during this fiscal year was $900,342 or nearly double (98%) that of member contributions (Figure 1).

Figure 1. CFRU members contributed $454,283 this year. An additional $367,160 was leveraged from external funding sources, and the University of Maine contributed $78,899 of in-kind support.

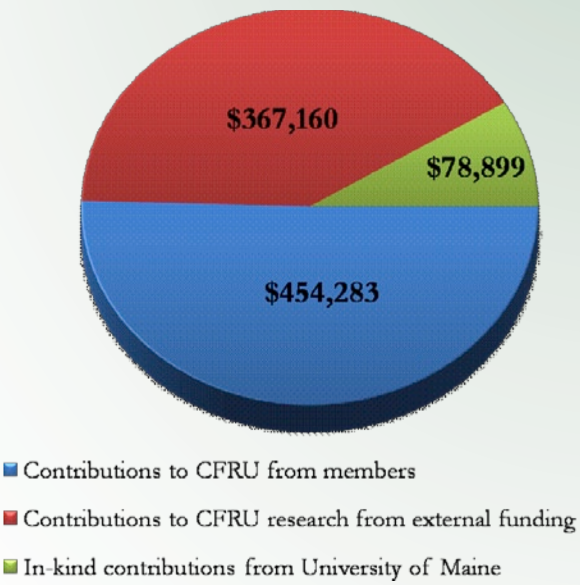


Figure 2. For every dollar contributed by one of our five largest members they received $6.95 from other members, $6.43 from external funding sources, and $1.38 from in-kind contributions by the University of Maine. Therefore, every dollar contributed by the five largest CFRU members leveraged an average of $14.77 to support CFRU research.

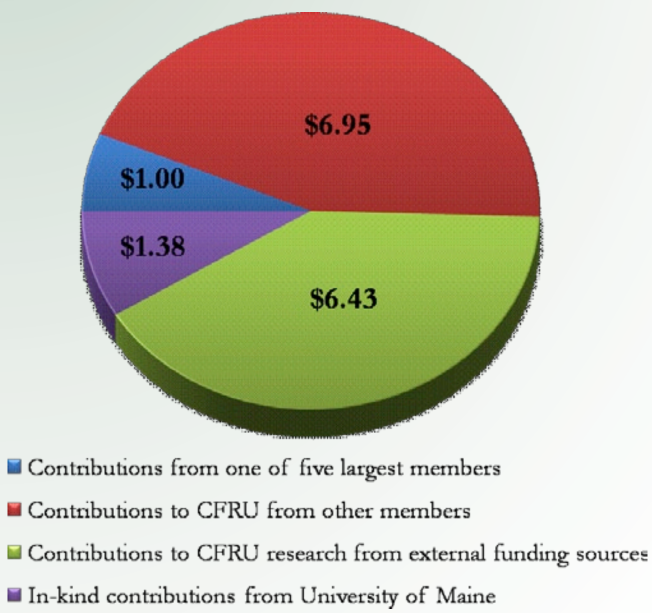


Table 1. CFRU Revenue for FY 2006-07 (as of December 31, 2007)

COOPERATOR	Acres Reported in 2007	Amount Invoiced in 2007	Amount Received in 2007	Balance
Forest Landowners / Managers:				
Irving, J. D. Ltd.	1,380,000	$74,000	$74,000	$0
Wagner Forest Management, Ltd.	1,163,482	$63,174	$63,174	$0
Black Bear Forest, Inc.	981,437	$54,025	$54,025	$0
Plum Creek Timberlands	908,600	$50,202	$50,202	$0
Seven Islands Land Company	793,000	$44,133	$44,133	$0
Prentiss and Carlisle	691,000	$38,778	$38,778	$0
Maine Bureau of Parks and Lands	385,000	$22,138	$22,138	$0
Huber, J. M. Corporation	385,000	$22,138	$22,138	$0
Katahdin Forest Management LLC	299,000	$17,193	$17,193	$0
The Forestland Group, LLC	249,153	$14,326	$14,326	$0
The Nature Conservancy	180,064	$10,354	$10,354	$0
Baskahegan Lands	101,629	$5,844	$5,844	$0
St. Aurelie Timberlands	61,605	$3,542	$3,750	-$208
Frontier Forest, LLC	53,338	$3,067	$3,067	$0
Appalachian Mountain Club	37,093	$2,133	$2,133	$0
Baxter State Park, SFMA	29,537	$1,698	$1,698	$0
Robbins Lumber Co.	27,275	$1,568	$1,568	$0
Timbervest, LLC *	22,589	$1,299	$1,314	-$16
Forest Society of Maine *	1,868	$1,000	$1,000	$0
Mill Owners / Wood Processors:				
Sappi Fine Paper	0	$21,913	$21,913	$0
Hancock Lumber Company	0	$1,000	$1,000	$0
Corporate Members:				
LandVest Inc.	0	$200	$200	$0
Peavey Corporation	0	$137	$137	$0
Field Timberlands	0	$100	$100	$0
Finestkind Tree Farms	0	$100	$100	$0
TOTAL	**7,750,670**	**$455,659**	**$454,283**	**$1,376**
* New members joining during FY 06-07.				

A substantial amount of leveraging comes from CFRU members pooling their resources. For example, every dollar contributed by our five largest members this year, yielded $6.95 from other member contributions, $6.43 from external funding sources, and $1.38 from in-kind contributions from the University of Maine. Therefore, every dollar contributed by the largest CFRU members leveraged an additional $14.77 to support their highest priority research projects (Figure 2).

Project (Investigators)	Approved Amount	Amount Spent	+ / -	%
AMINISTRATION	$173,585	$166,736	$6,849	3.9%
SILVICULTURE:				
Maine Commercial Thinning Research Network (Meyer, Wagner & Seymour)	$38,285	$37,657	$628	1.6%
Maine Commercial Thinning Research Network: Analysis of 5th-year growth & yield responses (Wagner et al.)	$24,736	$12,299	$12,437	50.3%
Hardwood silviculture graduate student (Wagner)	$8,000	$7,675	$325	4.1%
Evaluation of Biomass Harvest Systems (Benjamin & Wagner)	$22,748	$21,449	$1,299	5.7%
Post-harvest strategy for improving the composition of hardwood regeneration on beech-dominated sites in Maine (Wagner et al.)	$3,399	$3,399	$0	0.0%
Assessing the risk and impact of future spruce budworm outbreaks in Maine Forests (Wilson et al.)	$32,966	$0	$32,966	100.0%
Agenda 2020 PCT modeling proposal (Wagner & Saunders)	$8,800	$8,800	$0	0.0%
WILDLIFE ECOLOGY:				
Agenda 2020 future marten habitat modeling (Harrison et al.)	$6,000	$5,966	$34	0.6%
Relationships of snowshoe hares and lynx to forest harvesting (Harrison & Krohn)	$32,000	$28,391	$3,609	11.3%
BIODIVERSITY CONSERVATION:				
Quantifying biodiversity values across managed landscapes: Scorecard (Hagan)	$25,000	$25,000	$0	0.0%
Quantifying biodiversity values across managed landscapes: Riparian Index (Hagan)	$15,000	$15,000	$0	0.0%
Quantifying biodiversity values across managed landscapes in northern and western Maine (Harrison & Hagan)	$35,328	$29,275	$6,053	17.1%
Monitoring recovery of headwater stream temperature (Hagan, Whitman & Wilkerson)	$20,000	$20,000	$0	0.0%
Cost effective methods for tracking late-successional and other structural attributes important to forest biodiversity (Hagan & Whitman)	$25,000	$25,000	$0	0.0%
Assessing the contribution of riparian zones for meeting biodiversity goals of sustainable forestry (Hagan et al.)	$40,515	$40,515	$0	0.0%
TOTAL	$511,362	$447,163	$64,199	12.6%

Table 2. CFRU Expenditures for FY 2006-07 (as of December 31, 2007)

Silviculture

Commercial Thinning Research Network

Assessing the Risk and Impact of Future Spruce Budworm Outbreaks

Thinning Regimes for Spruce-Fir Stands

Improving Species Composition of Hardwood Regeneration

Biomass Harvest Systems for Improving Low-Value, Beech Stands

Silviculture and Ecology of Northern White Cedar

Commercial Thinning Research Network

Spencer R. Meyer, Robert G. Wagner, and Robert S. Seymour

INTRODUCTION

The CFRU Commercial Thinning Research Network (CTRN) completed its 7th season this year. As outlined in the last several CFRU Annual Reports, the network consists of two controlled studies examining commercial thinning responses in Maine spruce-fir stands. A dozen study sites were established on CFRU cooperator lands across the state beginning in 2000. The first study was established in mature balsam fir stands on six sites that had previously received precommercial thinning (PCT) and quantifies the growth and yield responses from the timing of first commercial thinning (i.e. now, delay five years, and delay 10 years) and level of residual relative density (33% and 50% relative density reduction). The second study, also established on six sites, was installed in mature spruce-fir stands without previous PCT (no-PCT) to quantify the growth and yield response from commercial thinning methods (i.e. low, crown, and dominant) and level of residual relative density (33% and 50% relative density reduction). See previous Annual Reports for more thorough description of the experimental design and implementation.

The development of a comprehensive CTRN database last year has allowed for better organization of long-term field data to feed CFRU modeling efforts.

FALL AND WINTER 2006-07: PCT SECOND THINNINGS

The experimental design of the PCT sites calls for two treatment plots at each site to be thinned every five years. Prescriptions were implemented based on inventories conducted during the 2006 field season. During the 2006-07 winter **Spencer Meyer**, with help from **Erik Nash**, **Matt Olson**, **Bob Seymour** and **Brian Milakovsky**, marked the PCT stands according to the prescriptions. Spencer oversaw all field operations during the harvests.

With the generous help from several of our cooperators and their contractors, we conducted harvests on six sites from November 2006 through May 2007.

Erik Nash admires his handiwork after marking a PCT stand for a 50% relative density reduction treatment at Lake Macawahoc in December 2006.

Because the **Plum Creek** site Ronco Cove shares road access with a major ITS snowmobile route, we had to conduct operations before much snow fell. Ronco Cove was harvested during November 2006 with the support of Plum Creek's district forester **Tommy Roberts** and the skillful operations of contractor **Chris Richards**. Over the course of about a week, Chris and his Timberjack 1270, a machine slightly larger than for which the study was designed, cut the stand to within a handful of trees of the prescription. Spencer Meyer cleaned the rest with a chainsaw. Forwarder operators brought the mostly fir pulpwood roadside and away it went. After all roadside wood was measured, 8.7 cords/ac were removed from the 33% removal treatment and 12.1 cords/ac were removed from the 50% removal treatment. Operations began at the Lazy Tom Plum Creek site in April 2007, again conducted by Chris Richards with a very similar, although different single-grip processor. This time the roadside wood amounted to 10.3 cords/ac for the 33% removal and 15.2 cords/ac from the 50% removal of fir pulp. One lesson learned is that the 12-foot width of a Timberjack 1270 class machine was a little too much to operate with ghost trails. The first thinnings in 2001-2002 used smaller processors, for which the experiment was designed. The larger machine was fine on the 50% removals (about 12-13 spacing, on average) but was not able to maneuver through the stands for the 33% removals, forcing Chris to pick his way from the main forwarder trails and Spencer to do some cleaning up with a chainsaw afterward. Regardless, the experimental design remained intact with the prescriptions being implemented with great precision.

Field crew members Nate Jones and Ben Gannon measure the logs harvested from the Lazy Tom thinning.

Black Bear Forest site Lake Macawahoc and the University of Maine site Compartment 23-A at the Penobscot Experimental Forest (PEF) were harvested in a whirlwind during December 2006. Under the leadership of **John Bryant** of Black Bear Forest, **Norm** and **Ed Pelletier** were contracted to complete the thinning for these two sites with their Rottne 2002 processors. These machines were what the study was originally designed for and in fact, the two machines the Pelletier brothers have now are two of the same machines that worked on the first thinning for the CFRU. During the last week of February 2007, Norm and Ed completed thinning operatiosn on both sites. The Lake Macawahoc operation yielded 11.8 and 11.7 cords/ac (33% and 50%, respectively) roadside pulp. The two are similar due to a pocket of low-grade poplar hardwood pulp in the 33% plot. The PEF harvest yielded 9.7 and 10.0 cords/ac (33% and 50%, respectively) roadside pulp.

The **Irving** site Weeks Brook was harvested mostly by a one-man hand sawyer, **Doug Cray**, who was contracted by Irving. Spencer Meyer assisted with the harvesting. Wood was felled and limbed but left in the woods due to inaccessibility and low quantity of the wood.

The Black Bear Forest site Alder Stream posed significant challenges because the winter access road was not in any condition to support logging equipment. Black Bear foresters including John Bryant, **Scott Olson** and **Dave Lemay** arranged for a handcrew led by contractor **John Dyer** to harvest the site during May 2007. Spencer Meyer and the crew headed into Alder Stream on fourwheelers loaded with chainsaws and necessary accoutrements. The harvesting was done in one fell swoop by the three very skilled sawyers and with a little help from the much less skilled Spencer. Again, the wood was left in the plots but the prescription was carried out accrding to plan.

Many thanks go to all our cooperators, especially those named above for all their support and assistance in getting the harvests completed on time. The CFRU staff really appreciates their time in dealing with our small-scale, inefficient, experimental prescriptions.

SUMMER 2007 FIELD SEASON

This year the field crew was led by **Benjamin Gannon** (University of Michigan) and consisted of **Nina Pinette** (Muhlenberg College), **Nathan Jones** (UMaine) and **Sasha Bogden** (UMaine). They did a terrific job getting to all the sites to conduct yearly measurements, visiting 12,510 trees from Danforth to T7 R19! During this 2007 field season, we collapsed our measurement schedule to "maintenance mode" so as not to measure stands more frequently than we can statistically detect any growth. We now conduct IM inventories every two years at the PCT sites with EM inventories in the between years; and IM inventories every fourth year at no-PCT sites with EM during the other years. This gives diameter data for every year and height data on a schedule more appropriate for the precision with which we can measure tree heights. More in-depth mortality codes were implemented this year, as well, allowing us to better track wind, natural and other mortality. As we've done each of the last few years, the crew took a much deserved break in July and headed to Baxter State Park for a couple of days of sausages over the fire and hiking Katahdin. We joined forces with the Acadian Forest Ecosystem Research Program (AFERP), led by graduate student **Matthew Olson** for a fine summit day!

Thanks to all those that were willing to do whatever it took to get the harvests done on time. Thisw picture shows John Dyer and his crew getting ready to harvest Alder Stream in May 2007.

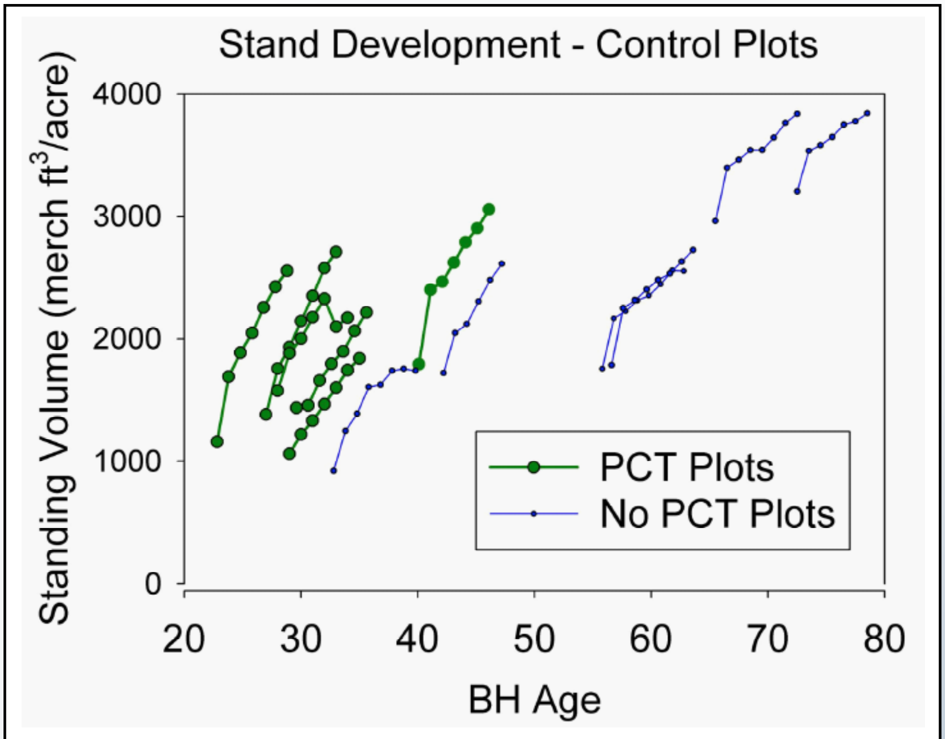


Figure 3. The control plots at PCT sites have more than doubled their standing volume in six years.

from the boles and taking other measurements.

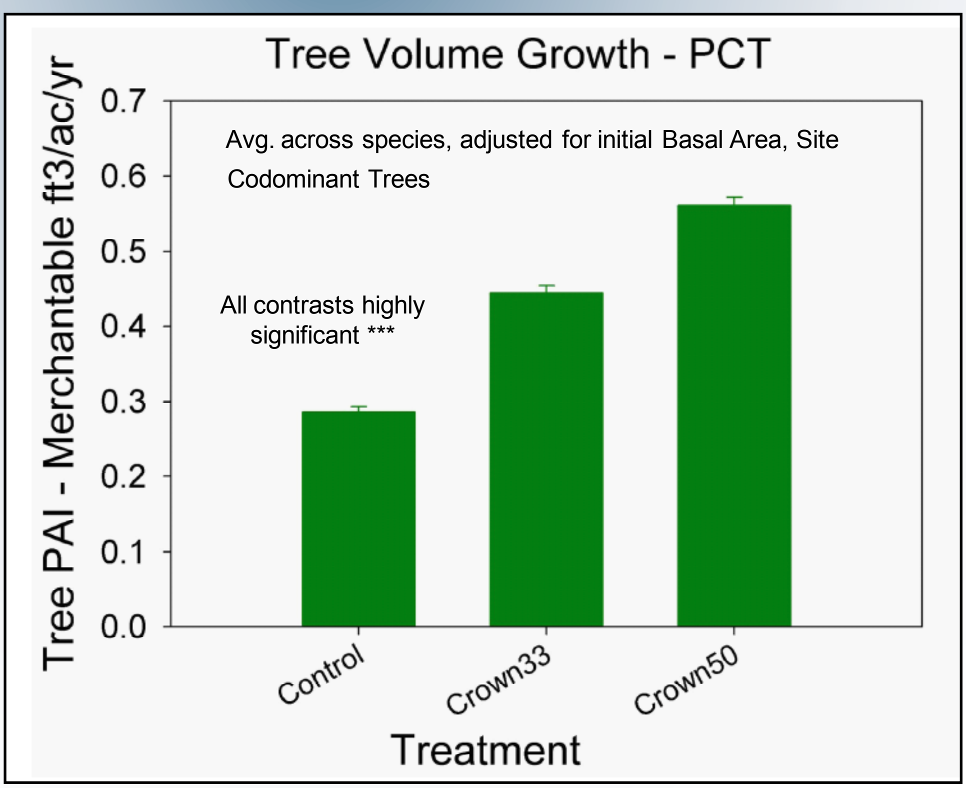
5TH-YEAR ANALYSIS

As part of the CTRN, Cooperators voted in April 2006 to fund a sub-project to analyze the first five years of CTRN data from both experiments. The complete results will be presented in a separate publication, but some highlights include:

Physiological Stress Partnership with USFS

For several years, **Dr. Rakesh Minocha** of the US Forest Service in Durham, New Hampshire has been collaborating with us on the CTRN study. Rakesh's interest in physiological stressors in forests has taken her crew to several of our study sites. This summer the crew visited Lake Macawahoc and the Penobscot Experimental Forest. Ben Gannon and the CTRN crew assisted the USFS crew for a week while the crew was shooting foliage from the crowns, taking wood plugs

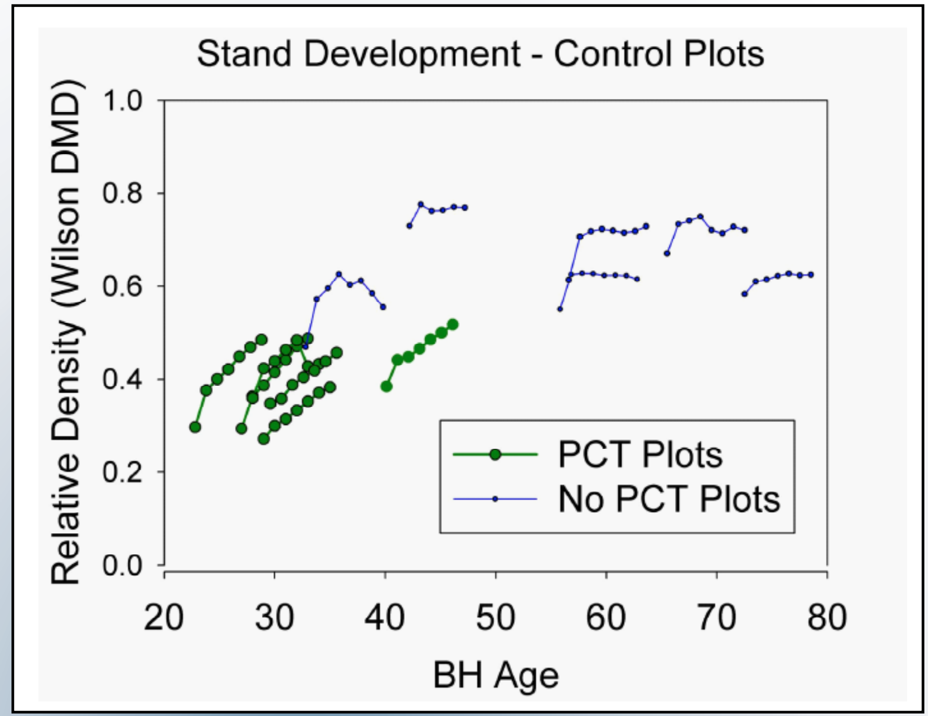
Figure 4. Individual codominant trees show 1.5 and 1.9 times (33% and 50% treatments, respecitvely) increases in net PAI than in the control treatments.



PCT Experiment

- The control plots have more than doubled in volume in only six years (Figure 3).
- Early thinning does not apparently have a growth drawback, despite what was once recommended based on FVS simulations.
- When adjusted for initial basal area, individual codominant trees exhibit a response of 1.5 and 1.9 times higher PAI (merchantable ft3/yr) in 33% and 50% removals, respectively, compared with the controls (Figure 4).
- Red spruce responds as well as balsam fir in PCT stands, although white spruce out-performs both.

Figure 5. PCT plots are still capturing gorwing space while No-PCT sites are losing stems to density dependent and windthrow mortality.



No-PCT Experiment

- Low-thinnings were the only consistently effective treatment, as both crown and dominant thinning suffered substantial negative net growth resulting from windthrow (Figure 5).
- Net merchantable PAI for low thinning is no different than for controls but individual codominant trees grew 1.4 times the PAI of control trees.
- Stands were not operable before about age 50 years.

We will continue our ongoing maintenance measurements for the base study and continue to look for ways to answer questions about thinning in even-aged spruce-fir stands. We are looking forward to seeing how the freshly harvested PCT stands respond in their first year.

For more information about the Commercial Thinning Research Network contact Spencer Meyer at spencer_meyer@umenfa.maine.edu or 207-581-2861.

Nina Pinette pretends the 12,510th tree is just as much fun as the 1st!

Assessing the Risk and Impact of Future Spruce Budworm Outbreaks in Maine Forests

Jeremy Wilson, Robert Wagner, Dave MacLean, Robert Seymour, and Chris Hennigar

INTRODUCTION

The spruce budworm is the most widespread and economically important forest insect pest in eastern North America. Periodic spruce budworm infestations have dramatic impacts on Maine forests containing high quantities of spruces and balsam fir. Repeated defoliations of these species result in considerable reductions in growth and extensive mortality. In the 1990s a spruce budworm decision support system (SBW DSS) was developed in New Brunswick (MacLean et al. 2000a; 2000b; 2001). The system is designed to help managers recognize future spruce budworm susceptibility and vulnerability in their forests and prioritize different management and protection strategies according to the marginal wood supply impacts associated with defoliation and mortality. The overall goal of this project is to adapt and implement components of the New Brunswick SBW DSS for two test townships in northern Maine.

STATUS

Unfortunately, we were unable to secure a qualified graduate student to work on the spruce budworm project last year. As a result, none of the funds awarded for 2006-2007 were spent. These funds have been returned to the CFRU and the project has been revised to make it a single year project in cooperation with a consultant (Chris Hennigar from UNB). Stand type and inventory information from two townships in northern Maine, under different management, will be utilized. Stand-scale spruce budworm impacts for each stand type

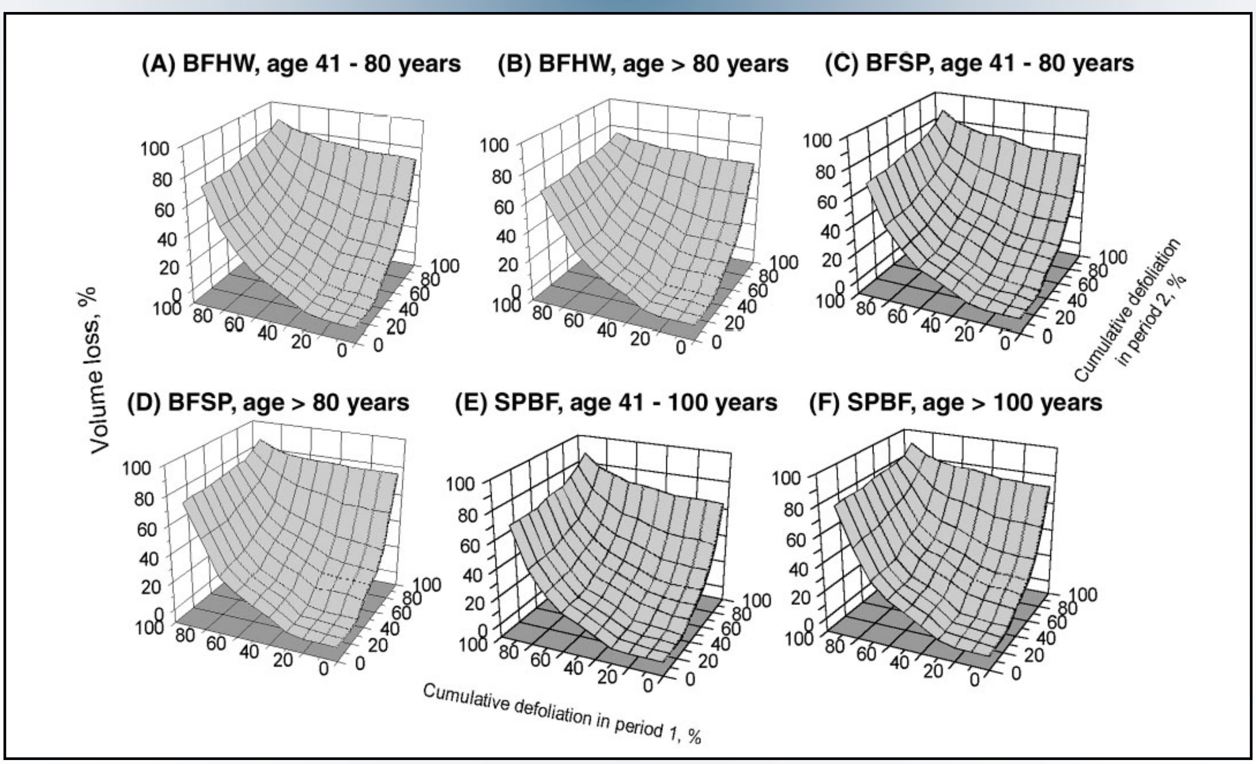


Figure 6. Predicted volume loss associated with different stand types and defoliation severities. From MacLean et al. 2001.

(Figure 6) will be used to modify yield forecasts by various spruce budworm outbreak scenarios (2010 start date). Scenarios include: 1) moderate outbreak, 2) severe outbreak, 3) protected (NB base case protection strategy <40% defoliation target during severe defoliation years) on a) 20, b) 40, and c) 100% of susceptible area for each township. Maximum stand-scale impacts associated with each scenario will be projected across the test townships from 2010 to 2050.

The revised project timeline includes: Data acquisition and needs analysis by January 2008; Stand-scale impact assessment by April 2008; Landscape scale analysis by June 2008; and Final report and presentation by Sept. 2008

For more information about this project contact Jeremy Wilson at jeremy_wilson@umenfa.maine.edu.

REFERENCES

MacLean, D.A., W.E. MacKinnon, K.B. Porter, K.P. Beaton, G. Cormier, and S. Morehouse. 2000a. Use of forest inventory and monitoring data in the spruce budworm decision support system. Computers and Electronics in Agriculture 28:101-118.

MacLean, D.A., K.B. Porter, W.E. MacKinnon, and K.P. Beaton. 2000b. Spruce budworm decision support system: lessons learned in development and implementation. Computers and Electronics in Agriculture 27:293-314.

MacLean, D.A., T.A. Erdle, W.E. MacKinnon, K.B. Porter, K.P. Beaton, G. Cormier, S. Morehouse, and M. Budd. 2001. The spruce budworm decision support system: forest protection planning to sustain long-term wood supply. Canadian Journal of Forest Research 31: 1742-1757.

Spruce budworm (right) has impacted Maine's forests during several outbreaks in modern history.

Thinning Regimes for Spruce-Fir Stands in the Northeastern United States and Eastern Canada

Mike Saunders, Robert G. Wagner, and Robert S. Seymour

BACKGROUND

Precommercial thinning (PCT) or spacing is among the most significant investments that forest landowners can make in the spruce-fir stands of Maine and throughout the region. Depending on site quality, these stand types are generally spaced from 5 to 20 years after harvesting when stem densities can exceed 10,000 stems/ac (Brissette 1996, Saunders and Wagner 2008). If not thinned, high stem densities can lead to substantial reductions in conifer growth and/or delays in final harvest (Daggett 2003), particularly if stands have significant hardwood and shrub competitors. Spacing can remove less desirable species and increase growing space availability to the remaining stems, leading to increased diameter growth and earlier commercial operability (Zhang et al. 1998).

Although there is ample observational and growing experimental evidence that PCT is advantageous, studies about the financial viability of spacing in spruce-fir stands have been inconclusive, particularly when coupled with later commercial thinning (CT) operations. Zhang et al. (1998) reported that spacing increased average stand values up to 18.8% based on lumber recovery 35 years after spacing. On the other hand, the CFRU Austin Pond study (Daggett 2003) demonstrated that stands without PCT or herbicides had internal rates of return (IRR) of 6.0%, while those with PCT and herbicides averaged an IRR of 5.8%. This prediction, however, was heavily dependent upon the reliability of the Northeast Variant of the Forest Vegetation Simulator (FVS-NE; Bush et al. 1995, Dixon 2002), an individual tree growth model that has been found to be highly inaccurate without calibration (Wagner et al. 2002, Pokharel and Froese 2008), particularly for younger stands.

Commerical thinning is one tool foresters have to capture value while increasing stand productivity for future harvests.

This project followed on Daggett's (2003) work at Austin Pond by calibrating FVS-NE for growth responses to PCT and CT in several archetypal conditions found in spruce-fir stands. The primary objective of this study was to identify the optimal spacing and commercial thinning regime as affected by site quality and initial species composition. In addition, this study provided new data from the longest-term thinning experiments in the region to help test and calibrate the FVS-NE model for predicting spruce-fir stand development.

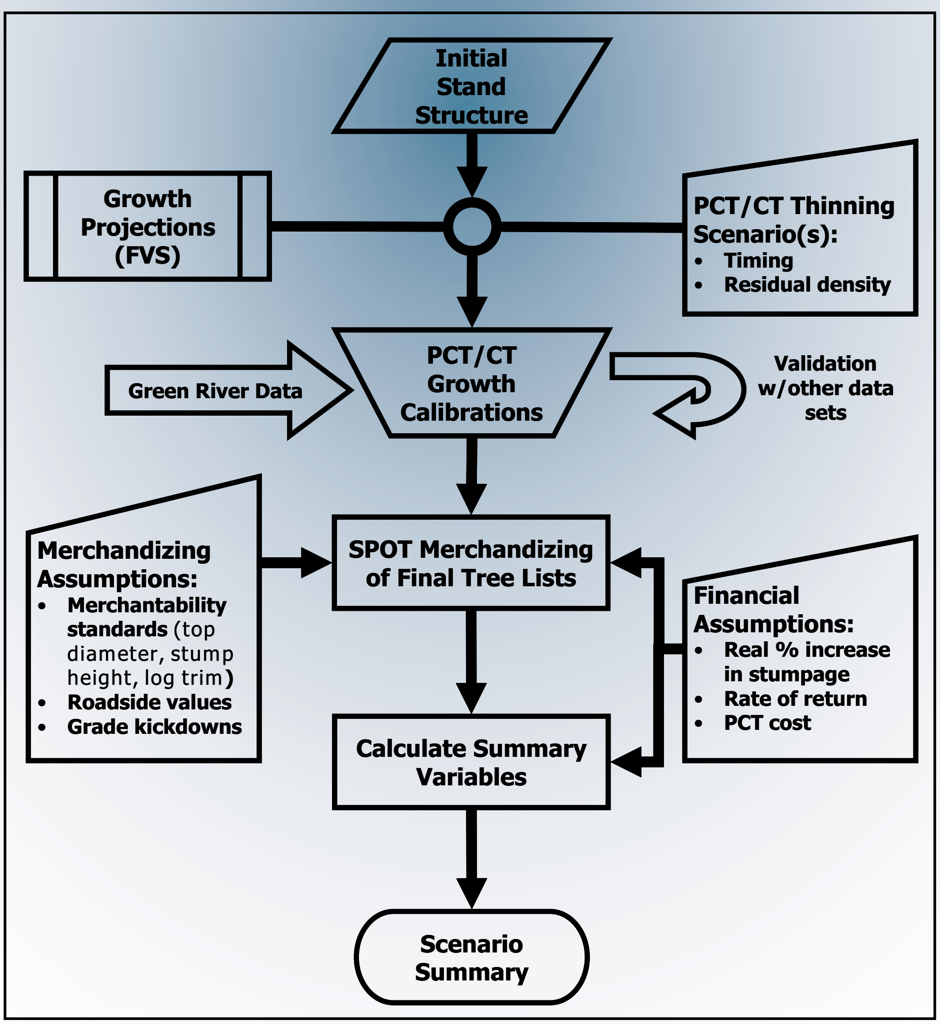
METHODS OVERVIEW

The modeling framework for this project is shown in Figure 7. First, calibration of large-tree diameter growth, small-tree height growth, and mortality submodels within FVS-NE were derived using growth data from two of the longest-running thinning experiments in the region. Data from New Brunswick Green River Spacing Study (Ker 1987) were provided by the Canadian Forest Service and used to model development of stands after PCT. In addition, data from the CFRU Commercial Thinning Research Network (Wagner et al. 2002) were used to estimate growth responses following CT.

After calibration, FVS-NE was then used to project the effects of different PCT and CT regimes on several archetypal stand conditions, varying by composition (listed as percentage of total basal area):

1) 100% balsam fir;
2) 75% balsam fir and 25% red spruce;
3) 50% balsam fir and 50% red spruce;
4) 80% balsam fir, 10% red maple, and 10% paper birch;
5) 60% balsam fir, 20% red spruce, 10% red maple, and 10% paper birch; and
6) 40% balsam fir, 40% red spruce, 10% red maple, and 10% paper birch.

Figure 7. Modeling framework used within this study.



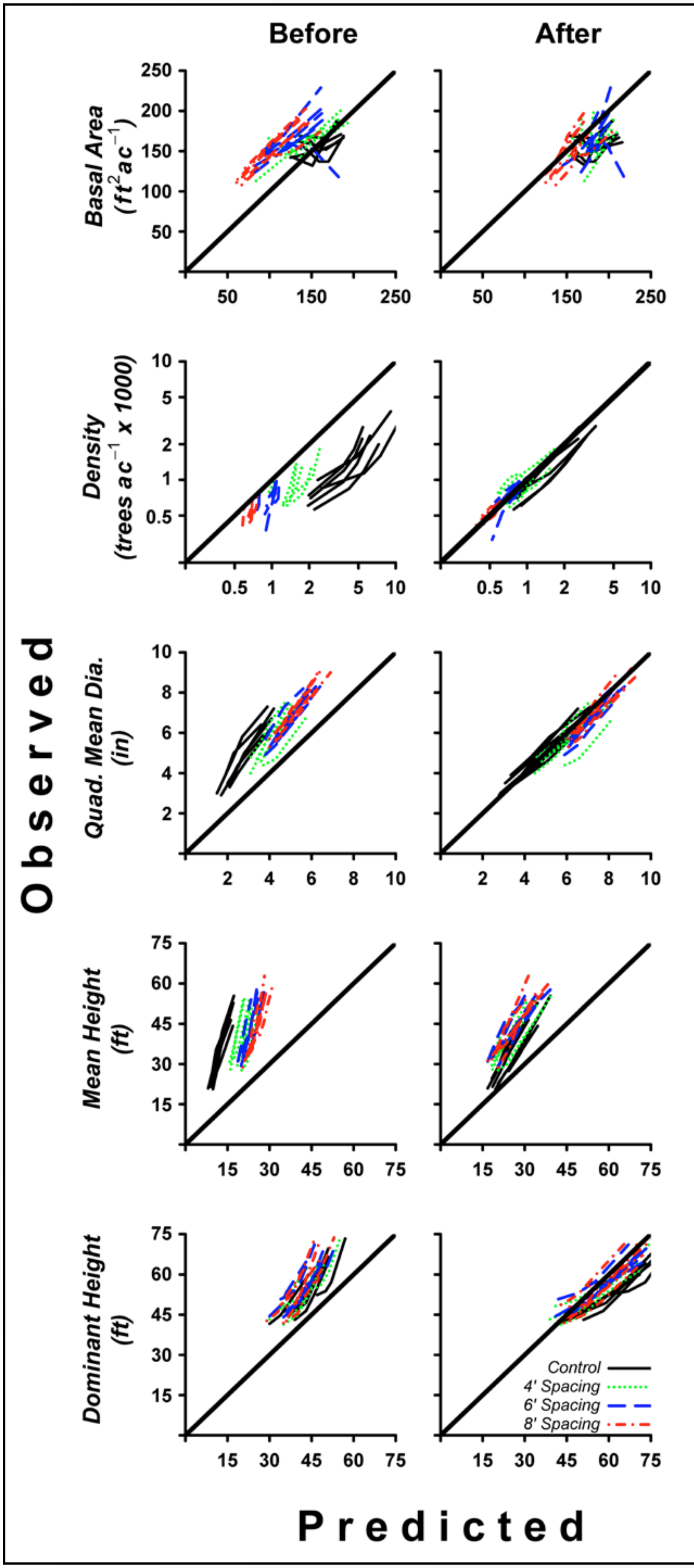


Figure 8. Comparison between observed development for treatment plots in the Green River thinning trials and FVS-NE projections for several key structural parameters, both before (left column) and after (right column) calibration. Values are only shown for inventories at least 20 years post-precommercial thinning.

The archetypal stands were then further varied by diameter distribution to approximate conditions both after a silvicultural clearcut (i.e. narrow DBH distribution) and after overstory release (i.e. broad DBH distribution). Thinning schedules varied by PCT spacing, either 6-ft (1,210 trees/ac), 8-ft (680 trees/ac), or none, as well as timing of CT, either early (height of dominant balsam fir and spruce = 40 ft), late (height = 55 ft), or none. PCT was conducted when trees reached 10 ft in height and was assumed to cost $200/ac. CT followed that of Randolph et al. (2001), removing about 40% of the pre-thinning basal area. Both thinnings favored red spruce slightly over balsam fir, and removed all hardwoods, which were allowed to resprout. Projections were made for balsam fir site indices of 40, 50, 60, 70, and 80 feet (50-year base).

Output tree lists from FVS-NE projections were then merchandized using algorithms from the Stand Product Optimization Tool (McConville 2003). These algorithms, termed SPOTlite, generated an optimized roadside value for a stand given user-specified minimum merchantable diameters and values for any desired product mix. Total and merchantable stand volumes, harvest cost, mean annual increments, net present values (assuming a 4% discount rate), and internal rates of returns were generated using SPOTlite and FVS-NE outputs for each simulation at 5-year intervals.

KEY RESULTS

Calibration

The uncalibrated version of FVS-NE did a poor job modeling development of spruce-fir stands in the Green River study (Figure 8, left side). Comparisons of FVS-NE simulations of the spacing treatments with the observed conditions revealed that FVS-NE underpredicted merchantable volume by 75% to 85% after 42 to 44 years. The volume underprediction resulted from an underprediction of basal area and quadratic mean diameters due to substantial overprediction of tree density, underestimation of mean height, and inadequate volume equations.

Calibration of FVS-NE significantly improved predictions of basal area, density, quadratic mean diameter, and dominant height (Figure 8, right side). Height predictions were improved, but were still problematic after calibration because the underlying model structure common to all FVS variants tend to differentiate height development more than is commonly observed in spruce-fir stands.

Simulation of Archetypal Stands

PCT was projected to increase diameter growth significantly, leading to 1.2" to 2.3" larger quadratic mean diameters after 30 years depending on site quality and spacing. Likewise, PCT stands had higher average height growth, but less height differentiation than unspaced stands. This difference had large implications for windfirmness at CT entry, with both 6-ft and 8-ft PCT spacings leading to more windfirm trees with height to diameter ratios < 80 (Wilson and Oliver 2000), except in the cases of late CT on higher quality sites. Unspaced stands had estimated height:diameter ratios > 80 in all cases. Further, since PCT led to larger piece sizes and lower stem densities, CT harvest costs were considerably lower in pure conifer stands that were spaced (i.e., those only containing balsam fir alone or with red spruce) when compared to unspaced stands (Figure 9). In mixedwood stands, however, CT harvest costs were higher, likely due to increased stem densities from hardwood sprouts that had not yet died.

Figure 9. Projected harvest costs at time of either early or late commercial thinning as affected by initial precommercial thinning treatment and stand composition in site index 50-60 stands. Age range of commercial thinning entry is given above each bar.

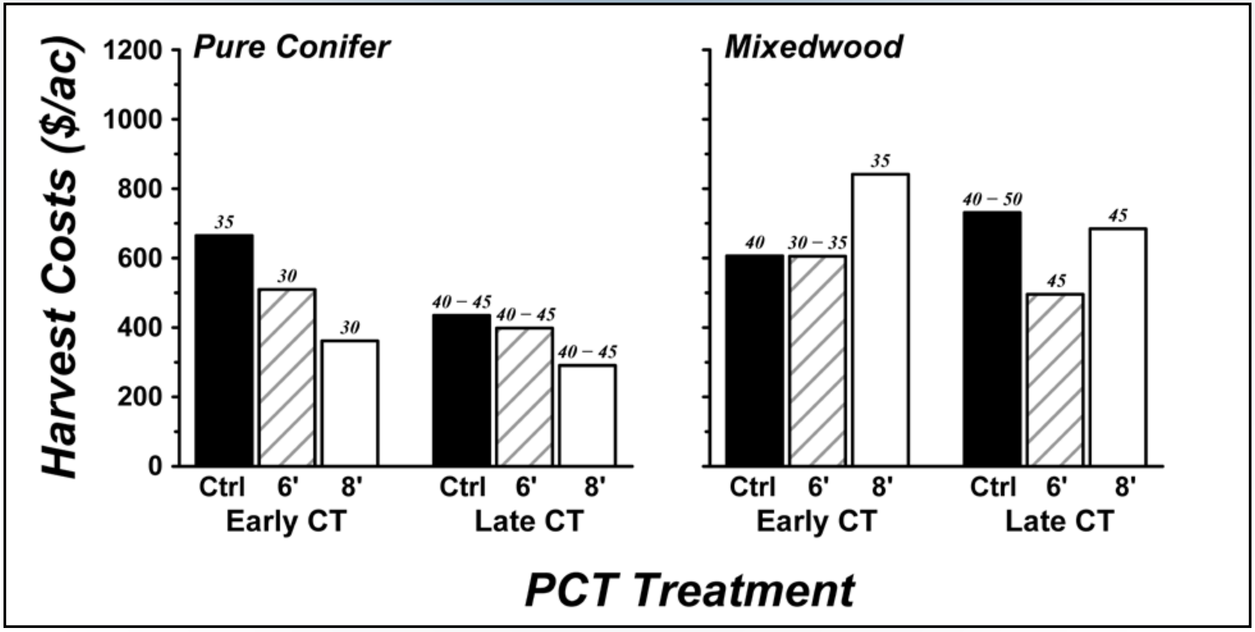
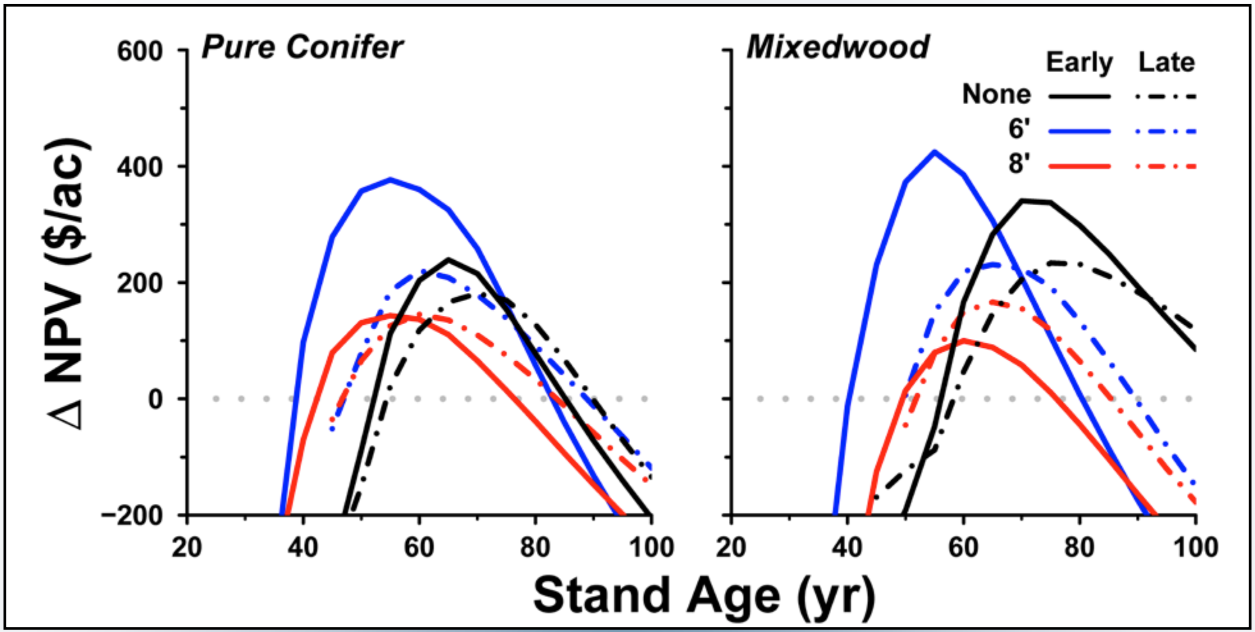


Figure 10. Difference in net present value (NPV) over stand age between early (solid lines) and late (dot-dash lines) commercial thinning and those stands not receiving commercial thinning for the three spacing treatments. Differences are based on the maximum NPV for no commercial thinning; therefore, all periods with positive values indicate a more favorable treatment in regards to financial performance. Values are given for site index 50 60 stands, summarized by pure conifer and mixedwood archetypes.



Although both total and merchantable volumes were greater in spaced (6-ft > 8-ft), pure conifer stands early in the rotation, unspaced stands eventually caught up or surpassed them, but usually after spaced stands received CT. In mixedwoods, unspaced stands never caught up to spaced stands. This difference strongly affected net present value (NPV), with pure conifer and mixedwood stands having peak NPV values up to $200/ac up to 15 years sooner and $1,000/ac up to 25 years sooner, respectively, when compared to unspaced stands. Internal rates of return for PCT ranged from 6.9% to 14.1% for 6-ft spacing and 6.4% to 11.5% for 8-ft spacing.

Commercial thinning was projected to increase diameter growth up to 74% in stands that received PCT, but by only 26% within the first 10 years after treatment when compared to unspaced stands. In unspaced, pure conifer stands, late CT had the highest merchantable yields across all site qualities, but in mixedwood stands, early CT was higher. In spaced stands, regardless of archetype or site quality, early CT led to the higher merchantable yields.

In terms of net present value, CT was advantageous on all but the poorest quality sites. Early CT generally maximized NPV on most sites and with most stand conditions (Figure 10), although late CT was advantageous with the wider 8-ft spacings and on the highest quality sites (site index 50 >70). The NPV of stands receiving early CT treatments were much higher than unthinned stands or late CT on mixedwood sites, likely because of the dramatically lower merchantable yields of the late CT or unthinned stands.

RECOMMENDATIONS

Results from this study strongly suggest that PCT is financially advantageous for nearly all spruce-fir stand conditions except those on lowest quality sites. PCT increases piece size, improves access, reduces harvest costs, shortens the period to commercial operability, and increases the financial yield considerably. An optimal thinning regime, based on this study, is for managers to PCT stands to a 6-ft spacing (1,210 trees/ac) followed by a CT entry when dominant softwood trees were near or slightly above 40-ft in height.

A possible exception to this recommendation is in stands where balsam fir composition is exceptionally high (> 80% of initial basal area) and/or sites are of the highest quality (site index 50 >70). To maximize NPV when facing these conditions, managers should PCT to an 8-ft spacing and then CT the stand later when dominant softwood trees are at least 55 ft in height.

This study also corroborates the importance controlling hardwood competition early in stand development with herbicides or other methods (see Daggett 2003). Our calibrated FVS-NE simulations suggested that even low hardwood densities in a stand can suppress spruce-fir growth significantly enough to substantially delay CT and thus substantially reduce long-term financial performance. This recommendation assumes, however, that interspecies relationships between hardwoods and spruce-fir are being modeled correctly, a piece of the FVS-NE model that was not addressed by calibrations in this study.

Finally, this study demonstrated the importance of calibrating FVS-NE submodels with data from long-term thinning experiments. Even during calibrations in this study, FVS-NE had to be "force-fit" to the data, using a multitude of adjustments to overcome deficiencies in the underlying model. We agree with Pokharel and Froese (2008) who suggested that reengineering the FVS diameter increment model is badly needed, as well as "de-coupling" the height growth submodel from the diameter growth submodel to better reflect changes in stem form (and therefore volume) resulting from silvicultural activities like thinning and vegetation management.

ACKNOWLEDGEMENTS

This work was funded by a U.S. Forest Service Agenda 2020 grant, Plum Creek Timber Company, and the Cooperative Forest Research Unit at the University of Maine. Data for this project was provided by Plum Creek Timber Company, J.D. Irving Limited, the Canadian Forest Service, and Cooperative Forest Research Unit.

For more information about this project contact Bob Wagner at bob_wagner@umenfa.maine.edu or 207-581-2903.

References

Brissette, J.C. 1996. Effects of intensity and frequency of harvesting on abundance, stocking and composition of natural regeneration in the Acadian Forest of eastern North America. Silva Fennica 30: 301-314.

Bush, R.R. 1995. Northeastern TWIGS variant of the Forest Vegetation Simulator. USDA Forest Service, For. Manage. Ser. Ctr., Fort Collins, CO. Available online at http://www.fs.fed.us/fmsc/fvs/variants/ne.php.

Daggett, H. 2003. Long-term effects of herbicide and precommercial thinning treatments on species composition stand structure, and net present value in spruce-fir stands in Maine: The Austin Pond study. M.S. thesis. Univ. of Maine, Orono, ME. 136 p.

Dixon, G.E. 2002. Essential FVS: a user's guide to the Forest Vegetation Simulator. USDA Forest Service, For. Manage. Ser. Ctr., Fort Collins, CO. 204 p. Available online at http://www.fs.fed.us/fmsc/fvs/documents/gtrs_essentialfvs.php.

Ker, M.F. 1987. Effects of spacing on balsam fir: 25-year results from the Green River spacing trials. In Proceedings of the Precommercial Thinning Workshop. Canadian Forest Service, Hugh John Flemming Forestry Centre, Fredericton, NB. pp. 58-75.

McConville, D.J. 2003. The Stand Product Optimization Tool. In 2003 CFRU Annual Report. MAFES Miscellaneous Report 2684. Maine Agric. For. Exp. Stn., Univ. of Maine, Orono, ME. pp. 41-42.

Pokharel, B., and Froese, R.E. 2008. Evaluating alternative implementations of the Lake States FVS diameter increment model. Forest Ecol. Manage. In press.

Wagner, R.G., Seymour, R.S., McConville, D.J., and Opland, D.M. 2002. Commercial Thinning Research Network. In 2002 CFRU Annual Report. MAFES Miscellaneous Report 431. Maine Agric. For. Exp. Stn., Univ. of Maine, Orono, ME. pp. 23-28.

Wilson, J.S., and Oliver, C.D. 2000. Stability and density management in Douglas-fir plantations. Can. J. For. Res. 30(6): 910-920.

Improving Species Composition of Hardwood Regeneration in Beech-Dominated Understories: First-Year Results

Robert G. Wagner and Andrew S. Nelson

BACKGROUND

Thousands of acres of mid-site hardwood stands on CFRU member lands are plagued by an abundance of American beech (*Fagus grandifolia*) that generally dominate and competitively exclude more desired hardwood species after stands are harvested using shelterwood and selection methods. Thus, the objective of this project is to develop a low-cost and effective treatment for improving the composition of hardwood regeneration in beech-dominated stands that can help restore the quality and long-term financial value of hardwood stands across Maine.

Glyphosate not only killed the undesirable beech but also caused some damange on the more desirable species (e.g. sugar maple). Next year's results will give an indication whether or not the injury is fatal to the desirable regeneration.

In spring 2006, three study sites were selected on Huber Resources (T2 R7), Prentiss & Carlisle (T2 R8), and Katahdin Forest Management (TA R7) lands. Each site had been shelterwood harvested within two years of selection, providing a good representation of post-harvest conditions when understory release treatments would be applied. Pre-treatment measurements revealed that beech, sugar maple, red maple, striped maple, and yellow birch were abundant on nearly all sample plots, providing excellent conditions for evaluating treatment effects for these species (see 2006 CFRU Annual Report).

On each site, we installed 16 treatment plots and 160 measurement plots to examine a factorial combination of three rates of glyphosate herbicide (Accord Concentrate) and four concentrations of EnTree 5735 tallow amine surfactant (Table 3). The treatments were designed and

EnTree 5735 surfactant (%)	Glyphosate (Accord Concentrate) application rate (lb/ac ae)			
	0	0.5	1.0	1.5
0.00	Control	x	x	x
0.25	not tested	x	x	x
0.50	not tested	x	x	x
1.00	not tested	x	x	x

Table 3. Factorial combinations of glyphosate and surfactant being compared.

applied in collaboration with Ron Lemin (UAP timberlands) and Maxwell McCormack (CFRU, retired).

All treatments were applied in mid August 2006 using a CO_2-powered backpack sprayer with an 11-ft tall extended boom that simulates ground application using a radiarc or other hydraulic spraying system. All treatments were applied to within 2.2% of the target rate.

To test the transferability of results from this experiment using hydraulic nozzles with the results that would be obtained from a mistblower application, a set of demonstration plots in tandem to the main study was also installed on each site. Using a backpack mistblower, we applied three glyphosate/surfactant combinations (0.5 lb/0.25%, 1.0 lb/0.5%, and 1.5 lb/1%) representing the range of herbicide and surfactant concentrations tested in the main study.

On each sample plot, the number of stems of each tree species was counted and the percent cover of each tree species was visually estimated to the nearest 5%. Pre-treatment measurements were made in July 2006 and first-year, post-treatment measurements were made in July 2007.

In September 2007, a new M.S. graduate student, Andrew Nelson, was hired from shared funding between the CFRU and the Henry W. Saunders Chair. Andrew and Laura Audibert led data collection and analysis of first-year results in summer 2007. Andrew's M.S. thesis project will include continued measurement and analysis of this study, as well as initiating a study of the spatial patterns of understory regeneration in beech-dominated stands in the summer of 2008.

FIRST-YEAR RESULTS

A preliminary analysis of the first-year results revealed substantial differences among the hardwood species in response to the herbicide treatments. Of particular interest was the strong difference in susceptibility to glyphosate between beech and sugar maple (Figure 11). It appears that 90% of beech stems can be selectively removed from the understory while leaving most all of the

Figure 11. First-year control of beech and sugar maple stem count following three rates of glyphosate herbicide and four concentrations of EnTree 5735 surfactant (hydraulic nozzle data).

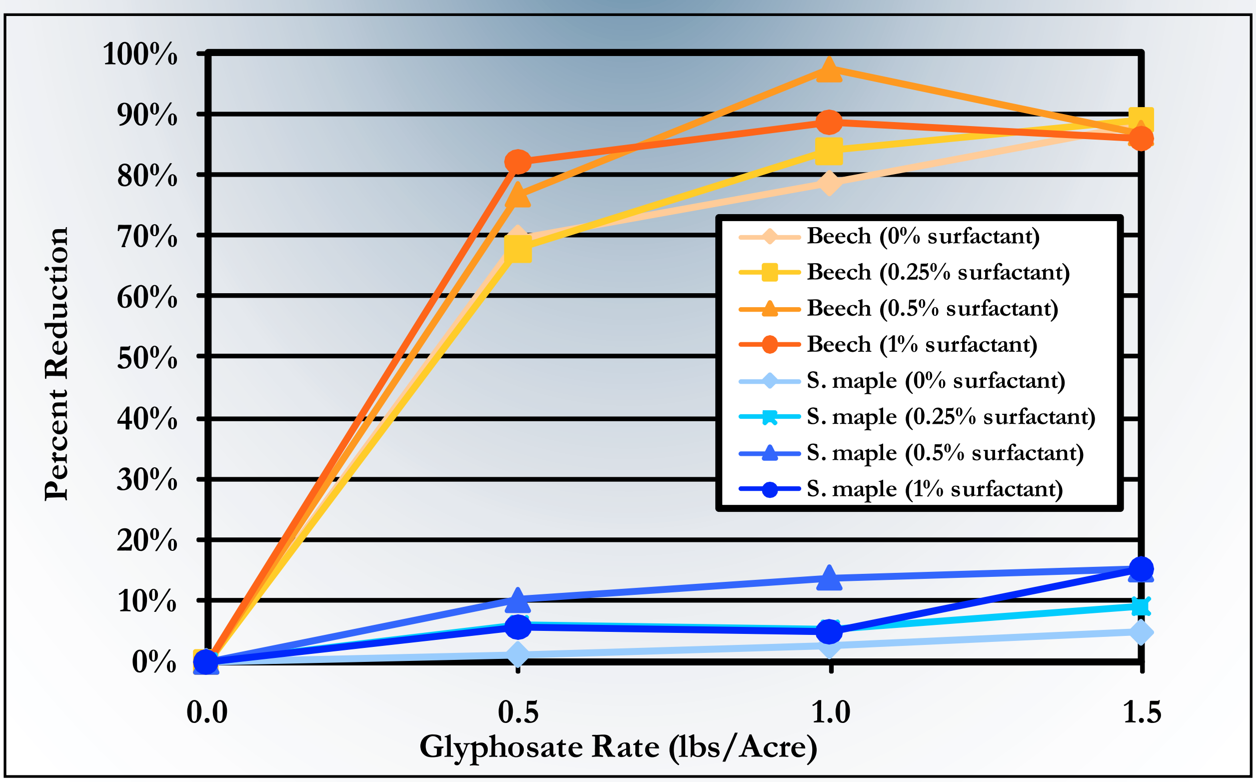
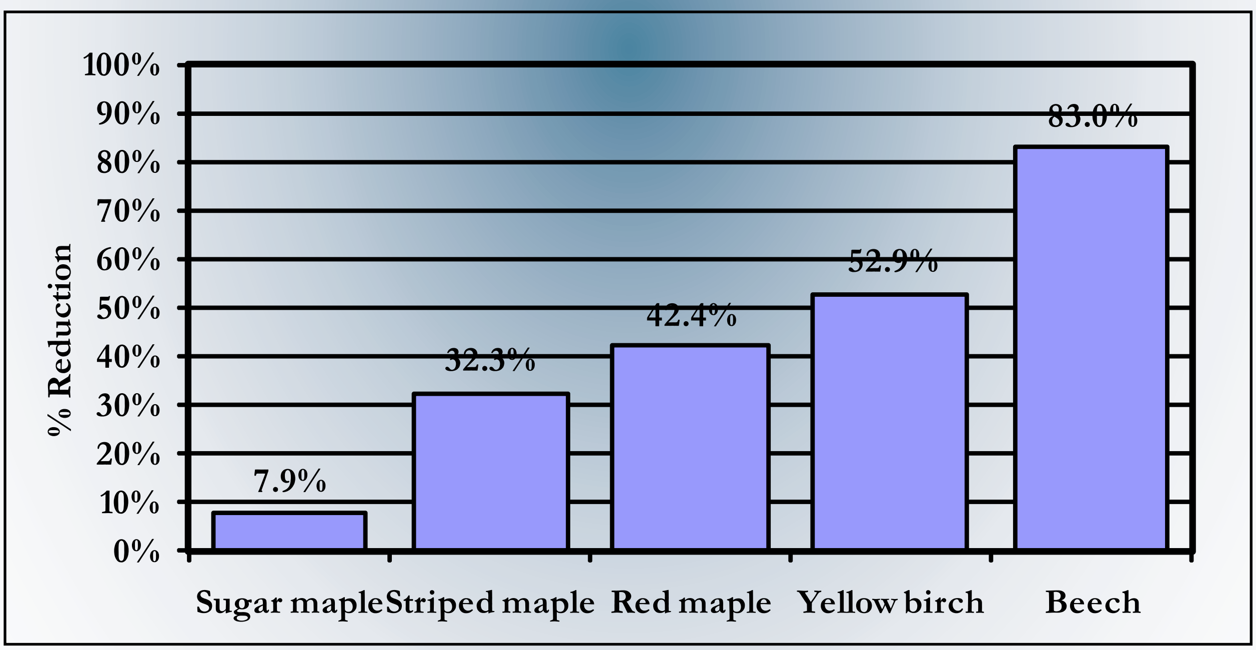


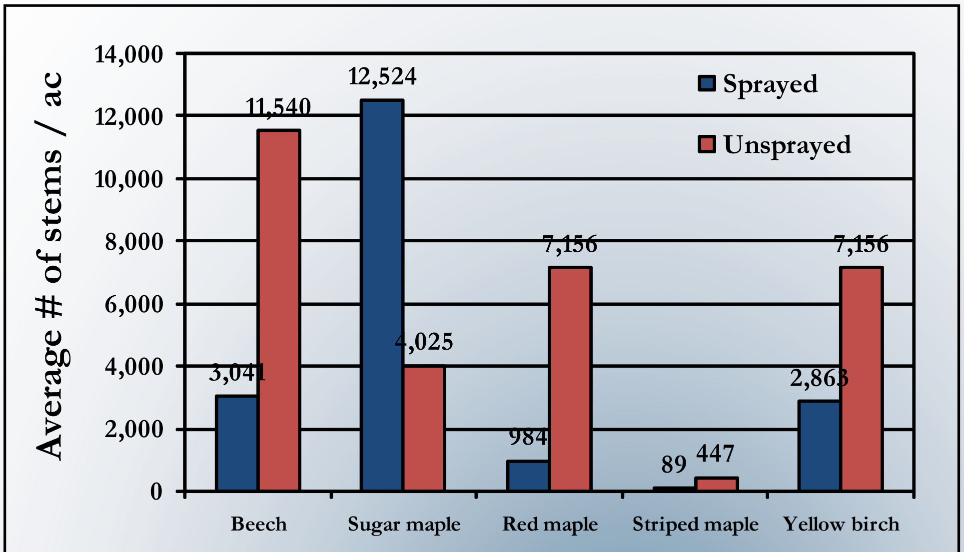
Figure 12. First-year control of beech and sugar maple with 0.5 lb/ac glyphosate herbicide and 0.25% EnTree 5735 surfactant at the Huber (T2R7) site. Photo on left shows the plot before treatment. The photo on right shows the same plot one year later. Note dead beech stems and large number of uninjured sugar maple seedlings in right photo.

Figure 13. Differences in hardwood species susceptibility to all glyphosate treatments based on first-year changes in stem count for all three sites (hydraulic nozzle data). Species ranking was similar for all treatments.



sugar maple stems and at rates from 0.5 to 1 lb/ac and with surfactant concentrations of only 0.25 to 0.5% (Figure 12). We also have found a substantial difference in the susceptibility of different hardwood species to the treatments, with the following order of susceptibility: beech > yellow birch > red maple > striped maple > sugar maple (Figure 13). Rates of at least 1 lb/ac with at least 0.25% concentrations appear necessary to provide control of striped maple. Unfortunately, most yellow birch were injured by most all of the treatments, so selectivity was not as good as hoped for this species.

Figure 14. Number of stems of understory tree regeneration for five tree species in the understory of adjacent sprayed and unsprayed stands three years after treatment in a Plum Creek Timber Company demonstration trail. The spray treatment was 1.25 qta/ac of Accord Applicators Concentrate with 12 oz/ac of Entry II surfactant applied by skidder-mounted mist blower.



Thus, the treatments tested in this study appear to offer promise in providing a low-cost method for shifting hardwood species composition toward sugar maple and red maple in the understory of beech-prone stands. A surprising initial result was the small degree of effect that surfactant concentration had in the study so far. Glyphosate rate appears to be most important, but rates at 1 lb/ac appear to be sufficient to provide good control of beech and relatively little damage to sugar maple.

PLUM CREEK DEMONSTRATION TRIAL

To provide an estimate of how the longer-term regeneration dynamics might play out following understory glyphosate treatment, we measured a spray demonstration trial that had been installed on Plum Creek Timber Company lands by Rocco Pizzo near Greenville, ME. A partially harvested stand with abundant beech regeneration was divided in half one year after harvest in 2004. During the following August, 1.25 qt/ac of Accord Applicators Concentrate with 12 oz/ac of Entry II surfactant was applied using a skidder-mounted mistblower on only one of the halves. In August 2007 (three years after treatment), ten circular sample plots with a 4-ft radius were sampled 100 ft apart along two transects (5 plots per transect) in both the sprayed and unsprayed halves. All tree species over 6 inches in height and less than 2.5 in DBH were measured. The number of stems and visually-estimated percent cover were recorded for each tree species. Comparing the understory composition in the sprayed and unsprayed halves of this trial provide a rough estimate of the longer-term improvements in understory species composition that can be achieved following an understory glyphosate treatment.

Results from this comparison are shown in Figure 14. Three years following treatment, the dominance of sugar maple over beech is clearly demonstrated in the understory that had been sprayed. In contrast, beech and red maple dominated the unsprayed stand. Unfortunately, as was found in the CFRU study above, there were fewer yellow birch in the sprayed than unsprayed stands. Results from this demonstration suggest that the patterns shown for the first year of the CFRU study may hold over time. Continued measurement of the CFRU study will document the applicability of first-year results to longer-term regeneration dynamics.

For more information about this project contact Bob Wagner at bob_wagner@umenfa.maine.edu or 207-581-2903.

Silviculture and Ecology of Northern White Cedar

Philip Hofmeyer, Robert S. Seymour and Laura Kenefic

BACKGROUND

This report is an update on findings from northern white-cedar (*Thuja occidentalis* L.) ecology and silviculture research in northern Maine. Our objectives for this study were to:

1) Compare growth of northern white-cedar to red spruce (*Picea rubens* Sarg.) and balsam fir (*Abies balsamea* L.) along a range of site classes and light exposures;

2) Describe early stem development and recruitment patterns;

3) Quantify cedar leaf area to sapwood area relationships and growth efficiency; and

4) Address some issues concerning sustainability of the northern white-cedar resource in Maine.

The goal of our research is to inform the decisions and actions concerning northern white-cedar management in Maine.

OBJECTIVE 1: COMPARATIVE GROWTH STUDY

Methods and results from growth comparisons of northern white-cedar to balsam fir and red spruce were reported in the 2006 CFRU Annual Report. To briefly summarize these findings:

- 60 sites were selected from northern Maine.

- 5 upper canopy cedar, balsam fir, and/or red spruce were sampled.

- Balsam fir basal area growth decreased on poorly drained sites; there were no differences in northern white-cedar or red spruce basal area growth by site class.

- Except on organic sites, balsam fir basal area growth was higher than red spruce and northern white-cedar.

- Balsam fir basal area growth increased as light exposure increased; there were no differences in northern white-cedar or red spruce basal area growth by light exposure class.

- Nearly 80% of outwardly sound northern white-cedar sampled had central decay; both incidence and proportion of area decayed increased as drainage improved.

Sapwood area was a significant covariate in basal area growth analyses by site class and light exposure for all species. The lack of differences in basal area growth by light exposure class are in part explained by the high correlation between sapwood

Cedar stumps very frequently have rotten cores but this one will make fine shingles.

area and light exposure class; all three species had a significant trend of increasing sapwood area as light exposure increased ($p<0.001$).

Though basal area growth did not differ among site classes in red spruce and balsam fir, we investigated site index among species. Trees occupying light exposure classes 1 and 2 (intermediate and lower codominant crown classes) were removed from the analysis. Trees with cores that were decayed, had periods of heavy suppression (i.e. budworm signals or overtopped trees), or exceeded 150 readable rings were also removed from the analysis. Sample size for each species stratified by site class was small because of the high incidence of decay and budworm signals. A five parameter Weibull function was fit to the core data:

$$SI = (b_1 H^{b_2})[1-\exp(b_3 A)^{(b_4 H^{b_5})}]$$

where SI is site index in feet at 50 years, H is total height in feet, A is tree age, and b_i are regression coefficients. Parameter coefficient estimates were published by Carmean (1989) for northern white-cedar and Steinman (1992) for red spruce and balsam fir. SI was converted from Imperial units to metric units.

Results suggest that site index was higher for balsam fir than northern white-cedar and red spruce on the lower site classes (Table 4). On the higher site classes, low sample size limited confidence in results. Site index values of red spruce in particular may have been impacted by the partial harvest-

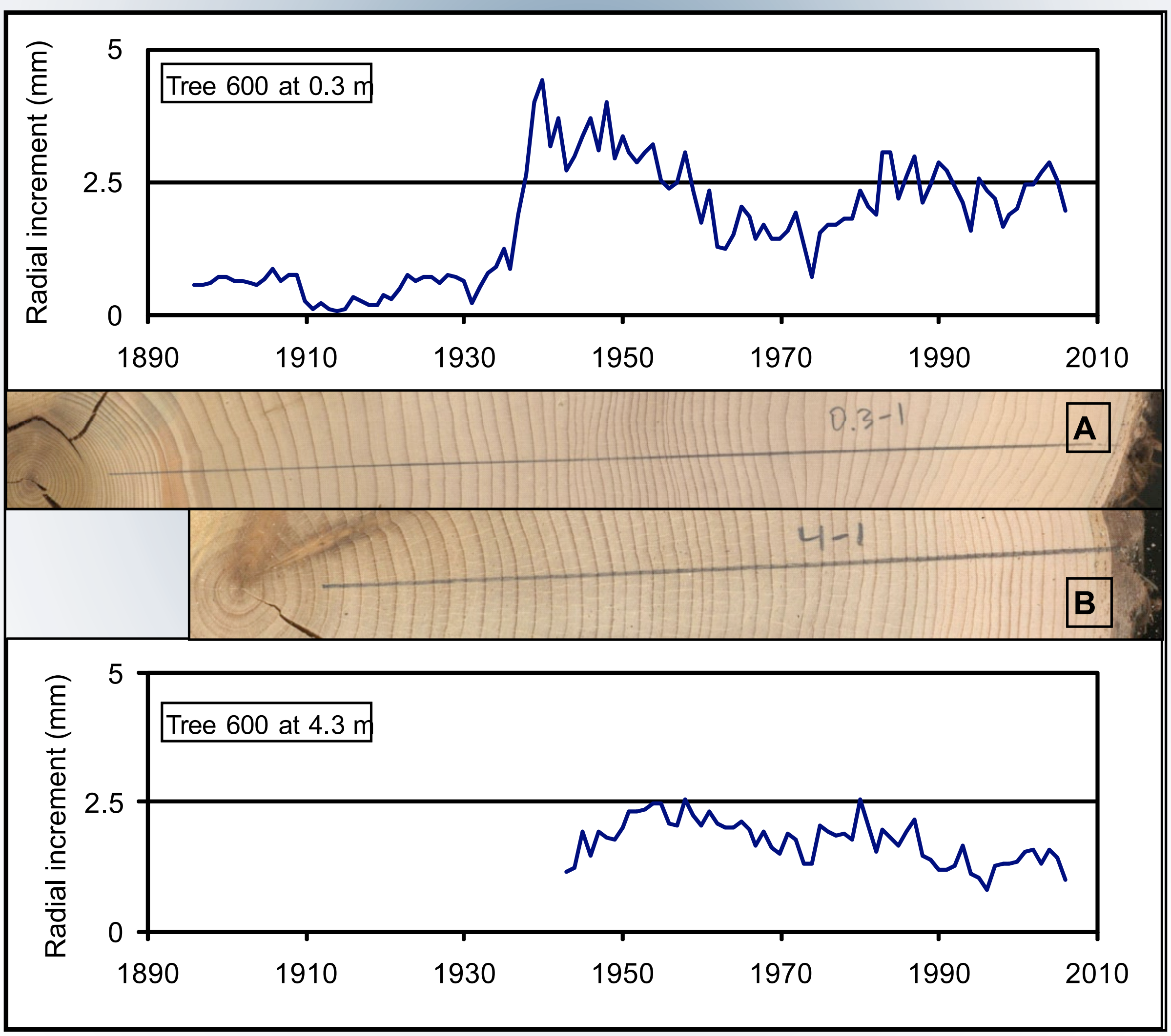


Figure 15. Pattern of suppression followed by release and relatively constant radial growth in the stump height disc (A), no core suppression in the mid height disc (B).

Table 4. Mean site index by site class determined from light exposure class 3-5 trees without core suppression (standard errors in parentheses).

Site Class	Balsam fir	Northern white-cedar	Red spruce	p-value
2	14.8 (1.188)b	no data	12.1 (1.372)	0.196
n	4	no data	3	
3	14.6 (0.687)b	9.8 (1.286)	10.9 (1.286)	0.015
n	7	2	2	
4	17.2 (0.956)a	10.3 (0.956)	12.5 (1.022)	<0.001
n	8	8	7	
5	13.2 (0.334)b	10.5 (0.732)	10.6 (0.437)	<0.001
n	24	5	14	
Organic	13.6 (0.434)b	9.6 (0.614)	11.2 (0.367)	<0.001
n	10	5	14	
p-value	<0.001	0.641	0.358	
Note: Means followed by differing letters were different at the α=0.05 level.				

ing history of these sites and the possibility that inferior trees have been left as residuals in past entries.

OBJECTIVE 2: EARLY STEM DEVELOPMENT

Early height and diameter growth was reconstructed from 78 sound northern white-cedar stems from 18 sites in northern Maine. Fifty-seven sample stems were donated by Maibec Industries, Inc. and 21 were felled for concurrent growth efficiency research. Cross-sectional discs were taken from the Maibec millyard stems at 0.3 m, 2.0 m, 4.2 m, and one at top height. Discs were taken from the growth efficiency trees at 1-m intervals starting from 0.3 m. Chronologies were read for each disc in Regent Instruments WinDendro software. Maibec stem ring counts were stan-

Figure 16. Stem profile of sample tree 42. Each line represents one year of height and diameter growth. Tighter lines indicate periods of suppressed height and diameter growth. Note the prominent basal flare below 2 m and the suppressed core.

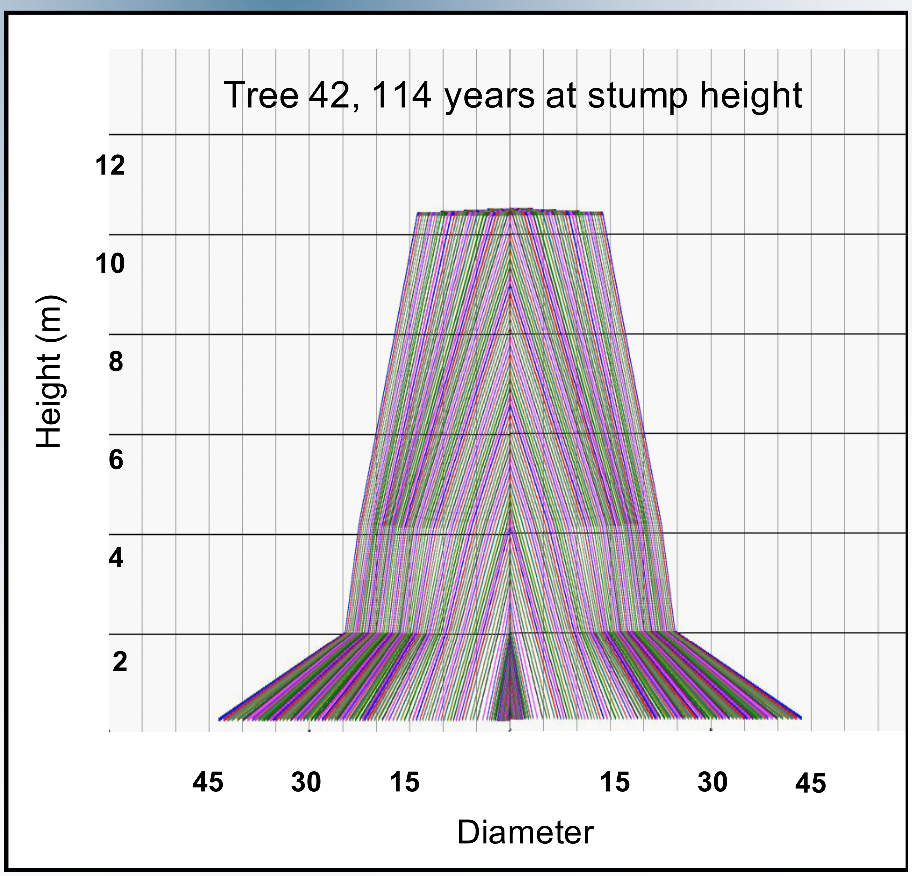


Table 5. Number of growth rings observed at 10 height/diameter combinations for 78 stem-analyzed northern white-cedar trees.

Height/ Diameter *	N	Min	Mean	Max	SE
SH 2.5	78	7	26.5	57	1.36
SH 12.7	78	28	85.9	171	3.24
SH 25.4	75	52	128.9	252	4.37
SH 38.1	65	77	170.1	317	5.81
BH 2.5	78	10	29.1	61	1.24
BH 12.7	78	30	68.4	139	2.59
BH 25.4	67	44	103.0	209	3.75
MH 2.5	78	22	67.1	129	2.44
MH 12.7	76	43	115.4	203	3.64
MH 25.4	57	86	184.0	320	5.91

* Height/diameter benchmarks are 2.5, 12.7, 25.4, and 38.1 cm in diameter at SH (0.3 m), BH (1.3 m), and MH (4.3 m).

dardized for each sample to number of rings per meter of height to pool data from both sample populations.

Ring counts were summarized for 10 height/diameter benchmarks. Number of years required to reach 2.5, 12.7, 25.4, and 38.1 cm (1, 5, 10, and 15 in) at stump height (SH, 0.3 m), breast height (BH, 1.3 m), and mid height (MH, 4.3 m) suggest that early stem development was generally slow (Table 5). Data were not available for all height to diameter combinations for smaller sample trees. No shingle stock tree (> 41 cm at BH) sampled had fewer than 114 growth rings at SH, the mean was 195 and the oldest sampled had 356.

Several growth patterns were frequently observed in the sample trees. Initial suppression was observed in 64 (82%) sample trees at SH though core suppression occurred in only 15 (19%) sample trees at MH. Periods of initial suppression were often followed by a release that resulted in sustained higher growth rates (Figure 15). Nearly every sample stem had prominent basal flaring, often extending well above breast height (Figure 16). Though annual radial increment is expected to exhibit a decreasing trend, many sample stems in this study had constant or slightly increasing annual radial increment at BH (Figure 17). Constant radial increment is indicative of increasing annual area increment.

These results suggest that northern white-cedar can respond positively once released after a period of suppression, often with sustained or increasing annual radial increment. Early height and diameter suppression followed by release in these samples suggests the importance that advance regeneration may have had in recruitment of mature cedar trees in northern Maine.

Figure 17. Pattern of constant or increasing radial increment commonly seen at breast height in northern white-cedar.

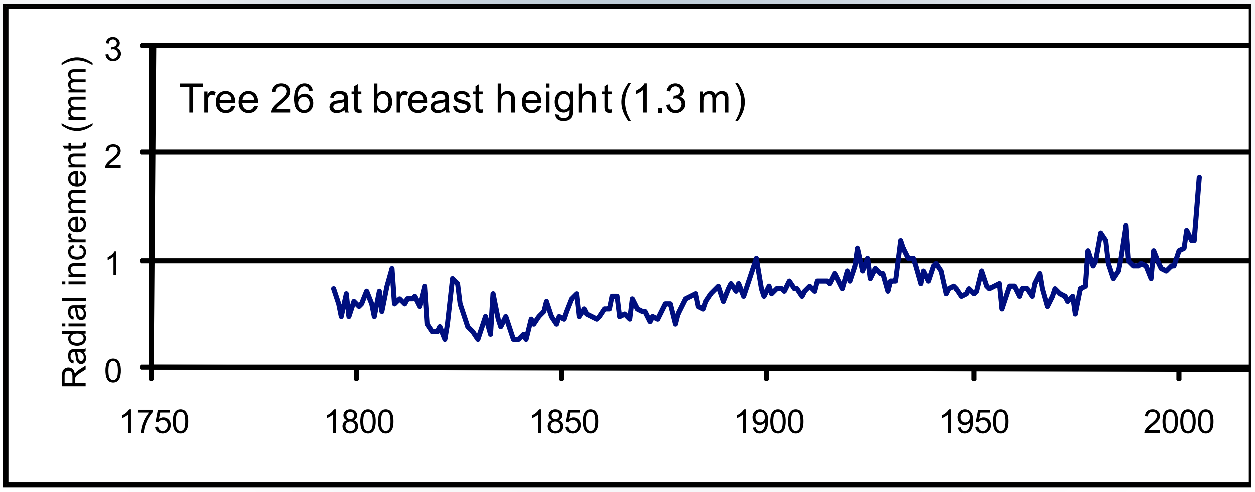
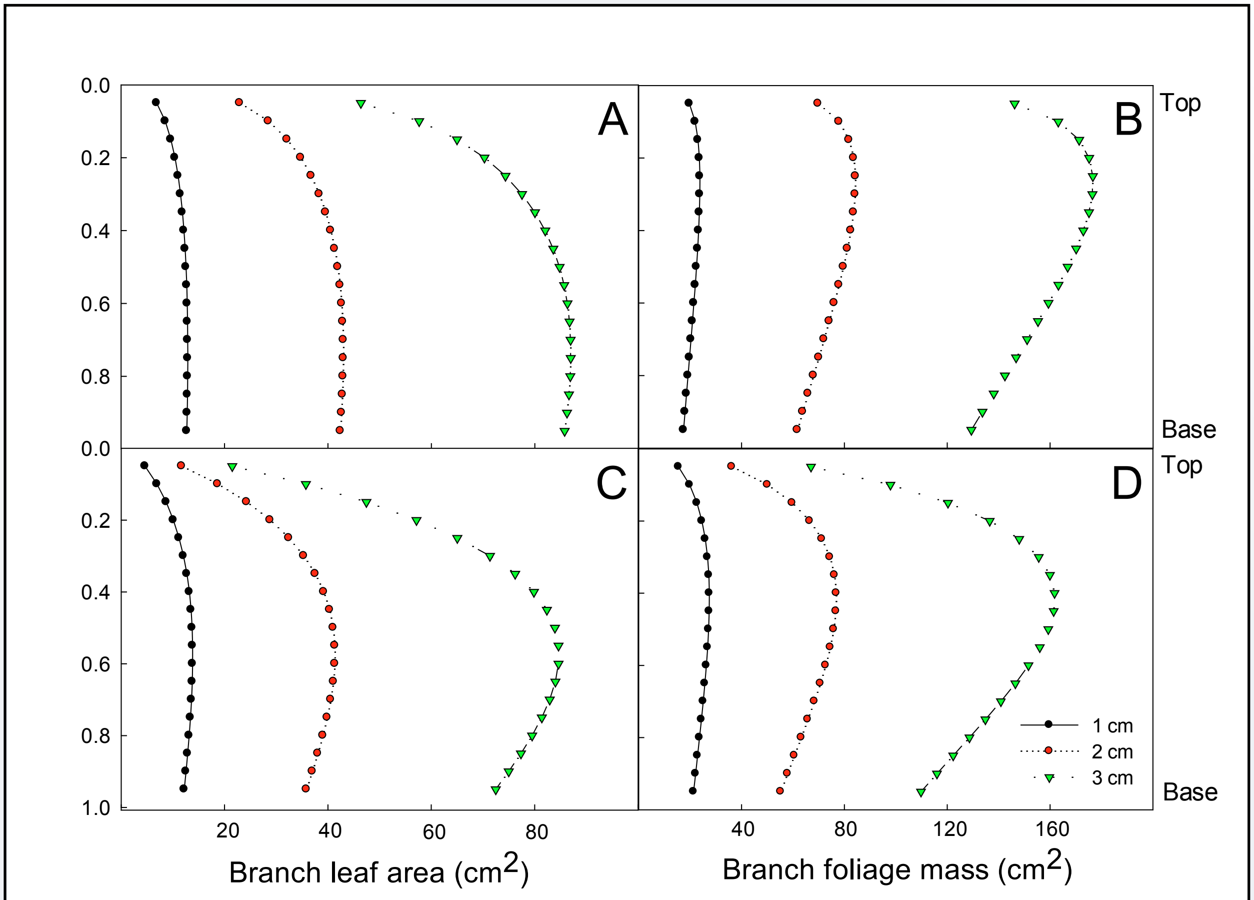


Figure 18. Branch leaf area (A) and branch foliage mass (B) as a function of relative distance (RD) into the crown and branch diameter (BD) as predicted by $SQRT(y) = (b_1BD^{b_2}) * (RDb_4\text{-}1) * (EXP\text{-}(b_3RD^{b_4}))$. Branch leaf area (C) and branch foliage mass (D) as predicted by $LN(y) = (b_1D^{b_2}) * (RDb_4\text{-}1) * (EXP\text{-}(b_3RD^{b_4}))$. The best-fit models were (B) and (C).



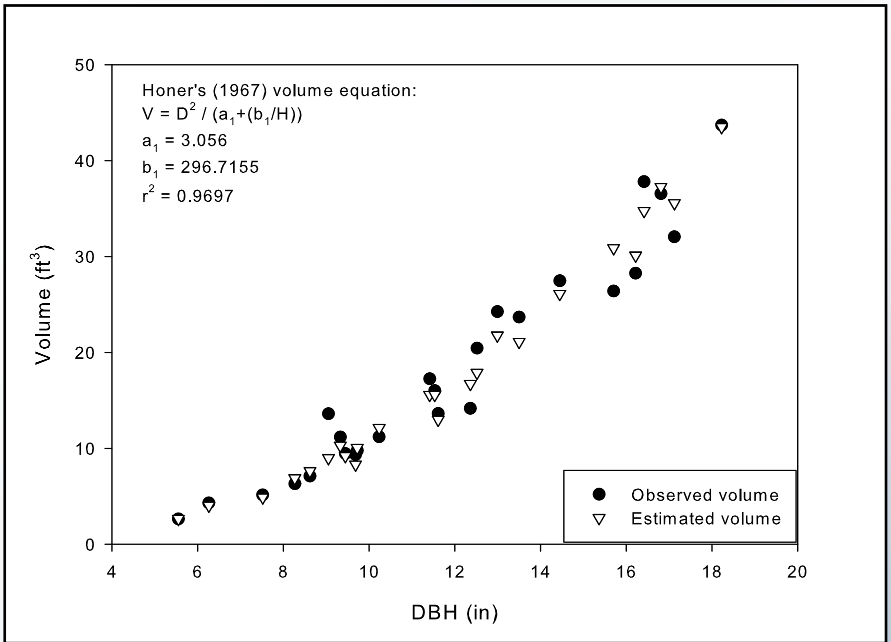
OBJECTIVE 3: GROWTH EFFICIENCY

Twenty-five northern white-cedar trees identified in the comparative growth study were destructively sampled to analyze leaf area and growth efficiency. One branch was randomly sampled from each of three live crown sections (lower quartile, mid quartile, top half) on each tree. Branch basal diameter and distance was recorded; five foliar sprays were removed and frozen. The remaining branch was cut, stored and dried for later analyses. All live branch diameters and distances along the bole were recorded. Cross-sectional discs were removed at 0.3 m and each 1-m interval thereafter. An additional disc was removed at the lowest live branch location if this did not coincide with the sampling interval. Frozen foliage was scanned in Regent Instruments WinSeedle software to determine foliage area and subsequently dried and weighed to determine specific leaf area

Table 6. Specific leaf area (cm^2/g) with respect to crown location and light exposure class.

Crown section	*n*	**Mean SLA**	**SE**
Lower Quartile	25	61.7a	1.75
Mid Quartile	25	55.6b	1.75
Upper Half	25	46.0c	1.75
p-value		<0.001	
Pooled light exposure class *			
1	12	58.3a	1.71
3	8	51.6b	2.1
5	5	49.6b	2.65
p-value		0.008	
* Light exposure classes 1 and 2 were pooled, as were 4 and 5.			
Note: Means followed by differing letters are different at the 0.05 level of significance.			

Figure 19. Honer's (1967) model form refit to obtain new parameter estimates.



(SLA, cm^2/g) for each sample branch. Dried branch samples were sorted into foliage, cone, and woody components to determine mass of each branch component. Branch foliage mass (BFM) was multiplied by SLA to determine the branch leaf area (BLA) for each sample. Four models were fit to estimate BLA and BFM for all previously measured live branches. BLA and BFM were summed for each tree to determine projected leaf area (PLA, m^2) and crown foliage mass (CFM, kg) for each sample tree. Cross-sectional discs were dried, sanded, and analyzed in Regent Instruments WinDendro software. Volume increment (VINC, dm^3) for the most recent two complete years of growth was determined for each tree in Regent Instruments WinStem software. Two nonlinear models were fit to describe VINC as a function of PLA. Growth efficiency (GE=VINC/PLA, dm^3/m^2) was determined for each sample tree and tested for differences among light exposure and site classes.

Analysis of variance (ANOVA, α=0.05) detected differences in SLA among crown sections (Table 6). Pooling light exposure classes 1 with 2 and 4 with 5 increased sample size enough to detected differences in SLA among light exposure classes. This suggests that cedar foliage morphology is re-

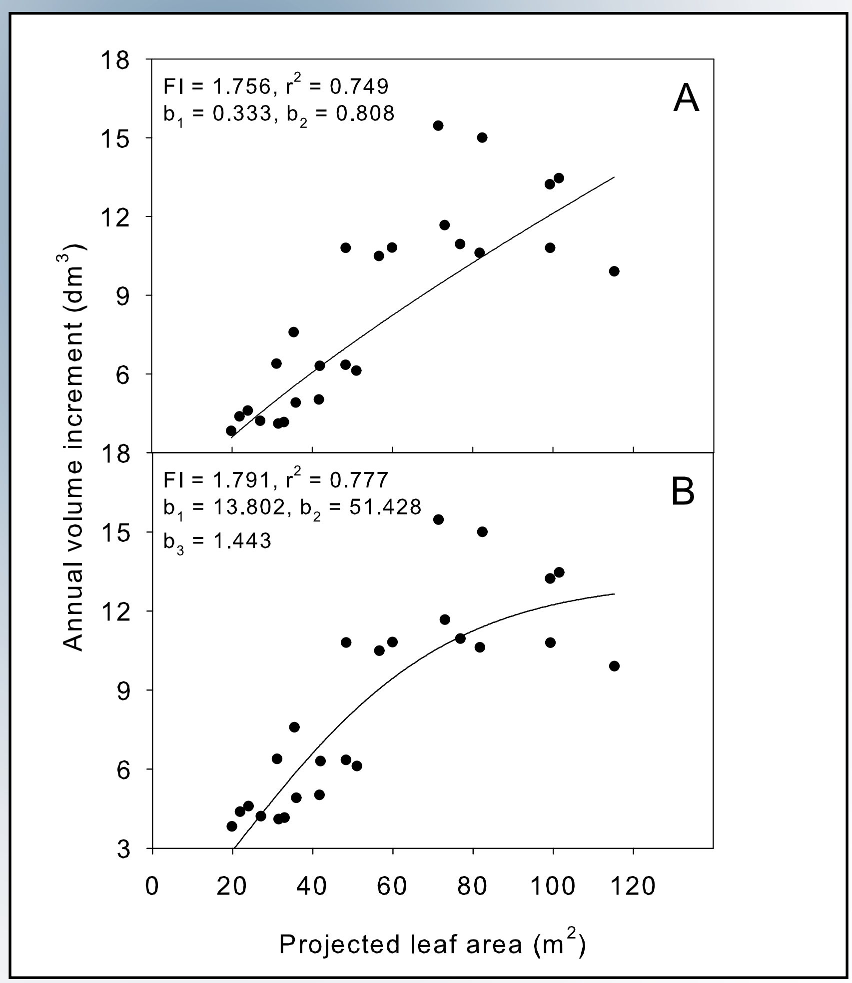


Figure 20. Volume increment as a function of projected leaf area as predicted by (A) [VINC 1] and (B) [VINC 2] for 25 northern white-cedar trees. Figures depict optimal model weights.

Figure 21. Northern white-cedar timberland (A) and net volume (B) by size class in Maine (after McWilliams et al. 2005).

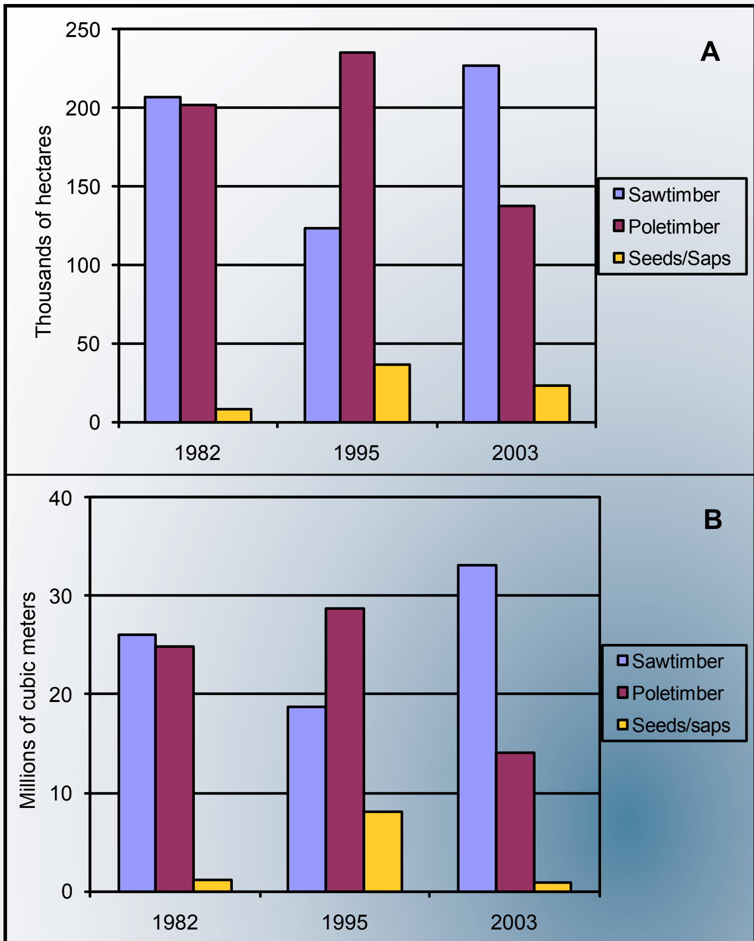


Table 7. Mean growth efficiency (GE) of 25 destructively sampled northern white-cedar trees by site and light exposure class.

Site class	*n*	**Mean GE (dm^3/m^2)**	**SE**
2	4	0.118	0.017
3	4	0.147	0.017
4	4	0.159	0.017
5	7	0.179	0.013
Organic	6	0.168	0.014
p-value		0.110	
Light exposure class			
1	9	0.166	0.013
2	2	0.163	0.029
3	9	0.153	0.013
4	4	0.161	0.020
5	1	0.121	0.040
p-value		0.839	

sponsive to environmental gradients of temperature, moisture, and light availability. Cedar trees develop long, flattened sprays lower in the crown and thick, round foliage higher in the crown.

Two forms of a nonlinear Weibull function were fit to BLA and BFM data to describe foliage characteristics within northern white-cedar crowns. Results of these models suggest that BLA peaks near the middle of the crown and BFM peaks toward the crown top (Figure 18). This relationship is likely caused by differences in foliage morphology described by SLA results.

Over 50 linear and nonlinear models were fit to PLA and CFM data with independent variables that included sapwood area (SA), live crown ratio (LCR), modified live crown ratio (mLCR), stem diameter, stem basal area (BA), and area inside bark (AIB). Though sapwood area models performed well, the best-fit models were:

$$\text{[AIB4] } PLA = b1AIBLLB^{b2}$$

$$\text{[BA4] } PLA = b1BA^{b2} * mLCR^{b3}$$

where PLA is projected leaf area, AIBLLB is area inside bark at the lowest live branch, BA is basal area outside bark, and mLCR is the modified live crown ratio (ratio of CL to distance from leader to breast height) (Valentine et al. 1994). Models were compared using Furnival's (1961) index of fit, generalized correlation coefficients (Kvalseth 1985), and residual analysis. Mean PLA for the sample trees was 56.3 m^2 + 5.65 SE.

Honer's (1967) volume equation was fit to the total stem volume determined in WinStem software. Though the original model was unbiased, refitting the model resulted in new parameter coefficients and a higher r^2 (Figure 19). Mean VINC for the most recent two complete growth years was 0.49 dm^3 + 0.064 SE.

Two nonlinear models were fit to describe VINC as a function of PLA:

$$[\text{VINC 1}]\ \text{VINC} = \beta 1 \text{PLA}^{\beta 2}$$

$$[\text{VINC 2}]\ \text{VINC} = \beta_1\left(1 - \text{EXP}\left[-\left(\frac{\text{PLA}}{\beta_2}\right)^{\beta_3}\right]\right)$$

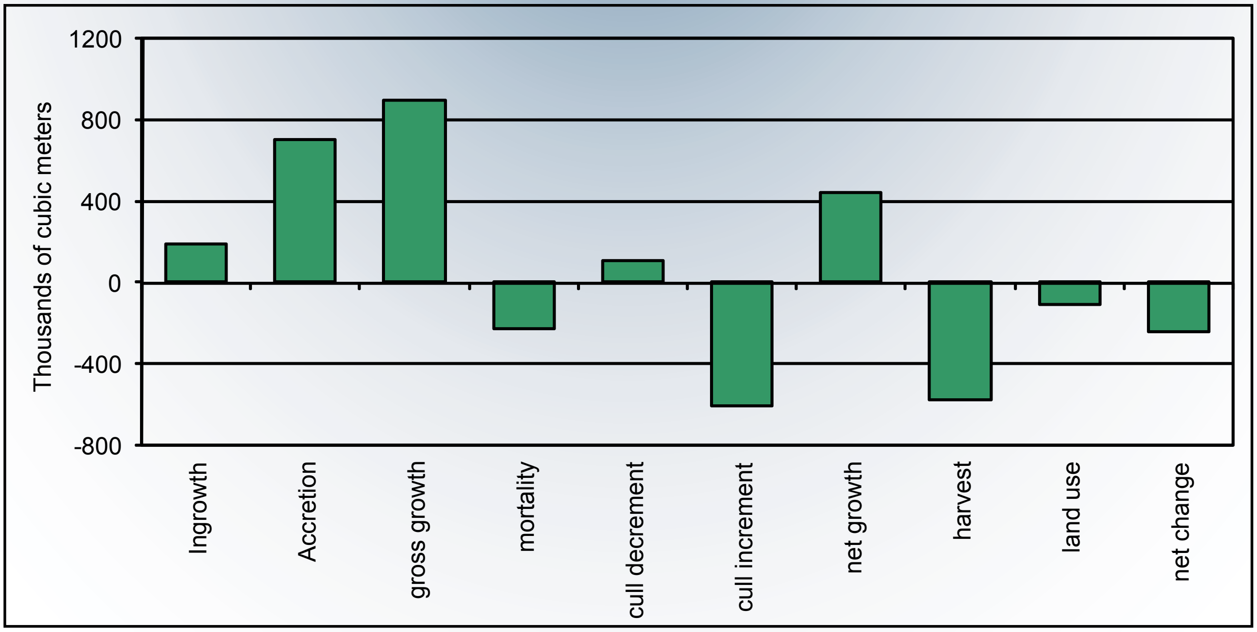
where VINC is annual stemwood volume increment (dm^3), PLA is projected leaf area (m^2), and β_i are regression coefficients. Northern white-cedar exhibits a pattern of decreasing VINC as PLA increases (Figure 20); however variability of this relationship is higher than reported for many other tree species. This variability could not be explained though cone production, crown attributes such as forking, or incidence of central decay.

ANOVA detected no differences in GE by light exposure class or site class (α=0.10, Table 7). Site class was marginally non significant with a trend of decreasing GE as soil drainage improves. This trend is opposite to GE findings from fertilization trials with other species (e.g. Brix and Mitchell 1983, Jokela and Martin 2000). GE has varied by canopy position in many tree species, often reportedly as a response to tradeoffs between photosynthesis and maintenance respiration. Northern white-cedar was expected to exhibit a trend of decreasing GE as light exposure class increased. Though light exposure class 5 did have the lowest mean GE, there was only one observation in this class. Northern white-cedar represents one of the few species that has shown little GE response to site and canopy position. This supports accounts of northern white-cedar as a stress tolerant, plastic tree species that readily adapts to a wide range of environmental conditions.

OBJECTIVE 4: SUSTAINABILITY OF THE NORTHERN WHITE-CEDAR RESOURCE IN MAINE

U.S. Department of Agriculture, Forest Service Forest Inventory and Analysis (FIA) data (McWilliams et al. 2005) suggest that sustainability of the northern white-cedar resource in Maine is a concern. Since 1982, northern white-cedar forestland has declined from 417,000 hectares to 388,000 hectares; declines in poletimber were most prominent (Figure 21A). Net volume of northern white-cedar growing stock increased from 52 million m^3 in 1982 to 56 million m^3 in 1995, but decreased to 48 million m^3 in 2003.

Figure 22. Average annual net change in northern white-cedar forestland since 1995 (after McWilliams et al. 2005).



Over this time period, sawtimber growing stock increased while poletimber and sapling growing stock decreased (Figure 21B). Declines in northern white-cedar growing stock from 1995 to 2003 were primarily attributed to cull increment and excessive harvesting (Figure 22). Cull increment was defined by McWilliams et al. (2003) as the net volume of growing stock trees in the previous inventory that are classified as rough or rotten trees in the current inventory.

Shifts in the size class structure reported by McWilliams et al. (2005) are disconcerting given the early stem development trends found in the stem-analyzed sample trees in this study. Mature northern white-cedar stems in this study were much older than previously considered. Most had a history of initial growth suppression and subsequent release that is indicates the importance that advance regeneration may have had. Trees with this growth pattern were typified by slow recruitment into sapling and poletimber size classes with an eventual release.

Anecdotal discussions with several Maine foresters suggested that northern white-cedar is commonly retained in partial harvests because of its low commercial value. Northern white-cedar has the lowest specific gravity and is the weakest wood of all commercial tree species in North America (Larson 2001). Because of its wood properties and likelihood of retention, increases in cull increment might have arisen from residual stand damage in partial harvests.

SUMMARY

The Bad News

Sustainability of the northern white-resource in Maine is a concern. Structural shifts over the past 20 years suggest that poletimber and seedling/sapling size classes require management attention. Though sawtimber volumes and prevalence on the landscape has increased over this time period, harvest has exceeded net growth. Cull increment in the past 10 years has been a substantial detriment to growing stock volumes, perhaps as a result of residual stand damage in partial harvest operations. Central decay resulting from butt rot fungi was common in outwardly sound northern white-cedar trees across all drainage classes. Age data from sound individuals suggest that the northern white-cedar resource may be older than originally considered, with particularly slow growth during early stages of development.

The Good News

Some conventional wisdom guiding cedar management had little support in data from this study. Though northern white-cedar trees were commonly decayed, incidence and proportion of decay was lower on poorly drained mineral and organic sites. Basal area growth did not differ among site classes or light exposure classes. Northern white-cedar has good growth potential relative to competing species; however growth may be slow during the establishment period. Growth efficiency did not differ among site or light exposure gradients which suggests that volume growth of a northern white-cedar tree of a given crown size will be similar regardless of soil drainage or canopy position.

Caveats

Early stem development patterns were biased to sound individuals and may not be representative of the entire northern white-cedar population in Maine. As growth was determined for outwardly sound individuals, this study may represent a "best case" scenario, particularly for northern white-cedar and balsam fir. Partial cutting history of the sites may have left inferior residuals of all species on the landscape.

Recommendations

Recent data from LaRouche et al. (2007) suggest that seedling establishment (abundance) was highest under partial shade conditions. Established northern white-cedar seedling height growth responds positively to increased light availability, however. They recommended selection and shelterwood systems to establish and recruit northern white-cedar. Data from this study suggest that advance regeneration should be fostered during intermediate treatments. Large crowned individuals should be retained as residuals in partial harvests and to increase tree-level volume growth. Avoid residual stand damage in partial harvest operations to reduce crown and root damage to this brittle tree species, which may be a mechanism for fungal entry. Decay and growth findings suggest focusing efforts on lowland sites with the best potential.

For more information about this project contact Bob Seymour at seymour@umenfa.maine.edu.

LITERATURE CITED:

Brix, H. and Mitchell, A.K. 1983. Thinning and nitrogen fertilization effects on sapwood development and relationships of foliage quantity to sapwood area and basal area in Douglas-fir. Can. J. For. Res. 13: 384-389.

Carmean, W.H., J.T. Hahn, and R.D. Jacobs. 1989. Site index curves for forest tree species in the eastern United States. USDA For. Ser. Gen. Tech. Rpt. NC-128. 142 p.

Furnival, G.M. 1961. An index for comparing equations used in constructing volume tables. For. Sci. 7: 337-341.

Jokela, E.J. and T.A. Martin. 2000. Effects of ontogeny and soil nutrient supply on production, allocation, and leaf area efficiency in loblolly and slash pine stands. Can. J. For. Res. 30(10): 1511–1524.

Kvålseth, T.O. 1985. Cautionary note about R2. Am. Stat. 39: 279-285.

Larson, D.W. 2001. The paradox of great longevity in a short-lived tree species. Experimental Gerentology 36(4): 651-673.

McWilliams, W.H.; Butler, B.J., Caldwell, L.E., Griffith, D.M., Hoppus, M.L., Laustsen, K.M., Lister, A.J., Lister, T.W., Metzler, J.W., Morin, R.S., Sader, S.A., Stewart, L.B., Steinman, J.R., Westfall, J.A., Williams, D.A., Whitman, A., Woodall, C.W. 2005. The forests of Maine: 2003. USDA, Forest Service Resource Bulletin NE-164. 188 p.

Steinman, J.R. 1992. A comprehensive evaluation of spruce-fir growth and yield in Maine as related to physical and chemical soil properties. Ph.D. Dissertation. University of Maine. 123 p.

Valentine, H.T., Baldwin, V.C., Gregoire, T.C. and Burkhart, H.E. 1994. Surrogates for foliar dry matter in loblolly pine. For. Sci. 40: 576-585.

Biomass Harvest Systems for Improving Low-Value, Beech-Dominated Hardwood Stands in Maine

Jeffrey G. Benjamin and Robert G. Wagner

A new project was initiated this year to investigate biomass harvest systems and to compare approaches for rehabilitating low-value, beech-dominated hardwood stands. The project is jointly funded by the Forest BioProducts Research Initiative (FBRI) and CFRU. This work could help Maine's forest managers meet the challenges an emerging bioenergy/bioproducts market while providing a low-cost silvicultural approach for rehabilitating young beech stands.

The forest landscape and composition in Maine has changed over the last 20 to 30 years. Thirty percent of Maine's timberland is currently in the seedling/sapling stage (Maine Forest Service 2005). The spruce budworm epidemic and subsequent salvage operations of the 1980s left many areas regenerating with low quality and undesirable hardwood species. Those areas that were not treated with herbicides and precommercially thinned due to low conifer stocking have developed into stands carrying significant volumes of low-value fiber. Many landowners would like to improve the composition and quality of these stands, but the cost of stand rehabilitation are currently prohibitive.

A stand condition where a significant opportunity exists in this regard can be found on mid-site sugar maple, red maple, and yellow birch sites that were shelterwood harvested over the past 20 or more years and have become dominated by diseased beech. Many of these stands still have a stable sugar maple and yellow birch overstory seed source with a mid-story and understory that is dominated by beech. There is currently no financially feasible silvicultural approach to rehabilitating these sites by shifting the regeneration to maple and yellow birch. An integrated system of biomass harvesting and vegetation management may provide a financially feasible means for landowners to rehabilitate older beech-dominated stands. This effort complements ongoing CFRU research related to improving hardwood regeneration in beech dominated stands (see Beech Control).

Although biomass harvesting equipment and systems were extensively investigated during the 1970s and 1980s in the United States and Canada, much has changed with forest harvesting practices in Maine since that time. Full-tree harvest systems, now the dominant harvest system in Maine, can be used to maximize stem utilization in today's commercial operations through use of tops and limbs as biomass. In fact, biomass harvest operations are most easily integrated with full tree operations. It is not known what effect smaller stem size and reduced trail spacing will have on biomass harvest operations.

The objectives of this project are to:

1) Compare the efficiencies, costs, and suitability of biomass harvest systems for rehabilitation of low value beech-dominated hardwood stands of different stand characteristics; and

2) Compare the efficacy and cost-effectiveness of combined biomass harvesting and vegetation management treatments for rehabilitating young beech-dominated stands.

METHODS

Site Selection

Target sites for this study were former shelterwood harvests where a sugar maple, red, maple, and yellow birch overstory has remained intact, but has regenerated primarily to a beech-dominated mid-story and understory. Huber Resources Corporation proposed harvest of such a site in 2007 in the area surrounding Springy Brook Mountain in TWP 32 (Figure 23). Biomass was expected to be a primary product from the harvest given the high proportion of low-quality beech present. The harvest plan called for the removal of existing beech in the overstory and understory, and to leave all sugar maple and yellow birch in the overstory, taking care not to damage the residual stand.

Experimental Design

Three uniform areas of 1.2 ha (73 m x 165 m) were identified on Springy Brook Mountain to serve as blocks in the randomized complete block experimental design.

Each block was divided in half (0.6 ha – 36.5 m x 165 m) to provide two harvest treatments in each site. The harvest treatments included a full-tree harvest with 40-ft and 60-ft trail spacings that were randomly assigned to each treatment plot. The harvesting productivity and residual stem damage are being compared between the two trail spacings. Within each harvest treatment plot, three vegetation treatment subplots of 0.2 ha (36.5 m x 55 m) were installed. Each of the three subplots were randomly assigned to each subplot. The vegetation treatments include 1) pre-harvest herbicide injection of beech stems, 2) post-harvest broadcast herbicide treatment of the understory, and 3) no vegetation treatment. The final experimental design is a randomized complete block 2x3 factorial design with two biomass harvest treatments and three vegetation control treatments, with three replications. Differences in the operational productivity will be studied among the harvest treatments and differences in beech, maple (sugar and red), and yellow birch regeneration will be compared among the three vegetation treatments.

Pre-Harvest Measurements

Eight fixed area sample plot centers were located on two transect lines within each of the six subplots. A total of 144 sample plots were installed across all three blocks. Transect lines were spaced at 12.2 m apart, and sample plots were spaced 12.5 m from the sub-block boundary on either end and 10 m from one another.

Figure 23. Beech dominated stand on Huber Resources lands selected for biomass harvest study.

The overstory was sampled (8% cruise) using 0.002 ha circular sample plots (2.52 m radius). All tree stems greater than 1 in (2.54 cm) DBH were sampled. Species and DBH were recorded for each tree included in the sample plot. The understory was sampled (2% cruise) using a 4.52 m^2 circular (1.2 m radius) sample plot nested at the center of the overstory sample plot. All tree stems >6 in (15.2 cm) in height were recorded. The number of stems by species within the sample plot also were recorded.

Pre-Harvest and Post-Harvest Vegetation Treatments

In mid July 2007, one third of the subplots selected for the preharvest herbicide injection were treated with full-strength Accord Concentrate using TSI Hypo Hatchet Tree Injectors. One injection per in DBH was applied to all overstory and mid-story beech and striped maple. Symptoms of herbicide injury were evident within two weeks of treatment (Figure 24) and leaves on the beech trees were nearly gone by the time of harvest treatment.

Figure 24. Beech trees showing symptoms immediately after injection of glyphosate herbicide using a hypo-hatchet in August 2007.

During August of 2008, one third of the subplots selected for post-harvest broadcast herbicide treatment will be treated with a broadcast herbicide treatment of the understory using a backpack sprayer. The objective will be to remove any beech seedlings or new suckers, while preserving any sugar maple and red maple regeneration. Based on the results of the current CFRU beech control study (see Beech Control), the likely treatment will be 1.0 lb/ac of glyphosate (Accord Concentrate) with 0.25% EnTree 5735 surfactant in 10 gals/ac of water

Harvest Treatments

Harvest operations began in mid-August by a contractor hired by Huber Resources Corporation. (Figure 25) Wayne Peters (owner-operator) carried out harvesting activities to the specifications of this project using a John Deere 540 feller buncher. Trail spacings were randomly assigned to each block and the operator was instructed to remove beech stems greater than 1 in DBH and to leave all sugar maple and yellow birch unless they were standing in the trail.

Harvest activities were recorded using two handheld digital video cameras so feller-buncher movements could be analyzed later. One camera was held inside the machine cab behind the operator to record machine movements associated with the felling head. The second camera was operated at a safe distance away from the machine to record machine movements associated with the carriage, cab and boom. Both video cameras were synchronized at the start of each harvest.

A time and motion study was conducted using the harvest videos and a handheld computer. Prior to the study a full tree harvest configuration was designed using UMT_Plus, a time and motion study software package. All of the basic work tasks associated with a full tree harvest (e.g. felling, tracking, and bunching) were included. Once the configuration was uploaded to a handheld computer, a continuous time study was conducted for each harvest video.

A post-harvest residual stem damage assessment was conducted using the methodology outlined by (Ostrofskey et al. 1986, Ostrofsky and Dirkman 1991, Nichols et al. 1994). Species, DBH and stem damage were recorded for all residual overstory stems from each harvest block. This will allow comparisons of stem damage between harvest treatments and also serves as an estimate of biomass remaining on site post harvest which is critical to biomass removal estimates.

Although biomass was expected to be a primary product from this harvest, the contractor sorted out any pulp quality logs as well. Roadside products (biomass or pulp) from each harvest treatment and block were piled separately at each landing to allow tracking of production. Weight of pulp logs delivered to a local mills can be tracked back to each harvest block. Biomass production will be estimated from pre-harvest biomass estimates based on cruise data, pulp production, and residual biomass estimates.

FUTURE PLANS

Data collection on harvest activities is now complete. Analysis of harvest treatments with respect to time and motion data, biomass production estimates, and residual stem damage will continue next year as part of the M.S. Thesis research of Charles Coup, a new graduate student hired to coordinate field activities for this project. The final phase of the vegetation treatment study (post-harvest herbicide application) will be completed next field season with final results available in 2009.

Figure 25. Beech stand immediately after biomass harvest in fall 2007.

Wildlife

Quantifying Biodiversity Values Across Managed Landscapes in Northern and Western Maine

Predicting Responses of Forest Landscape Change on Wildlife Umbrella Species

Quantifying Biodiversity Values Across Managed Landscapes in Northern and Western Maine

Erin Simons, Daniel J. Harrison, Andrew Whitman, John Hagan and Ethel Wilkerson

PROJECT OVERVIEW

Most sustainable forestry frameworks expect forest managers to accommodate the habitat needs of wildlife and plant species to avoid species loss. Those landowners who participate in certification programs are required to maintain forest biodiversity, including viable populations of all wildlife and plant species. Each certified landowner has developed strategies for meeting biodiversity goals, but approaches for systematically addressing the adequacy and success of biodiversity conservation efforts are poorly developed and untested. Current regulations require landowners to conserve deer wintering areas, bald eagle nesting areas, shoreland zones, and wetlands, but sustainable forestry lacks guidelines for ensuring that area-sensitive species and species requiring late- or early-successional habitats are accommodated in long-term forest management planning. Existing planning tools are often applied independently and no framework exists for comprehensively integrating biodiversity conservation in managed forest landscapes.

Sustainable forestry certification programs have largely relied on policy response indicators to address the biodiversity concerns. Policy response indicators describe a landowner's policies, practices, and institutional capacity to protect a value, in this case biodiversity. Although policy response indicators are important, they are not designed to document the present status or condition of biodiversity. CFRU has funded previous projects to quantify condition indicators for managed forests in Maine at the stand- (i.e., late successional index, early-successional bird and snowshoe hare habitat index, riparian biodiversity index) and landscape-scales (i.e., predictive models of marten and lynx occurrence and umbrella species analyses). Condition indicators provide more concrete, precise, and quantitative assessments of the status of selected components of biodiversity.

Previous research funded through CFRU, NCASI, and others have positioned Maine to be a leader in landscape-scale biodiversity conservation on commercial forestlands. Area-sensitive umbrella species (e.g. marten and lynx) have been evaluated and tested as effective biodiversity conservation tools for > 85% of the forest-generalist, deciduous-forest specialist, and coniferous-forest specialist vertebrate species (n = 111) occurring in northern Maine. Easy to use, spatially explicit modeling tools have been developed for these two umbrella species which provide an opportunity to simplify landscape-scale biodiversity planning. Additionally, indices have been developed for quantifying late- and early-successional biodiversity values at the stand-level and for quantifying riparian biodiversity. Past CFRU-funded research has generated the tools required to develop a number of quantifiable biodiversity values, which could be integrated into a landscape-scale biodiversity management, planning, and performance-scoring framework. We have proposed to apply and evaluate a series of biodiversity indices (collectively called a "Biodiversity Scorecard") across a set of townships that have different ownership and forest management histories. The specific objectives for this research are:

1) Map and quantify biodiversity values for each component metric of the Biodiversity Scorecard to assess the range of variability across a diverse set of owners, owner types and forest management regimes in northern Maine. Evaluate the time and information needs required to apply the Biodiversity Scorecard and improve its efficacy to a diverse group of landowners.

2) Evaluate the scalability and performance of each component metric of the Biodiversity Scorecard to determine whether some or all of the individual biodiversity values accrue from the township- to multi-township scale.

3) Forecast and quantify change in each component metric of the Biodiversity Scorecard based on three alternative forest management scenarios: 1) natural succession, 2) continuing recent forest management trends for included ownerships, and 3) management plans modified with specific biodiversity considerations directed at balancing fiber extraction objectives with the indices included in the Biodiversity Scorecard. Use results to evaluate the costs and benefits of biodiversity conservation at scales of one to eight townships.

4) Quantify changes in maximum allowable harvest associated with biodiversity planning and alternatively, the changes in future biodiversity resulting from proceeding with a maximum allowable harvest strategy without associated biodiversity planning.

SUMMARY OF PROGRESS IN 2007

The UMaine and Manomet collaborators participated in a series of meetings in the first year of this three year project to determine which Biodiversity Scorecard components would be included in the analysis, and what data would be required to support the analysis. A number of the scorecard metrics, including late-successional (LS) forest and early successional (ES) species, were initially developed based on data available from conventional landowner forest stand maps. Because of the need for a common landcover data set that could be used to evaluate metrics across multiple townships, we eventually decided to use satellite-derived products to map each component metric of the Biodiversity Scorecard. Based on our preliminary work, we determined that satellite-derived products perform well for some metrics, but that further field testing will be required for others.

To facilitate our satellite-based analyses for the majority of the Scorecard metrics (landscape metrics based on predicted occurrences of martens and lynx, late-successional conifer metrics, late-successional deciduous metrics, early-successional bird metrics),

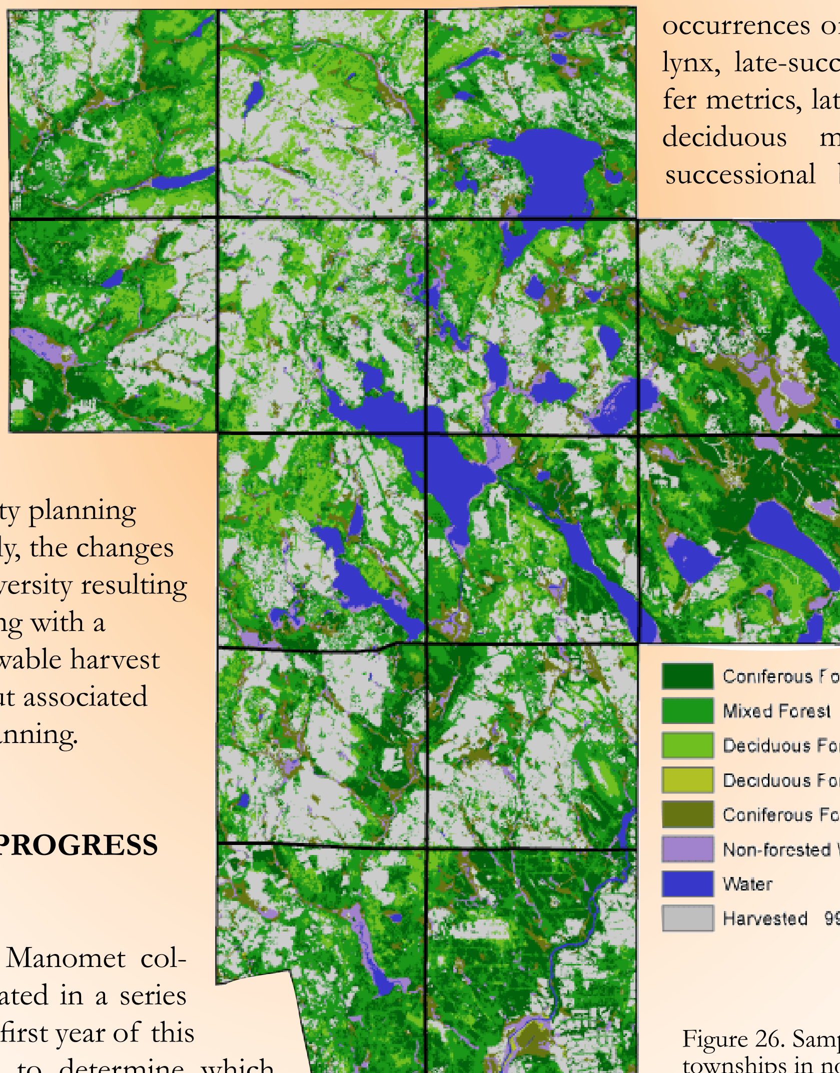


Figure 26. Sample of 14 townships in north-central Maine, representing the forest management legacies that have been created since the 1970s spruce budworm outbreak.

we selected 14 townships in north-central Maine (Figure 26) that are representative of the variety of forest management legacies that have been created since the 1970s spruce budworm outbreak for inclusion in our analysis of current and future forest conditions: (T4 R14 WELS, T4 R15 WELS, T5 R14 WELS, T5 R15 WELS, T6 R13 WELS, T6 R14 WELS, T6 R15 WELS, T7 R13 WELS, T7 R14 WELS, T7 R15 WELS, T7 R16 WELS, T8 R14 WELS, T8 R15 WELS, T8 R16 WELS). The selected townships form a contiguous area (344,181 acres) in north-central Maine and are composed of approximately 60 parcels that include a representative mix of owners (n=9) and owner types. Much of our activity during the current year involved building satellite-derived coverages for these townships and extracting information from the U.S. Forest Service Forest Inventory and Analysis (FIA) and other datasets to allow the ongoing model building, which will allow us to simulate future forest conditions under alternative forest management scenarios.

During 2007, predictive occurrence models were finalized for marten (original models based on interpreted aerial photography were reconstructed, validated and verified using satellite imagery) and lynx occurrence models were reconstructed based on new technologies using satellite classifications from related projects and using field survey data collected for lynx during the winter of 2007 by the Maine Department of Inland Fisheries and Wildlife. Additionally, the fieldwork and modeling framework for estimating landscape densities of hares was finalized in 2007 and methodologies for cross-walking metrics for calculating early-successional bird metrics from interpreted aerial photography to satellite imagery were evaluated.

PLANS FOR 2008

We will complete our assessment of the utility of satellite-derived products for scorecard evaluation based on field visits. A random set of points within the 14 townships will be selected and visited in the field summer 2008. We will develop stand-level data for the 14 townships, including harvest history, overstory composition, and estimations of stand size class and stocking density. These data will serve as the basis of our evaluation of current conditions and metric scalability (Objectives 1 and 2), and potential future conditions based on alternative forest management strategies (Objectives 3 and 4). Forest stand projections will be implemented using Remsoft's Woodstock (Version 3.26) forest modeling system in conjunction with the Stanley (Version 5.0) spatial harvesting software. Current (2007) conditions will be quantified in the 14 townships, and a retrospective time series of satellite imagery will be used to quantify past trends in four Scorecard Metrics in these townships by applying the marten occurrence model, the lynx occurrence model, the snowshoe hare model, and the early successional bird model.

TIMELINE

All aspects of the project are on schedule without significant deviations. The funding timeline associated with this project is October 2006 - September 2009. All products will be delivered by December 2009.

For more information about this project contact Dan Harrison at harrison@umenfa.maine.edu.

CFRU members help to manage Maine's forest biodiversity by managing over eight million acres of forestland.

Predicting Responses of Forest Landscape Change on Wildlife Umbrella Species

Erin Simons, Kasey Legaard, Dan Harrison, Steve Sader, Jeremy Wilson and William Krohn

SUMMARY OF PROGRESS IN YEAR 3

Ph.D. students Erin Simons and Kasey Legaard completed their comprehensive exams and are progressing rapidly towards the completion of their dissertation objectives related to the funded project. We made significant progress on all components of the project in 2007. After updating the harvest detection time series, which was started in 2006 to ca. August 2007, we were able to document trends in annual harvest area (1988-2007) and evaluate changes in habitat supply for American marten (*Martes americana*) and Canada lynx (*Lynx canadensis*) by applying predictive species occurrence models. We selected townships for inclusion in future stand projections (Forest Projections) that capture the harvest legacies that have evolved since the 1970s spruce budworm outbreak and created stand maps to be used in projections based on the harvest detection time series and U.S. Forest Service Forest Inventory and Analysis (FIA) plot data. We also developed a set of alternative forest management scenarios that we are currently using to evaluate the effects of different timber harvesting strategies on landscape change and future habitat supply for lynx and marten.

PROJECT OVERVIEW

Over the last few decades, timber harvesting patterns in Maine's commercial forestland have evolved under the influence of a widespread spruce budworm outbreak and significant changes in forestland ownership and forest policy. After the 1970s-1980s spruce budworm outbreak commercial forest management shifted toward increased reliance on partial harvests, following the implementation of the Maine Forest Practices Act (MFPA). One of the consequences of this shift was that the total area of timberland being harvested annually doubled between 1989 and 2000. In addition, between 1995 and 2002 approximately 1.6 million acres of Maine's commercial timberland changed hands from forest industry ownership to non-industrial private ownership (Maine Forest Service 2003), the effects of which are difficult to predict. These events have undoubtedly changed timber harvesting patterns, which will influence both the future characteristics (e.g., age structure and species composition) and the future biodiversity of Maine's forest.

Focusing conservation efforts on umbrella species can simplify biodiversity conservation in a managed forest. Rather than managing for each species in a diverse array, management can potentially be focused on a few species with habitat requirements that capture those of many other species. Because of their habitat specificity and large area requirements, Canada lynx and American marten have been proposed as umbrella species for landscape planning in Maine. Together they represent a range of ecological conditions (early successional forest and mature forest, respectively) associated with habitat occupancy. Hepinstall and Harrison (In preparation) found that if areas in Maine with a probability of occurrence >50% for lynx and >80% for marten were protected, 86% of the 130 vertebrate species that they considered, including forest generalists, conifer forest specialists, hardwood forest specialists, and early successional species, would be incidentally benefited by the lynx and marten habitat protection.

Because of their important roles as individual species and as umbrella species, we have developed an integrated framework based on a time series of satellite imagery and spatial modeling in order to track and model changes in landscape structure and habitat supply for marten and lynx. The objectives of this effort are to:

1) Use predictive species occurrence models developed for lynx and marten in Maine (Predictive Modeling and Evaluating Umbrella-Species) to evaluate past trends in forest management on lynx and marten habitat supply (Forest Change and Harvest Trends), and

2) Simulate the effects of alternative forest management scenarios on lynx and marten habitat and evaluate tradeoffs between wildlife habitat and wood fiber management objectives (Forest Projections). This analysis will provide a better understanding of the effects of past and future forest management on landscape pattern, forest structure, and habitat sustainability, and allow us to make recommendations to forest managers about future management options.

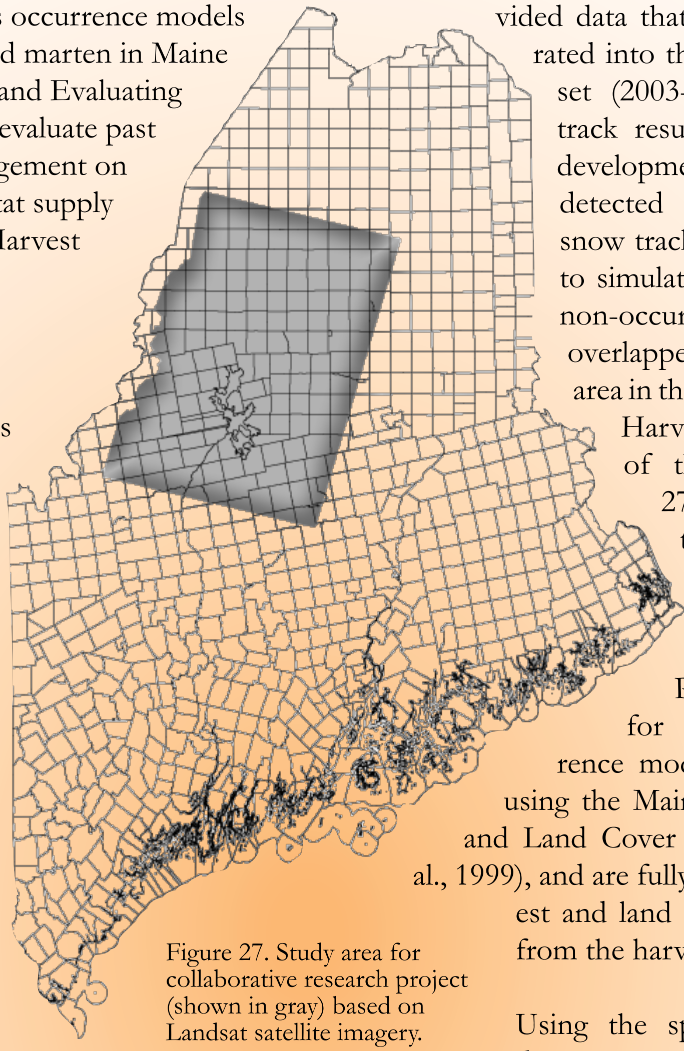


Figure 27. Study area for collaborative research project (shown in gray) based on Landsat satellite imagery.

PRIMARY ACTIVITIES IN 2007

I. PREDICTIVE MODELING AND EVALUATING UMBRELLA-SPECIES

The final development of a model for predicting home-range scale lynx occurrence in Maine was completed in 2007. This work is a continuation of previous research (Robinson 2006, M.S. thesis), the results of which are described in the 2006 CFRU Report "Responses of snowshoe hare and Canada lynx to forest harvesting in northern Maine." An additional year of data from the 2006 Maine Department of Inland Fisheries and Wildlife (MDIFW) winter snow track surveys provided data that could be incorporated into the pre-existing dataset (2003-2005 winter snow track results) used in model development. Lynx tracks detected during the winter snow track surveys were used to simulate an occurrence vs. non-occurrence dataset that overlapped with the study area in the Forest Change and Harvest Trends section of this project (Figure 27), so that predictor variables could be derived using the harvest detection time series. Predictor variables for the marten occurrence model were developed using the Maine GAP Vegetation and Land Cover map (Hepinstall et al., 1999), and are fully transferable to forest and land cover maps derived from the harvest detection series.

Using the spatially overlapping datasets, we created an integrated framework for evaluating trends in landscape change and wildlife habitat supply. The top models for predicting lynx and marten occurrence were applied to forest cover maps, also generated as part of the Forest Change and Harvest Trends section, which allowed us to relate changes in probability of species occurrence to forest management activities.

II. FOREST PROJECTIONS

Townships representative of the variety of forest management legacies that have been created since the 1970s spruce budworm outbreak were selected for inclusion in forest stand projections. The harvest detection time series (Forest Change and Harvest Trends), allows for the estimation of area harvested per harvest interval at both broad- and fine-scales. Harvest data were combined at approximate 10-year intervals, and townships within the project study area (Figure 27) were evaluated on the basis of trends in decadal harvest intensity.

The selected townships form a contiguous area (344,181 acres) in north-central Maine and are composed of approximately 60 parcels that include a representative mix of owners (n=10) and owner types, including non-governmental organization, large commercial private (with and without conservation easements), small commercial private, and state. Stand-level data for these townships were generated that closely approximate the level of detail available from conventional forest stand maps, including harvest history, overstory composition, and estimations of stand size class and stocking density (based on FIA plot data for our study area). These data form the underlying information that will be used for forest stand projections. Forest stand projections are being implemented using the Remsoft Woodstock (Version 3.26) forest modeling system in conjunction with the Stanley (Version 5.0) spatial harvesting software (Remsoft 2002) based on customized growth and yield tables derived by Dr. Jeremy Wilson.

Townships are projected under a set of alternative forest management scenarios to evaluate the potential gains and tradeoffs between management targeted at wildlife habitat and/or wood fiber objectives. An initial set of scenarios have been designed to make comparisons focused on lynx and marten habitat and economic considerations. These include: 1) no forest management, 2) continuation of recent (2001-2007) township-scale harvest trends, 3) increase the maximum size allowed for clear-cuts (>250 acres), and 4) increase the residual basal area (trees 4.5 inches in diameter) standard of a "clear-cut" from 30 to 60-80 ft^2/ac.

By evaluating specific alternative forest management strategies, this analysis will allow us to make recommendations to forest managers concerning the maintenance or creation of lynx and marten habitat.

III. FOREST CHANGE AND HABITAT TRENDS

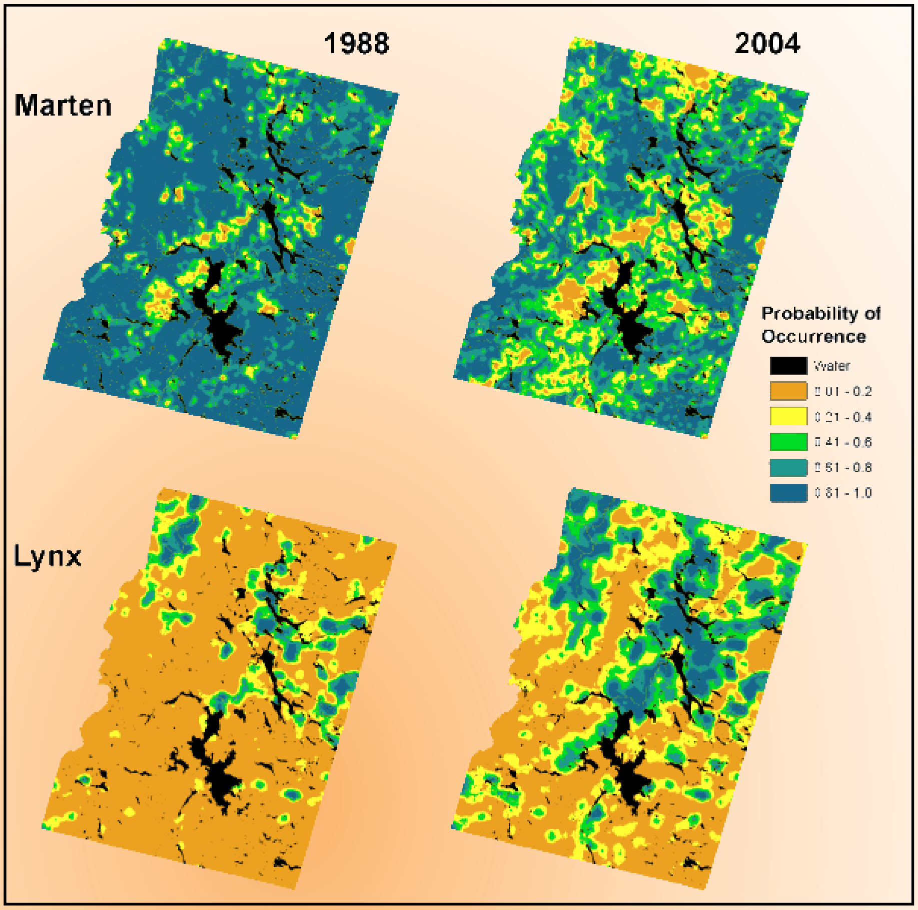
In Year 2 of this project we developed a means by which older digital land cover products can be updated based on established forest change detection techniques developed by the Maine Image Analysis Laboratory (e.g. Sader and Winne, 1992; Sader et al., 2003), and completed a retrospective time series of forest cover maps (1988-2004) for northern Maine based on Landsat Thematic Mapper (TM) satellite imagery. The methods for this process (also described in the 2006 CFRU Report "Predicting responses of forest landscape change on wildlife umbrella species") and preliminary results were presented at the 2006 Eastern CANUSA Conference in Quebec City.

In Year 3, the time series was further updated to ca. August 2007, which has allowed us to describe current landscape structure and the cumulative effects of two decades of landscape change across roughly four million acres of northern Maine. Because the study area (Figure 27) includes the greater part of 176 townships, we were able to evaluate forest harvest trends aggregated over a diverse set of owners broadly representative of the unorganized townships of northern Maine (e.g. commercial forest products companies, family-owned corporations, investment entities, and NGOs). Accuracy assessment of forest change detection products spanning large areas and multiple change intervals is complicated by limited availability of independent reference data such as aerial photography. We therefore designed and completed a quantitative accuracy assessment of the harvest time series based on visual interpretation of Landsat TM images, a method proven to be a credible substitute for the air photo interpretation for both clearcut and partial-harvest mapping (Cohen et al., 1998; Sader et al., 2003).

PRELIMINARY RESULTS

For both lynx and marten, the most important variable that determines landscape-scale occurrence is the amount of preferred habitat. Modeling results showed that for lynx, this habitat is conifer

Figure 28. 1988 and 2004 probability of occurrence surfaces for marten (top) and lynx (bottom). Both sets are shown using the same color scheme, with higher probabilities of occurrence identifeid by cooler colors and lower probabilities identified by warmer colors.



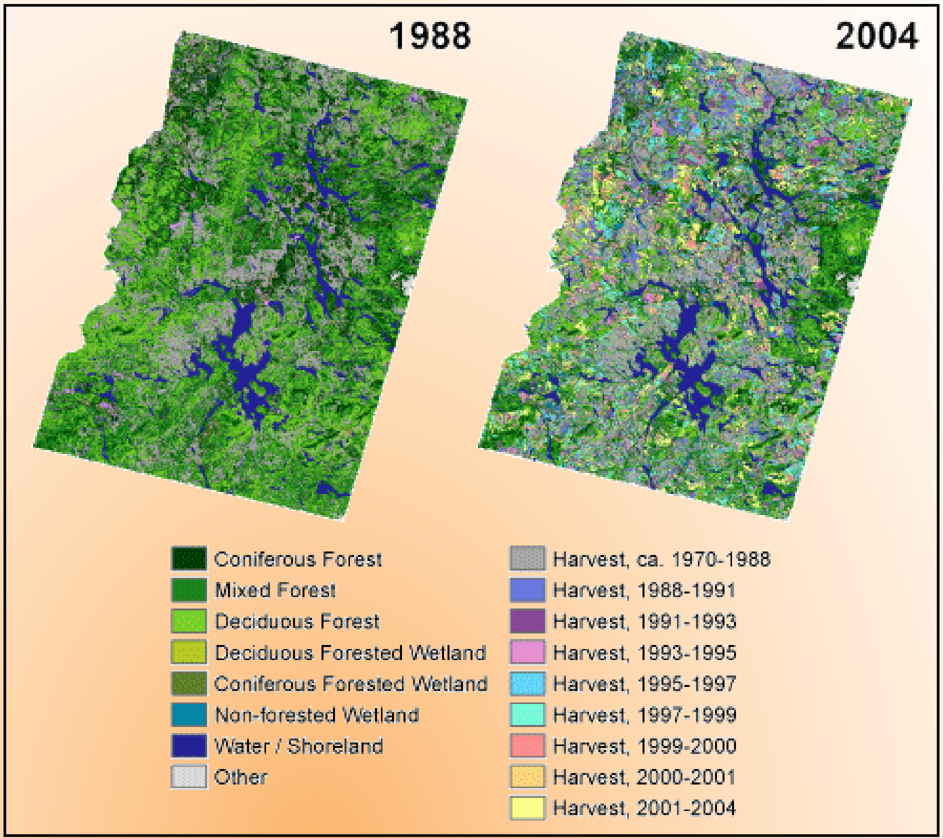
or mixed regenerating forest between the ages of 11-34 years post-clearcut. For marten, preferred habitat is mid- to late-successional forest (conifer, deciduous, or mixed) with sufficient tree height and canopy cover. Application of the predictive species occurrence models to the harvest detection time series showed that the broad-scale trends in probability of occurrence for lynx and marten have followed different trajectories (Figure 28). Figure 28 presents 1988 and 2004 probability of occurrence surfaces for marten (top panels) and lynx (bottom panels). In 1988, there were more areas of higher probability for marten than for lynx. Areas of lower probability of marten occurrence coincided with the early-successional habitats that resulted from 1970s and 80s salvage clearcuts. By 2004, the area associated with higher probability of marten occurrence had become significantly reduced and the area associated with higher probability of lynx occurrence had expanded. This expansion over the 16 years has occurred as an increasing amount of regenerating forest has reached the age range associated with high snowshoe hare densities (11-34 years).

Forest cover maps for 1988 and 2004 are shown in Figure 29, produced by backdating and updating the 1993 Maine GAP vegetation and land cover map using the harvest detection time series. For the period 1988-2004, harvest class user (and producer) accuracies range from 85-94% (82-98%), indicating somewhat variable but very low rates of both commission and omission error. Within our study region, annual harvest area estimates remained roughly constant from the late 1980s through the mid-1990s at approximately 80,000 ac/year, increased sharply to about 125,000 ac/year by 2000, and then decreased to approximately 75,000 ac/year by 2004. During the late 1980s, coniferous and mixed forest types were each harvested at rates more than double that of deciduous forest. By 2004 coniferous and deciduous forest types appear to be harvested at similar rates, roughly half that of mixed forest.

PLANS FOR 2008

Using the time series of harvest detection and forest cover maps, we will document cumulative effects of evolving management practices, including changes in landscape pattern, forest age class distributions, forest composition, and consequent changes in lynx and marten habitat supply (i.e., completion of Forest Change and Habitat Trends). In addition, we will be using various quantitative techniques, including regression models, to analyze trends in forest harvest activity apparent in the retrospective time series. Based on the alternative forest management scenarios outlined above (Forest Projections), we will compare forest and habitat conditions and timber volume removed to evaluate future tradeoffs (2007-2057). These analyses will ultimately enable us to make recommendations to the forest companies that participate with CFRU, the Maine Department of Inland Fisheries and Wildlife, and the U.S. Fish and Wildlife Service about strategies that will promote future habitat for lynx and marten habitat in northern Maine.

Figure 29. Forest harvest and land cover maps for 1988 (left) and 2004 (right).



For more information about this project contact Dan Harrison at harrison@umenfa.maine.edu.

LITERATURE CITED

Cohen, W.B., Fiorella, M., Gray, J., Helmer, E., and Anderson, K.. 1998. An efficient and accurate method for mapping forest clearcuts in the Pacific Northwest using Landsat imagery. Photogrammetric Engineering and Remote Sensing 64(4): 293-300.

Hepinstall, J.A., Sader, S.A., Krohn, W.B., Boone, R.B., and Bartlett, R.I. 1999. Development and testing of a vegetation and land cover map of Maine. Maine Agriculture and Forest Experiment Station, Technical Bulletin 173, Orono, ME.

Maine Forest Service. 2003. Fourth annual inventory report on Maine's forests. U. S. Department of Conservation, U. S. Department of Agriculture.

Remsoft. 2002. Woodstock and Stanley Function Overview. Remsoft Inc., Fredericton, NB, Canada. Available from http://www.remsoft.com/forest/index.html.

Robinson, L. 2006. Ecological relationships among partial harvesting, vegetation, snowshoe hares, and Canada lynx in Maine. M.S. Thesis, University of Maine, Orono.

Sader, S.A. and Winne, J.C. 1992. RGB-NDVI colour composites for visualizing forest change dynamics. International Journal of Remote Sensing 22: 3055-3067.

Sader, S.A., Bertrand, M., and Wilson, E.H. 2003. Satellite change detection of forest harvest patterns on an industrial forest landscape. Forest Science 49: 341-353.

Biodiversity

Cost Effective Methods for Tracking Structural Attributes Important to Forest Biodiversity

Headwater Stream Study

Riparian Biodiversity Project

Cost Effective Methods for Tracking Structural Attributes Important to Forest Biodiversity

Andrew Whitman and John Hagan

INTRODUCTION

A growing challenge for forest landowners is managing for structural attributes important to biodiversity, such as large trees, snags and down woody debris. Large trees provide important substrates for epiphytes (Selva 1994), and den and nesting sites for furbearers and large bodied birds (DeGraff and Rudis 1986, Tubbs et al. 1987). Snags provide food, shelter, and substrate for many animals (DeGraff et al 1992, Hammond 1997). In New England, down coarse woody debris (CWD) provides foraging habitat or cover for over 30% of the mammals, 45% of the amphibians, and 50% of the reptiles (Degraff and Rudis 1986). Current forest certification standards acknowledge the importance of structural attributes and require that landowners manage for them. Yet cost effective methods for measuring and managing for structure are lacking.

Structural attributes are difficult to inventory with great precision because their abundance varies tremendously within stands and across landscapes (Stahl et al. 2001). There are many methods for inventorying these variables but each method has its pitfalls (Stahl et al. 2001). Although several studies have estimated statistical precision of different down CWD sampling methods, none have evaluated the tradeoffs between cost (amount of sample area and number of samples) and the ability to statistically detect change. For northeastern forests, statistical guidance can help landowners select the best CWD protocol to achieve their objectives with regard to sampling cost (e.g., plot size, prism factor, etc.), and statistical efficiency.

It 2007, we collected field data to evaluate the two most promising down CWD protocols: the perpendicular distance sampling (PDS) method and line intercept sampling (LIS) method. The PDS method is conceptually similar to the prism methods used for trees where the effective sampling radii increase with log diameter (Williams and

John Williamson measuring CWD for the perpendicular distance sampling (PDS) method (A. Whitman photo)

Gove 2003). Downed CWD volume then can be calculated based on counts of logs (Williams and Gove 2003). The LIS method requires measurement of log diameter where logs cross a randomly oriented transect. We also collected field data to evaluate the use of 5-, 10- and 15-basal-area factors (BAF) for sampling large trees and snags.

STATUS

In northern Maine, we met our goal of randomly sampling over 150 points using the PDS and LIS methods for CWD and 5-, 10-, and 15-BAF prisms in three landscape types expected to vary distinctly in their per acre volumes of down CWD: intensively managed (n=50), extensively managed (n=58), and unmanaged (n=50). For the PDS method, we applied two commonly used factors (KPDS =500 and KPDS =250 that are analogous to prism factors) which have different effective sampling radii. For the LIS method, we sampled 328 ft of line transect and noted the distance of each piece of CWD along each transect. Field crews counted 2848 logs using the LIS method, 596 logs using the PDS method, and 519 large trees and snags (> 18 in DBH) using 5, 10, and 20 BAF prisms. We sampled 18 old-growth sites in order to identify reference points for each protocol.

RESULTS

All of the structural attribute data have been entered and are being analyzed as part of a graduate student project (John Williamson, Duke University). The field crew encountered two major limitations with the PDS method. First, its sampling time can be great. In stands with thick underbrush or high relief, finding logs can be problematic. Moreover, when large (> 18 in DBH) logs are likely present (as is the case in much of northern Maine) then the limiting radii for the search area can exceed 100 ft. This large effective search area made it impractical to use PDS when large logs occur even at low levels of abundance. Second, when stands were densely stocked or had thick underbrush, it was often difficult to determine the line of sight to the plot center. Without a line of sight, it was impossible to assess the perpendicularity of a point on the log, which is essential to determining whether a log was to be counted.

These two limitations for the PDS method were experienced by the crews and are reflected in sampling statistics. On average, the PDS method required measuring fewer pieces of down CWD per sample point than the LIS method: five pieces versus 19 pieces, respectively. The PDS method took slightly more time per sample point than the LIS method: averaging 25 versus 22 minutes, respectively. Moreover, the PDS method took much more time than the LIS method in unmanaged stands: 20 minutes versus 52 minutes, respectively. In unmanaged stands, the PDS method may be impractical to use along side standard timber inventory protocols. Here, the PDS method can be demanding by requiring the search of > 0.5 ac whereas an LIS protocol might simply require surveying a 328-ft transect. Additional analyses will be conducted to identify the tradeoffs between cost and statistical power for the LIS method and the PDS method and identifying reference levels for each method.

Large trees and snags were detected at 52% of the sample points. In late-successional (LS) stands, very large (> 30 in DBH) trees and snags can have limiting search radii exceeding 300 ft when using a 5-BAF prism. This makes using a 5-BAF prism impractical for sampling large trees along side standard timber inventory protocols in LS stands. Additional analyses will be conducted to establish the statistical power of different BAF for sampling large trees and snags using different prisms and to identify LS reference levels.

TASKS

- Field work (summer 2008): Developing effective methods for surveying for LS stands

- Report (Oct 2008): Effective methods for tracking of forest structure and LS forest in northern Maine.

- Manuscript (Oct 2008): Effective monitoring of forest structure and LS forest in an industrial forest

- Presentation: Effective monitoring of forest structure in the industrial forest (May 2008 CFRU biennial workshop).

For more information on this study contact Andy Whitman, Manomet Center for Conservation Sciences, 14 Maine Street, Suite 305, Brunswick, ME 04011 (207) 721-9040 or email awhitman@prexar.com.

Katie Mann measuring CWD for the line intercept sampling (LIS) method (A. Whitman photo).

ACKNOWLEDGEMENTS

Matt Stelmach assisted fieldwork. John Williamson led field work and entered data. Fieldwork was conducted on the lands of Plum Creek Timber Company. Funding was provided by the Cooperative Forestry Research Unit of the University of Maine and the Manomet Center for Conservation Sciences.

REFERENCES

DeGraff, R.M. and D.D. Rudis. 1986. New England Wildlife: habitat, natural history, and distribution. USDA Forest Service, Northeastern Experimental Station, Broomall, Pennsylvania, General Technical Report NE-108.

Hammond, H.E. J. 1997. Arthropod biodiversity from Populus coarse woody material in north-central Alberta: A review of taxa and collection methods. The Canadian Entomologist 129: 1009-1033.

Selva, S.B. 1994. Lichen diversity and stand continuity in the northern Hardwoods and Spruce-Fir forests of northern New England and western New Brunswick. The Bryologist 97: 424-429.

Stahl, G., A. Ringvall, and J. Fridman. 2001. Assessment of coarse woody debris – a methodological overview. Ecological Bulletins 49: 71-84.

Tubbs, C.H., R.M. Degraff, M. Yamasaki, and W.M. Healy. 1987. Guide to wildlife tree management in New England northern hardwoods. USDA Forest Service General Technical Report NE-118, Broomall, PA 30 pp.

Williams, M. and J. Gove. 2003. Perpendicular distance sampling: an alternative method for sampling downed coarse woody debris. Canadian Journal of Forest Research. 33: 1564-1579.

Zar, J. 1984. Biostatistical Analysis. Prentice-Hall, Inc. Englewood, NJ

HEADWATER STREAM STUDY

Ethel Wilkerson and John Hagan

INTRODUCTION

In 2001 we began a before-and-after study to evaluate the effectiveness of different stream buffer widths for protecting water temperature, water chemistry, and other stream and riparian biological values. The study was prompted by public concerns about the impacts of timber harvesting on very small perennial headwater streams, for which there are no shade or buffer requirements in state regulations. Our goal was to understand the level of stream protection afforded by different buffer widths, including no buffers.

The study was originally designed to run three years (one pre-treatment year, 2001, and two post-treatment years, 2002-2003). However, because of significant increases in stream temperature that persisted through the second post-harvest year, the CFRU continued the study to monitor timing of temperature recovery. In 2007 we collected our 6th year of post-harvest temperature data from the experimental streams. This report provides water temperature results for all seven field seasons (2001-2007) and data on recovery (i.e. regrowth) of riparian vegetation and canopy cover (i.e. shade) as well as trees lost to blowdown within the buffer strips.

STUDY DESIGN

At the beginning of the study (2001) we assigned 15 headwater (1st-order) streams in western Maine to one of 5 study treatments (Table 8). All streams were measured for water temperature both before harvest (2001), and after harvest (2002- 2007). In each year of the study we deployed automatic temperature recorders at 100-m intervals along a 500-m study reach in each of the 15 study streams (Figure 30). Within the 300-m harvest zone, we measured overhead shade levels and height of understory. Beginning in 2002 (1st post-harvest year), we recorded the number of trees lost to blowdown each year within the buffers.

RESULTS

Stream Temperature: Has temperature recovered six years after the harvest?

In 2007, six years after the harvest, mean weekly maximum water temperatures in the "no buffer" streams were not significantly elevated over pre-harvest levels (Figure 31). This follows five consecutive years of significantly elevated stream temperatures (2.0-3.4^{o}C) in streams harvested without a buffer. We conclude that stream temperature increases have now begun to moderate

Figure 30. Study layout.

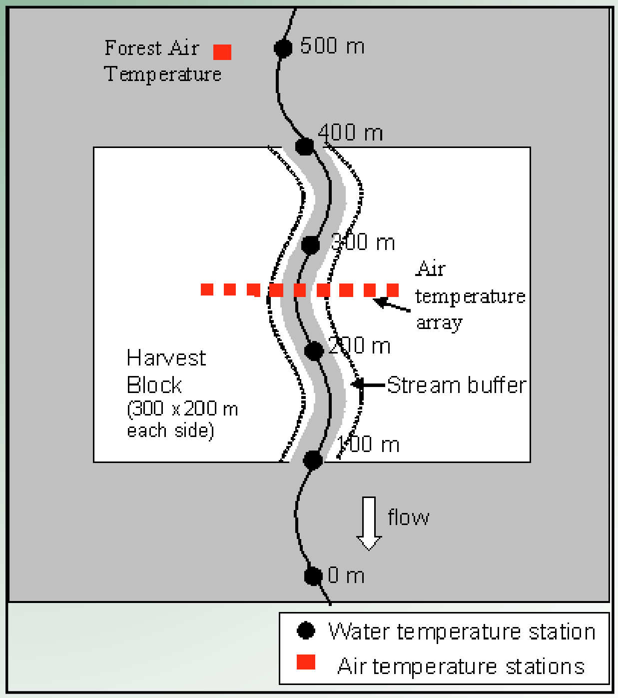


Table 8. Harvest treatments used in this study.

Treatment	Harvest Prescription	Replicates
No Buffer	Clearcut harvest zone, no-buffers	3
11-m Buffer	Clearcut harvest zone with partially harvested 11-m buffers, both sides	3
23-m Buffer	Clearcut harvest zone with partially harvested 23-m buffers, both sides	3
Partial Harvest	Partial cuts with no designated buffer	3
Control	No harvesting	3

in streams without a buffer. Summer air temperature in 2007 was cooler than in five of the six post-harvest years (Figure 31). Stream temperatures are correlated with air temperatures (Ice 2000), which means that interpretation of stream temperature recovery must take into account summer climate. If reductions in water temperature continue in 2008 we can conclude with certainty that stream temperatures have returned to pre-harvest levels.

Streams harvested with an 11-m buffer had only an 8% reduction in canopy levels over the stream channel following the harvest (Wilkerson et al. 2006). Shade levels remained over 85% and as a result we observed only small (0.8-1.2^{o}C) increases in stream temperature after the timber harvest (Figure 31). No increase in temperature was observed for the 23-m buffer, partial-cut buffer, or control stream treatments in any of the post-harvest years.

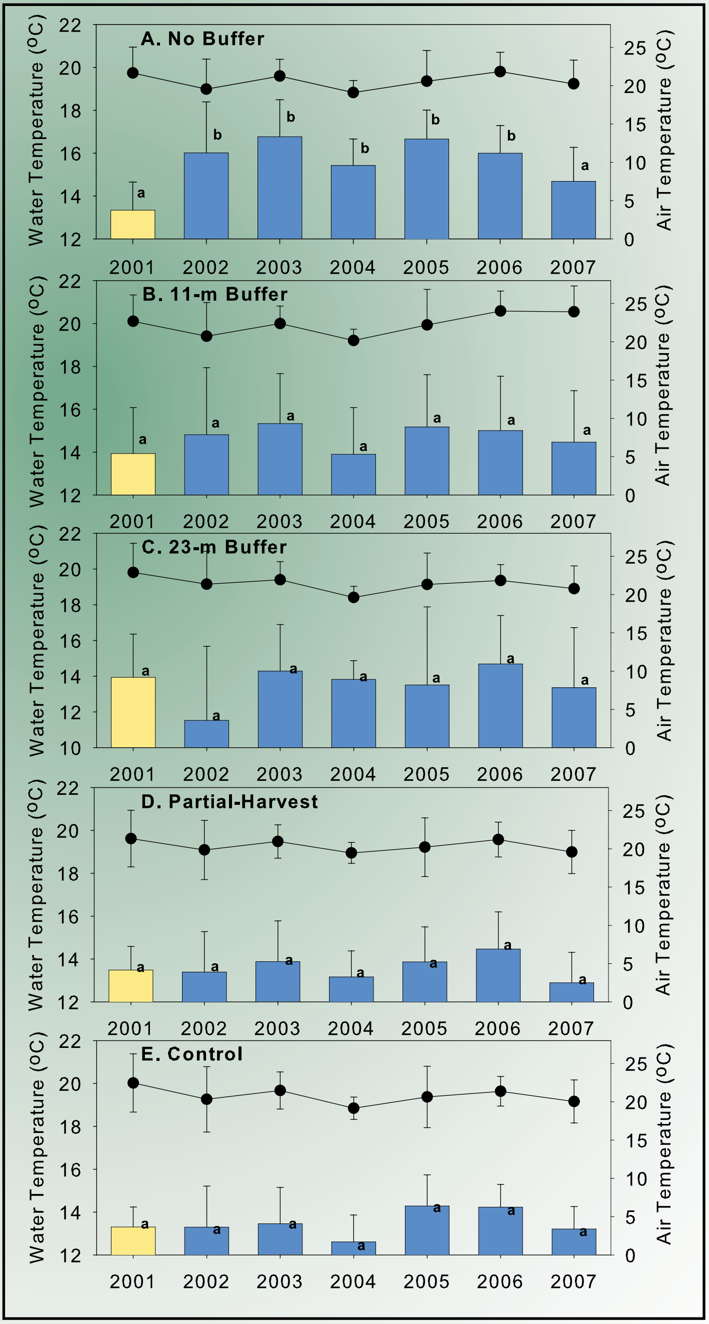
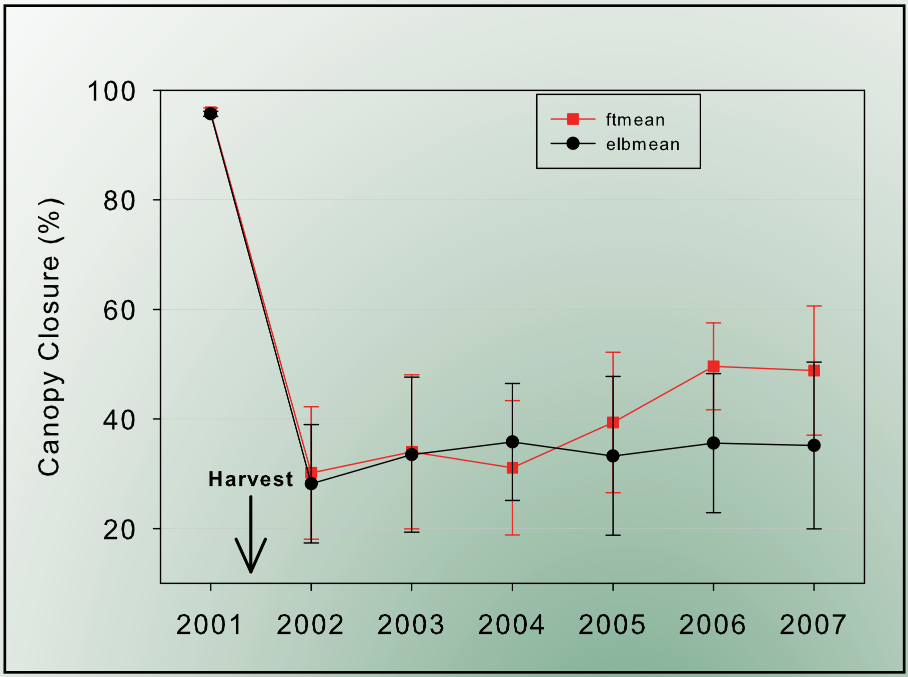


Figure 31.The mean weekly maximum temperature from June 15- August 15 in the pre-harvest year (2001) and the six post-harvest years (2002-2007). Different letters represent a statistical differences (alpha=0.05) from the pre-harvest year. Water temperature readings were taken at the lower end of the harvest zone (100-m station). Air temperature readings were taken within intact forest, 100 m from the nearest harvesting and 50 m from the stream channel.

Figure 32. Average shade levels within the harvest zone of the streams without a buffer in the pre-harvest (2001) and six post-harvest years (2002-2007). Shade levels were measured at approximately 0.3 m and 1.4 m above the stream channel.



no-buffer stream channels (Figure 32). Shade levels were higher closer to the water's surface because the streamside vegetation is less than 1 m in height (Figure 32). Six years after the harvest, shade levels were at 35% approximately 1.4 m above the stream and 49% 0.3 m above the stream (Figure 33). Temperature moderation in streams harvested without a buffer suggests that 35-49% shade may be effective at protecting the stream channel from solar radiation. Data to be collected in 2008 will help us understand the shade issue better.

Temperature Recovery: the importance of shade.

Shrubs and saplings can partially shade the stream from solar radiation and mitigate temperature impacts associated with harvesting (Feller 1981). To track regrowth of vegetation, we have monitored the height of the recovering streamside understory vegetation and shade over the stream channel. To account for the contribution of low vegetation (<1 m tall) to shade levels we measured shade with a spherical densitometer 0.3 m above the stream channel. We also measured shade at the traditional height (1.4 m).

The height of the understory streamside vegetation in the streams without a buffer rapidly increased following the timber harvest. In 2007, the average height of understory was 0.88 m (Table 9), an increase of 0.45 m since measurements began in 2003 (the second post-harvest year). As the height of the understory vegetation has increased, so have shade levels over the stream channel. Immediately after the harvest, shade decreased 66-68% on the

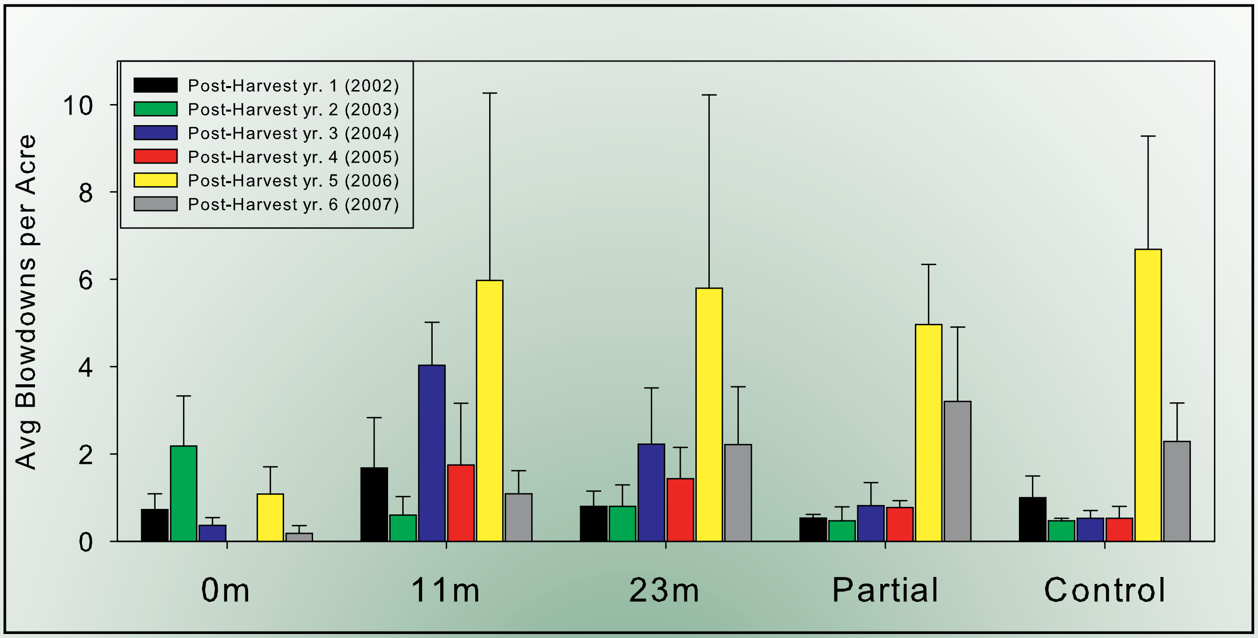
Blowdown Within the Buffers: how much, how frequently, and what species?

Riparian buffers can be susceptible to wind related mortality (Grizzel and Wolff 1998). Blowdown within buffers can reduce the ecological functionality of the buffer strips for protecting streams (Jackson et al. 2007). To document blowdown within stream buffers we tracked the number, size, and species of trees within the buffers that died each year after the harvest due to wind damage. The number of blowdown trees at each site was adjusted for the buffer area (this varied by site due

Table 9. Average height (m) of the dominant type of understory vegetation within the harvest zone of streams without a buffer. Measurements were taken in 1 m^2 plots on both sides of the stream channel every 20 m in 2003-2007 (second through sixth post-harvest years).

Year	Mean (m)	SE
Post-Harvest yr. 2 (2003)	0.43	0.02
Post-Harvest yr. 3 (2004)	0.69	0.04
Post-Harvest yr. 4 (2005)	0.76	0.03
Post-Harvest yr. 5 (2006)	0.78	0.03
Post-Harvest yr. 6 (2007)	0.88	0.04

Figure 33. The average number of blow down per acre of buffer in the six years following the harvest (2002-2007). Blowdown in the control treatment group was only measured within 23 m of the stream channel.



to harvest prescription and differences in removal rates and harvesting techniques). Blowdown in control streams was only measured within 23 m of the stream channel.

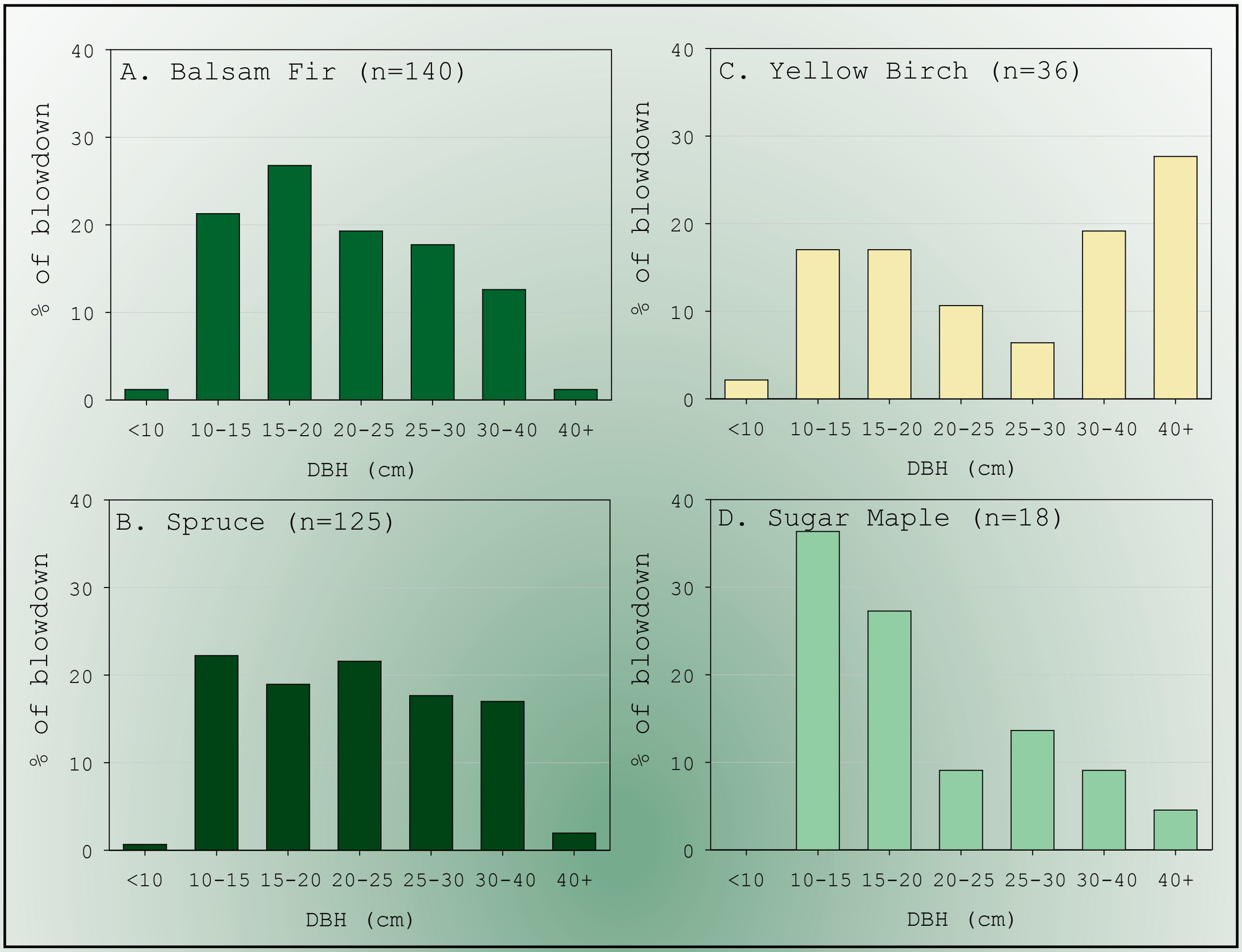
In the six years after the harvest the average amount of blowdown for each treatment group ranged from 5 to 15 trees blown down per acre of buffer (Figure 33). Not surprisingly, the amount of blowdown was smallest in the streams harvested without buffers due to almost complete removal of trees adjacent to the stream channel. Streams with buffers 11-m wide had the most blowdowns at 15 trees per acre of buffer (Figure 33). Unharvested streams had an average of 11 blowdowns per acre within 23 m of the stream channel. Thus, relatively narrow 11-m buffers showed about a 37% increase in blowdown rate relative to natural blowdown rates in intact forest.

The number of blowdown per year varied greatly among years. The occurrences of blowdown were episodic, with 2006 having the greatest

Table 10. Percentage of blown down trees by species within each treatment group.

	Treatment Group				
Species	No Buffer (%)	11-m Buffer (%)	23-m Buffer (%)	Partial Harvest (%)	Control (%)
Balsam Fir	32	21	49	43	62
Beech	4	4	1	5	4
Cedar	0	8	0	4	1
Quaking Aspen	0	6	0	0	0
Red Maple	0	1	1	3	2
Spruce	24	43	38	16	15
Sugar Maple	16	8	1	3	2
White Birch	4	2	2	1	1
Yellow Birch	20	7	3	19	6

Figure 34. The percentage of blowdown (in all treatment groups) by size class for a) Balsam Fir, b) Spruce, c) Yellow Birch, d) Sugar Maple.



number of blowdowns in the majority of treatment groups (Figure 33). In the control treatment group the number of blowdowns in 2006 was 3-14 times greater than in other years of the study. This is likely due to a number of heavy rain and high wind events in the spring of 2006 (UNH 2006). We observed no changes in water quality or increases in stream temperature over the course of the study, indicating the amount of blowdown we observed did not alter the functionality of the buffers.

The species most impacted by blowdown were balsam fir (21-62% of all blowdown) and spruce (15-38% of blowdown), regardless of harvest treatment (Table 10). Yellow birch and sugar maple comprised a smaller proportion of blowdown (up to 16% and 20% respectively, Table 10) even though some sites had a large hardwood component. For balsam fir, blowdown was most common (27%) in the 15-20 cm size class but 85% of the blowdown was between 10-30 cm DBH (Figure 34a). Spruce blowdown was fairly evenly distributed across size classes with 97% of blowdown between 10-40 cm DBH (Figure 34b). Mortality of yellow birch occurred predominately (47%) in trees larger than 30 cm DBH (Figure 34c) while the greatest proportion (64%) of sugar maple mortality was between 10-20 cm DBH (Figure 34d).

CONCLUSIONS

1) Six years after harvest, stream water temperatures were no longer significantly elevated over pre-harvest levels on the streams without a buffer. Water temperatures have decreased for two years in a row and if this trend continues in 2008

we can conclude the water temperatures in streams without a buffer have returned to pre-harvest levels.

2) Streamside vegetation in the unbuffered streams has grown to an average height of 0.88 m in the six years following harvest. This low vegetation averages 49% shade near the water's surface. The moderation in strea Figure 34. The percentage of blowdown (in all treatment groups) by size class for a) Balsam Fir, b) Spruce, c) Yellow Birch, d) Sugar Maple. The moderation in stream temperatures in temperatures in 2007 suggests that the streamside vegetation is effectively protecting stream channels from solar radiation.

3) Blowdown within the 11-m, 23-m, and partial harvest treatments did not compromise the ability of buffer strips to shade the stream from inputs of solar radiation. Blowdown within harvested buffers ranged from 5-15 blowdown per acre in the six years following the harvest. Natural blowdown rate averaged 11 trees/ac along control streams.

4) The most common species of blowdown mortality were balsam fir and spruce. Large frequencies of blowdown also occurred in sugar maple between 10-20 cm DBH and yellow birch larger than 40 cm.

PLANNED ACTIVITIES

This winter and spring we will be submitting several manuscripts for publication. In May 2008, we will begin a seventh post-harvest field season on a subset of the original study streams. We will continue to measure water temperature, understory vegetation communities, and over stream canopy closure on streams without a buffer, streams with an 11 m buffer, and controls (n=9).

ACKNOWLEDGEMENTS

Our work in 2007 was made possible by the cooperation and support from Plum Creek Timber Co, Seven Islands Land Co., GMO, and Wagner Timberlands. We thank the CFRU, NCASI, and Manomet Center for Conservation Sciences for funding this project.

Comments are questions about this report are welcomed. For more information about this project contact Ethel Wilkerson or John Hagan at 207-721-9040 or by e-mail at ewilkerson@prexar.com or jmhagan@prexar.com.

REFERENCES

Feller, M.C. 1981. Effects of clearcutting and slashburning on stream temperature in southwestern British Columbia. Water Resour. Bul. 17:863-867.

Grizzel, J.D. and N. Wolff. 1998. Occurrence of windthrow in forest buffer strips and its effect on small streams in the northwest Washington. Northwest Sci. 72:214-223.

Ice, G. 2000. How direct solar radiation and shade influences temperature in forest streams and relaxation of changes in stream temperature. Cooperative Monitoring, Evaluation and Research (CMER) Workshop: Heat transfer processes in forested watersheds and their effects on surface water temperature. Lacey, Washington, February 2000.

Jackson, C.R., D.P. Batzer, S.S. Cross, S.M. Haggerty, C.A. Sturm. 2007. Headwater streams and timber harvest: Channel, macroinvertebrate, and amphibian response and recovery. Forest Science 53: 356-370.

University of New Hampshire, Coastal Ocean Observing Center. 2006. May's Historic Storm. Gulf of Maine Monitor, Issue 1, Durham, NH, 8pp.

Wilkerson, E., J.M. Hagan, D. Siegel, A.A. Whitman. 2006. The effectiveness of different buffer widths for protecting headwater stream temperature in Maine. Forest Science 52(3):221-231

Riparian Biodiversity Project

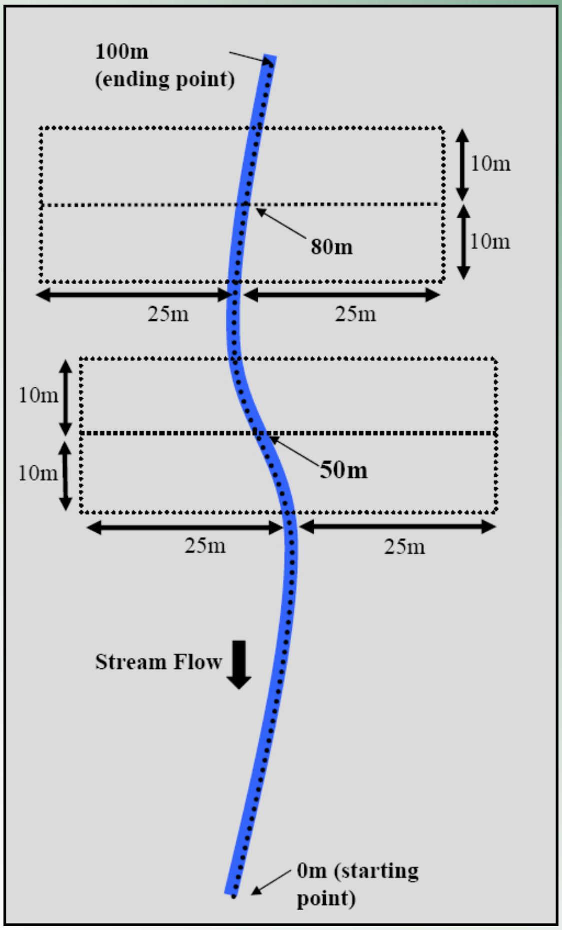
Ethel Wilkerson and John Hagan

INTRODUCTION

Streams and associated riparian zones are common features in forested landscapes and can occupy a large proportion of the landscape (Bren 1995). Riparian areas are located at the intersection of aquatic and terrestrial habitats and are considered biodiversity "hotspots" (Richardson and Danehy 2007). To protect water quality, Maine state forestry regulations require the establishment of riparian management zones (RMZs) adjacent to streams and other water bodies. While RMZs can effectively protect water quality, what other ecological and biodiversity benefits might be provided by RMZs? Can forest within RMZs contain similar structures and ecological functions of unharvested forest, such as late-successional forest structure and species (LeDoux and Wilkerson 2006)? The objective of the Riparian Biodiversity Project is to document the degree to which RMZs provide ecological benefits beyond simply protecting stream water quality (e.g., Wilkerson et al., 2006).

In 2007, we conducted a field study to assess the ecological and biodiversity values of RMZs, as well as to report on the ability of RMZs to protect water temperature. Comprehensive data analysis is now underway.

Figure 35. Study layout: the in-stream transect was 100 m long with 2-25x20 m riparian transects on each side of the stream channel.



STUDY DESIGN

In this study we quantified an array of structural, functional, and compositional attributes of RMZs to determine how RMZs are contributing to overall biodiversity goals of sustainable forestry (Table 11). During the summer of 2007, we visited 140 streams in commercial forest landscapes across the state of Maine (Figure 35). At each stream we established transects within the stream channel and adjacent riparian areas (Figure 36). Because management history often differed on opposite sides of the stream channel we considered RMZs on each side of the stream as a separate sampling unit (n=260).

RESULTS

At each site, we measured the width of the RMZ and estimated the number of years since the last timber harvest. By stratifying buffer widths by time since the last harvest we can examine how

Table 11. Parameters measured at each site and their contribution to different components of biodiversity

	Aquatic Habitat	Terrestrial Habitat	LS Attributes	Water Quality
Structural Elements				
Tree size		✓	✓	
Canopy Layers		✓		
Basal Area		✓	✓	
Large standing dead wood		✓	✓	
Large fallen dead wood		✓	✓	
Compositional Elements				
Selected LS mosses			✓	
Selected LS lichens			✓	
Scat Surveys (deer, moose, bear)		✓		
Process/Function Elements				
Canopy Cover		✓	✓	
Erosion/scarification index				✓
Leaf litter depth		✓		
In-Channel Elements				
In-stream large woody debris	✓			
Canopy cover	✓			✓
In-stream sedimentation	✓			✓

riparian management practices on small streams have changed over time. Only 6% of streams did not have a buffer that had adjacent harvests within the last five years. Approximately 20% of streams harvested 5-10 years ago did not have buffers, and 40% of streams harvested more than 15 years ago (Figure 37).

In addition to fewer streams being harvested without a buffer, the widths of RMZs have increased over time. In more recent harvests (<5 yrs ago) 60% of the RMZs were greater than 20-m wide compared to only 40% in harvests occurring over five years ago. This trend is a result of changes in state regulations but also an increased awareness of the role of forested buffers in maintaining water quality and biodiversity.

Canopy Cover-Stream Temperature and Amphibian Habitat

Increases in solar radiation to the stream channel can result in increases in stream temperature (Brown and Krygier 1970). Data collected during the Headwater Streams Project (a CFRU-funded project) illustrated the relationship between shade levels over stream channel and changes in stream temperature (Wilkerson et al. 2006). In streams with shade levels <40% we observed significant increases

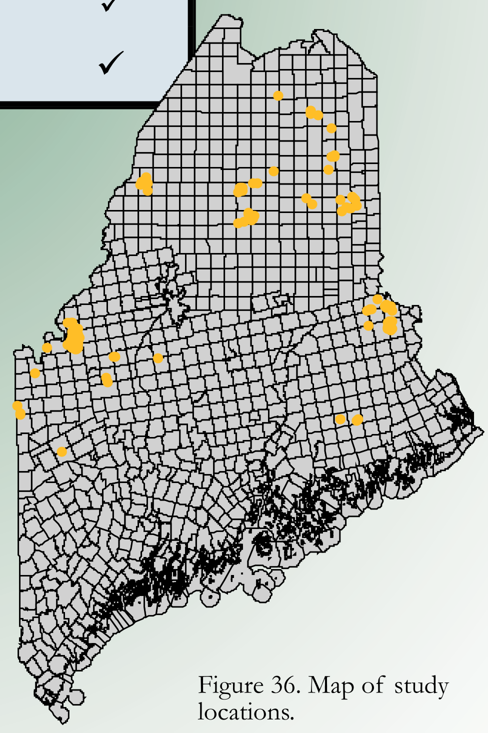
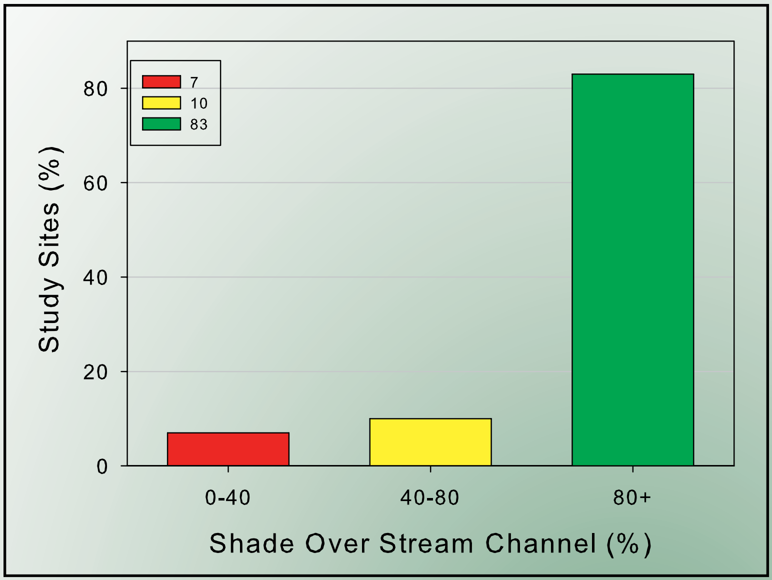


Figure 36. Map of study locations.

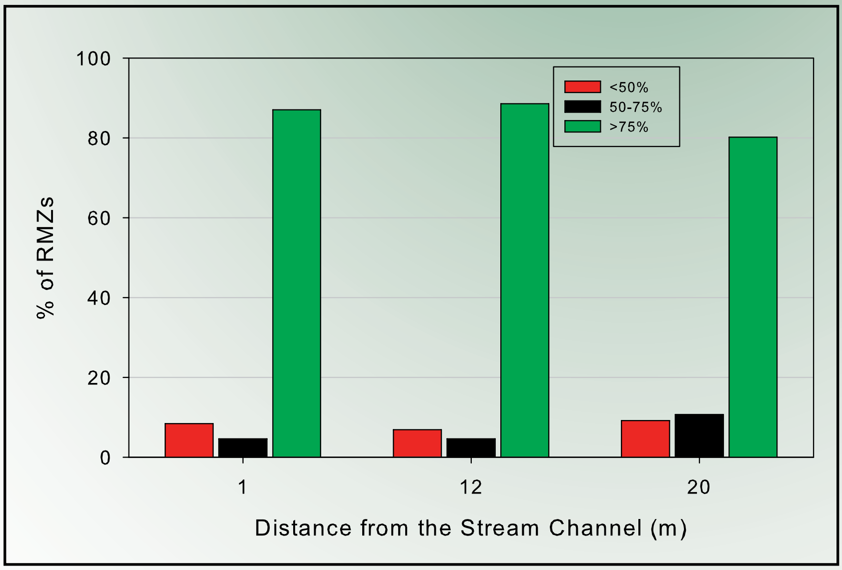
Figure 37. The percentage of sites with average shade levels over the stream channel within different categories. Thresholds for different risk levels for increases in stream temperature were assigned based on data from Wilkerson et al. 2006.



in stream temperature. Streams with shade levels >80% had no changes in stream temperatures (Wilkerson et al. 2006). Based on these results we classified average shade levels of the study sites into 3 categories: (1) <40% shade: sites at risk for local increases in stream temperature, (2) 40-80%: sites potentially vulnerable to increases in local stream temperature, and (3) >80% shade: sites not vulnerable to increases in stream temperature. At the 260 sites we visited in 2007, 7% had average shade levels of <40% over the stream channel, making them at risk for temperature increases (Figure 38). However, 83% of sites had average shade levels over the stream channel greater than 80% (Figure 38) indicating they were not vulnerable to increases in temperature.

Canopy cover in riparian areas is also important for populations of amphibians (deMaynadier and Hunter 1995). Amphibian habitat guidelines recommend that forestry operations maintain >75% shade within 30 m of a water body (Calhoun and deMaynadier 2004). Over 80% of the RMZs we sampled met this criterion (Figure 39). Depending on the distance from the stream channel, 5-11% of the RMZs had shade levels between 50-75% (Figure 39), which meet the shade guidelines for amphibian habitat between 30-120 m from water bodies (Calhoun and deMaynadier 2004). Between 7-9% of the RMZs had shade levels below 50%, which are below the recommended levels for amphibian habitat.

Figure 38. The percent of RMZ sites with different shade levels at 1 m, 12 m, and 20 m from the stream channel. Thresholds for shade levels were determined based on recommended guidelines for conserving amphibians during forest harvest operations (Calhoun and deMaynadier 2004). Shade levels between 50-75% (black bars) meet the shade recommendations for amphibian habitats 30-120 m from water body. Shade levels >75% (green bars) met shade levels for amphibian habitats <30 m from a water body.



Late Successional Attributes

Some structural elements important to biodiversity, particularly late successional (LS) forest attributes, can be challenging to maintain in intensively managed upland areas. LS structures (big trees, snags, logs) require rotation lengths longer than are economically viable in managed forests (Hagan and Whitman 2004).

Because state regulations limit harvest activity within RMZs, RMZs might function to maintain LS attributes across the landscape.

The LS Index developed by Whitman and Hagan (2007) used density of trees >40 cm DBH as an indicator of the seral stage of forest stands. Scores for the LS Index range from 0 to 10, with conditions ranging from clearcuts (score = 0) to old-growth forests (score = 10) (Figure 40a). Stands with LS Index scores of >6 are considered to contain LS attributes similar to old (>100 yrs) forest (Whitman and Hagan 2007).

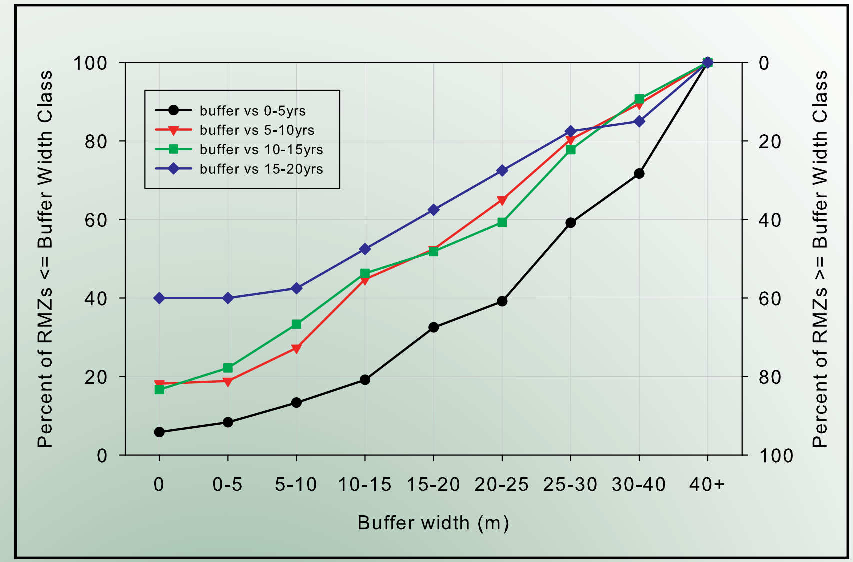
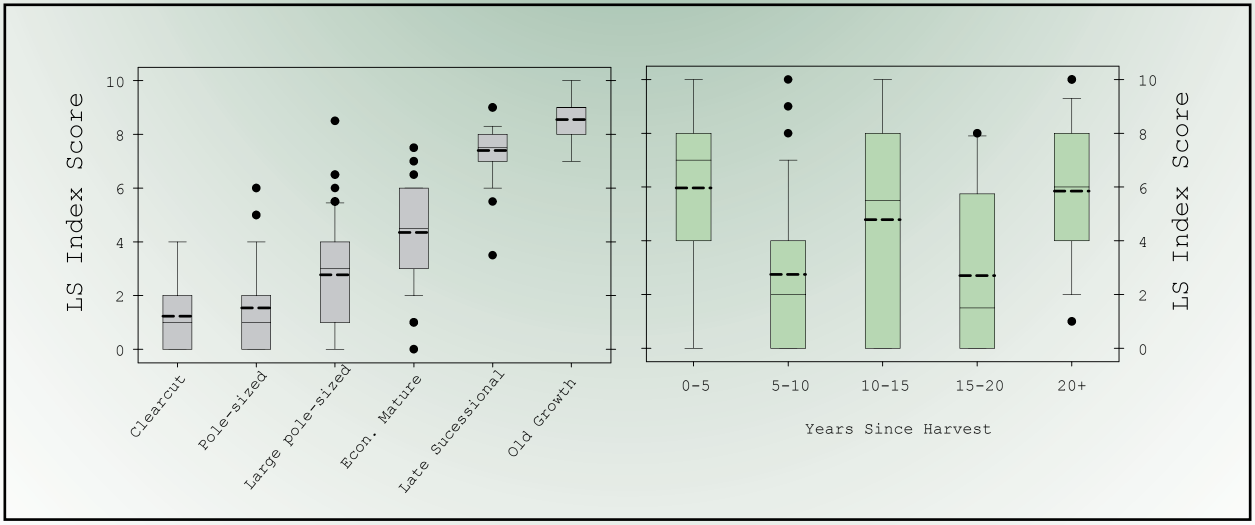


Figure 39. The cumulative percent of RMZs with buffer widths wider and narrower than a particular buffer width category. Sites were stratified by the number of years since the most recent timber harvest (0-5 yrs, 5-10 yrs, 10-15 yrs, and 15+ yrs).

The median LS Index score for RMZs harvested within the past 5 years was 7 (Figure 40b) indicating that the majority of these RMZs had attributes of LS forest (Figure 40b). Median LS Index scores for other groups of RMZs ranged from ≤2 (RMZs harvest between 5-10 and 15-20 years ago) to 5-6 (RMZs harvested 10-15 and 20+ years ago) (Figure 40b).

There was large variability in the LS Index scores within each harvest age group as indicated by the size of the interquartile boxes (Figure 40b). This high variability could be due to differences in management history (number of entries, target species, harvest prescription, etc.), site condition (soil type, productivity, topography, etc.), and institutional policies and practices of different landowners (state land verses private land, etc.).

Figure 40. A) LS Index scores for different seral classes of forest (Whitman and Hagan 2006). B) LS Index scores of RMZs stratified by the number of years since the most recent timber harvest. The size of each box shows the variability (interquartile range) of scores within each group. The solid line represents the median score for the group.



Many of the RMZs sampled contained attributes similar to LS forest. However, the large variability in LS Index scores made it difficult to interpret how well RMZs can maintain LS forest across the landscape. The variability among sites calls into question the efficacy of using RMZs as a primary conservation tool for LS forests. A more detailed analysis will be performed and the conclusions will be distributed to CFRU members through Manomet's Mosaic Science Note publication series.

CONCLUSIONS

1) Within the past 5 years only 6% of streams harvested did not have buffers, and RMZs were wider than for streams harvested between 5-15+ years ago. This reflects changes in riparian management guidelines, but also may reflect increased awareness of water quality and biodiversity issues.

2) More than 80% of RMZs had adequate shade to prevent increases in stream temperature and to maintain amphibian habitat. Only a few (7%) of the sites had shade levels (<40%) that put sites at risk for local increases in stream temperature. At 9% of the RMZs shade levels within the riparian areas were below the recommended shade threshold for amphibian habitat (50%).

3) Many RMZs had structural attributes of LS forests. However, high variability in the LS Index scores make it difficult to gauge the effectiveness of RMZs in maintaining LS forests across the landscape. A more thorough analysis is presently underway.

ACKNOWLEDGMENTS

The Riparian Biodiversity Project was made possible by the cooperation and support from Baskahegan Company, Baxter State Park, Black Bear Forest, Inc., J.D. Irving Woodlands, Maine Bureau of Parks and Lands, Plum Creek Timber Company, Seven Islands Land Company, and The Nature Conservancy. Funding was provided by the Cooperative Forest Research Unit at U. Maine and Manomet Center for Conservation Sciences. Comments and questions about this report are welcomed. Contact Ethel Wilkerson (ewilkerson@manomet.org, 207-721-9040) for more information.

REFERENCES

Bren L.J. (1995) Aspects of the geometry of riparian buffer strips and its significance to forestry operations. Forest Ecology and Management, 75:1-10.

Brown, G.W. and J.T. Krygier. 1970. Effects of clear-cutting on stream temperature. Water Resource Res. 6:1133–1139.

Calhoun, A. and P. deMaynadier. 2004. Forestry Habitat Management Guidelines for Vernal Pool Wildlife. MCA Tech. Paper No.6, Metropolitan Conservation Alliance, Wildlife Cons. Soc., Bronx, NY. 32pp.

deMaynadier, P.G. and M.L. Hunter, Jr. 1995. The relationship between forest management and amphibian ecology: A review of North American literature. Environmental Reviews 3:230-261.

Hagan, J.M. and A.A. Whitman. 2004. Late Successional Forest: A disappearing age class and implications for biodiversity. Manomet Center for Conservation Sciences, Brunswick, ME, FMSN-2004-2.

LeDoux, C.B. and E. Wilkerson. 2006. A Case Study Assessing Opportunity Cost and Ecological Benefits of Streamside Management Zones and Logging Systems for Eastern Hardwood Forests. USFS Research Paper, NRS-1.

Richardson, J.S. and R.J. Danehy. 2007. A synthesis of the ecology of headwater streams and their riparian zones in temperate forests. Forest Science 53:131-147.

Whitman, A.A. and J.M. Hagan. 2007. An index to identify late-successional forest in temperate and boreal zones. Forest Ecology and Management 246:144-154.

Wilkerson, E., J.M. Hagan, D. Seigel, and A.A. Whitman. 2006. The Effectiveness of Different Buffer Widths for Protecting Headwater Stream Temperature in Maine. Forest Science 52:221-231.

Appendices

Outreach

List of Figures

List of Tables

Contact information

Outreach

JOURNAL PUBLICATIONS

Fuller, A. K., D. J. Harrison, and J. H. Vashon. 2007. Winter habitat selection by Canada lynx in Maine: prey abundance or accessibility? Journal of Wildlife Management 71:1980-1986.

Harrison, D. J., W. B. Krohn, L. Robinson, A. K. Fuller, and C. L. Hoving. 2007. Multi-scalar habitat preferences of snowshoe hares: how does a prey specialist coexist with a specialist predator. Pp. 175 in K. Sjoberg and T. Rooke, editors, International Union of Game Biologists Conference Proceedings, Department of Wildlife, Fish, and Environmental Studies, Swedish University of Agricultural Sciences (SLU), Umea, Sweden.

Homyack, J.A., D.J. Harrison, and W.B. Krohn. 2007. Effects of precommercial thinning on snowshoes hares in Maine. Journal of Wildlife Management 71: 4-13.

ARTICLES IS PERIODICALS

Harrison, D. J. Contributed to an article on Canada lynx issues in Maine titled: Cats in a quandary that appeared in the December-January 2008 issue of National Wildlife magazine.

Wagner, R.G. 2007. New harvest classification system developed for Maine forests. New England Society of American Forests News Quarterly, April 2007, Volume 68, Number 2, pg 19. http://www.nesaf.org/PDFs/Quarterlies/2007/QuarterlyApril07.pdf

RESEARCH REPORTS

Harrison, D., W. Krohn, L. Robinson, and J. Homyack. 2006. Temporal and spatial relationships among hares, lynx and forestry. Pages 53-57 in CFRU Annual Report 2005-2006, Maine Agricultural and Forest Experiment Station Miscellaneous Report 440, University of Maine, Orono.

Meyer, S.R. 2006. New Hardwood Growth and Yield Model (GNY) Can Help You Manage Your Stands. CFRU Results Series #4. 1 p.

Meyer, S.R. (Ed.) 2006. Cool and Clear: CFRU Studies Water Quality in the Maine Woods. CFRU Spotlight #2. 4 pp.

Robinson, L., W. Krohn, and D. Harrison. 2006. Responses of snowshoe hare and Canada lynx to forest harvesting in northern Maine. Pages 58-64 in CFRU Annual Report 2005-2006, Maine Agricultural and Forest Experiment Station Miscellaneous Report 440, University of Maine, Orono.

CFRU strives to always be disseminating the most recent forest research information to our stakeholders and other audiences.

Simons, E., K. Legaard, D. Harrison, S. Sader, J. Wilson, W. Krohn, and L. Robinson. 2006. Predicting responses of forest landscape changes on wildlife umbrella species. Pages 48-52 in CFRU Annual Report 2005-2006, Maine Agricultural and Forest Experiment Station Miscellaneous Report 440, University of Maine, Orono.

Wagner, R., R. Seymour, M. Saunders, J. Wilson, L. Kenefic, D. Denico, and K. Fergusson. 2007. Forest Harvest Classification System for Maine. Report by Maine Society of American Foresters Task Force.

Wagner, R., R. Seymour, M. Saunders, J. Wilson, L. Kenefic, D. Denico, and K. Fergusson. 2006. Interpretation of residual stand codes for Maine forest harvest classification system. Report by Maine Society of American Foresters Task Force.

THESES

Hearn, B. J. 2007. Factors affecting habitat selection and population characteristics of American marten (Martes americana atrata) in Newfoundland. Ph.D. Dissertation, University of Maine, (advisor D. HARRISON)

CONFERENCE PROCEEDINGS

Fuller, A.K., D.J. Harrison, and J. Vashon. 2006. Influence of forest practices on winter habitat selection and movement paths by Canada lynx in Maine. Published abstract of paper presented at Carnivores 2006 Conference, St. Petersburg, FL.

Robinson, L., D. J. Harrison, W.B. Krohn, J. Vashon, and M.A. McCollough. 2006. Ecological factors associated with the distribution of Canada lynx occurrence in northern Maine. Published abstract of paper presented at Carnivores 2006 Conference, St. Petersburg, FL.

Seymour, R., M. Saunders, D. Ray, M. Olson, and R. Wagner. 2007. Multi-aged silviculture in the Acadian Forest of northeastern North America – the case for area-based stand structures. In Proceedings of 6th North American Forest Ecology Workshop, June 18-22, 2007, The University of British Columbia, Vancouver.

Wagner, R.G. 2007. Forest Regeneration Trends in Canada: The Role of Dinosaurs, Political Correctness, and Emerging Pressures. 58th Distinguished Forest Industry Lecturer. Myer Horowitz Theatre, University of Alberta, Edmonton, AB. November 8, 2007. (Invited presentation)

PRESENTATIONS

Fuller, A. K., and D. J. Harrison. "Stand-scale habitat relationships of lynx in northern Maine." Presentation at Maine Lynx Workshop, Bangor, ME. December 1, 2006.

Fuller, A. K., and D. J. Harrison. "Stand-scale habitat relationships of lynx in northern Maine." Paper presented at International Carnivores 2006 Conference, St. Petersburg, FL. November 14, 2006.

Fuller, A. K., D. J. Harrison, and B. J. Hearn. "Application and testing of models to predict occurrence and density of endangered Newfoundland martens." Presentation to Newfoundland marten recovery team, Corner Brook, Newfoundland, Canada. January 3, 2007.

Fuller, A. K., and D. J. Harrison. "The relative roles of fine- and coarse-grained habitat choices by Canada lynx during winter." Paper presented at The Wildlife Society 14th Annual Conference, Tucson, Arizona. September 23, 2007.

Fuller, A. K., and D. J. Harrison. "Foraging paths reveal scale-dependent habitat decisions by Canada lynx." Paper presented at Canada Lynx on the Border, Biological and Political Realities for Conservation Planning: An International Workshop, Grand Portage, Minnesota. October 26, 2007.

Harrison, D. J. "Applying umbrella species as tools for land conservation: case examples using martens and lynx in Maine." Presentation to the Board of Directors, Forest Society of Maine, Falmouth, Maine. September 11, 2007.

Harrison, D. J. and W. K. Krohn. "Long-term results from research on snowshoe hares and lynx in relation to forest management activities in Maine." Presentation to Advisory Committee, Maine Cooperative Forestry Research Unit, University of Maine. October 4, 2006.

Harrison, D. J. Was a co-leader of a field tour for professional foresters highlighting the management of deer wintering habitat in northern Maine. October 10, 2007.

Harrison, D. J. "What is a predator ecologist and what does it do?" Presentation to first year students in WLE 100. October 12, 2007. Workshops

Harrison, D. J., W. B. Krohn, A. K. Fuller, and L. Robinson. "Hare population dynamics and lynx and hare habitat selection in Maine." Presentation at National Interagency Lynx Biology Team Meeting, Duluth, MN. October 20, 2006.

Harrison, D. J., W. B. Krohn, J. A. Homyack, L. Robinson, and A. K. Fuller. "Temporal and spatial variation in snowshoe hare populations in relation to forest harvesting in Maine." Presentation at Maine Lynx Workshop, Bangor, ME. December 1, 2006.

Harrison, D. J. and J. McCloskey. "Documenting occurrence patterns of northern goshowks in Maine." Proposal presentation to Advisory Committee, Maine Cooperative Forestry Research Unit, Orono, Maine. April 25, 2007.

Harrison, D.J. "Forest carnivores, forestry, and fragmentation: modeling landscape sustainability using marten and lynx." Seminar presented to Division of Biological Sciences and School of Forest Resources, University of Montana, Missoula. April 30, 2007

Harrison, D. J., E. Simons, and K. Legaard. "Forest carnivores, forestry and fragmentation: Using American marten as the canary in the coal mine." Department of Biological Sciences Seminar Series, University of Maine. May 4, 2007.

Harrison, D. J. "The role of predation on population dynamics of white-tailed deer." Presentation to Commissioner's Task Force to Assess the Northern and Eastern Maine Deer Population. June 12, 2007.

Harrison, D. J., W. B. Krohn, L. Robinson, A. K. Fuller, and C. L. Hoving. 2007. "Multi-scalar habitat preferences of snowshoe hares: how does a prey specialist coexist with a specialist predator." Paper presented at International Union of Game Biologists XXVIII Congress, Uppsala, Sweden. August 17, 2007.

Harrison, D. J., W. B. Krohn, L. Robinson, S. Scott, A. K. Fuller, and C. L. Hoving. "Temporal and spatial variation in snowshoe hare densities in eastern North America: relationships to lynx and forest management." Invited paper presented at Canada Lynx on the Border, Biological and Political Realities for Conservation Planning: An International Workshop, Grand Portage, Minnesota. October 26, 2007.

Hearn, B. J. "Factors affecting habitat selection and population characteristics of American marten in Newfoundland." Ph.D. dissertation defense seminar presented to Department of Wildlife Ecology, University of Maine. April 24, 2007.

Hearn, B. J., D. J. Harrison, C. Lundrigan, W. J. Curran, and A. K. Fuller. "Multi-scale habitat selection by the endangered Newfoundland marten." Paper presented at The Wildlife Society 14th Annual Conference, Tucson, Arizona. September 23, 2007.

Krohn, W. B., D. J. Harrison L. Robinson, and C. Hoving. "Results for species occurrence modeling with lynx across 3 spatial scales in Maine." Presentation at National Interagency Lynx Biology Team Meeting, Duluth, MN. October 20, 2006.

Krohn, W. B., D. J. Harrison, C. Hoving and L. Robinson. "Factors influencing patterns of lynx occurrence across multiple spatial scales in eastern North America." Presentation at Maine Lynx Workshop, Bangor, ME. December 1, 2006.

Meyer, S.R. Maine ForCAST Initiative: Forest Conditions, Assessment, Status and Trends New England Society of American Foresters Winter Meeting. March 22, 2007.

Meyer, S.R. Cooperative Forestry Research Unit: Addressing Forest Management Challenges for Landowners. JD Irving Stakeholders Meeting, Deeresdale, NB. April 18, 2007.

Meyer, S.R. Maine ForCAST Initiative: Forest Conditions, Assessment, Status and Trends. Presentation to Plum Creek silviculture managers. Orono, ME. April 23, 2007.

Meyer, S.R. An Update on the Cooperative Forestry Research Unit. A presentation to Plum Creek silviculture managers. Orono, ME. April 23, 2007.

Meyer, S.R. An Overview of the Cooperative Forestry Research Unit – a presentation to the Maine Land Use Regulation Commission staff. Augusta, ME. May 22, 2007.

Robinson, L., D. J. Harrison, W. B. Krohn, J. Vashon, and M. McCollough. "Modeling habitat occupancy of lynx in northern Maine." Paper presented at International Carnivores 2006 Conference, St. Petersburg, FL. November 14, 2006.

Simons, E., K. Legaard, D. J. Harrison S. Sader, and W. B. Krohn. "Forest harvesting trends affecting lynx and marten habitat in Maine as revealed by change

detection of multiple LANDSAT TM images, 1988-2004." Presentation at Maine Lynx Workshop, Bangor, ME. December 1, 2006.

Simons, E. M., L. Robinson, D. J. Harrison, W. B. Krohn, and K. R. Legaard. "Ecological factors associated with landscape-scale occurrences of Canada lynx in northern Maine." Paper presented at Canada Lynx on the Border, Biological and Political Realities for Conservation Planning: An International Workshop, Grand Portage, Minnesota. October 25, 2007.

Simons, E., K. Legaard, D. J. Harrison, S. Sader, and W. B. Krohn. "Trends in forest harvesting in Maine as revealed by change detection of multiple LANDSAT TM images." Poster presented at 2006 CANUSA Conference, Quebec City, Canada. October 20-21, 2006..

Wagner, R.G., Maine Forests, Their Management, and Biomass Potential. Project Learning Tree Workshop for High School Science Teachers, Maine Audubon Nature Center, Falmouth, ME (Nov 2007)

Wagner, R.G., Latest results from CFRU Commercial Thinning Research Network and Acadian Forest Ecosystem Research Program. Maine Forest Service foresters field tour, Penobscot Experimental Forest, Bradley, ME (Nov 2007)

Wagner, R.G., Latest research results from University of Maine's Cooperative Forestry Research Unit. Forest Resources Association, Brewer, ME (Oct 2007)

Wagner, R.G., Overview of University of Maine's Cooperative Forestry Research Unit. University of North Carolina and Virginia Tech Forest Nutrition Cooperative, 2007 Annual Meeting of Advisory Board, Blacksburg, VA. October 18-20, 2007 (Oct 2007)

Wagner, R.G., Overview of University of Maine's Forest BioProducts Research Initiative. Ensuring Forest Sustainability in the Development of Wood-Based Bioenergy: A National Dialogue. Pinchot Institute for Conservation. Pocantico Conference Center, Tarrytown, New York. September 17-19, 2007. (Sep)

Wagner, R.G., Linking dynamic forest ecosystems with societal demands for products and environmental protection: Overview of FBRI Theme 1. AAAS panel review. University of Maine, Orono, ME (Aug 2007)

Wagner, R.G., Maine Forests, Their Management, and Biomass Potential. Project Learning Tree Workshop for High School Science Teachers, University of Southern Maine, Gorham, ME (Feb 2007)

Wagner, R.G., Cooperative Forestry Research Unit Overview. Joint Standing Committee on Agriculture, Conservation and Forestry, Maine Legislature, (Jan 2007)

Wagner, R.G., Herbicides in Christmas Tree Culture: Environmental Fate & Toxicity. Maine Christmas Tree Association Annual Meeting and pesticide re-certification training, Maine Agriculture Trade Show, Augusta Civic Center, Augusta, ME (Jan 2007)

Wagner, R.G., Maine Forest Harvest Classification System: Task Force Report. Maine Society of American Foresters, Fall meeting, Orono, Maine. (Oct 2006)

You want ME to move?

List of Figures

Chris Richards maneuvers his Deere 1270 processor at Lazy Tom.

List of Tables

Next year, we are going to talk a lot about biomass and wood chips...

Contact Information

Jeffrey Benjamin (Ph.D.)

CFRU Cooperating Scientist, Assistant Professor of Forest Resources, University of Maine, Orono, ME
(207) 581-2727; jeff_benjamin@umenfa.maine.edu

John M. Hagan (Ph.D.)

CFRU Cooperating Scientist, Program Director
Manomet Center for Conservation Sciences, Brunswick, ME
(207) 721-9040; jmhagan@prexar.com

Daniel J. Harrison (Ph.D.)

CFRU Cooperating Scientist, Professor of Wildlife Ecology, University of Maine, Orono, ME
(207) 581-2867; harrison@umenfa.maine.edu

Philip Hofmeyer

Graduate Assistant, School of Forest Resources, University of Maine, Orono, ME
(207) 581-2878; philip.hofmeyer@umit.maine.edu

William B. Krohn (Ph.D.)

Leader, Maine Coop. Fish and Wildlife Research Unit, Assistant Professor of Wildlife Ecology, University of Maine, Orono, ME (207) 581-2870; wkrohn@umenfa.maine.edu

Spencer R. Meyer

CFRU Research and Communications Coordinator, Cooperative Forestry Research Unit, University of Maine, Orono, ME
(207) 581-2861; spencer_meyer@umenfa.maine.edu

Michael Saunders (Ph.D.)

Assistant Professor of Hardwood Silviculture,
Purdue University, West Lafayette, IN
(765) 494-2155; msaunder@purdue.edu

Robert S. Seymour (Ph.D.)

CFRU Cooperating Scientist, Curtis Hutchins Professor of Forest Resources, University of Maine, Orono, ME
(207) 581-2860; seymour@umenfa.maine.edu

Erin Simons

Assistant Scientist, Center for Research on Sustainable Forests, University of Maine, Orono, ME
(207) 581-2869; Erin_Simons@umit.maine.edu

Dana M. Smith

CFRU Administrative Assistant, University of Maine, Orono, ME
(207) 581-2893; dana.smith@umit.maine.edu

Robert G. Wagner (Ph.D.)

CFRU Director, Henry W. Saunders Distinguished Professor in Forestry, School of Forest Resources, University of Maine, Orono, ME
(207) 581-2903; bob_wagner@umenfa.maine.edu

Andrew A. Whitman

Forest Ecologist, Manomet Center for Conservation Sciences, Brunswick, ME
(207) 721-9040; awhitman@prexar.com

Ethel Wilkerson

Project Manager, Manomet Center for Conservation Sciences, Brunswick, ME
(207) 721-9040; ewilkerson@prexar.com