COOPERATIVE FORESTRY RESEARCH UNIT

2008 Annual Report

COOPERATIVE FORESTRY RESEARCH UNIT

ANNUAL REPORT

2008

Spencer R. Meyer
Editor

About the CFRU

Founded in 1975, the CFRU is one of the oldest industry/university forest research cooperatives in the United States. We are composed of 30 member organizations including private and public forest landowners, wood processors, conservation organizations, and other private contributors. Research by the CFRU seeks to solve the most important problems facing the managers of Maine's forests.

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Credits

This annual report is compiled, designed and edited by Spencer R. Meyer, Associate Director. Individual sections are written by authors as indicated, otherwise by Spencer Meyer. Photography compliments of Spencer Meyer, CFRU archives, or as indicated.

A Note About Units

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

Contents

Executive Summary

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

In 2008, we celebrated our 33rd year of conducting research on the sustainable forest management of Maine's forests. Together, 30 of Maine's landowners, managers, wood processors and conservation organizations partner with us at the University of Maine to improve our understanding about Maine's forests and how best to use them for all of society's values. Using over 8 million acres of our members' forestland as a laboratory, the CFRU is poised to address the myriad questions and concerns that arise about the forest. This report summarizes the significant accomplishments of the CFRU during 2008.

This year, the CFRU welcomed three new companies, **Tall Timbers Trust**, **LLC, EMC Holdings** and **Mosquito, LLC** to our proud list of members. Between direct contributions from our members and additional, externally leveraged support our total program value reached $864,000 this year. This year's unprecedented amount of overall support for our program allowed us to make great strides in our three core areas of research: Silviculture and Productivity, Wildlife Habitat and Biodiversity Conservation.

A total of 14 research projects were conducted this year, including commercially thinning spruce-fir forests, improving the value of hardwood stands, assessing the vulnerability of our forest to the spruce budworm, evaluating biomass harvest systems, developing recommendations for managing deer wintering areas (DWA), improving our understanding of the relationship between forest management and the federally threatened Canaday lynx, developing strategies for adapting to climate change and quantifying the biodiversity values of managed forests in Maine.

One notable project, Capturing 30 Years of Research*,* is investigating all previous work the CFRU has completed since its inception. So far we have identified more than 100 completed projects that have contributed to our understanding of the forest. With this immense body of scientific research under our belt, the CFRU is now more capable than ever to help landowners answer tomorrow's questions about the forest. We trust that you will enjoy reading about our most recent accompishments in this *2008 Annual Report*.

Research Highlights

Silviculture & Productivity

Spruce Budworm

Based on the spruce budworm decision support system, and Maine's large acreage of susceptible stands, managers can expect a greater than 20 % reduction in spruce-fir volume 10-15 years into an outbreak. (...more)

Vegetation Management

Two years post-treatment, the optimal combination of 1 lb/ac glyphosate and 0.5 % shows promise for controlling unwanted beech regeneration in hardwood stands. (...more)

Wildlife Habitat

Snowshoe Hares

Evidence suggests hare populations in northern Maine exhibit less extreme cycling than in the boreal forest. Results suggest that these fluctuations and the impacts of forest management are important considerations for lynx management. (...more)

Deer Wintering Areas

A state-of-the-art synthesis of scientific literature on deer wintering areas (DWA) resulted in 15 findings and recommendations about managing for DWA. Among other findings, it is clear that due to their dynamic nature, DWAs require careful management to balance their wood production and utility as quality habitat. (...more)

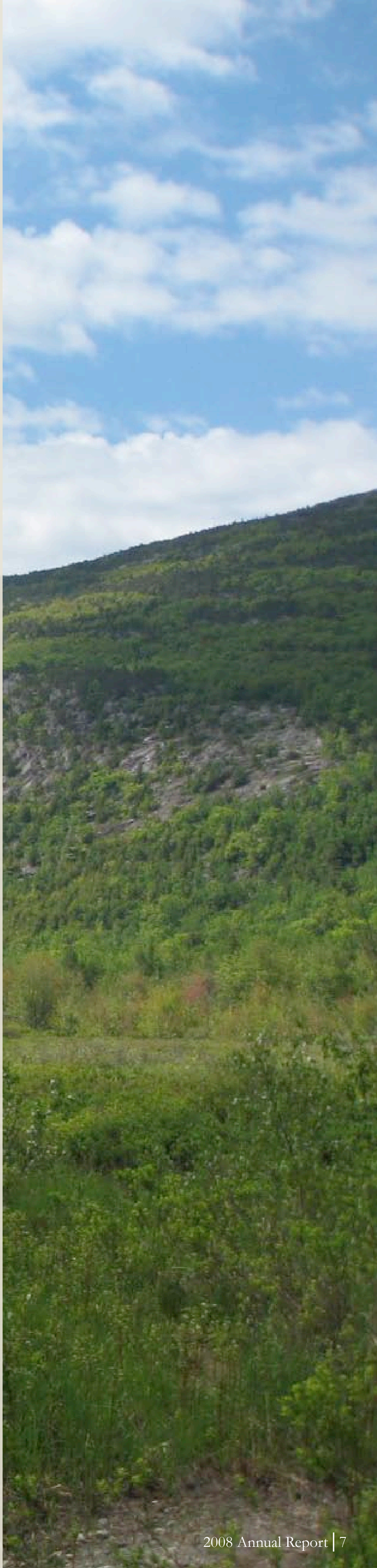
Biodiversity Conservation

Adaptation to Climate Change

A combined approach with resistance, resilience and response offers the best strategy for adapting to climate change. Responding to climate change will require that growth and yield models reflect the changing conditions brought on by climate change. (...more)

Headwater Streams

Seven years after harvest, stream temperatures have recovered to pre-harvest levels, however, streams with southern and southeastern slopes are more susceptible to impacts on brook trout habitat. (...more)



Membership

ADVISORY MEMBERS

John Bryant (Chair)
American Forest Management

Mark Doty (*Vice Chair*)
Plum Creek Timber Company

Kenny Fergusson (*Financial Officer*)
Huber Resources Corporation

Kip Nichols (*Member-at-Large*)
Seven Islands Land Company

Greg Adams
JD Irving, Ltd.

John Brissette
USFS Northern Research Station

Ron Bugeau
Hancock Lumber Company

Tom Charles
Maine Bureau of Parks and Lands

Steve Coleman
Landvest

Brian Condon
The Forestland Group

David Dow
Prentiss & Carlisle Company

Claude Dufour
Landvest

Gordon Gamble
Wagner Forest Management

Laurie McElwain
Baskahegan Company

Kevin McCarthy
Sappi Fine Paper

Marcia McKeague
Katahdin Forest Management

Jake Metzler
Forest Society of Maine

David Publicover
Appalachian Mountain Club

Carol Redelsheimer
Baxter State Park, SFMA

Jim Robbins
Robbins Lumber Company

Dan Russell
Huber Engineered Woods

Nancy Sferra
The Nature Conservancy

G. Bruce Wiersma
University of Maine, CRSF

MAJOR COOPERATORS

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

OTHER COOPERATORS

Field Timberlands
Finestkind Tree Farms
Hancock Lumber Company,
LandVest
Mosquito
Peavey Manufacturing Company
Western Maine Nurseries, Inc.

People

STAFF

Robert G. Wagner
CFRU Director,
Director of School of Forest Resources

Spencer R. Meyer
Assoiate Director

Matthew Russell
Forest Data Manager

Dana M. Smith
Administrative Assistant

Rosanna Libby
Administrative Assistant

COOPERATING SCIENTISTS

Jeffrey Benjamin
Assistant Professor
of Forest Operations

John M. Hagan
President,
Manomet Center for Conservation Sciences

Daniel J. Harrison
Professor of Wildlife Ecology

Robert S. Seymour
Curtis Hutchins Professor of
Forest Resources

PROJECT SCIENTISTS

John Gunn
Senior Program Leader,
Manomet Center for Conservation Sciences

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Leader, Maine Cooperative
Fish and Wildlife Research Unit

Aaron Weiskittel
Assistant Professor of
Forest Biometrics and Modeling

Andrew A. Whitman
Natural Capital Initative Leader,
Manomet Center for
Conservation Sciences

Ethel Wilkerson
Program Manager,
Manomet Center for
Conservation Sciences

Jeremy S. Wilson
Irving Chair for
Forest Ecosystem Management

John Bryant
Chair, Advisory

Chair's Report

2008 was a very rewarding year for CFRU scientists and staff. It was also my first year as a CFRU Advisory Committee member. Joining as the incoming CFRU Chair meant I truly had to "learn on the fly," which was made virtually seamless by the valued coaching and support of Bob Wagner and Spencer Meyer. From the first meeting, Bob provided the necessary background on issues and Spencer provided gentle reminders to keep me on track. I appreciate their guidance as I learned the role as Chair. Thanks to the CFRU Advisory Committee members for their professionalism, patience and understanding as we worked through our discussions and decisions. The role of CFRU Advisory Committee Chair is easiest when you get support from others.

CFRU welcomed new members **Tall Timber Trust, LLC**, **EMC Holdings, LLC**, and **Mosquito, LLC**, which raised the total membership to an all-time high acreage of over eight million acres. Six landowners represent 75 % of the total acreage; however, the diverse landowner representation is what makes CFRU a strong unit. CFRU continues to recruit a diverse membership in order to manage member interests.

CFRU staff changes include **Spencer Meyer's** new role as Associate Director, and the addition of **Dr. Aaron Weiskittel** (as CFRU Growth & Yield specialist), **Rosanna Libby** (as Administrative Assistant), and **Matt Russell** (as Forest Data Manager). **Dana Smith** left CFRU in 2008 to pursue graduate studies. My personal thanks to Dana for her help during CFRU meetings and field sessions.

In May, CFRU held a day-long forester workshop attended by over 75 foresters. This indoor workshop is an excellent opportunity for foresters, land managers, and scientists to discuss and debate ongoing and completed research efforts. I receive regular, positive feedback on the value of the CFRU forester workshops, as it enables field foresters to understand how CFRU research might assist them in their daily forest management decisions. The October fall meeting and field tour, held in Greenville, focused on lynx and snowshoe hare habitat requirements. Thanks to **Plum Creek** and **Black Bear** Forest for hosting us.

Please take time to review the extensive 2008 research highlights contained in this report, as it is an impressive summary. This research exemplifies CFRUs use of limited funds to accomplish priority research for the cooperators in order to respond to the many demands on the Maine forests. In 2009, the Cooperative Forest Research Unit will enter the 34th year of practical, applied research in Maine. Time changes everything; however, CFRUs long-standing commitment to the issues and priorities of the Maine forest has created a strong legacy. The challenges of the dynamic Maine forest create the need to shift priorities, and focus on short-term issues without neglecting the commitment to long-term research. CFRU does this well, which is a testament to the quality of the leadership and staff.

Director's Report

Fiscal year 2008 was a strong one for CFRU. Despite the global financial crisis and the substantial downturn in the forest products industry, the CFRU has remained strong. We were able to welcome three new members to the coop, bringing our total membership to 8.1 million acres. We thank **Tall Timber Trust, LLC, EMC Holdings, LLC,** and **Mosquito, LLC** for joining the CFRU this year.

With the support of CFRU members, our scientists and graduate students were able to deliver a strong set of research results on over a dozen ongoing projects. There was a strong emphasis on a variety of silviculture and forest management investigations, including a return to the origins of CFRU with a new investigation on the risks of spruce budworm outbreaks on Maine forestlands. Continued landmark work with the Canada lynx has further advanced our understanding about the long-term implications of forest dynamics and management practices on lynx habitat. In addition, we were happy to quickly develop a state-of-the-art literature review on deer wintering areas to help inform current political discussions about this important issue across northern Maine. A notable effort to compile and organize 30 years of CFRU research data into a single computerized database also was tackled this year. Results from this work are described in the following report.

I thank our Executive Committee, Chair **John Bryant** (**Black Bear Forest, Inc.**), Vice Chair **Mark Doty** (**Plum Creek Timber Co.**) and Member-at-Large **Kip Nichols** (**Seven Islands**) for their hard work and support this year. **Spencer Meyer** took on his new duties as Associate Director of the unit this year and has done a great job with these new responsibilities. **Dr. John Hagan** (**Manomet Conservation Sciences**) left the CFRU as a Cooperating Scientist this year after nearly a decade of formal cooperation with the unit. We thank John for the fine cooperation and excellent synergy that we were able to develop between Manomet and CFRU over the years. **Dr. Aaron Weiskittel** joined the UMaine faculty, is leading the CFRU growth & yield research efforts, and has initiated a number of new important projects. **Matt Russell** joined the CFRU from Virginia Tech on a temporary appointment to lead the 30-year data compilation effort. **Dana Smith** left the CFRU this year to pursue graduate studies after more than four years as our Administrative Assistant. We thank Dana for the great job she did. We also welcome **Rosanna Libby** as our new CFRU Administrative Assistant.

Robert G. Wagner
CFRU Director

Activities

The CFRU Advisory typically meets three times a year to conduct business. Advisory members work with CFRU scientists and staff to develop and implement the research objectives of the program. The Advisory is also responsible for reviewing and approving all funded research projects carried out by the CFRU. In 2008 the Advisory held business meetings on January 23 in Orono, April 7 in Bangor and October 29 in Greenville. In January, scientists brought pre-proposals before the Advisory. Preliminary decisions were made at that meeting and in April the scientists brought revised, complete proposals to the Advisory for full consideration. Projects funded at the April 2008 meeting will began in October 2008 and will be fully described in the 2009 Annual Report.

In addition to Advisory business meetings, the CFRU hosts several other types of events to communicate with our stakeholders about our research:

Munsungan Workshop: Deer Wintering Areas in Maine

On December 10, 2007 the CFRU partnered with the Center for Research on Sustainable Forests to produce the Munsungan Series round table, ***Deer Wintering Areas in Maine***. This event for resource managers, scientists and policy makers was designed to foster discussion about how to best co-manage forests for wood products and quality habitat that allows white-tailed deer to survive Maine's harsh winters. Organized and led by Spencer Meyer, this workshop included presentations by representatives from Maine Inland Fisheries and Wildlife, University of Maine, Maine Bureau of Public Lands, forest landowners, Université Laval and the province of New Brunswick. Presenters and the nearly 100 participants engaged in terrific dialogue, which helped frame CFRU research efforts on deer wintering areas (see DWA report).

Foresters' Workshop: Bridging Science and Stewardship

On May 14, 2008 about 90 foresters from all over Maine met in Brewer for the CFRU workshop entitled, ***Bridging Science and Stewardship***. After an introduction to the CFRU by Spencer Meyer, CFRU

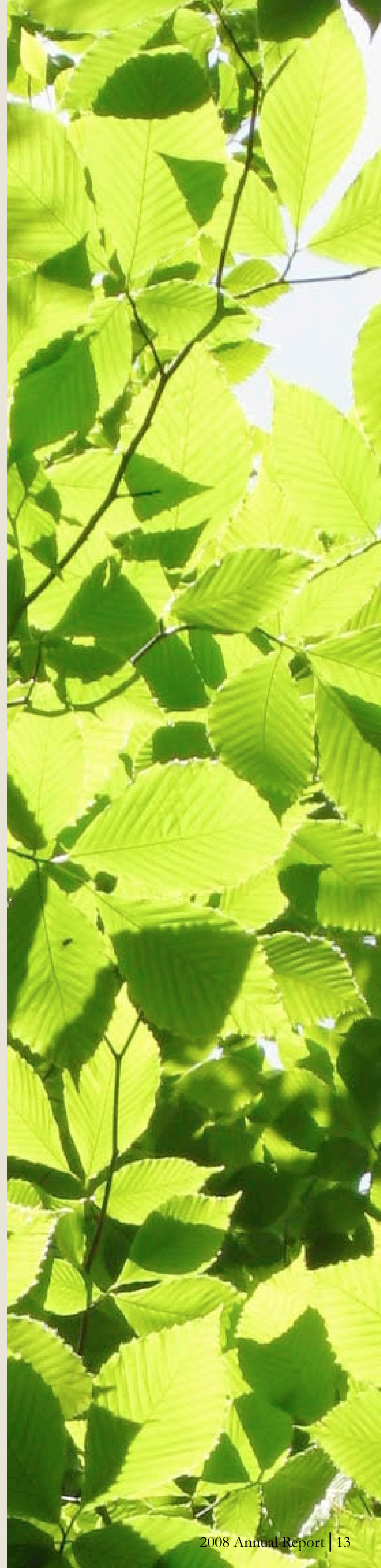
Scientists, Dr. Dan Harrison, Dr. Bob Seymour, Dr. Bob Wagner, Dr. Jeremy Wilson, Andrew Whitman, and Ethel Wilkerson presented on eight different CFRU projects. Foresters left the day with a pocket full of continuing education credits and new tools to help them improve their management of the forest.

Fall Field Tour:
Lynx on the Landscape - What You Need to Know

Each year, the CFRU holds a fall field tour, typically the day after the October business meeting, to showcase results from recent research. This year, a total of about 40 Advisory members, scientists and other CFRU members convened in Greenville on October 29 for the workshop and tour entitled, ***Lynx on the Landscape: What You Need to Know***. The event was designed for managers to learn about the practical, on-the-ground applications of the monumental Canada lynx research that has been conducted under the leadership of Dr. Dan Harrison. In the morning, Dr. Angela Fuller and Dr. Dan Harrison's Ph.D. student, Erin Simons, presented their latest findings. In the afternoon, Plum Creek and Black Bear Forest (American Forest Management) hosted us at several stands in Shirley and Lily Bay, while Dan Harrison, Angela Fuller, Erin Simons, and another Harrison student, Shonene Scott (M.S.) led us through discussions on the values of stand tpes for lynx habitat. Participants agreed the combination of scientifiic presentations and on-the-ground discussions made for a very successful day.

The 4th Biennial Eastern Canada - United States Forest Science Conference

On behalf of the CFRU, Bob Wagner and Spencer Meyer organized the 4th biennial Eastern Canada - United States Forest Science Conference (ECANUSA) on October 17-17, 2008. This event, held in the recently renovated Wells Commons at the University of Maine was a terrific success with over 140 forest scientists, foresters, wildlife biologists, policy makers and students participating. Four keynote presentations by Dr. George Jacobson (Universty of Maine), Dr. Guy Larocque (Canadian Forest Service), Matt Smith (FORECON) and Eric Kingsley (Innovative Natureal Resource Solutions) set the stage for 56 oral and 36 poster presentations. It all came together under the central themes of climate change and bioenergy. Specific topics included silviculture and forest production, landscape management, social science, wood products, forest operations, and forest ecology. We look forward to the next ECANUSA, to be hosted by Université de Moncton in Edmundston, New Brunswick.



Financial Report

Thirty members representing almost 8.1 million acres of Maine's forestland contributed $479,433 in dues to support CFRU this year (Table 1). We welcomed back the landbase formerly known as Clayton Lake Timberlands and now known as **Tall Timbers Trust, LLC** (245,000 ac). We are also pleased to have new members **EMC Holdings** (23,526 ac) and **Mosquito, LLC** (16,222 ac) join us this year. We welcome our new and returning members and thank our other members for their ongoing support.

CFRU project scientists and staff spent $103,228 (19.1 %) less than $541,460 that was approved by the Advisory Committee (Table 2). All projects came in under or on budget. Due to the timing of personnel hires, the combined surplus of $41,805 for the *30 Years* and *White Pine* Silviculture projects is being carried forward to FY 2009. Additionally, the *Commercial Thinning* project was able to reduce its annual measurement schedule and the *Spruce Budworm* projec was completed by contracting with a consultant rather than hiring a graduate student for multiple years and so actual costs were substantially lower than anticipated. These savings (other than those approved to be carried forward to FY 2009) were returned to the central account for future use on other CFRU projects.

CFRU spent 57 % of its expenditures on research projects and 43 % for administration, including staff/scientist salaries and other expenses (meetings, field tours, web maintenance, database, travel, computers, safety, phones, printing, and office supplies). Research expenses were divided among eight silviculture projects (40 %), three wildlife ecology projects (28 %), and five biodiversity conservation projects (32 %) (Table 2).

Using contributions from CFRU members, project scientists were able to leverage an additional $330,957 from external sources to support CFRU-sponsored research projects. When added to the $95,187 of in-kind contributions from the University of Maine, total contributions supporting CFRU research during this fiscal year was $864,376 or nearly double (180 %) that of member contributions (Figure 1).

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, $5.80 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 $14.42 to support their highest priority research projects (Figure 2).

Table 1. CFRU revenue and membership for FY 2007-08

Cooperator	Reported Units		Invoiced	Contributed
Landowners/Managers	**8,086,835**	**acres**	**$452,527**	**$452,527**
Irving, J. D. Ltd.	1,380,000		$74,000	$74,000
Wagner Forest Management, Ltd.	1,157,389		$62,869	$62,869
Black Bear Forest Inc.	968,673		$53,355	$53,355
Plum Creek Timberlands	925,600		$51,094	$51,094
Seven Islands Land Company	793,000		$44,133	$44,133
Prentiss and Carlisle	704,178		$39,469	$39,469
Maine Bureau of Parks and Lands	390,000		$22,425	$22,425
Huber, J. M. Corporation	385,000		$22,138	$22,138
Katahdin Forest Management, LLC	299,000		$17,193	$17,193
The Forestland Group, LLC	249,153		$14,326	$14,326
Tall Timber Trust, LLC[1]	245,000		[2] $17,609	$17,609
The Nature Conservancy	180,064		$10,354	$10,354
Timbervest, LLC	121,129		$6,965	$6,965
Baskahegan Lands	101,709		$5,848	$5,848
Frontier Forest, LLC	53,338		$3,067	$3,067
Appalachian Mountain Club	37,093		$2,133	$2,133
Baxter State Park, SFMA	29,537		$1,698	$1,698
Robbins Lumber Co.	27,224		$1,565	$1,565
EMC Holdings, LLC[1]	23,526		$1,353	$1,353
Mosquito, LLC[1]	16,222		$933	$933
Wood Processor Members	**1,829,509**	**tons**	**$22,869**	**$22,869**
Sappi Fine Paper	1,829,509		$22,869	$22,869
Corportate Members			**$4,037**	**$4,037**
Huber Engineered Woods, LLC			$1,500	$1,500
Forest Society of Maine			$1,000	$1,000
Hancock Lumber Company			$1,000	$1,000
LandVest, Inc.			$200	$200
Peavey Corporation			$137	$137
Field Timberlands			$100	$100
Finestkind Tree Farms			$100	$100
Total All Members			**$479,433**	**$479,433**

Note: CFRU Dues are paid in the year preceding fiscal year in which they will be spent. Money collected in FY 07-08 represent FY08-09 Dues

[1] New members in 2007-08

[2] Tall Timbers Trust, LLC joined at the very end of FY 2007 and wished to pay last quarter dues of that year as well as FY 2008 dues at the same time. This was all credited to FY 2008, as part of standard U. Maine accounting practices.

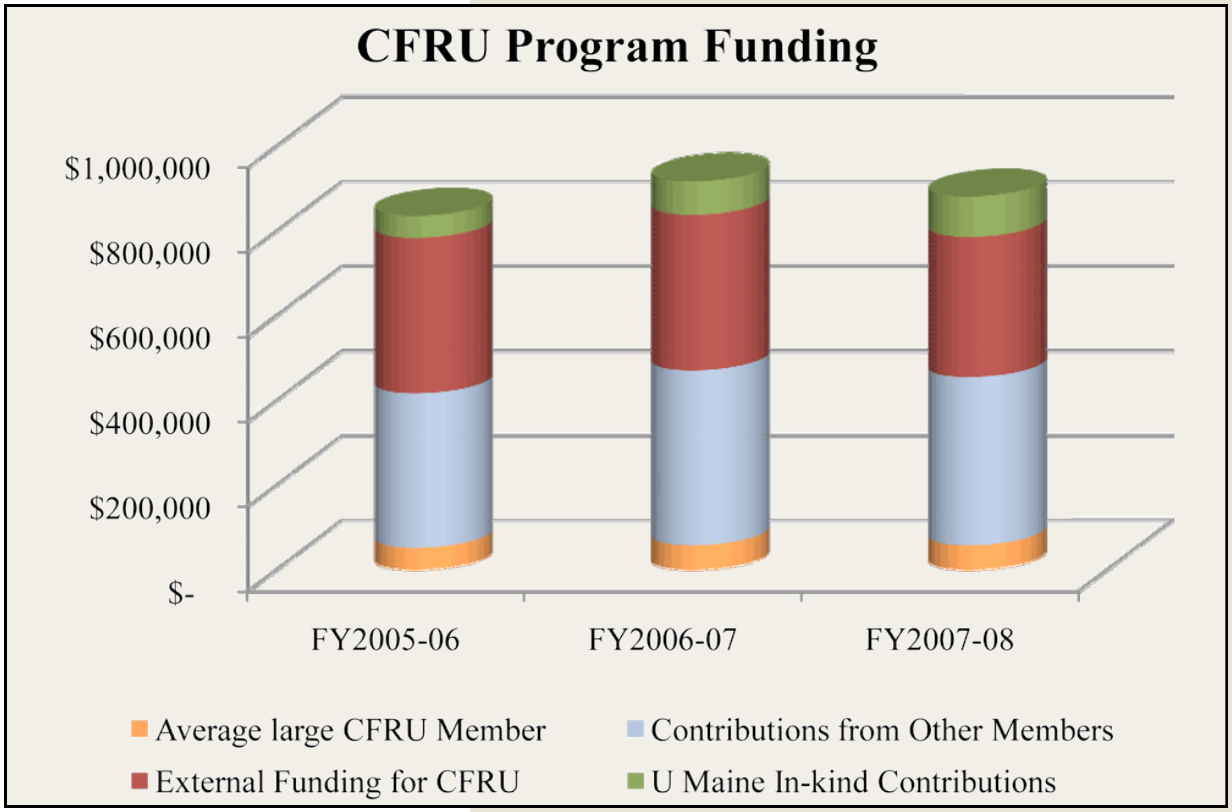
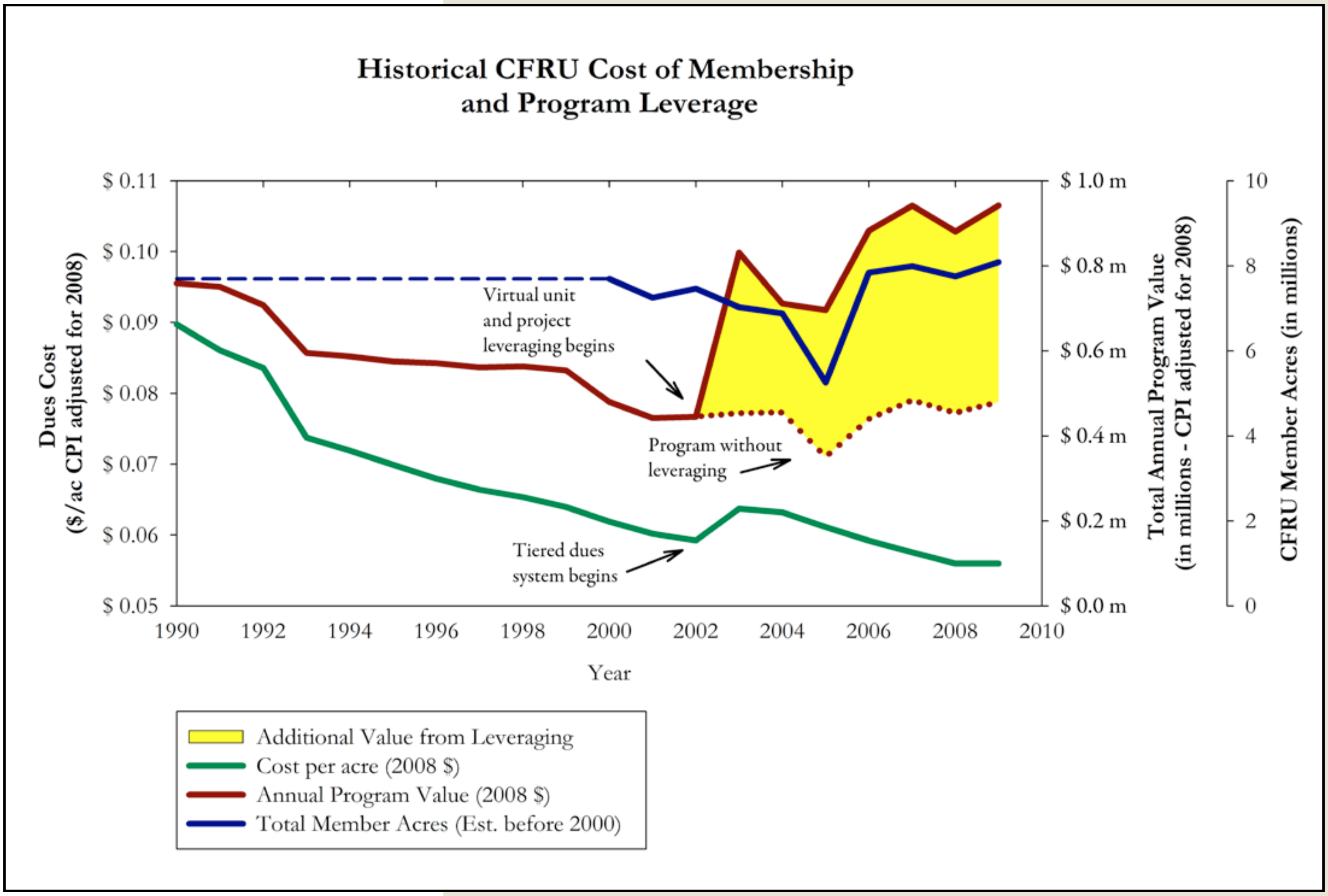


Figure 1. Individual CFRU members continue to receive excellent leverage from other members , external funding sources and University of Maine in-kind contributions. The average large CFRU leverages $15 for every $1 contributed.

Figure 2. Since the early 2000s, the CFRU has been steadily increasing its total progam value by leveraging external funding, while effectively lowering its membership cost. Note that all values are adjusted by the consumer price index (CPI) and are expressed in 2008 dollars.



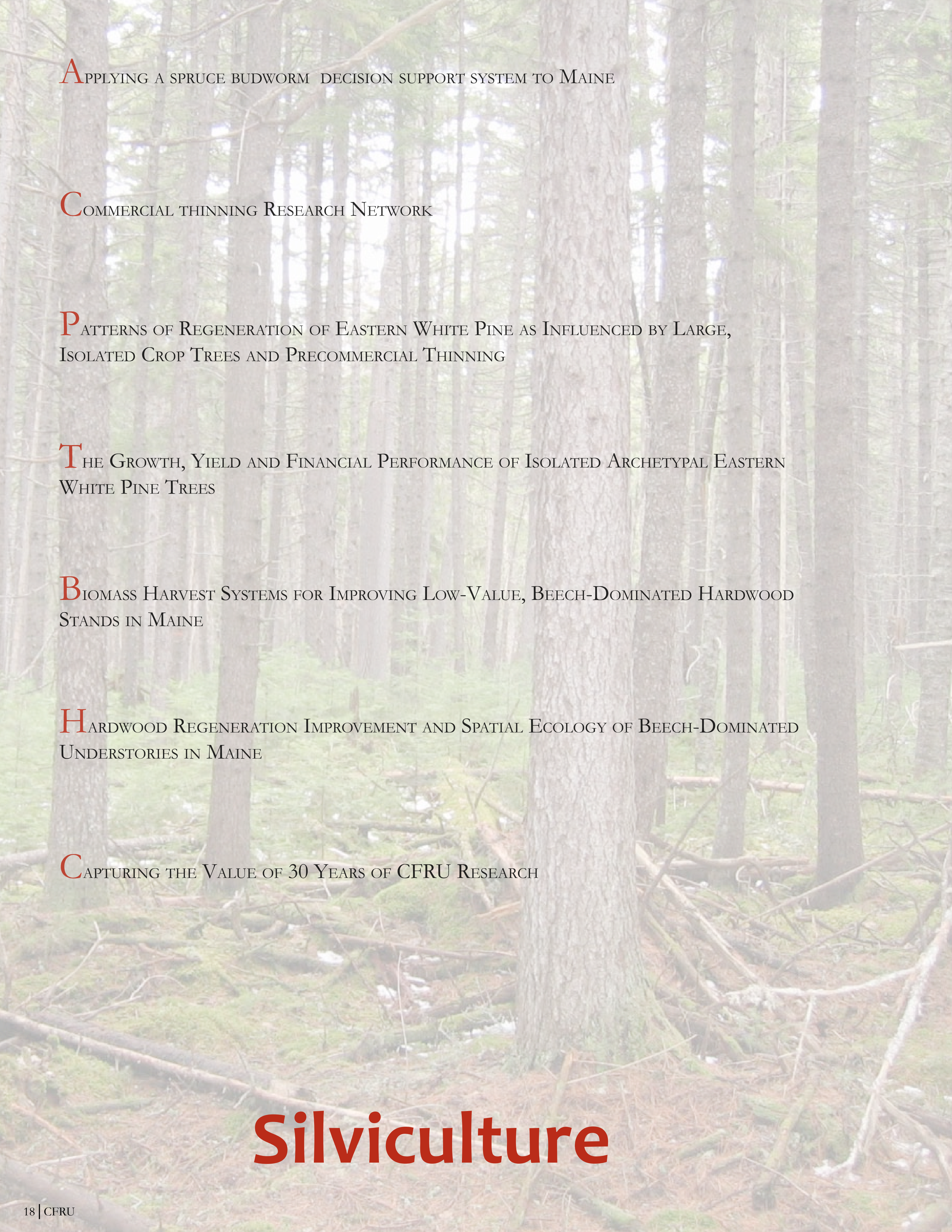
PROJECT	Principal Investigator	Approved Amount	Amount Spent	Balance	% Surplus
Administration[1]		$201,092	$190,993	$10,099	5.0 %
Ongoing Projects					
Silviculture and Productivity:					
Commercial Thinning Research Network	Meyer et al.	$43,912	$26,721	$17,191	39.1 %
CTRN: 5th Year Analysis	Wagner et al.	$12,437	$-	$12,437	100.0 %
Improving the Species Composition of Hardwood Regeneration	Wagner	$4,024	$4,024		0.0 %
Assessing Spruce Budworm Risk and Impact in Maine Forests	Wilson et al.	$31,089	$12,860	$18,229	58.6 %
Capturing the Value of 30 Years of CFRU Research[2]	Meyer & Wagner	$44,880	$20,580	$24,300	54.1 %
Crop Tree Silviculture of White Pine in Mixed Stands[2]	Seymour	$34,188	$16,683	$17,505	51.2 %
Hardwood Silviculture Graduate Student	Wagner	$8,000	$8,000		
Evaluation of Biomass Harvest Systems	Benjamin & Wagner	$12,848	$10,154	$2,694	21.0 %
Wildlife Habitat:					
Relationships of Hares and Lynx to Forest Harvesting	Harrison & Krohn	$38,250	$37,633	$617	1.6 %
IF&W Fall 2007 Lynx Monitoring	Elowe	$20,000	$20,000		
DWA Literature Synthesis	Pekins	$12,375	$12,375		
Biodiversity Conservation:					
Practical Responses to Climate Change	Hagan	$15,000	$15,000		
Quantifying Biodiversity Values Across Managed Landscapes	Harrison & Hagan	$36,365	$36,209	$156	0.4 %
Monitoring Recovery of Headwater Stream Temperature	Hagan et al.	$17,000	$17,000		
ForCAST Initiative	Wiersma et al.	$10,000	$10,000		
Fiscal Year Balance		**$541,460**	**$438,232**	**$103,228**	**19.1 %**

Notes:

1 Includes approved $12,000 contribution towards the purchase of new field vehicle.

2 FY 2007-08 surplus approved as carryover to FY 2008-09 for ongoing projects.

Table 2. CFRU Expenditures for FY 2007-08



Applying a spruce budworm decision support system to Maine

Commercial thinning Research Network

Patterns of Regeneration of Eastern White Pine as Influenced by Large, Isolated Crop Trees and Precommercial Thinning

The Growth, Yield and Financial Performance of Isolated Archetypal Eastern White Pine Trees

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

Hardwood Regeneration Improvement and Spatial Ecology of Beech-Dominated Understories in Maine

Capturing the Value of 30 Years of CFRU Research

Silviculture

Applying Spruce Budworm Decision Support System to Maine

Authors

Jeremy S. Wilson
Chris R. Hennigar
Dave A. MacLean
Robert G. Wagner
Robert S. Seymour

INTRODUCTION

Northeastern forests of the United States and Canada have long been subject to cyclical spruce budworm (*Choristoneura fumiferana* Clem.; [SBW]) outbreaks (Royama et al. 2005). Another outbreak in Maine will probably begin during the next decade. Spruce budworm host species include balsam fir (*Abies balsamea* (L.) Mill.; [BF]), white (*Picea glauca* (Moench) Voss; [WS]), red (*P. rubens* Sarg.; [RS]), and black spruce (*P. mariana* (Mill.) BSP; [BS]). Stand susceptibility or probability of defoliation is a function of species (BF > WS > RS > BS; Hennigar et al. 2008), while vulnerability (i.e., mortality and growth loss response) to defoliation is a function of species (BF > WS > RS > BS) and age (mature > immature) (MacLean 1980; Erdle and MacLean 1999). The Spruce Budworm Decision Support System (SBW DSS), originally developed by the Canadian Forest Service, is available to assist with spruce budworm management planning. It quantifies the marginal timber supply benefits of protecting stands against budworm defoliation (MacLean et al. 2000, 2001, and 2002). In recent years, the DSS has evolved in terms of 1) stand-species impact resolution (separation of host species defoliation and volume impact projections; Hennigar et al. 2008), and 2) better integration of stand-impact projections with industrial-scale timber supply models such as Woodstock® (Remsoft 2007) to allow optimized re-planning of the harvest schedule and salvage of budworm-killed timber volume (Hennigar et al. 2007).

We adapted and applied the SBW DSS to two Maine townships that reflect a range of forest information and stand types. These were a 10,500 ha northeastern township owned by Irving Woodlands, LLC and a 9,700 ha southeastern township managed by American Forest Management (aka Black Bear Forest). Using the tools and approach developed for this project, we are also conducting a statewide spruce budworm impact analysis using FIA data. Preliminary results from this analysis are presented.

STAND IMPACT MATRICES

A spruce budworm stand-impact matrix (SIMPACT; MacLean et al. 2001) was developed, which specifies marginal changes to stand volume for a moderate and severe defoliation scenario by stand type and maturity. The SIMPACT was calculated using data from over 11,000 forest development survey plots measured in stands throughout New Brunswick, ranging from tolerant hardwood spruce to pure BF and with ages between 10 and 150 years old. Stand tables compiled from survey plots were pro-

"Maine has a large acreage of susceptible stands and even under a moderate scenario a greater than 20 % reduction in spruce-fir inventory volume can be expected 10-15 years into an outbreak."

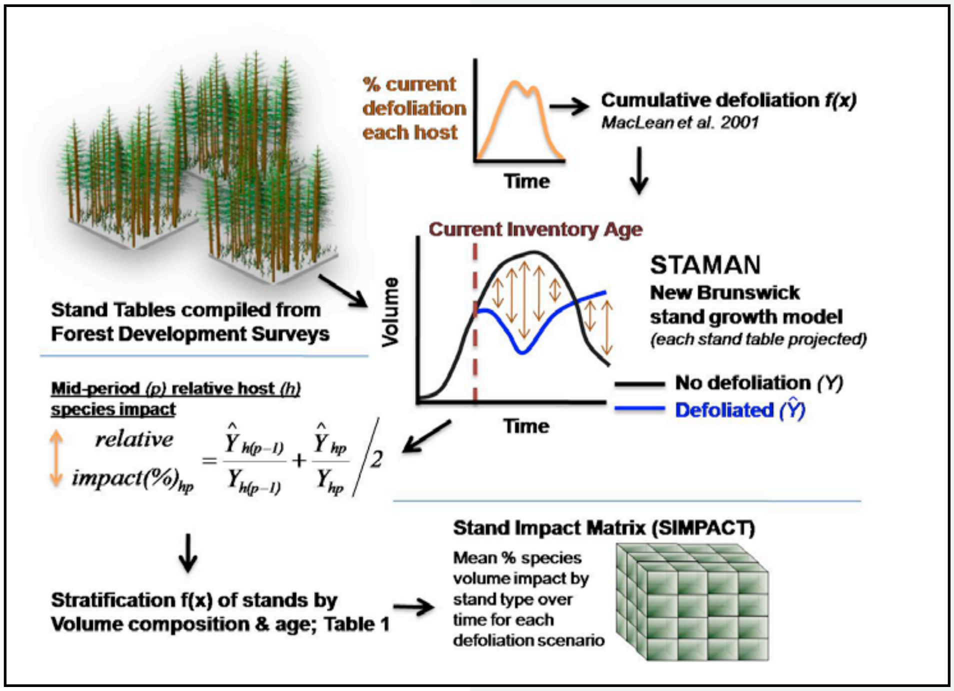


Figure 3. Steps to construct the spruce budworm DSS stand-impact matrix. Percnt species impact represents volume remaining by species for defoliated relative to undefoliated yield over time. Calculation of relative periodic salvageable volume is similar, except only volume of periodic mortality caused by spruce budworm is compared against no defoliation yield projections.

jected using STAMAN (**STA**nd **MAN**agement; MacLean, 1996; Erdle and MacLean 1999; New Brunswick Growth and Yield Unit 2002), with and without defoliation, to quantify relative host species volume impacts and salvageable volume over time (Figure 3).

Stand modeling of spruce budworm impacts to develop the SIMPACT parallel methods used in the SBW DSS (MacLean et al. 2001; Hennigar et al. 2007) with addition of explicit separation of relative defoliation differences expected between BF and each spruce species (Hennigar et al. 2008), and separation of host species volume impact projections. During a large spruce budworm outbreak, this reduced abundance of preferred hosts (BF and WS) in Maine may cause increased feeding on less preferred hosts (RS and BS) and reduce differences between spruce and fir projected defoliation levels found in New Brunswick by Hennigar et al. (2008). To capture the range of potential volume impacts for alternative assumptions of spruce susceptibility to defoliation, all scenarios combinations were modeled with spruce defoliation scaled according to Hennigar et al. (2008) and again with BF defoliation levels applied to all host species as modeled in MacLean et al. (2001). Since relative impacts vary little across stands within types (also shown in Figure 10 in Erdle, 1999), relative impacts can be applied to similar stand type volume projections in Maine (Table 3). This assumption simplifies the SBW DSS implementation by 1) avoiding growth and survival calibration and stand table initialization of STAMAN for Maine stands and 2) allowing pre-existing yield projections available in a forest database to be used.

Table 3. Spruce budworm stand-impact stratification criteria (percent volume loss over-time) by species composition, management, and maturity. Criteria were used to average more than 11,000 New Brunswick forest inventory plot impact projections by stand type into the SBW DSS stand-impact matrix (SIMPACT) for each defoliation scenario. The same criteria were applied to each stand in each Township, allowing the SIMPACT and the GIS inventory to be linked by stand-impact type.

% Species Composition[1]		
% Host	**% Host as FW**	**Impact Type[2]**
75-100	75-100	FW
	50-74	FWRB
	<50	RBFW
10-74	50-100	FWMX
	<50	RBMX
<10		NH

1 FW = balsam fir and (or) white or Norway spruce, RB = red and (or) black spruce, MX = mixed non host, NH=non host.

2 Stratified stand-impact types shown are also broken down by treatment (planting, pre-commercial and commercial thinning) vs. no treatment and stand development stage for immature (-I; <=40 years old) and mature (-M; > 40 years old); with the maturity designation appended to the end of the impact type name (not shown).

ESTIMATING IMPACTS

SBW DSS in Microsoft Access

Three forest information sources are required for calculation of future spruce-fir inventory impact using the SBW DSS framework: 1) area of stand types (i.e., GIS), 2) classification of current landbase stand types by budworm stand-impact type (i.e., volume composition and age dependant (Table 3), and 3) host species volume projections for each stand type. This information provides the necessary information (e.g., stand type, inventory age or time) to link to relative volume impacts in the SIMPACT by defoliation scenario (Figure 4). GIS shapefiles were converted to Microsoft Access geodatabases for each township, and respective township yield tables were compiled and imported, as well as the SIMPACT look-up table produced from STAMAN runs. A series of select and action queries were developed within each township database to link future stand conditions (time and/or age, host species yield) with the SIMPACT table to quantify volume losses over time for outbreak and protection scenarios. The maximum volume loss for each stand 15 years post severe outbreak initiation was used to rank stands for foliage protection priority, where area with highest volume loss was selected first for protection across 10, 20, 40, and 70 % of susceptible area.

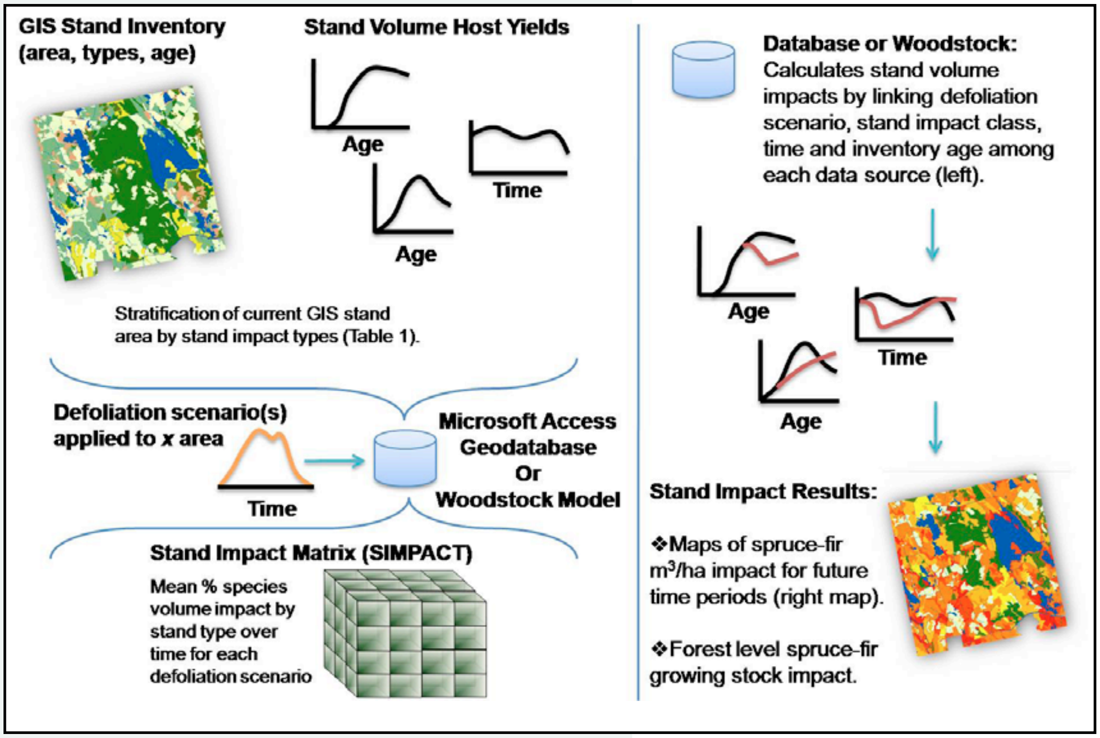


Figure 4. Schematic representation of information sources used and application in the spruce budworm DSS to calculate spruce-fir stand volume impacts and operable salvage volume over time.

Relative time-dependant volume impacts are multiplied against base yield volumes for each area record to calculate absolute volume impact across space and time (Figure 5). Definition of spatio-temporal impacts allow managers to evaluate the vulnerability of a landscape and concentrate harvest and foliage protection efforts in areas with the highest potential volume loss first.

SBW DSS in the Remsoft Spatial Planning System

More informed pest management decisions can be made if the forest harvest schedule is known or can be projected. Quantifying impact at the time of harvest allows for more effective spatial prioritization of foliage protection treatments; e.g., mature fir-spruce (highly vulnerable) stands destined for harvest during the first 1-10 years of the outbreak will not require protection, while young spruce plantations harvested in 15-25 years may require foliage protection to keep trees alive and reduce growth loss to meet planned harvest levels. Integration of the SIMPACT directly into timber-supply modeling environments such as RSPS (Woodstock) allows harvest schedules to be re-planned to minimize harvest volume losses (Hennigar et al. 2007) for different defoliation scenarios. This integrated framework can simultaneously schedule salvage and foliage protection treatments (e.g., to maximize volume return for a given protection budget constraint).

An existing Woodstock formulation for the northeast township was modified to include an additional GIS theme to identify spruce budworm impact zones (i.e., outbreak-protection scenario). The resulting model stand types with merchantable yields by species and partial cut,

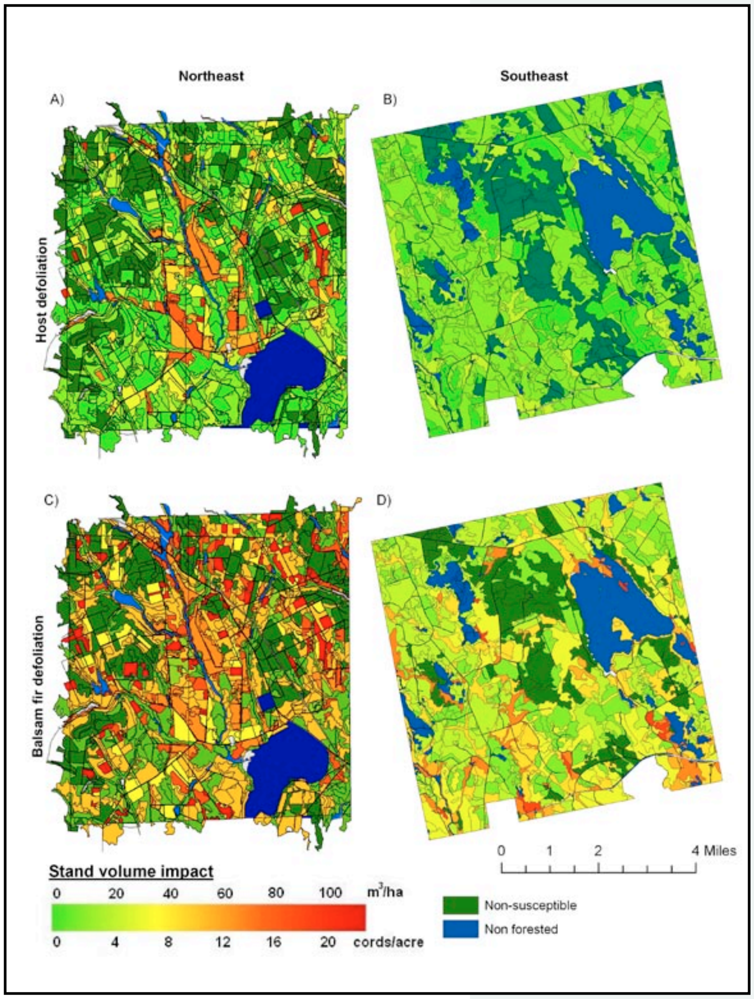


Figure 5. Projected 2025-29 merchantable inventory reduction for the northeast (A, C) and southeast (B, D) Townships caused by a severe spruce budworm outbreak initiating in 2010 using reduced defoliation on spruce relative to balsam fir (A, B) spruce species defoliation equal to balsam fir levels (C, D). Future forest condition does not consider harvesting.

shelterwood, selection cut, commercial thin, clearcut, planting, and pre-commercial thin treatments. Areas harvested were assumed to remove salvageable volume in direct proportion to volume removed during that treatment (e.g., clearcut = 100 % and partial cut = 30 % removal of budworm-caused mortality). In practice, a partial harvest operation would target budworm-caused mortality, thus this may underestimate salvaged mortality.

The northeast township objective function was modified in order to minimize the maximum defoliation-caused harvest reduction through iterative re-optimization methods described by Hennigar et al. (2007). We omitted non-declining spruce-fir-jack pine (SFJ) harvest constraints until 2024 to avoid infeasibilities due to unavoidable harvest reductions from SBW caused growing stock mortality. Percent harvest reductions under alternative outbreak intensities, re-planning, salvage, and protection are shown in Figure 6. Using the SBW DSS in combination with a forest planning tool allows for dramatic reductions in volume loss through adjustments to harvest plans, salvage harvesting, and the application of foliar protection.

SBW vulnerability throughout Maine

Over three thousand Forest Inventory and Analysis (FIA) plots representing all of Maine were projected using the Forest Vegetation Simulator Northeast Variant (FVS NE; Dixon 2002) and stratified according to the stand impact types presented in Table 3. The results of

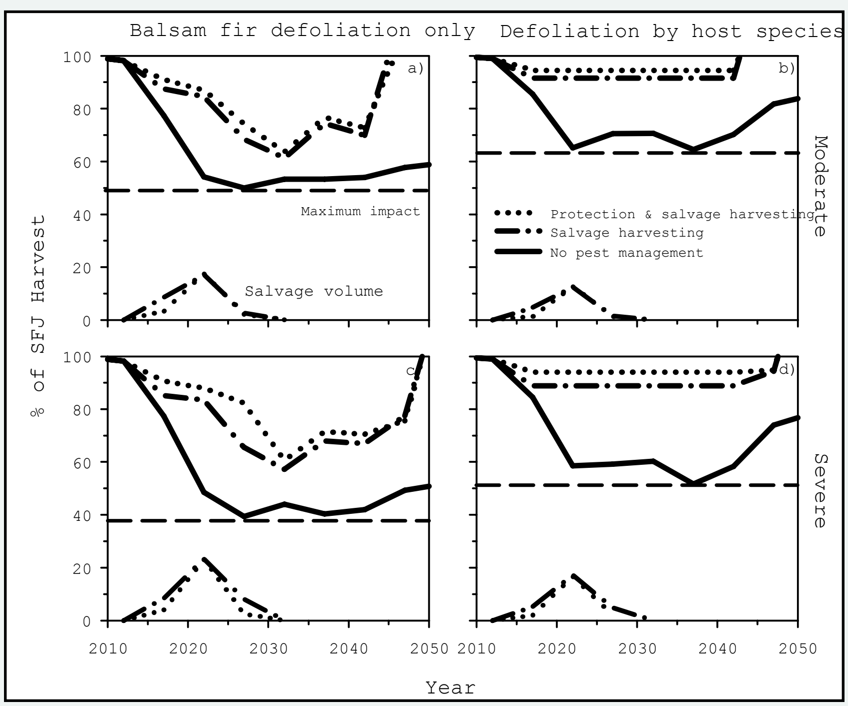


Figure 6. The three lines in each graph represent % of maximum non-declining base (no spruce budworm defoliation) spruce-fir jack pine (SFJ) harvest for the northeast township for: i) budworm outbreak with no protection, salvage, or harvest re-planning, ii) outbreak with salvage and re-planning, and iii) outbreak with salvage, re-planning, and 20 % susceptible area protected. Each is shown for moderate and severe outbreak scenarios and for fir defoliation level applied to all species (a, c) and reduced defoliation on spruce species relative to fir (b, d).

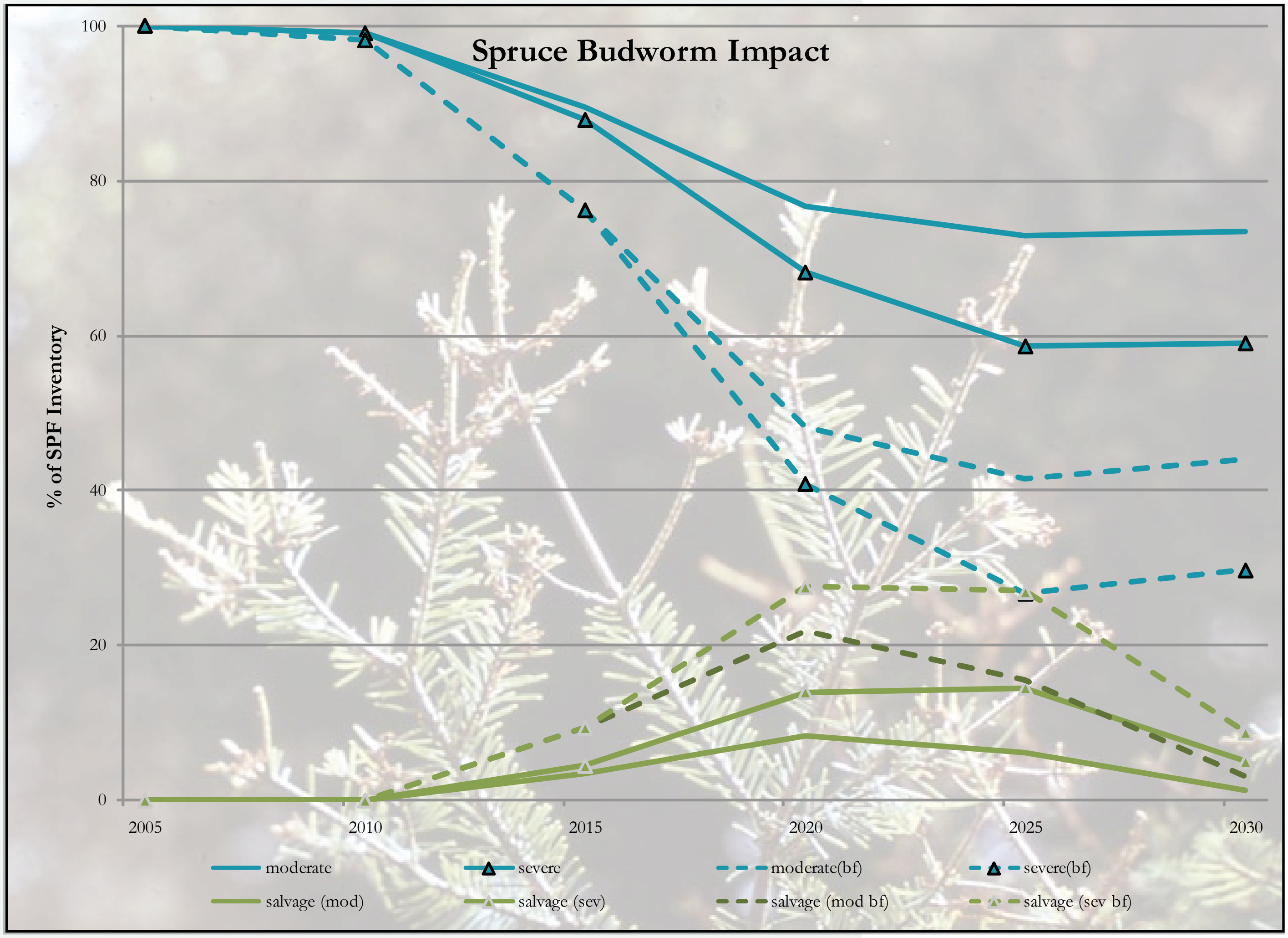


Figure 7. Percent of base (i.e., no spruce budworm defoliation) spruce-fir inventory projected with no harvest for moderate and severe outbreaks beginning in 2008 for all of Maine. A (bf) in the label means estimates do not reflect host susceptibility differences. Salvage estimates reflect volume of periodic mortality available for salvage harvesting.

this stratification are presented in Table 4. More than 10 million acres of forestland in Maine are projected to contain at least 10 % of their volume in spruce budworm host species in 2008. Projected stands were evaluated in the Microsoft Access version of the SBW DSS to estimate the impact of alternative outbreak scenarios on spruce-fir volumes in Maine beginning in 2008. Results from both a moderate and severe outbreak with no protection are shown in Figure 7. Maine has a large acreage of susceptible stands (Table 4) and even under a moderate scenario using host specific impacts a greater than 20 % reduction in spruce-fir inventory volume can be expected 10-15 years into an outbreak. This represents a spruce-fir inventory reduction of almost 1.5 billion ft^3.

Modified versions of the Canadian SBW DSS have been developed and successfully applied to a variety of forest information sets in Maine.

SBW Impact Type	Area (ac)	SF Volume (ft^3)
FW-I	329,088	87,965,213
FW-M	112,908	105,698,296
FWMX-I	207,015	74,069,433
FWMX-M	268,446	211,149,836
FWRB-I	137,260	63,553,899
FWRB-M	89,508	110,364,420
RBFW-I	263,108	68,122,734
RBFW-M	776,555	976,314,476
RBMX-I	1,648,945	328,305,718
RBMX-M	6,423,593	3,459,155,502
Total	10,256,426	5,484,699,526

Table 4. 2008 acreage and spruce-fir volume in Maine for each SBW stand impact type (Table 3). Estimates based on Forest Inventory and Analysis (FIA 2002-2006) plots in Maine and Forest Vegetation Simulator Northeast Variant (FVS NE) projections.

These tools can be used to evaluate volume impacts associated with alternative spruce budworm outbreak, harvest, and protection scenarios. The SBW DSS facilitates our understanding of potential spruce budworm vulnerability and makes it possible to adapt forest management plans and prioritize protection activities to proactively reduce impacts from an outbreak.

Spruce budworm outbreaks have been documented in Maine as far back as the early 1800s. Budworm persists on the landscape and shows itself during periodic outbreaks, like that of the late 1970s and early 1980s, which has stongly influenced today's forest conditions.

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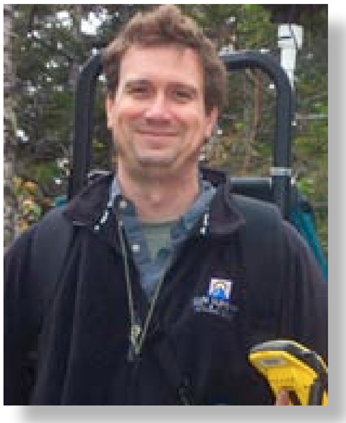

For more information about this project, please contact Jeremy Wilson.

Commercial Thinning Research Network

Authors

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Robert S. Seymour
Matthew Russell

INTRODUCTION

The CFRU Commercial Thinning Research Network (CTRN) completed its 8th 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 (i.e., 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 (i.e., 33 % and 50 % relative density reduction). See previous Annual Reports for more thorough description of the experimental design and implementation.

During this year, the CFRU Advisory approved ongoing funding for the CTRN study through the 2012 fiscal year. The first two entries on the PCT experiment are behind us and we continue annual measurements on our way to the third and final planned commercial entry in the PCT stands during the 2012 winter. This continued funding includes approval to expand the CTRN study to add three new sites to investigate the same PCT treatments we are already testing but on intermediate sites, as opposed to the existing high-quality sites. The CTRN data thus far suggest our study did not adequately capture the range in variability by leaving out medium quality PCT stands. The three new stands will gather information necessary to apply PCT responses information appropriately in growth and yield efforts.

FIELD SEASON

This long-term study relies on many years of tree growth data to feed into CFRUs ongoing growth and yield efforts. With last years winter harvests complete on the PCT sites (see 2007 Annual Report) this summer focused on annual remeasurements. This year the summer field crew was led by CFRU Data Manager, Matthew Russell and included UMaine School of Forest Resources undergraduate students Kyle Gay,

"Of the original 12,373 tagged trees in this study, 1,013 have been harvested through treatments, 2,414 have died due to various forms of mortality (e.g., windthrow) and 8,946 remain alive and well."

Erica Kaufmann, and Alexandria Small. The crew bounced around the state visiting all 12 research sites from Danforth to Rangeley to T7 R19.

At the end of the summer, some time was spent investigating options for the three new medium-quality PCT sites mentioned above. Initially, finding stands that met the criteria but had uniform enough stocking to which we could apply the experimental design proved difficult. Several stands were surveyed but no adequate candidates were found this summer. Plans for the 2009 field season include identifying and installing these three new sites.

Dedicated CFRU field crews have been remeasuring the tagged trees since 2001. These data get used by CFRU growth and yield modeling efforts.

Measurements, including tree diameter and condition (e.g., alive, windthrow, snag, split top, etc.) on all live trees (including ingrowth), total tree height and height to crown base on a subsample of trees, and the condition of dead and downed trees were recorded to get a more accurate picture of specific causes of mortality. This study is both one of growth and one of attrition - of the original 12,373 tagged trees in this study, 1,013 have been harvested through treatments, 2,414 have died due to various forms of mortality (e.g., windthrow) and 8,946 remain alive and well. The complete CTRN database now contains about 91,000 unique tree measurements. This long-term database is already being used by the School of Forest Resources new assistant professor, Dr. Aaron Weiskittel, in his efforts to refine the Forest Vegetation Simulator (FVS) and the data contributed substantially to the PCT modeling project completed this past year by Mike Saunders, Bob Wagner and Bob Seymour.

For more information about this project, please contact Spencer Meyer.

USFS PHYSIOLOGICAL STRESS COLLABORATION

CFRU continues to collaborate with researcher Dr. Rakesh Minocha of the US Forest Service, Northern Research Station, on her physiological stressors work. As they have done each of the past several summers, Dr. Minocha and her team visited two CTRN sites this year to collect foliage and wood samples, as well as typical tree and stand mensuration information.The CTRN summer crew met the team and took them to the Rump Road and Sarah's Road sites near Oquossoc. This was the first time the USFS team had visited these two particular sites and so they and the CTRN crew spent the better part of a week working together to collect the necessary information. Over 200 red spruce trees were sampled by the crews in the one-week period. Foliage and wood plug samples continue to give insight into the effects that commercial thinning treatments have on tree physiological stress. With several years of data from multiple CTRN sites (both PCT and no-PCT) Dr. Minocha expects to be able to compare stress responses in trees due to commercial thinning operations. We look forward to ongoing collaboration and some more insight about how our spruce-fir forests respond to thinning.

Patterns of Regeneration of Eastern White Pine as Influenced by Large, Isolated Crop Trees and Precommercial Thinning

Authors

Kate E. Zellers
Robert S. Seymour
William H. Livingston
Robert G. Wagner

INTRODUCTION

The spruce budworm (*Choristoneura fumiferan*) epidemic of the 1970s and early 1980s led substantial salvage harvesting of spruce-fir stands. During this time, landowners commonly left unaffected immature eastern white pines to harvest at a later date. These pines had the benefit of being released, as the spruce and fir were cut, and are now growing as large, isolated crop trees, above the regenerating stand. It is known that large dominant trees contribute a disproportionately large amount of seed to a stand. This stand condition offers a unique opportunity to study the effects of such large, isolated reserve trees on the composition of the regenerating stratum. It is ideal for determining these effects, and define the species composition that maximizes stand value.

Precommercial treatments are often employed in white pine stands in an effort to increase stand value. However, it is not known what precommercial schedules should be implemented in mixed-conifer stands. While many approaches have been tried, the optimum density and spacing of eastern white pine saplings within these mixed-conifer stands is still unknown. Guidelines must be developed to maximize the financial returns from potential pine crop trees, as well as the regenerating stratum, while minimizing damage from the white pine weevil (*Pissodes strobi* [Peck]), in an effort to benefit both landowners and processors.

OBJECTIVES

The overall goal of this research is to assess the potential for management of future pine crop trees in developing sapling stands, including those stands with large pine reserve trees. The specific objectives are to:

1) Determine the composition and structure of the young stands in response to leaving pine reserve trees,
2) Determine the quality of the young pines relative to white pine weevil attack, blister rust infection, and natural branch shedding,
3) Determine any effect the presence of large pine reserve trees may have on the developing regeneration stratum of all species, and
4) Determine if any precommercial treatments can optimize the value of the entire stand (pine plus other conifers) and facilitate the development of high-quality pine crop trees

METHODS

Thirteen study sites were chosen throughout the spruce-fir region of Maine, each with a component of eastern white pine. Nine of these sites have large pine reserve trees growing above a developing mixed-

"Guidelines must be developed to maximize the financial returns from potential pine crop trees..."

species matrix. Harvesting of these sites took place between the years of 1884 and 1994. The remaining four study sites are mixed species sites that have were precommercially thinned between the years of 1981 and 2000.

Growing white pine among other species in a relatively dense understory helps promote good stem form which will lead to valuable crop trees.

Reserve Pine Sites

Plot centers were established on a 40 m x 40 m grid at each of nine study sites. A fixed radius plot of 0.1 ha was established at each plot center, and all reserve trees were measured for species and DBH, as well as distance and direction to plot center. A nested 0.001-ha plot was also established at each plot center, and all trees < 30 cm DBH were tallied by 2-cm diameter class, by species. Up to three pine in each diameter class were measured for total height, base of live crown, branch diameters at highest whorl < 2 m, and aged with an internode count. Incidence of weevil injury was recorded by height of attack, and stem offset was measured from pith to pith. Evidence of blister rust infection was also recorded. If pine was not present in 0.001-ha plot, a 0.02-ha plot was established to determine if the area was stocked with pine.

PCT Sites

Plot centers were established on a 40 m x 40 m grid at each of four study sites. If reserve trees were present, protocol for 0.1-ha plots was employed, as outlined above. A fixed radius plot of 0.02-ha was established at each plot center, and all trees were tallied by 2-cm diameter class, by species. Assessment and measurement of all pine was carried out as outlined above in the 0.001-ha plot protocol.

FUTURE WORK

Field data collection was completed throughout the summer and fall of 2008. Our data analysis will seek to determine the effects of reserve pines on species composition, stand densities, and relative density of pine within the developing stand. Relationships between these stand characteristics and pine sapling quality in regards to white pine weevil attack, blister rust infection, and natural branch shedding will be examined. The effects of precommercial thinning at varying relative densities of pine will be examined with respect to stem quality of the developing pine, to determine optimum species composition and density.

For more information about this project, please contact Robert Seymour.

ACKNOWLEDGEMENTS

Funding for this project is being provided by the Cooperative Forestry Research Unit and the Northeastern States Research Cooperative. Study sites were provided courtesy of the Maine Bureau of Parks and Lands, the USDA Forest Service, Baskahegan Company, Plum Creek Timber Company, Prentiss and Carlisle, Katahdin Forest Management, and American Forest Management. The field crew included Nicole Mercier, Michael Puleo, and Christopher Zellers, all of the University of Maine School of Forest Resources.

The Growth, Yield and Financial Performance of Isolated Archetypal Eastern White Pine Trees

Authors

Christopher Zellers
Robert S. Seymour
Aaron Weiskittel
Jeffrey Benjamin

INTRODUCTION

Traditional silvicultural systems that result in large diameter trees that yield knot-free lumber can maximize financial returns, yet often involve significant investments in precommercial thinning and pruning operations, especially when grown in pure, even-aged stands. Recent research has shown that white pine can display high-quality stem form when grown in stratified mixed stands with shade tolerant conifers such as spruce, fir and hemlock. Eastern white pine's ability to continue high growth rates and remain windfirm longer than other species allows for the retention of isolated pines through a second rotation of the associated species. The high stand density found in such mixed-conifer stands also promotes natural branch shedding, which may reduce the need for pruning operations.

The spruce budworm (*Choristoneura fumiferan*) salvage cuts of the late 1980s and early 1990s resulted in stands of isolated white pines with a mixed-conifer regeneration stratum, as outlined in the above silvicultural system. Ten such sites were located throughout the state of Maine. At each site, ten trees were selected representing the range of diameters of the supercanopy white pines. Each of these trees were measured for growth rates, stem class form, leaf area, sapwood area, as well as conventional measurements.

OBJECTIVES

The objectives of this study are to:

1) Model the growth response and efficiency of heavily released white pine trees growing in isolation,

2) Examine the external log characteristics with respect to product recovery, and

3) Create a financial maturity guideline at the tree and stand levels for several future market scenarios, using a range of guiding rates of return.

"Recent research has shown that white pine can display high quality stem form when grown in stratified mixed stands with shade tolerant conifers such as spruce, fir and hemlock."

METHODS

Eight forest stands throughout the spruce-fir region of Maine that were regenerated more than fifteen years ago and have a significant component of heavily released white pine reserve trees were selected. Fixed radius plots (0.1-ha) were established to survey the reserve overstory. Each reserve tree was measured for DBH (1.37 m) and crop tree

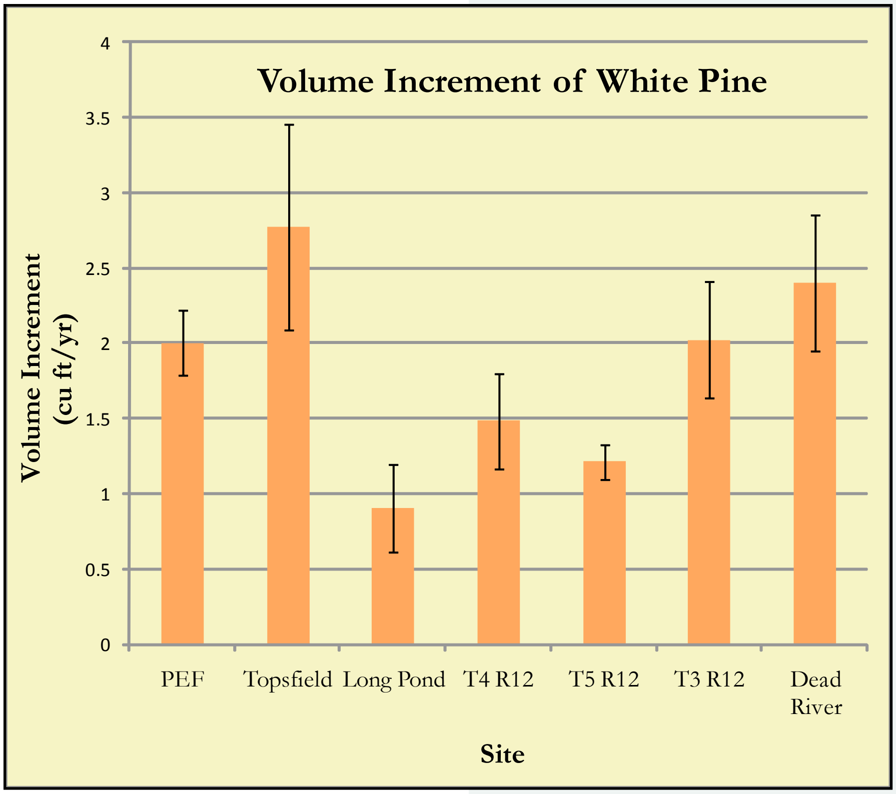

Figure 8. Annual volume increment of mature eastern white pine trees growing in isolation.

suitability. Suitable trees were stratified into 10-cm diameter classes, and a proportional subset (n=99) were selected at random. Each tree in the subset was measured for total height, base of live crown height, crown radii in six directions, diameter at 5.18 m, and bark thickness in two locations at both 1.37 m and 5.18 m. Two increment cores were extracted at 1.37 m, and one at 5.18 m. Competitive environment was assessed with a variable radius plot with a basal area factor (BAF) prism of 2.5 (metric), using the subject tree as the plot center.

Two subject trees per site (n=16) were measured for basal diameter and height of each live branch. Three branches from three relative positions in the crown were destructively sampled to obtain specific leaf area. Whole tree projected leaf area will then be calculated using the branch summation method (Gilmore and Seymour 1997, Marshall and Monserud 1999).

Increment cores were analyzed for basal area increment at 1.37 m and 5.18 m. Basal area increment were compared to determine shifts in resource allocation at the two heights following release. Linear, mixed-effect models were used to model growth of the financially valuable butt log.

A sawmill simulator, developed by Dr. Jeffrey Benjamin, was employed to merchandize butt logs at a range of small-end diameters and knotty-core diameters. Long-term wholesale price trends, provided by Random Lengths Publications, Inc., for white pine were then used to create a financial maturity guideline for varying guiding rates of return.

PRELIMINARY FINDINGS

The increment cores revealed little to no release effect, as these trees were likely dominants and codominants prior to the harvest of the surrounding stand. The response to the harvest was more evident in resource allocation, with greater accumulation of basal area at breast height than at the top of the first log. This increase in stem taper is likely a response to increased wind stress.

Site indices were calculated for each tree, which were used to "back-grow" the trees to the time of the harvest. Previous diameters were then estimated from the increment cores, and a white pine volume equation (Leak et al, 1970) was employed to determine the change in volume following release. Annual volume accretion (Figure 8) ranged from 0.9 (± 0.2) to 2.8 (± 0.6) ft^3/yr.

White pine grown in their own stratum can continue to exhibit high growth rates long after other species in the stand are ready for harvest.

Branch and leaf samples are currently being processed for leaf area calculations. This will allow a comparison of the growth efficiency of these large, isolated trees to those of smaller pines grown in a low density monoculture.

ACKNOWLEDGEMENTS

This project is being funded by the Northeastern States Research Cooperative and the Cooperative Forestry Research Unit. Study sites were provided courtesy of the Maine Bureau of Parks and Lands, the USDA Forest Service, Baskahegan Company, Plum Creek Timber Company, Prentiss and Carlisle, Katahdin Paper Company, and American Forest Management. Kate Zellers, Nalbert Tero, Mike Puleo, and Nicole Mercier, all From The University of Maine, assisted in data collection.

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For more information about this project, please contact Bob Seymour.

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

Authors

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"Though there were no statistically significant differences in mean productivity, the blocks harvested with the wider trail spacing had 10-60 % greater productivity than those with narrower spacing."

INTRODUCTION

This project was initiated in 2007 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) at the Uniersity of Maine and the CFRU. This work will 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 study continued in 2008 with an analysis of the time and motion data and an assessment of residual stand damage.

This report presents results from the biomass harvesting phase of rehabilitating young beech-dominated hardwood stands in Maine. The objective was to investigate the influence of two trail spacings on a whole-tree biomass harvest operation. The first spacing of 18.3 m was selected based on its dominant use in whole-tree operations in Maine. A narrower spacing of 12.2 m was selected to determine if feller-buncher productivity could be improved by limiting its movement to the harvest corridor, relying mainly on the boom reach to harvest treatment zones. An assessment of residual stand damage was used to determine the relative impact of the two harvest layouts.

METHODS

Three study blocks, each 1.2 ha (73.2 m x 165.0 m) in size, were established in natural hardwood stands dominated by small diameter, diseased beech trees in Township 32, Hancock County, Maine. Blocks were located within 1,500 m of one another. Each of the three study blocks were divided in half (0.6 ha – 36.6 m x 165.0 m) and assigned one of two treatments; 1) mechanized whole-tree harvest using a trail spacing of 18.3 m (measured from trail centerlines) and 2) mechanized whole-tree harvest using a trail spacing of 18.3 m. Trail spacings were established by using one trail in the center of harvest blocks assigned a spacing of 18.3 m, and three trails in harvest blocks assigned a spacing of 12.2 m. The harvest prescription for each block was to remove the existing beech-striped maple understory, including all stems > 2.54 cm DBH, while leaving overstory sugar maple and yellow birch unless they were standing in the trail.

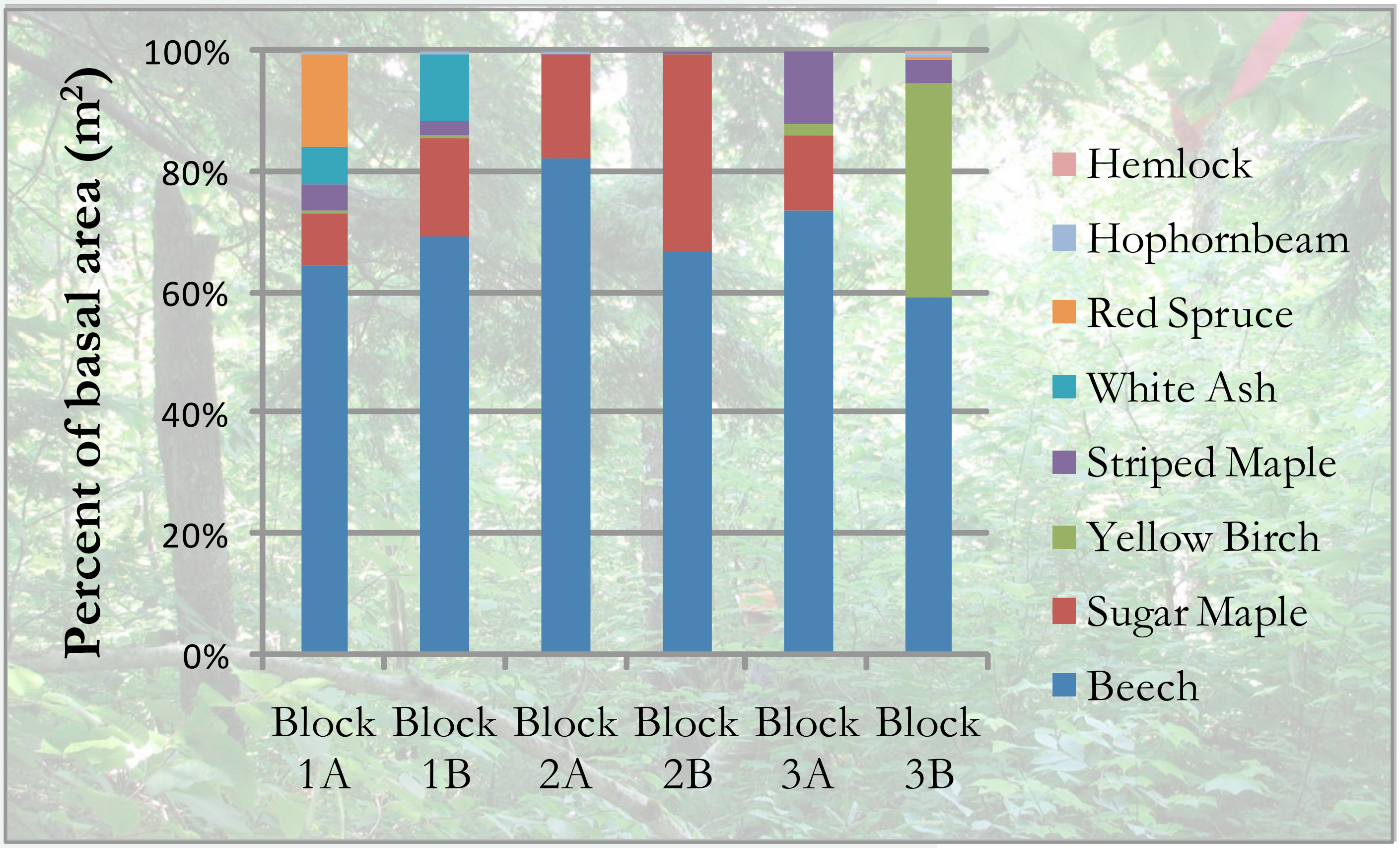


Figure 9. Pre-harvest species composition by harvest block.

A pre-harvest cruise was used to assess stand composition (Figure 9), stand structure (Figure 10) and biomass quantity. Twenty four, 0.002-ha fixed radius sample plot centers were established in each harvest block. All stems, including both live and standing dead, > 2.54 cm at DBH within the plot were sampled. Species and DBH were recorded for each sampled tree. Total green tree weight estimates were calculated using species specific DBH-weight relationship equations developed by Young *et al*. (1980).

Harvest operations were conducted by a contractor hired by Huber Resources Corporation using a John Deere 853G tracked feller-buncher with an FS22 continuous type disk saw felling head. 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. A post-harvest time study was conducted on each harvest block using the harvest videos and UMTPlus® time and motion study software (Laubrass Inc. 2006). The harvesting work cycle was divided into the following elements:

Productive movement - Begins when the feller-buncher starts to move (i.e., track movement), and ends when the harvester stops moving.

Selecting tree - Begins when the feller-buncher begins swinging and/or moving the boom towards the tree and ends just before the tree is cut.

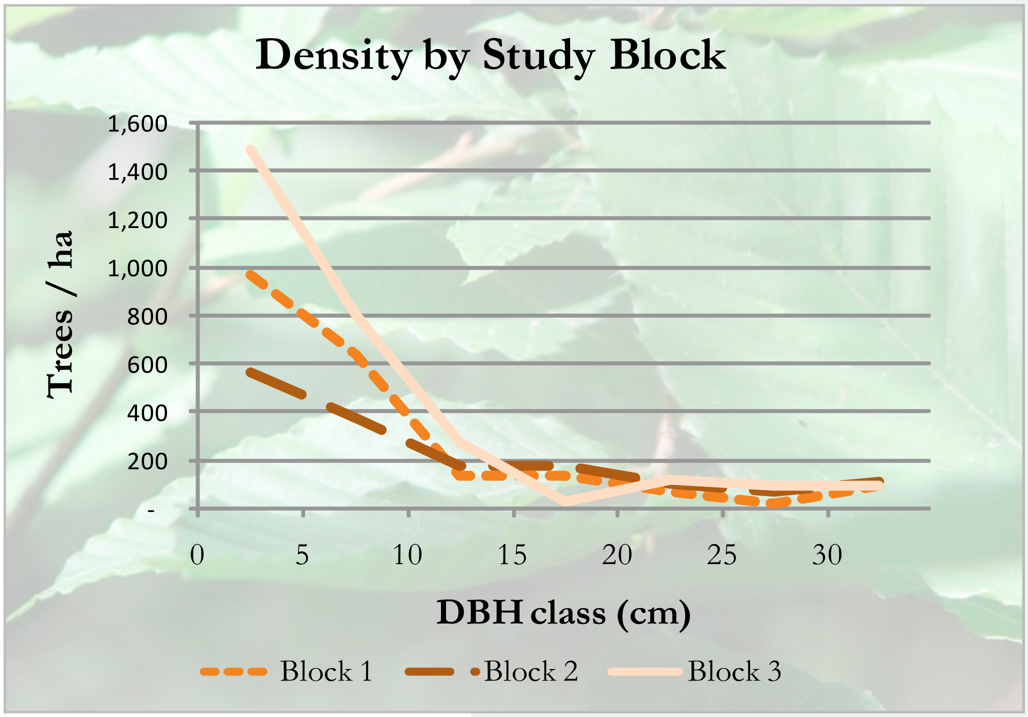


Figure 10. Pre-harvest stand density by study block.

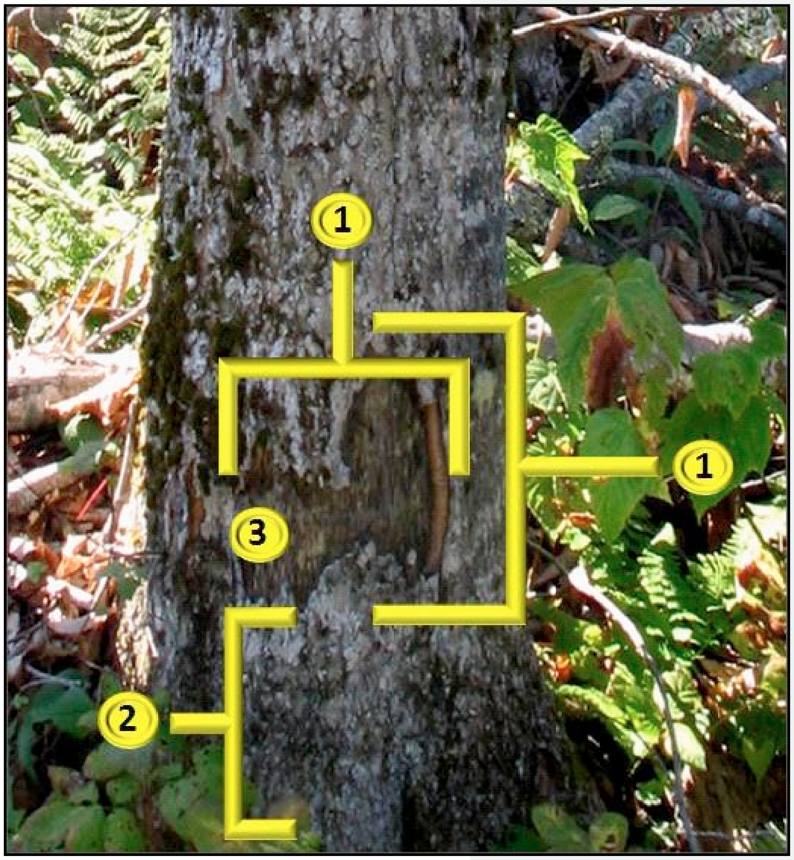
Felling - Begins when the head begins cutting through the tree and ends when the stem has been accumulated (i.e., the accumulator grab arms on the head have secured the tree).

Bunching - Begins after the feller-buncher has cut the last tree and starts moving towards the twitch location and ends when the bunch is dropped from the felling head.

Time-study analysis began when the feller-buncher started cutting within the harvest block and ended when it exited the harvest block. The same researcher conducted the time studies for all blocks. All analysis is based on productive machine hours.

Biomass was the primary product from this harvest; however, the contractor also sorted out pulp-quality logs. Each truckload of pulp was weighed at the mill to determine the total tonnage removed from each block. Biomass produced on each block was estimated by subtracting pulpwood weights and estimates of residual biomass based on post-harvest cruise data from pre-harvest biomass estimates.

Figure 11. Wound severity characteristics identified for each bole wound.



All stems > 2.54 cm DBH were evaluated for damage in each block immediately following harvesting and skidding operations using the following methodology adapted from Ostrofskey *et al.* (1986). All stems recorded by species and DBH and identified as "injured" or "uninjured." For each bole wound encountered the following measurements were taken (Figure 11): 1) length (parallel to stem) and width (perpendicular to stem) at wound extremes – used to calculate an area for each wound (A = L x W), 2) distance from the lowest point of the wound to the ground, and 3) wound severity class (Figure 12). A damage rating was assigned to each wound using measures 1 and 3 (Table 5). One way ANOVA was used to identify significant differences between trail spacings (α=0.05).

Analysis of variance was used to determine whether the harvesting treatments were statistically different. All statistical analyses were performed using a significance level of $\alpha = 0.05$. The Shapiro-Wilk's W-statistic was used to test the null hypothesis that samples came from normally distributed populations. A Brown-Forsythe test was used to verify the assumption of equal variance of the two samples.

Figure 12. Examples of wound severity classes (*left*) Scuff, bark contacted but not broken; (*middle*) Cambial, bark removed to cambium; and (*right*) Wood damage, bark removed and sapwood abraded and broken.

RESULTS

Production studies

Overall, total harvesting times varied from 1.9 hours (blocks 2a and 2b) to 2.6 hours (block 3a), but there were no significant ($F = 0.80$, $p = 0.4204$) differences in total harvesting time between treatments. On average, blocks harvested using the wider trail spacing harvested 16.8 more tonnes of total biomass (pulpwood and biomass) per productive hour than blocks harvested using the narrower trail spacing; however, the difference was not significant ($F = 0.53$, $p = 0.5059$). The highest feller-buncher productivity (106.9 tonnes/productive hr) was achieved on block 2a using the wider trail spacing, and the lowest productivity (52.3 tonnes/productive hr) occurred on block 1b using the narrower trail spacing. The number of trees felled per productive hour varied by harvest block from 292 – 381, but also was not significantly different between treatments ($F = 0.59$, $p = 0.4862$).

Similar proportions of time were allocated to each of the four work tasks tracked in the time study (Figure 13). There were no significant differences in total bunching times ($F = 0.94$, $p = 0.3876$), moving times ($F = 0.28$, $p = 0.4082$), or selecting times ($F = 0.54$, $p = 0.5042$) between treatments. Total felling time composed an insignificant proportion (less than 2 %) of the total harvest times and was not analyzed.

Table 5. Determination of Damage Classes.

Wound Severity Classes		
Class No.	Description	
1	Scuff (bark contacted but not broken)	
2	Cambial (bark removed to cambium)	
3	Wood damage (sapwood abraded and broken)	
Wound Damage Ratings		
Wound Size	Severity Class	Damage Rating
< 65 cm^2	1,2	A
> 65 to < 323 cm^2	1,2	B
> 323 cm^2	1,2	C
< 65 cm^2	3	D
> 65 to < 323 cm^2	3	E
> 323 cm^2	3	F
Wound Damage Classes		
None	---	
Minor	A, B	
Moderate	C, D	
Severe	E, F	

Stand damage studies

At least 30 % of the trees in each block were damaged to some degree. Out of a total of 663 residual trees assessed for damage across the three harvest blocks treated using the 18.3-m trail spacing, 211 (32 %) were found to be injured. Mean diameter of trees wounded was 4.1 cm (± 0.25 cm). The blocks treated with the 12.2-m trail spacing had a higher proportion of residual trees injured (85 out of 407, 45 %); however, the difference was not significant ($F = 6.394$, $p = 0.06475$). Half of the residual stems on blocks 2b and 3a were injured. Mean diameter of trees wounded at this spacing was 6.4 cm (± 0.25 cm). 37 % and 35 % of all injured trees had observed root and/or crown damage for the wider and narrower trail spacing, respectively.

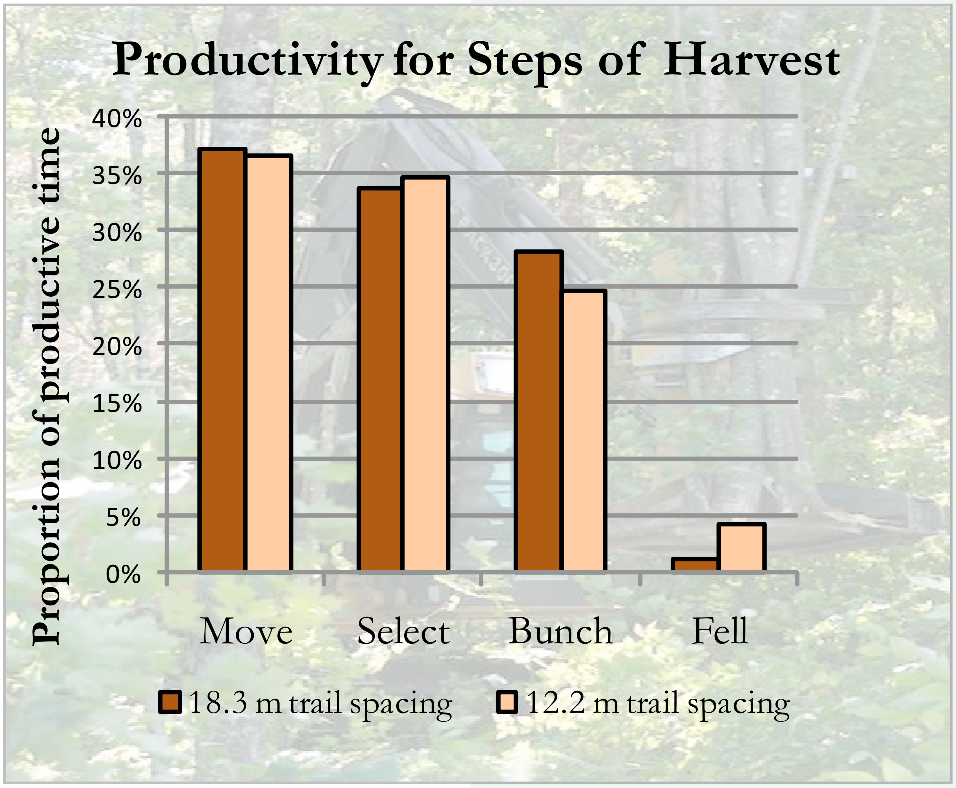


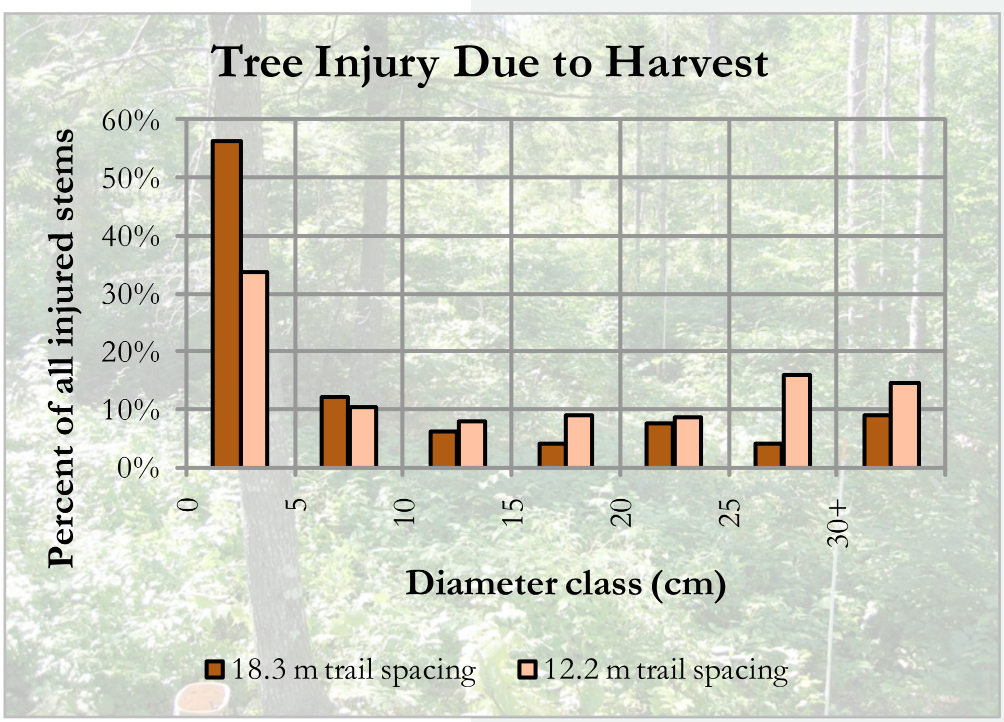
Figure 13. Allocation of time to each work element by harvest treatment.

Only a small proportion of the stems wounded in either treatment received multiple wounds and the average number of injuries found on trees wounded multiple times was relatively low. At the wider trail spacing the mean number of wounds per injured tree was 1.2 with 83 % of injured trees receiving only one wound. On blocks treated with the narrower trail spacing, the mean number of wounds per injured tree was 1.3, with 74 % of injured trees receiving only one wound. Less than 6 % of wounded trees on any of the six harvest block received three or more wounds. Forty percent of wounds occurring in the 18.3-m spacing and 30 % at the 12.2-m spacing suffered "moderate" to "severe" damage. These wounds are likely to lead to value and/or volume loss. Differences in the proportion of trees injured in each diameter class (Figure 14), and the number of wounds found in each height class (Figure 15) were not significant ($p > 0.05$).

DISCUSSION AND CONCLUSION

Reducing skid trail spacing to a 12.2-m interval limited feller-buncher activity to the trail corridor while the 18.3-m spacing required the feller-buncher to track short distances off of the trail in order to harvest the block. Prior to conducting the experiment, expectations were that limiting feller-buncher activity to the harvest trail would result in substantial decreases in the amount of time required to move trees from the stump to the bunch site, thus increasing productivity. Theoretically, the narrower spacing should have allowed trees to be harvested from the residual strips between trails much faster, but required that the operator spend more time harvesting corridors to the back of the block. Twice as much time should have been dedicated to harvesting trail corridors at the narrower trail spacing in this study. On the other hand, while the wider trail spacing theoretically

Figure 14. Proportion of trees injured by diameter class and harvest treatment.



should have reduced the amount of time dedicated to harvesting trail corridors, more time should have been required to move from bunching sites on the trail out to the block boundaries and back.

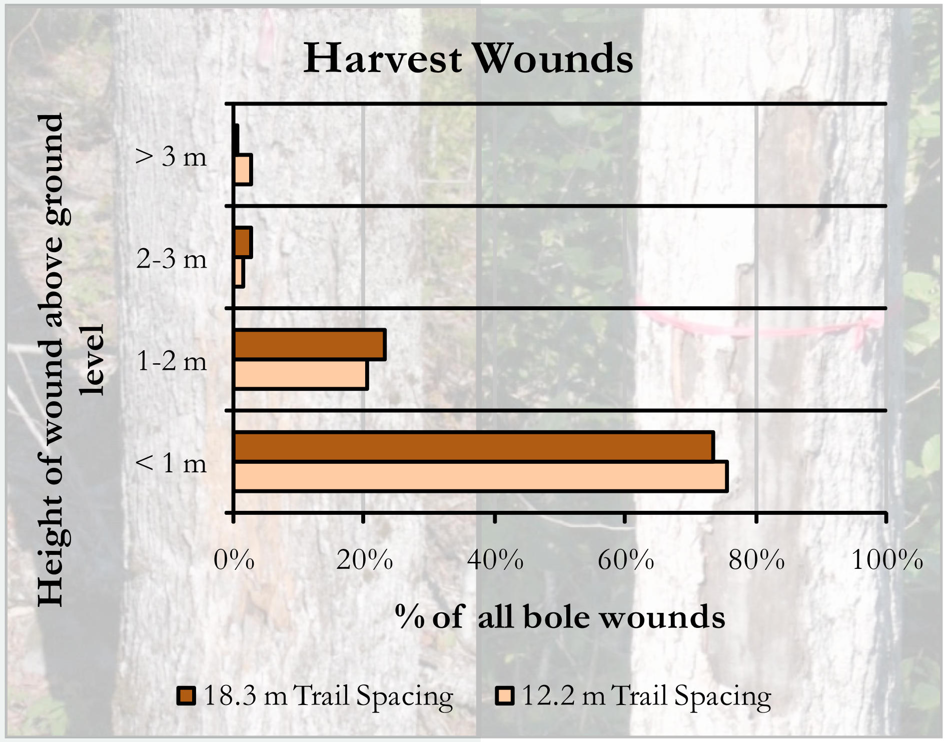
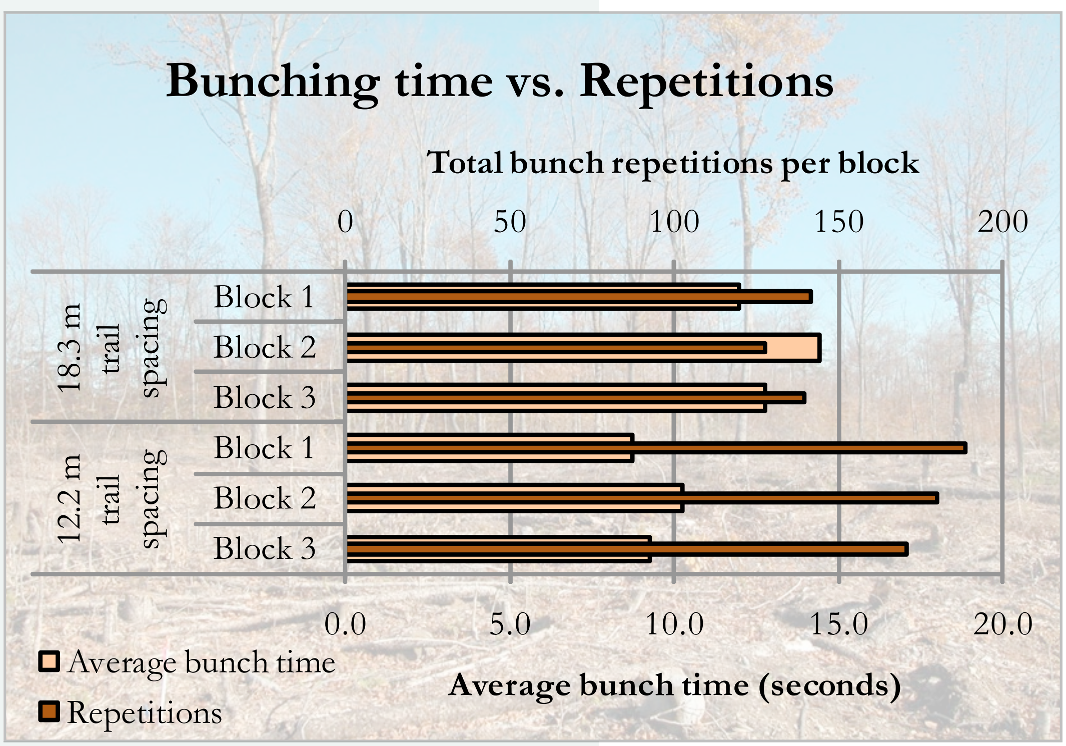


Figure 15. Proportion of all recorded bole wounds by height class and harvest treatment

Based on these assumptions bunching time was expected to be impacted the greatest using the narrower trail spacing; however, total bunching time at this spacing was only 5 % less than the wider trail spacing. The insignificant difference between total harvest times can be explained by comparing the average bunching event times with the number of repetitions. The average bunching time per harvest cycle was 13 seconds for the 18.3-m trail spacing but only 9.0 seconds for the 12.3 m trail spacing. However, the feller-buncher made more bunches (on average 43 more per block) at the narrower trail spacing than the wider trail spacing (Figure 16). Because of these results the trade-offs proved to be relatively equal, resulting in insignificant productivity differences between the two treatments.

Although no significant differences were found between mean productivity using the 18.3-m and 12.2-m trail spacings, it is important to note that productivity was considerably greater in the blocks harvested at the wider trail spacing than the narrower trail spacing. In each of the three harvest block pairs (A and B) the block harvested using the wider trail spacings had productivity levels 10-60 % greater in all cases than the block treated with the narrower trail spacing. The ANOVA test may not have been sensitive enough to conclude that the difference in productivity was statistically significant due to small sample size and the amount of variation in productivity levels between harvest blocks in each treatment.

Figure 16. Comparison of average bunch time (dark bars) with the number of bunch repetitions (light bars) by harvest treatment and block.



Proportions of residual stand damage were comparable with those reported in other mechanized whole-tree partial harvests in northern hardwood stands (Kelley 1983, Nichols *et al.* 1993). Although not significantly different by treatment, the highest overall proportion of injured trees occurred in block 2b treated with the narrower trail spacing, while the lowest overall proportion occurred in block 2a treated with the wider trail spacing.

While Ostrofsky *et al.* (1986) found that residual stand damage levels were significantly different between trail spacings of 20 m and 40 m, it may be that the substantially narrower trail spacings used in this study were too similar to result in different damage proportions. It is also possible that at these narrow trail spacings the relationship between distance from trail and probability of being wounded becomes less distinct. Similarities in proportions and character (i.e., height above ground, area, severity) of residual damage among treatments in this study should be somewhat expected since blocks were harvested and yarded using the same machines, operators, and harvesting method. Based on the results of this study we cannot conclude that there are any advantages to selecting one of the two trail spacings over the other.

Hypo-hatchets were used to inject herbicide into the diseased beech before the harvest.

FUTURE PLANS

The results of a 1-year post-harvest regeneration inventory conducted in early July indicated that herbicide treatment should be postponed until 2009.

ACKNOWLEDGEMENTS

This project is supported by the National Science Foundation under Grant No. EPS-0554545 and by the Cooperative Forestry Research Unit, College of Forest Resources, University of Maine, Orono, ME. Appreciation is extended to Huber Resources Corporation for use of their land, and for their cooperation and support during the execution of this study. We also thank Wayne Peters Logging for their cooperation in carrying out the harvest operations of this study.

For more information about this project, please contact Jeff Benjamin.

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Hardwood Regeneration Improvement and Spatial Ecology of Beech-Dominated Understories in Maine

INTRODUCTION

The third year of this project focused on two studies: 1) measurement and analysis of second-year responses from an experiment evaluating methods of understory beech control to improve the composition of hardwood regeneration in recently harvested hardwood stands, and 2) establishing a new study to better understand the spatial patterns of natural regeneration in the understory of beech-dominated stands.

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

Thousands of acres of mid-quality hardwood stands on CFRU member lands are plagued by an abundance of American beech that generally dominate and competitively exclude more desired hardwood species after stands are harvested using shelterwood and selection methods. Prior research using glyphosate to control undesirable regeneration in northeastern forests has shown that beech can be effectively reduced and maple species relatively preserved if applied late in the growing season (Ostrofsky and McCormack 1986, Pitt et al. 1993). We focused this study on developing a low-cost and effective method that maximizes control of undesirable hardwood species (e.g., beech and striped maple) while minimizing the damage to desirable tree species by using an optimal combination of Accord Concentrate® rate and EnTreé 5735®surfactant concentration.

In spring 2006, three study sites were selected on CFRU Cooperator 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 typically be applied. Pretreatment 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 on these species (see 2006 CFRU Annual Report). On each site, 16 treatment plots and 160 sample plots were installed to examine the effects of all combinations of three rates of glyphosate herbicide (Accord Concentrate®) and four concentrations of EnTreé 5735® tallow amine surfactant (Table 6).

Authors

Andrew Nelson
Robert G. Wagner

"The optimal treatment combination of 1 lb/ac glyphosate and 0.5 % surfactant appears to offer promise as a low-cost method for shifting hardwood species composition toward sugar maple and red maple in the understory"

EnTreé® 5735 surfactant (%)	Glyphosate (Accord Concentrate®) application rate (lb/A 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 6. Combinations of glyphosate and surfactant being compared in this study.

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

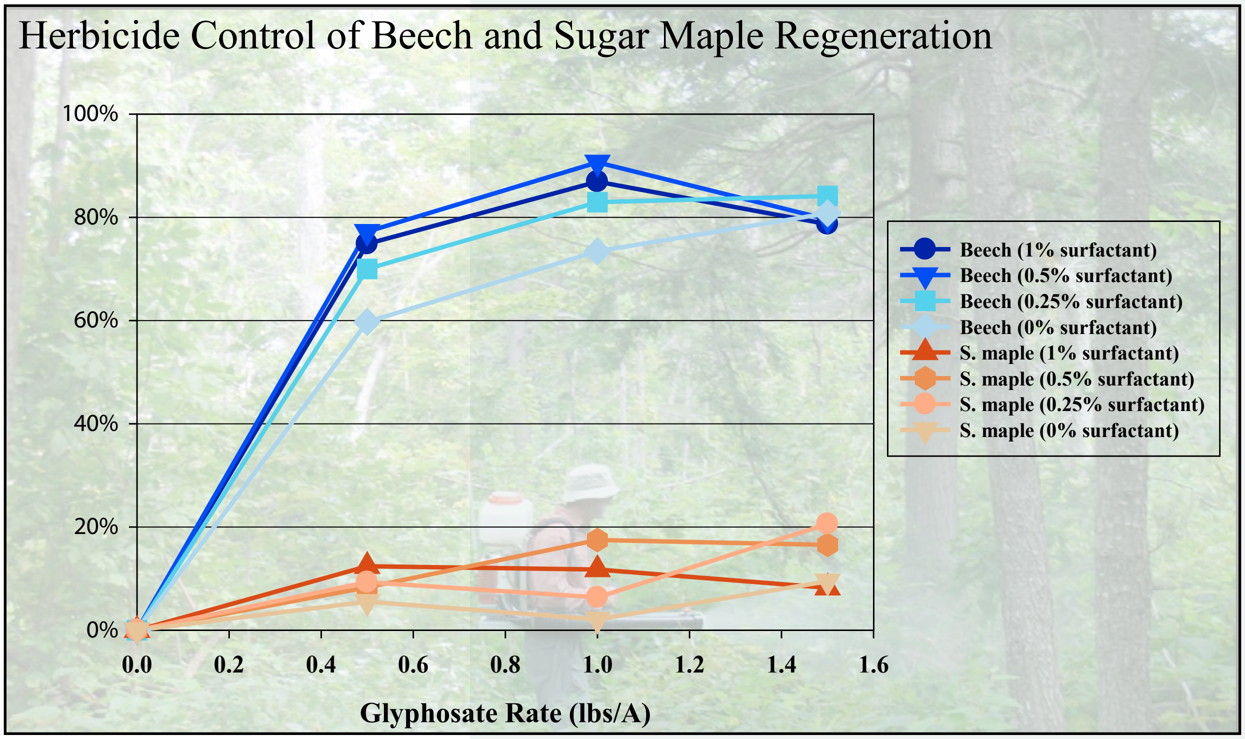
An additional set of plots was installed on each site to test the transferability of the hydraulic nozzle results to those obtained using a mistblower application. Using a backpack mistblower, we applied three glyphosate/surfactant combinations (0.5 lb/0.25 %, 1.0 lb/0.5 %, and 1.5 lb/1 %) representing the range of herbicide and surfactant concentrations tested with the hydraulic nozzle. Due to the nature of mistblower applications, these treatments actually delivered three-fold more spray volume than the parallel hydraulic nozzle applications. Thus, the 0.5 lb/ac mistblower rate was actually applied as 1.5 lb/ac, the 1.0 lb/ac as 3.0 lb/ac, and the 1.5 lb/ac as 4.5 lb/ac.

On each sample plot, the number of stems of each tree species was recorded and the percent cover of each tree species was visually estimated to the nearest 5 %. Pre-treatment measurements were made in July 2006 and the two post-treatment measurements made in July 2007 (results reported in 2007 CFRU Annual Report) and July 2008 (results reported here).

Second-Year Results

The second-year results were consistent with those reported for the first year indicating that the initial responses have held up for at least two growing seasons. Of particular interest was the substantial difference in susceptibility of beech and sugar maple to the treatments (Figure 17).

Figure 17. Second-year control of beech and sugar maple stem count following three rates of glyphosate herbicide and four concentrations of EnTreé 5735 surfactant (hydraulic nozzle data).



The optimal combination of glyphosate rate and surfactant concentration where beech control was maximized and sugar maple control minimized was with 1 lb/ac glyphosate rate and 0.5 % surfactant concentration. On average, this rate selectively controlled 85 % of the beech stems while reducing sugar maple density by only 10 %. Adding 0.25 % surfactant concentration to 1 lb/ac glyphosate increased beech control by 10 % while only marginally increasing sugar maple control by 4 %. Striped maple and yellow birch control were 53 % and 61 % at the 1 lb/ac-0.25 % rate, an increase of 7 % and 20 % compared to no surfactant, respectively.

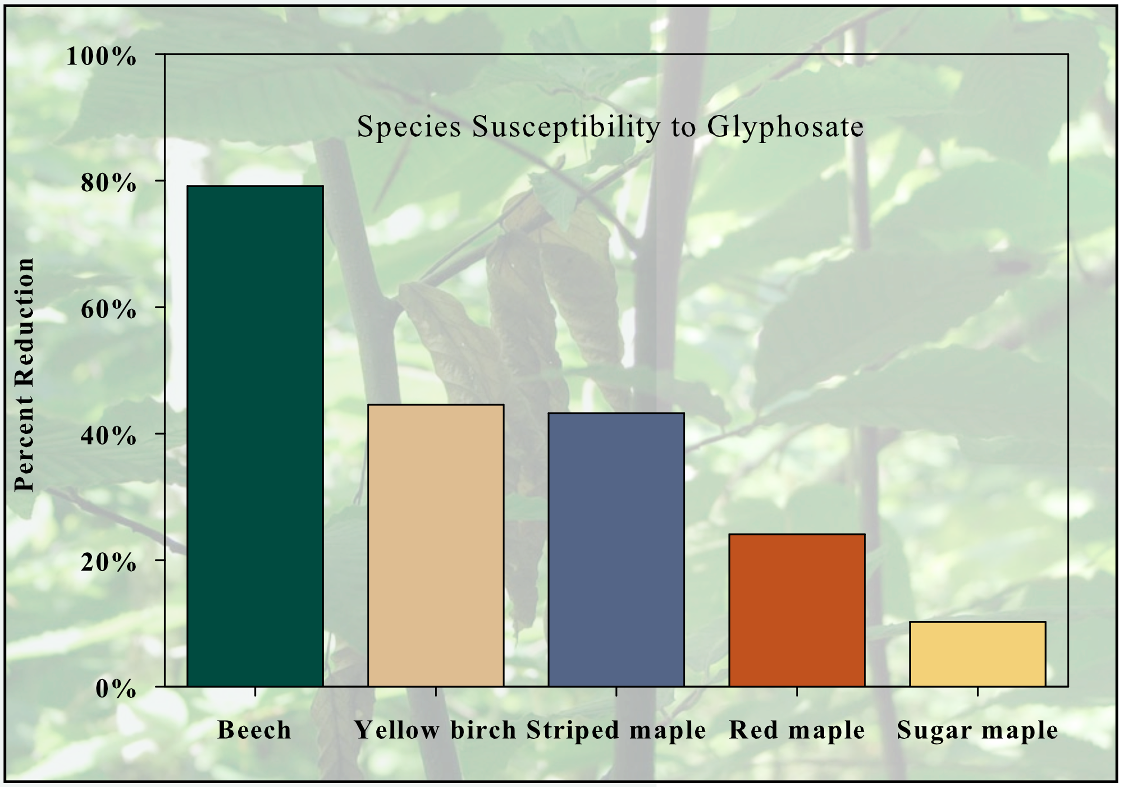


Figure 18. Difference in hardwood species susceptibility to all glyphosate treatments based on second-year changes in stem count for all three sites (hydraulic nozzle data). Species ranking was similar between treatments.

We also found that the hardwood species showed substantial differences in their susceptibility to the treatments, with the following order of susceptibility from highest to lowest: beech > yellow birch > striped maple > red maple > sugar maple (Figure 18). The order of susceptibility differed from the first-year results primarily due to difficulties in distinguishing between red maple and sugar maple severely damaged by the herbicide treatments during the first-year post-treatment measurements. Unfortunately, yellow birch remained 45 % controlled on average two years following treatment, indicating its relatively high susceptibility and the lack of new recruitment in this short time frame following treatment.

Although the mistblower applications applied three-fold higher rates of glyphosate and surfactant, preliminary analysis revealed that there was no substantial difference in control between the two methods of application for any of the tree species. Beech control was on average 4 % higher for the mistblower than the hydraulic applications, while sugar maple control was 8 % higher. The 3.0 lb/ac and 0.5 % surfactant mistblower rate showed 86 % control of beech but only 21 % sugar maple control (Figure 19). Yellow birch and striped maple control differed by 9 % and 4 % between methods, respectively. The similarity in percent control for each species between the hydraulic nozzle and mistblower application methods indicates that the results of this study are robust across a range of application methods.

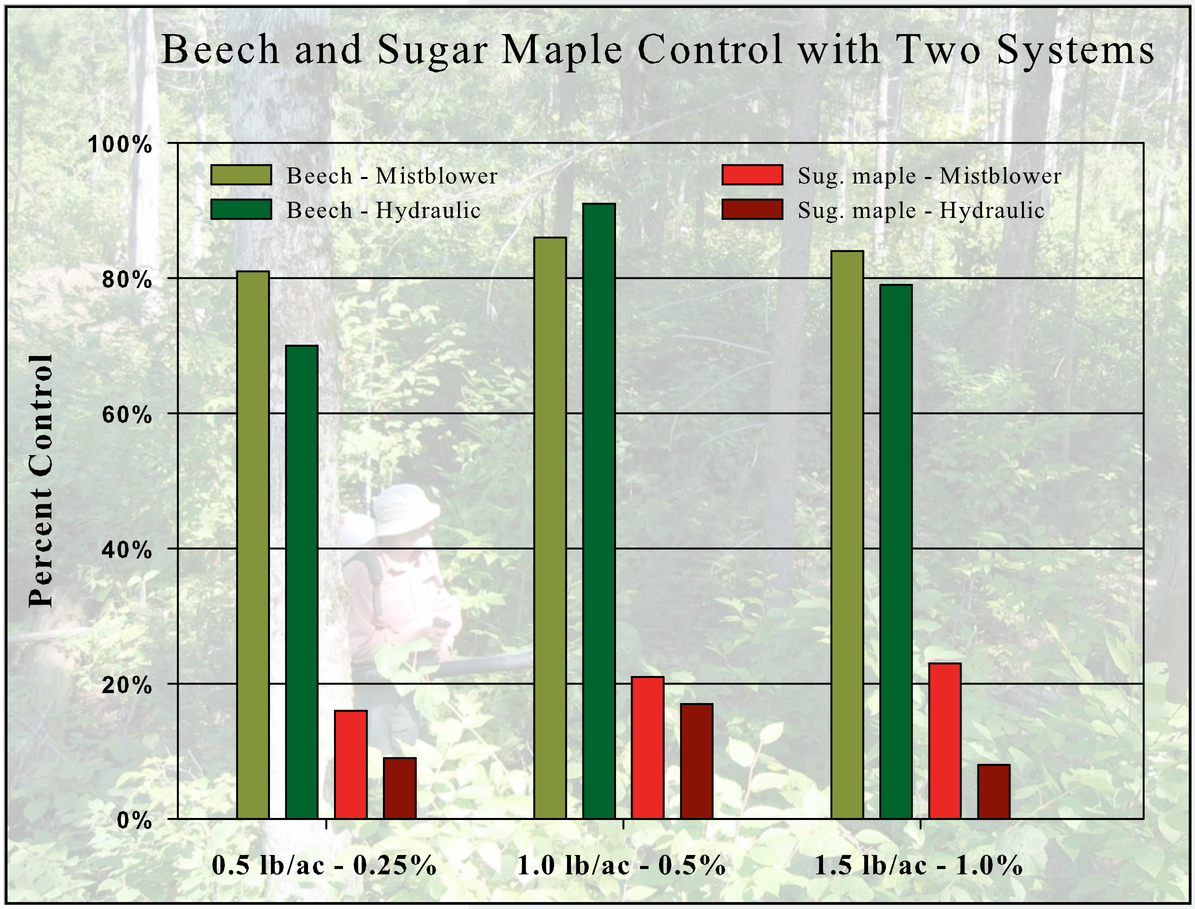


Figure 19. Difference in beech and sugar maple control for mistblower and hydraulic nozzle applications.

Conclusions

The optimal treatment combination (1 lb/ac glyphosate rate and 0.5 % surfactant concentration) appears to offer promise as a low-cost method for shifting hardwood species composition toward sugar maple and red maple in the understory of beech-prone stands when applied shortly after shelterwood harvest. Results from this study also indicate that the rate of glyphosate herbicide is somewhat more important than the surfactant concentration in producing desired results. The results indicate that the control seen initially following the treatments were sustained through the second year, and that substantial numbers of sugar and red maple regeneration remain relatively free of beech competition. Continued measurement of this study will determine whether these substantial differences alter longer-term stand dynamics and improve future hardwood stand composition.

Spatial Patterns of Hardwood Regeneration in Beech-Dominated Understories

Spatial ecology is a relatively new field that studies how organisms are arranged in space (e.g., clumped versus uniform distributions) in an effort to understand ecological processes. This field can be incorporated into silviculture by understanding how forest management influences the spatial patterns of natural regeneration and using this knowledge to inform future practices. For instance, heavy overstory retention in northern hardwood stands following harvest may favor the development of dense understory beech potentially inducing desirable regeneration to develop only in isolated clumps, thus reducing future stand

A backpack CO_2 sprayer was used to control the experimental application of glyhposate herbicide. A very reglar rate of application was achieved with this system, which simulates an understory treatment that might be conducted with a skidder-mounteed mistblower in an operational setting.

stocking. In contrast, reducing overstory retention may allow for desirable regeneration to occur more uniformly, potentially enhancing the future forest structure. Therefore, the goal of this new study is to describe the differential spatial patterns between hardwood species regeneration following first shelterwood entry harvests in beech-dominated stands in relation to overstory retention, regeneration age, and beech regeneration origin (i.e. seed versus root sucker).

In summer 2008, a 24 x 24 m sampling grid was installed at each of the three glyphosate trial sites (see description in previous section) that was representative of the regeneration composition and overstory retention. The grids were located in areas of contiguous hardwood regeneration cover with no bisecting skidder trails. The grids were specifically located away from the herbicide experiment to eliminate any interference between the studies. Each grid was divided into 1 x 1 m sample plots in which stem density and visual cover estimates of all regenerating species were counted by species and height class. All trees ≥ 4 cm DBH were recorded by species, diameter, and location to investigate how spatial patterns of the regeneration related to overstory retention. Other plot characteristics used to describe the understory structure include *Rubus*, shrub, herb, bare ground, and slash cover. A number of regenerating stems were also cut to determine age structure of the regeneration by species and site. Beech was also sampled to determine its origin (i.e. seed versus root sucker). We hypothesize that beech regeneration will be dense across each site and will occur primarily as taller regeneration. In contrast, we hypothesize that sugar maple will be clumped in areas around parent trees and will primarily be in the smaller height classes beneath the beech regeneration. Initial results from this spatial analysis will be reported in the 2009 CFRU Annual Report.

For more information about this project, please contact Robert Wagner.

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Capturing the Value of 30 Years of CFRU Research

Authors

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BACKGROUND

The CFRU has historically been the premier research institution guiding silviculture, biodiversity, and wildlife habitat research in the state of Maine. CFRU research has consisted of well over 100 individual research projects in its 34 years. Given the dynamic nature of scientific research on forests, many of these projects are long-term in scope while others last only a year or two. In terms of metadata, a certain level of uniformity exists among all projects. For example, study site description, experimental design employed, and principal investigators can all be associated with an individual project. The type of data collected varies from project to project, however, similarities exist between many CFRU studies. For example, tree growth data from precommercially thinned (PCT) plots at the Austin Pond research site can be related to similarly-treated plots from the Maine Commercial Thinning Research Network.

As projects are completed, research priorities fluctuate, and associated scientists come and go, data from these projects are frequently abandoned and poorly undocumented. For those that are well documented, media types may soon become outdated and impractical to use. Rarely are data from these projects updated to present-day software. Over the years, this has led to discontinuity in terms of data consistency across CFRU research. To date, the CFRU has not effectively documented and utilized data arising from its own research. Allocating necessary resources and personnel to data management can provide the framework for a successful long-term research program (Burton 2006). Furthermore, CFRU growth and yield efforts and other long-term research projects rely on using previously collected data and well-organized historical databases greatly facilite predictive models and forecasting.

"Furthermore, CFRU growth and yield efforts and other long-term research projects rely on using previously collected data and well-organized historical databases greatly facilite predictive models and forecasting."

OBJECTIVES

The *Capturing the Value of 30 Years of CFRU Research* project was initiated to:

1) Identify, compile, and archive relevant and important (past and present) CFRU datasets for future use, and

2) Develop protocols to archive future CFRU datasets. Ultimately, this project will merge past, present, and future CFRU research.

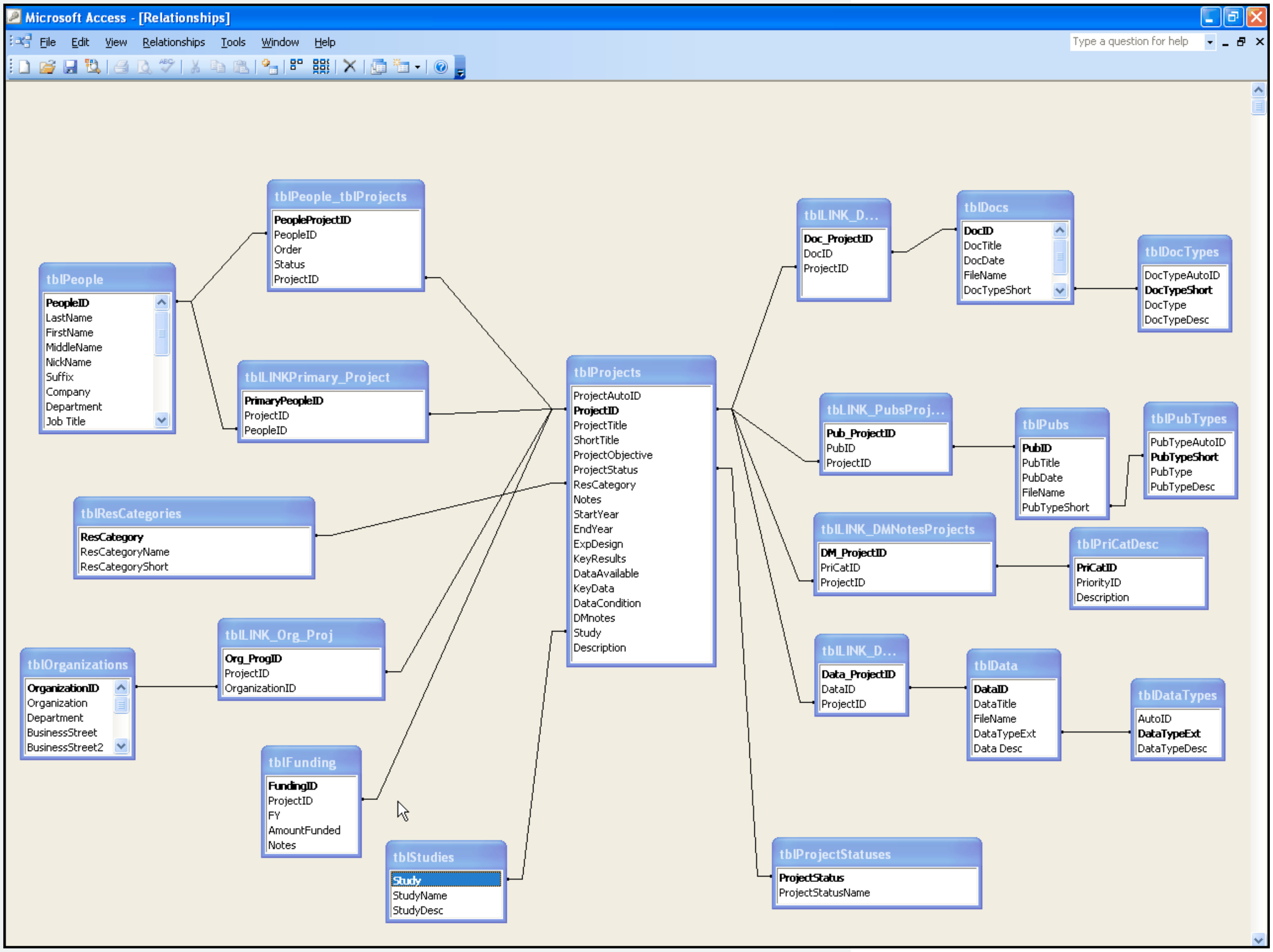

Figure 20. A relational database managemetn system was used for the CFRU database because of the complex relantionships existing betweeen CFRU research projects.

STATUS

Over 100 unique projects, including ongoing current projects, have been identified since CFRUs inception in 1975. Given that projects evolve over time, a project is defined as any research with CFRU funding that generates a unique and distinct set of data. For the purposes of documenting projects, each has been categorized as high, moderate, or low priority. Many high-priority projects are long-term studies characterized as multidisciplinary and often contain growth and yield data. For example, projects stemming from the Austin Pond and Weymouth Point study areas are treated as high-priority; hence, all effort will be made to consult researchers to obtain and document metadata in addition to plot- and individual tree-level measurements. High-priority projects are those that are most likely to be revisited in the future and/or data will be utilized by a variety of researchers.

Given that parallel types of information are found within each project, several consistencies have become apparent. To utilize this uniformity, a Microsoft Access relational database is being constructed (Figure 20). The database provides consistency across projects while allowing flexibility for documenting data files associated with individual projects. Metadata recorded for each project includes project title, years of project, funding, associated investigators, and key results (Figure 21). Similarly, the previously developed CFRU publications database (totaling over 300 documents such as Annual

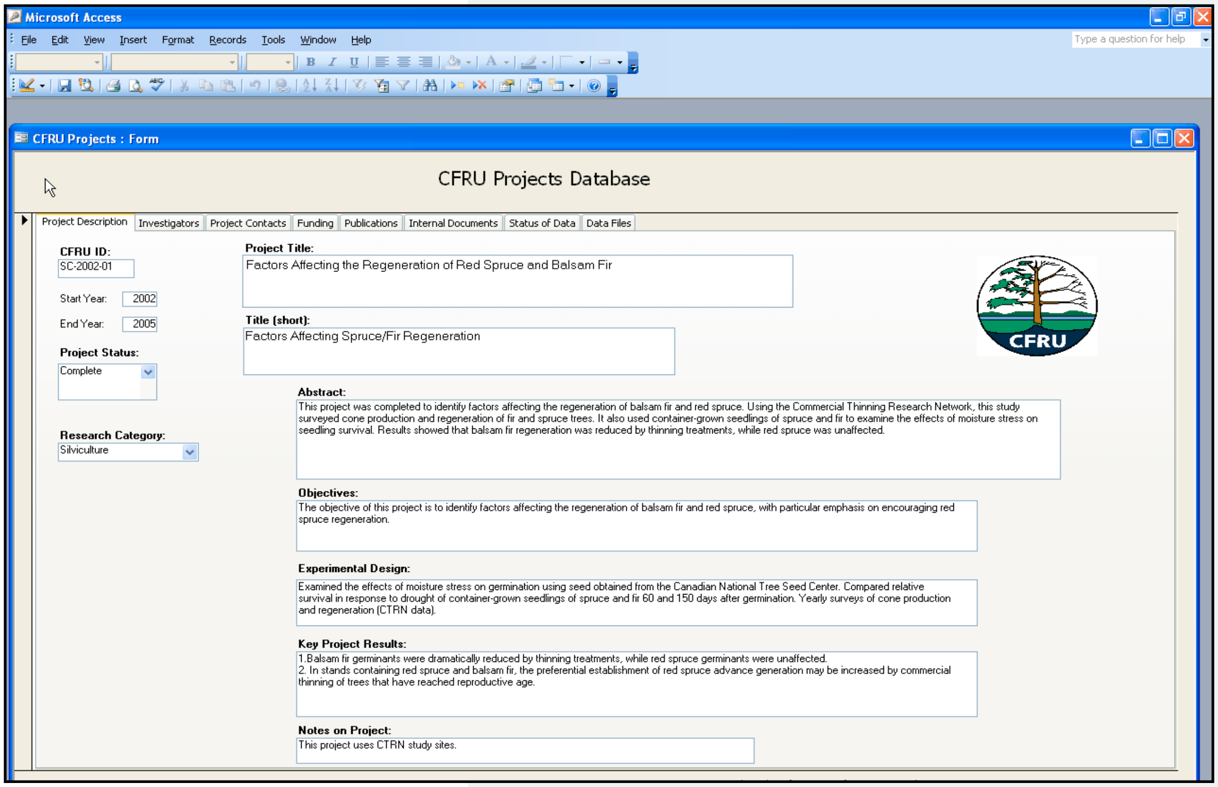

Figure 21. Each CFRU project has had full metadata entered into the database for future reference.

Reports, peer-reviewed publications, and final reports) is being used in concert with the developing CFRU Projects database in order to link each project with its associated publications. Internal documents such as research proposals and project update presentations (as given at Advisory meetings) are also being related to specific projects. Non-funded proposals associated with rejected projects are also being documented in order to track the overall research priorities of CFRU. To date, publications, internal documents, and complete metadata have been designated and related to each high-priority project.

Specific data (i.e., plot- and tree level measurements) have been compiled in various forms. Some of these data reside in digital form while other data exist on handwritten field datasheets or as computer printouts. Non-digitized data such as individual tree data from CFRUs strip-thinning study established in the early 1980s (McCormack and Lautenschlager 1989), is being scanned and digitized to ensure the longevity of these valuable documents. Similarly, separate databases from older research are being constructed for individual studies that possess pertinent sets of data. Some of these include:

- Archiving all digital data collected from Austin Pond into a central database. This includes early conifer response measurements (Newton et al. 1992) and tree measurements quantifying the long-term effects of herbicide and PCT treatments (Daggett and Wagner 2002);

- Compiling more than 20 years of tree improvement data files from Katherine Carter (CFRU, retired) in a separate Microsoft Access database;

- Documenting ecosystem- and tree-level data collected from the Weymouth Point Paired Watershed Study (Briggs et al. 2000) and archiving irreplaceable metadata (e.g., original watershed maps and aerial photos) for future use.

Many of these data from individual studies exist in outdated media types. To ensure their value and use in the future, this work will help to preserve CFRU research by storing data in a format that meets current technology and software standards. Similarly, the physical location and condition of wood and soil samples collected over the years is being recorded.

As research methods and initiatives have changed through time, data management systems have not always kept up with technological advances. The completion of this project brings 30 years of CFRU research in line with today's data management standards.

Ongoing collaborations with CFRU Cooperators, Scientists, and Staff continue to be vital to this project. Individuals such as Maxwell McCormack (CFRU, retired) and Ron Lemin (UAP Timberland) have provided valuable insight concerning methodologies and data collected from past projects. Many metadata collected with CFRU funds by other organizations (e.g., Manomet Center for Conservation Sciences) have been obtained for inclusion in the database. This project has worked closely with the *Refinement of the FVS-NE Individual Tree Growth Model* project in order to utilize CFRU datasets in growth and yield modeling efforts. This resultant database can be used as a tool for CFRU researchers and cooperators to inform future research priorities.

This project will continue to compile and archive CFRU datasets in the relational database. Project completion, which includes the relational database as well as a CFRU Final Report, is expected in June 2009.

For more information about this project, please contact Spencer Meyer.

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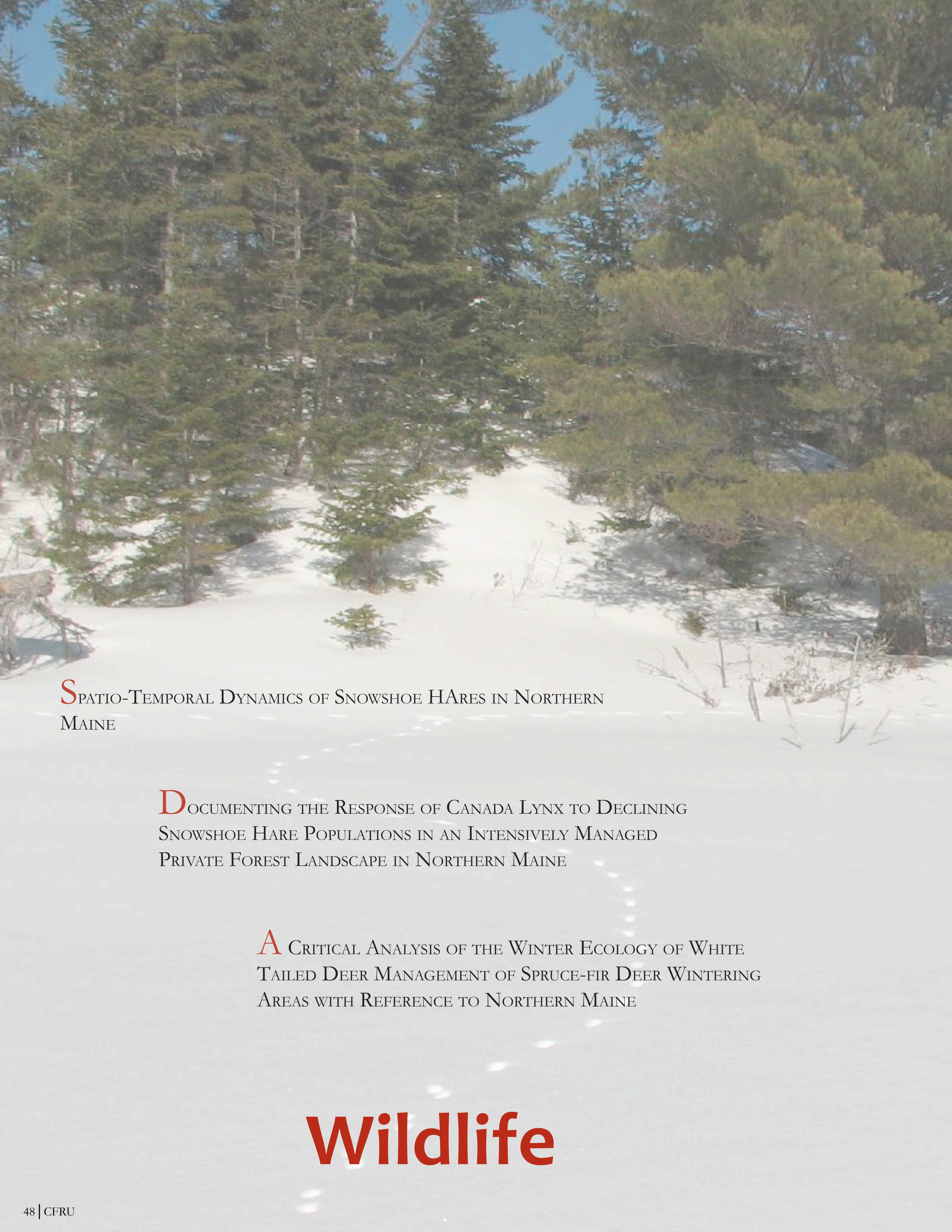

Spatio-Temporal Dynamics of Snowshoe HAres in Northern Maine

Documenting the Response of Canada Lynx to Declining Snowshoe Hare Populations in an Intensively Managed Private Forest Landscape in Northern Maine

A Critical Analysis of the Winter Ecology of White Tailed Deer Management of Spruce-fir Deer Wintering Areas with Reference to Northern Maine

Wildlife

Spatio-Temporal Dynamics of Snowshoe Hares in Northern Maine

Authors

Shonene Scott
Daniel Harrison
William Krohn

INTRODUCTION

Snowshoe hare (*Lepus americanus*) play an important ecological role in the community dynamics of boreal ecosystems through trophic interactions which influence the structure of plant and predator communities. Herbivory pressure by snowshoe hare results in altered plant growth patterns, secondary chemicals associated with plant defense and plant species composition in forested areas. In turn, snowshoe hare are important prey for a suite of mammalian and avian predators, including the federally threatened Canada lynx (*Lynx canadensis*). Snowshoe hare abundance is closely tied to forest structure, and timber harvest activities alter the composition and structure of forests, affecting the quality and availability of snowshoe hare habitat. An understanding about the longer term spatial and temporal dynamics inherent in snowshoe hare populations is necessary in order to promote snowshoe hare persistence within managed forests.

Snowshoe hare populations in the northern boreal forest of Canada and Alaska are reported to exhibit dramatic cyclic behavior synchronized over large areas, with a periodicity of 8-11 yr and amplitudes ranging from 5- to 25-fold, occasionally exceeding 100-fold. The closely correlated snowshoe hare and lynx population cycles of the northern boreal forest have been extensively studied; yet, uncertainty remains regarding population dynamics in snowshoe populations at the southern extent of the species's distribution. More specifically, little information is available about trends in hare populations in the Acadian forest region. Southern hare populations have been hypothesized to be either cyclic with reduced amplitude and irregularly fluctuatiing, or stable. Based on the literature, the pattern of hare fluctuations in Quebec appear to be inconsistent between regions, with stronger evidence for hare cycles in western portions of the province compared to relatively stable hare populations south of the Saint Lawrence River.

The goal of this research is to evaluate the temporal and spatial patterns in density fluctuations of snowshoe hares and to evaluate the relative influence of natural population fluctuations and human-induced habitat change via commercial forest management activities on hare population dynamics within the Acadian forest. Specifically, we evaluated whether observed temporal variations in hare density occurred synchronously across northern Maine, and assessed whether dynamics were consistent with those documented for cyclic hare populations in the northern boreal forest.

"Our results suggest that both natural population fluctuations at a regional-scale and effects of forest management at a local scale will need to be considered when planning for lynx conservation in Maine."

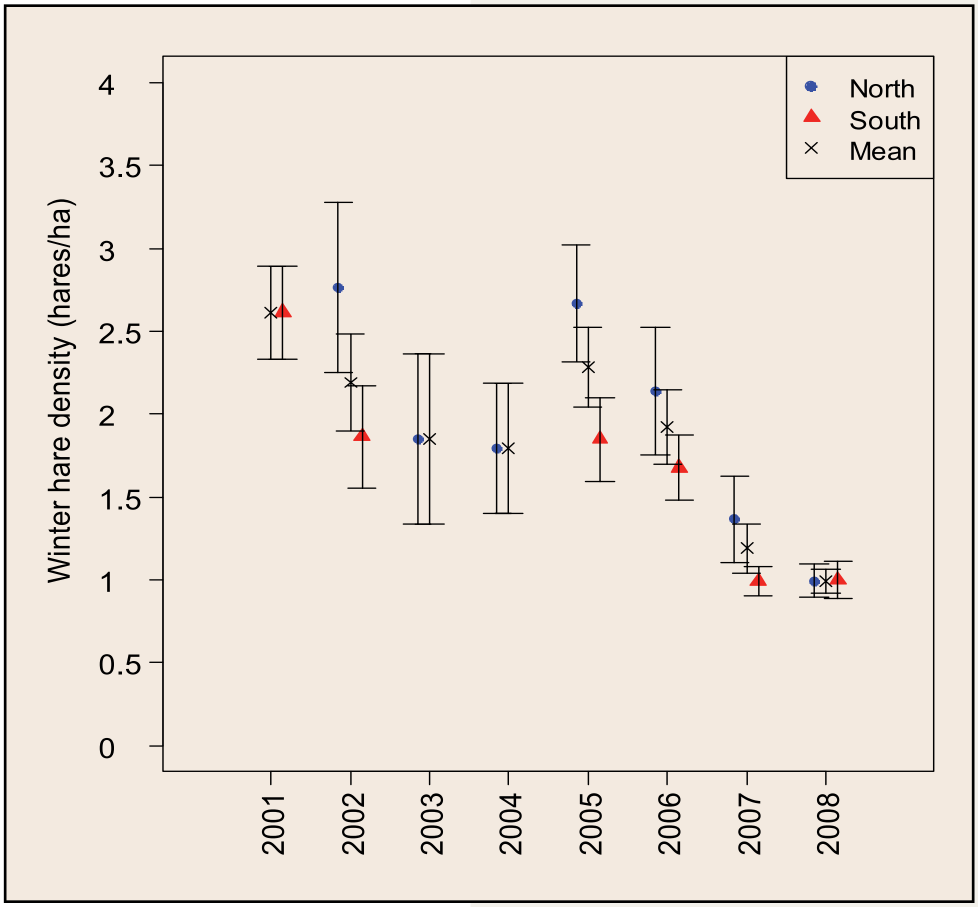

Figure 22. Mean ± standard error winter hare densities in regenerating conifer stands in the north (near Clayton Lake) and south (near Telos checkpoint) study locations, and both locations combined, Maine, 2001 to 2008. Results of analyses indicate that hare populations in both locations fluctuated in synchrony and have declined in phase since 2005.

METHODS

We monitored snowshoe hare abundance biannually using fecal pellet survey protocols developed for Maine (Homyack et al. 2006). The hare density trend for this analysis was complied from data collected over the period from 2001 to 2008. Selected pellet count stands were distributed between two study areas: the southern area located near the Telos checkpoint in to the North Maine Woods, and the northern area near Clayton Lake. Stands in these two locations have been monitored since 2005 (Robinson 2006) and include 15 regenerating conifer clearcuts (20-35 years post-harvest, sprayed with herbicide), six overstory removals, four shelterwoods, and 11 selection cuts. Additionally, during summer 2007 we established survey plots within seven mature coniferous and six mature coniferous-deciduous mixed stands (not harvested since 1970) in the southern area to provide baseline data for hare abundance in those stand types. In 2008 we monitored relative hare abundance in a total of 42 stands, reducing the number of partial harvest stands from 21 to 14 to allow us to survey the 13 new mature stands within our fixed budget. Hare density estimates for 2005 to 2008 were combined with previous results obtained for the same seven regenerating conifer clearcuts in the southern area that have been monitored since 2001 (Homyack et al. 2007) and with four regenerating conifer clearcuts in the northern area monitored during 2002 to 2004 (Mullen 2003, J. Vashon, Maine Department of Inland Fisheries and Wildlife, unpublished data).

Additionally, we measured structural vegetation characteristics during June 2008 to investigate the influence of vegetation structure on hare density trends. Twenty-three vegetation characteristics were measured in all stands in the southern area and within the partial harvest stands in the northern area. Details concerning this portion of the research will be provided in Shonene Scott's M.S. thesis, which has an anticipated completion date of May 2009.

Results provided here on the spatial and temporal dynamics of snowshoe hares in northern Maine were based on winter density estimates from regenerating conifer clearcuts. In Maine, regenerating conifer stands have repeatedly been shown to have the highest hare densities among harvested and mature forest stand types. Those stands provide dense understory characteristics, which are important to hares for cover from thermal extremes and predation. Additionally, these habitats may serve as refugia during population lows.

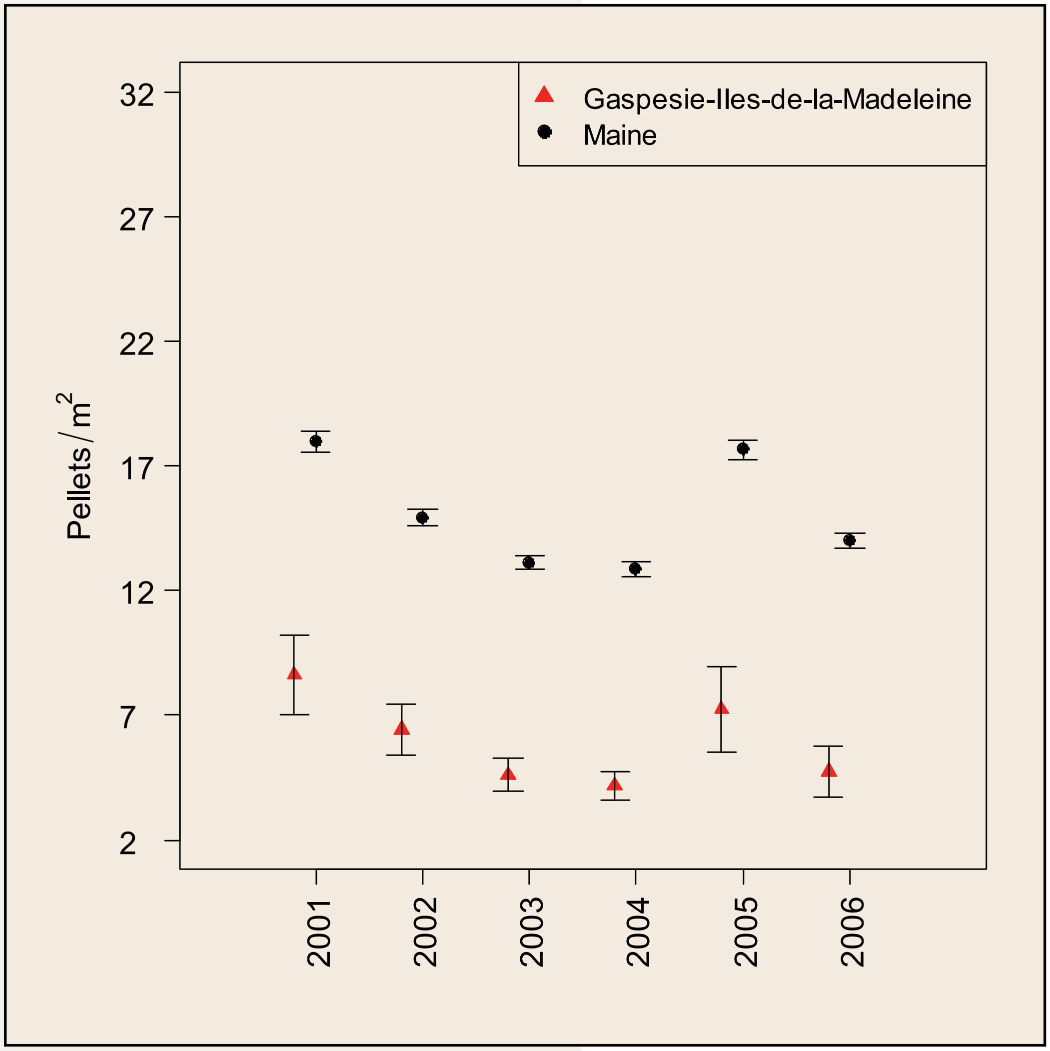

Figure 23. Comparison of snowshoe hare fecal pellet density from regenerating conifer stands in northern Maine and the optimal and suboptimal habitats in the Gaspe Bay Peninsula administrative region (Gaspésie-Îles-de-la-Madeleine), 2001 to 2006.

To determine if hare density fluctuations occurred in synchrony throughout northern Maine, the hare density trend for the northern area was compared to the hare density trend for the southern area. These two locations were separated by > 56 km to facilitate this analysis. Density fluctuations between the two areas were considered synchronous if the trends exhibited similar patterns of fluctuation, identical period length (duration of one cycle), and occurred in phase (i.e., peaks and lows occurred simultaneously). We analyzed density data for differences within and between locations using analysis of variance (ANOVA) to identify the timing of peak and low densities. We calculated finite rate of change in density ($\lambda=N_t/N_{t-1}$) and investigated similarity in density change between locations using Spearman's Rho correlation.

We described the temporal dynamics of hare density change using the density time series for both locations combined. We assessed differences in hare density between years using ANOVA and Tukey's Honestly Significant Difference (HSD) tests. We measured the period (duration of a single cycle), amplitude (high density ÷ low density), and finite rate of change (λ) in snowshoe hare density fluctuations to compare population dynamics of hares in the Acadian forest to the classic 10-yr cycles reported for boreal populations.

RESULTS AND DISCUSSION

Average hare density in our northern study area remained relatively stable from 2002 to 2005, then declined significantly to a low in 2008 (Figure 22). A similar pattern was observed in the southern area where hare density remained relatively stable from 2001 to 2005, then declined significantly to lows in 2007 and 2008. The high density in 2005 and the low in 2008 occurred in phase between locations, and the trend in λ was highly correlated (rho=0.79). Results indicate that fluctuations in hare density occurred synchronously between locations. Because of the similarities in hare density trends between locations, we pooled the data between locations for the remaining temporal analyses.

The combined hare density time series exhibited a similar pattern to the location-specific trends, with only the decline after 2005 statistically significant. Because of the relatively stable hare density prior to 2005, we considered 2005 the peak year. The peak hare density of 2.3 ± 0.24 hares/ha, and the low 1.0 ± 0.07 hares/ha, resulted in an amplitude of 2.3:1 (Table 7). The population declined at an annual rate of 24 % annually from 2005 to 2008. No periodicity was apparent from the observed trend.

The density trend that we observed suggests two possible temporal patterns. The relatively stable fluctuations in hare density prior to 2005 are suggestive of a population which is fluctuating or stable. However, the three year decline after 2005 is suggestive of the declining phase of a cycling population of reduced amplitude compared to amplitudes observed in the boreal forest. A typical hare cycle in the boreal forest lasts for a period of 8-11 years. Within that period, the decline phase lasts 2-4 years, followed by a low phase of 2-4 years, then an increase phase of approximately five years. If this is true in Maine, we can expect hare populations to remain low for another 1-3 years before entering an increase phase.

The high density in northern Maine (2.3 hares/ha) was substantially lower than the majority of peak densities reported for cycling populations in the boreal forest, but intermediate to peaks reported elsewhere within the geographic range of hares (Table 7). Likewise, the low density in Maine (1.0 hares/ha) was higher than most low densities reported for boreal populations, but similar to the low point of cycles observed during a few previous studies. The extent of population change that we observed from 2001 to 2008 was significantly smaller than the extreme magnitudes of change observed in boreal populations of Alaska and Canada. The rate of decline after 2005 was also slower than that was observed during the decline phase in other cyclic populations.

Table 7 Characteristics of the snowshoe hare density population trend for northern Maine, 2001 to 2008, compared to characteristics from cyclic populations in the boreal forest of Canada and Alaska.

Attribute	Density (hares/ha)	
	Maine	Boreal
Peak	2.3	1.6 - 23.0
Low	1.0	0.01 - 1.0
Amplitude	2.3	7 - 105
λ during decline	0.76	0.3 - 0.6
Periodicity		8 - 11
Pattern	Fluctuating or Reduced-amplitude cycles	Cyclic
Synchronous	Yes (56 km)	Yes

One interesting observation from the literature comes from the Ministry for Natural Resources and Wildlife, Quebec. This monitoring program uses fecal pellet counts by administrative region to provide information for setting Canada lynx harvest limits. The pellet density from the Gaspe Bay Peninsula region (Gaspésie-Îles-de-la-Madeleine) showed a trend that was strikingly similar to population changes that we observed in northern Maine (Rho = 0.9; Figure 23). This result provides evidence that hare fluctuations in Maine may be occurring in geographic synchrony at much broader scales. Future pellet surveys conducted by our lab, in conjunction with ongoing surveys by the Ministry for Natural Resources and Wildlife, Quebec, will provide for interesting future comparisons across the Acadian forest region. Evidence of geographic synchrony between the Telos, Clayton Lake, and Quebec study areas suggests that extrinsic factors are driving broad-scale fluctuations in hare density rather than local-scale factors driven by local forest management. Possible extrinsic factors include spatially correlated climatic effects and/or the community-level influences of mobile predators.

CONCLUSION

Overall, evidence suggests that hare populations in northern Maine, 2001 to 2008, fluctuated synchronously and did not exhibit the extreme cyclic dynamics documented in the boreal forest. The 2.3-fold difference in peak and low density in Maine was significantly reduced compared to large amplitudes observed in the boreal forest. Peak densities were lower than many peaks observed in boreal populations but comparable to others. Likewise, low densities were higher than the extreme lows observed in some boreal populations but comparable to other temporal lows. The density trend suggests that hares in Maine exhibit cyclic population dynamics with reduced amplitude compared to populations in the boreal forest, or population fluctuations lacking a predictable pattern. Ongoing work will provide the additional years of density estimates needed to verify or rule-out cyclic behavior. Our results suggest that both natural population fluctuations at a regional-scale and effects of forest management at a local scale will need to be considered when planning for lynx conservation in Maine.

FUTURE PLANS

In 2009 we will survey hare densities within 42 stands of the different types and across both study locations to provide additional data for our long-term hare density trend, and to monitor fluctuating hare densities. Shonene Scott will complete her M.S. thesis completing the analysis summarized here, plus an analysis of the influence of vegetation structure during stand development processes in even-aged regenerating conifer clearcuts on hare density, and the consequences of declining hare density on the probability of Canada lynx occurrence in areas in northern Maine. Additionally, we will complete a manuscript on the effect of partial harvesting and associated stand structure on stand-scale hare densities.

For more information about this project, please contact Dan Harrison.

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Documenting the Response of Canada Lynx to Declining Snowshoe Hare Populations in an Intensively Managed Private Forest Landscape in Northern Maine

Authors

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"It is imperative that lynx population demographics and associated habitat use be studied at both high and low hare densities to establish realistic recovery objectives and effective management efforts for lynx in the northeast."

PROJECT OVERVIEW

In 2000, Canada lynx (*Lynx canadensis*) were listed as federally threatened species in 14 conterminous United States including four eastern states (Maine, New Hampshire, Vermont, and New York). In the east, the only documented lynx population occurs in Maine. The United States Endangered Species Act requires that Critical Habitat be designated and a recovery plan be established to facilitate conservation efforts and ultimate recovery of a listed species. With the recent designation of critical habitat for lynx, including 10,000 square miles in Maine, the US Fish and Wildlife Service (USFWS) will finalize a recovery plan for lynx. This plan will identify the management actions needed to recover the lynx population, criteria for measuring the recovery rate, and warrants to remove lynx from the federal list of threatened species.

Current information on lynx habitat use and requirements in Maine is based on a radio telemetry study conducted during a period of high snowshoe hare and lynx abundance (Vashon et al. 2008a and 2008b, Fuller et al. 2007). Recently, lynx reproductive rates and snowshoe hare densities have declined in Maine. Current models indicate that a 20 % change in hare densities can have a dramatic impact on the long-term viability of some lynx populations (Steury and Murray 2003). The decline in hare densities in northern Maine provides an opportunity to study how hare densities influence lynx population demographics and population viability in the northeast. Specifically, will lynx persist at lower hare densities or are higher hare densities needed to sustain lynx in Maine? It is imperative that lynx population demographics and associated habitat use be studied at both high and low hare densities to establish realistic recovery objectives and effective management efforts for lynx in the northeast.

In 2007, the University of Maine, Maine Department of Inland Fisheries and Wildlife, and the USFWS initiated a cooperative study to assess the variability in lynx population demographics and possible threshold densities of hares needed to support lynx in Maine. This study continues the ongoing lynx telemetry efforts in northern Maine, but with the benefit of using GPS technology. Support from the Cooperative Forest Research Unit and its members provided the matching funds that leveraged an additional $90,000 in federal grants for our field efforts in 2008.

PRIMARY ACTIVITIES IN 2008

An IF&W biologist assesses the health of a lynx kitten.

In 2008, we purchased replacement batteries for seven GPS collars (Lotek Wireless) and purchased an additional 11 store-on-board GPS collars (Sirtrack Limited, New Zealand). We switched GPS collar manufacturers based on a pilot study in Montana that revealed greater battery expectations (two years), a reliable collar release mechanism, and more intensive sampling (a fix every 4.5 hr vs. 1 fix/day).

In 2008, our capturing efforts were initiated to

1) Replace VHF radio collars with GPS collars (n=11 lynx),
2) Recover a previously deployed GPS collar and its data from a resident male lynx,
3) Increase our sample to 20 lynx monitored with GPS collars and
4) Equip lynx kittens (~5-12 months old) with satellite collars.

From January 9th to April 9th, a 6-person field crew set cage traps to capture lynx and conducted track surveys to document kitten survival rates and snowshoe hare abundance in the Musquacook study area. Beginning on July 31st, a 4-person field crew set foot-hold traps for lynx and counted snowshoe hare fecal pellets on the study area. Each lynx captured in traps in 2008 was equipped with a GPS collar that was programmed to obtain between one and four locations a day to document lynx movements, home-range size, and habitat use patterns. In addition, each GPS collar was equipped with a mortality sensor. Warden pilots monitored the mortality signal twice a week during the winter months and once a week during the remainder of the year. We investigated each mortality site and performed necropsies to determine the cause of death. During the winter, we documented kitten survival rates by tracking, on foot, each radio-collared adult female that produced a litter in 2007 and counting the number of kitten tracks. Beginning in

Lynx tracks abound in the winter forest.

May, all radio-collared female lynx were located at least twice a week to document den initiation and the production of kittens.

PRELIMINARY RESULTS

In 2008, we equipped 17 lynx (11 males and six females) with GPS collars. We captured six different (four males and two females) lynx 29 times during our winter trapping effort and 12 lynx (eight males and four females) 13 times during the summer/fall trapping effort. One male lynx captured this winter and five lynx (three males and two females) captured this fall had not been previously radio-collared. Four (two males and two females) of these lynx were equipped with GPS collars. Two male lynx, whose satellite collars were inaudible for two years were captured this year and their collars were replaced with GPS collars. A total of eight VHF collars were removed from lynx and replaced with GPS collars. Although we did not capture any kittens during winter and fall trapping effort, satellite collars were deployed on two lynx caught during the fall. This included a male lynx whose GPS collar was no longer collecting locations when he was captured in the fall. We were able to retrieve the data from the collar before releasing the lynx with a satellite collar.

TELEMETRY MONITORING

When we initiated our capture efforts in 2008, 15 radio-collared lynx (eight males and seven females) were being monitored, including one male lynx equipped with a GPS collar. In 2008, we increased our sample to 21 radio-collared lynx (13 males and eight females). However, we lost the signals from a GPS and satellite collar in 2008 when the collars reached the end of the battery life before we could recapture the animal. The GPS collar release mechanism deployed prematurely (error at manufacture that has been corrected) on another lynx. We were able to recover the collar and data, but did not recapture the lynx to reequip her with a GPS collar. We also documented the mortality of two adult female that died of unknown causes. At the end of 2008, 17 lynx (12 males and five females) were being monitored including 13 equipped with a GPS collar (10 males, three females), two lynx equipped with a satellite collar (one male and one female) and two males equipped with VHF collars.

Den Site Visits

By the end of the winter, we were monitoring 15 lynx, including five adult females. However, we lost the signals from two female lynx just prior to the kitten rearing period. Despite a small sample size, this year marked the third year of low production with none of three females equipped with collars in June producing a litter. Two of the females had produced a litter in 2007.

Snow Track Surveys

During the winter of 2008, we back-tracked two radio-collared female lynx that produced kittens the previous spring and documented the tracks of three of four kittens. In March, we conducted snow track surveys to assess the abundance of snowshoe hares along permanent transects distributed within our study area. Snowshoe hare fecal pellets were counted in May and September at 16 sites. These counts will be used to document trends in snowshoe hare abundance in our study area.

Maine IF&W biologists prepare to collar a lynx.

PLANS FOR 2009

In 2009, we will continue our winter, summer, and fall capture efforts to maintain a sample of 20 radio-collared lynx, increase our sample of female lynx, and recover GPS locations collected to date. Throughout the year, we will continue to monitor radio-collared lynx to document mortalities and reproduction (in the spring). During the winter of 2009, we will attempt to recapture two lynx whose collar signals were lost in 2008, a female lynx whose collar dropped off prematurely, and two male lynx currently equipped with VHF collars. This winter, we will also track five radio-collared female lynx, and any female lynx captured during 2009 trapping efforts, to determine if they are traveling with kittens.

David Mallett, the graduate research assistant for this study, will continue with his course work at the University of Maine, finalize his thesis proposal, assist with field research efforts and continue snowshoe hare pellet counts on the University of Maine long-term study plots.

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For more information about this project, please contact Jennifer Vashon.

Photographs in this project report are compliments of Maine Inland Fisheries and Wildlife.

A Critical Analysis of the Winter Ecology of White Tailed Deer Management of Spruce-fir Deer Wintering Areas With Reference to Northern Maine

Authors

Peter J. Pekins
Matthew D. Tarr

Editor's Note:

The following is the Executive Summary, as excerpted from the complete report by Pekins and Tarr, entitled A Critical Analysis of the Winter Ecology of White Tailed Deer and Management of Spruce-Fir Deer Wintering Areas With Reference to Northern Maine. *The complete citation appears at the end of this report.*

EXECUTIVE SUMMARY

The winter survival of white-tailed deer (*Odocoileus virginianus*) is related directly to occupation of deer wintering areas (DWA) at the northern extent of their range where snow depth limits mobility and forage resources. While the specific composition of DWAs varies across the northern range of white-tailed deer, all are comprised of two basic habitat components; mature conifer stands which provide deer cover and improve their mobility, and other forest or non-forest habitats that provide deer with forage. Winter mortality is an annual event, even in average winters, because population size and density, adequacy of a DWA, predation risk, and local conditions vary. Management of DWAs is usually grounded in habitat protection that requires balancing a deer population with availability and condition of DWAs. However, typical mature spruce-fir stands operating as DWAs are not static, typically "breakdown" over time, and require constant management for both wood production and integrity as a perpetual DWA. Management of deer populations and DWAs on commercial forestland presents a unique situation of balancing a high-profile, valuable public resource (i.e., deer) critically dependent upon specialized forest habitat, with the need to effectively manage that forest habitat for its economic value. Considerable variation exists in productivity and management of spruce-fir forests, deer management goals, societal input and values, biological influences on deer and spruce-fir forests, and other human impacts where DWAs exist.

This document provides an analysis of the current knowledge of the winter ecology of white-tailed deer and management of spruce-fir DWAs that is essential to guide deer and DWA management, and to identify knowledge gaps and confounding factors that will influence future management and research decisions associated with both in northern Maine. Of particular consequence in Maine are the relationships between and among increased public concern with depressed deer

"Management of deer populations and DWAs on commercial forestland presents a unique situation of balancing a high-profile, valuable public resource critically dependent upon specialized forest habitat, with the need to effectively manage that forest habitat for its economic value."

populations in northern Maine, aging of regulated DWAs and Maine Land Use Regulation Commision (LURC) zoning, and trends in forest harvesting and ownership. The following highlights 15 major points, questions, and recommendations contained within the document. Readers should refer to Chapters I-IV of the complete report for background information and Chapter V for an expanded summary and recommendations.

Survival of fawns is most dependent upon constant forage intake during winter conditions.

All deer occupying a deer wintering area (DWA) will experience a negative energy balance or weight loss because winter forage of deer is of moderate-low quality from a nutritional standpoint. Forage availability and intake are of most importance from the standpoint of energy balance, however, nutritional value and intake rate tend to decline throughout winter as deer remove the current annual growth (CAG) of most browse, and increasing snow depth reduces access to forage. Because intake rate is directly related to digestibility of the diet, providing high forage diversity and availability in DWAs helps maintain high intake rate.

The seasonal fat cycle in adult does is their primary physiological adaptation to withstand extended periods of limited forage availability in winter. Body fat accounts for 35-50 % and 10-25 % of the daily energy expenditure (DEE) of adult does and fawns, respectively, during a 90-100 day period of confinement in a DWA. Because the reciprocal proportions are met by forage consumption, reduced forage intake increases the contribution of fat to the DEE. Therefore, on a relative scale, survival of adult does is most influenced by length of winter, whereas survival of fawns is most dependent upon constant forage intake.

The average DEE of deer is considered low and similar to their maintenance energy requirements (1.6-1.8 x FMR; fasted metabolic rate) indicating that energy conservation is their principal survival strategy. Measurements of DEE and energy balance models indicate that deer mortality should be expected when severe winter conditions extend beyond 90-100 days. Fawns experience earlier and higher mortality than adult deer because, on a relative basis, they have higher DEE and less body fat and access to forage due to their age and size. Because fat reserves and body condition are best maintained through high metabolizable energy intake (MEI), maximizing browse availability and enhancing mobility to improve access to browse should be promoted in DWA management.

Winter mortality of deer is both density-dependent due to forage competition caused by high population density in a confined area with limited resources, and density-independent from predation by coyotes. However, both sources of mortality are largely dictated by winter severity, principally snow depth that affects forage availability and mobility of deer, and their abundance, distribution, and relative vulnerability to predation. Coyotes predate all sex/age classes of deer, but fawns are most vulnerable, and predation is greatest when forage competition and malnutrition occur in late winter. Thus, the probability of additive mortality from predation is influenced by winter conditions that exacerbate all mortality factors, indicating the value in managing DWAs for high browse availability and mobility of deer.

Well-established coyote populations in Maine should be considered a permanent source of winter mortality that has effectively lowered the carrying capacity where deer are confined to DWAs for extended periods. Historic population goals established during periods of coyote-free DWAs are likely not attainable and deer population goals need to reflect coyote predation during winter. Coyote predation should be considered a limiting not regulatory factor of deer populations because depressed regional deer populations in Quebec have recovered after a series of mild winters, arguably the most influential factor, in combination with habitat restoration and coyote population control.

Deer typically have reduced productivity after severe winters because of high mortality and reduced body condition of does that affect fecundity and fawn survival. The impact of a severe winter can have a lagged, two to three year effect, and a series of consecutive severe winters that continually depress productivity and enhance predation can produce regional population decline. Conversely, a series of mild winters is probably required to grow a depressed deer population at its northern extent through reduced mortality from malnutrition and predation, and higher productivity through improved nutritional status and body condition of yearling and adult does. The potential impact of severe winters on northern deer populations is best addressed by maintaining large DWAs that provide optimal cover, forage, and deer density.

The thermal cover of mature softwood must be balanced with adjacent hardwood browse to maintain adequate nutrition opportunities for deer.

The disproportionate importance of DWAs is evident by the fact that DWAs generally represent only 5-15 % of the annual range. However, deer display very strong fidelity to their DWA and are very reluctant to abandon it. This has several implications to DWA management including 1) maintenance and habitat improvement should focus on DWAs currently used by deer, 2) colonization of a DWA where deer are removed (e.g., predation, severe winter) will probably not be immediate, and 3) what happens to deer when their DWA is removed is unknown, and 4) it is also unknown how deer colonize new DWAs in a landscape that has been heavily fragmented by timber harvesting. Research designed to investigate such topics is warranted in Maine if increasing the northern deer population is a management goal in face of reduced mature spruce-fir habitat, and a trend toward shorter rotation age in spruce-fir habitat that is in decline. This research would likely require considerable investment in radio-collared deer for at least five years, and should include aspects that investigate annual mortality factors and movement through and occupation of habitats within a landscape perspective.

CFRU members and researchers and Maine Inland Fisheries and Wildlife biologists discuss silvicultural options in a zoned deer wintering area duriong a recent field tour.

Snow depth, usually ≥ 30 cm, is the main factor that triggers deer to occupy DWAs; deer become confined to dense conifer stands when snow depth exceeds 40-50 cm. The use of a DWA expands and contracts as snow and sinking depth influence deer mobility. All DWAs are comprised of two basic habitat components; mature conifer stands that provide deer shelter and improve their mobility, and other forest or non-forest habitats that provide forage. The best DWAs contain high interspersion of cover and food that provide deer access to resources throughout winter under a wide range of snow conditions.

The best winter cover for deer is provided by mature forest stands that are comprised of at least 50 % conifers with 50 % crown closure, and at least 10 m tall. Although exactly how much conifer cover deer require is unknown, where snow depth regularly exceeds 50 cm, deer may require conifer stands with at least 70 % crown closure, and where snow depths rarely exceed 20 cm, 30 % conifer cover may be adequate. DWAs > 100 ha should be the focus of management and conservation efforts.

Extensive commercial clearcutting that removes softwood and creates abundant browse reduces the carrying capacity of deer winter habitat in northern Maine. Silvicultural techniques to manage spruce-fir timber can be identical to those used to create ideal DWA conditions. How these techniques are applied to accomplish both goals on the same property will require creativity and compromise on the part of both the landowner and any regulatory agency. Three main objectives should be considered when creating and maintaining an ideal DWA including:

1) Maintain an adequate amount of functional cover at all times,

2) Perpetuate a constant, abundant supply of accessible forage, and

3) Maintain a high level of interspersion and mobility that provides functional cover and accessible food.

Maintenance of DWAs on commercial timberland requires a conscious effort on the part of the landowner to identify areas where mature spruce-fir stands can be developed and perpetuated. Timber harvesting can and should be used to shift the location of these stands over time to ensure they don't become over-mature and lose their ability to provide cover for deer. In some situations, timber harvesting may need to be deferred in order to develop and maintain mature conifer cover. Establishing minimum cover requirements based on annual winter severity will help ensure adequate cover is maintained to meet DWA objectives, while minimizing the burden to private landowners.

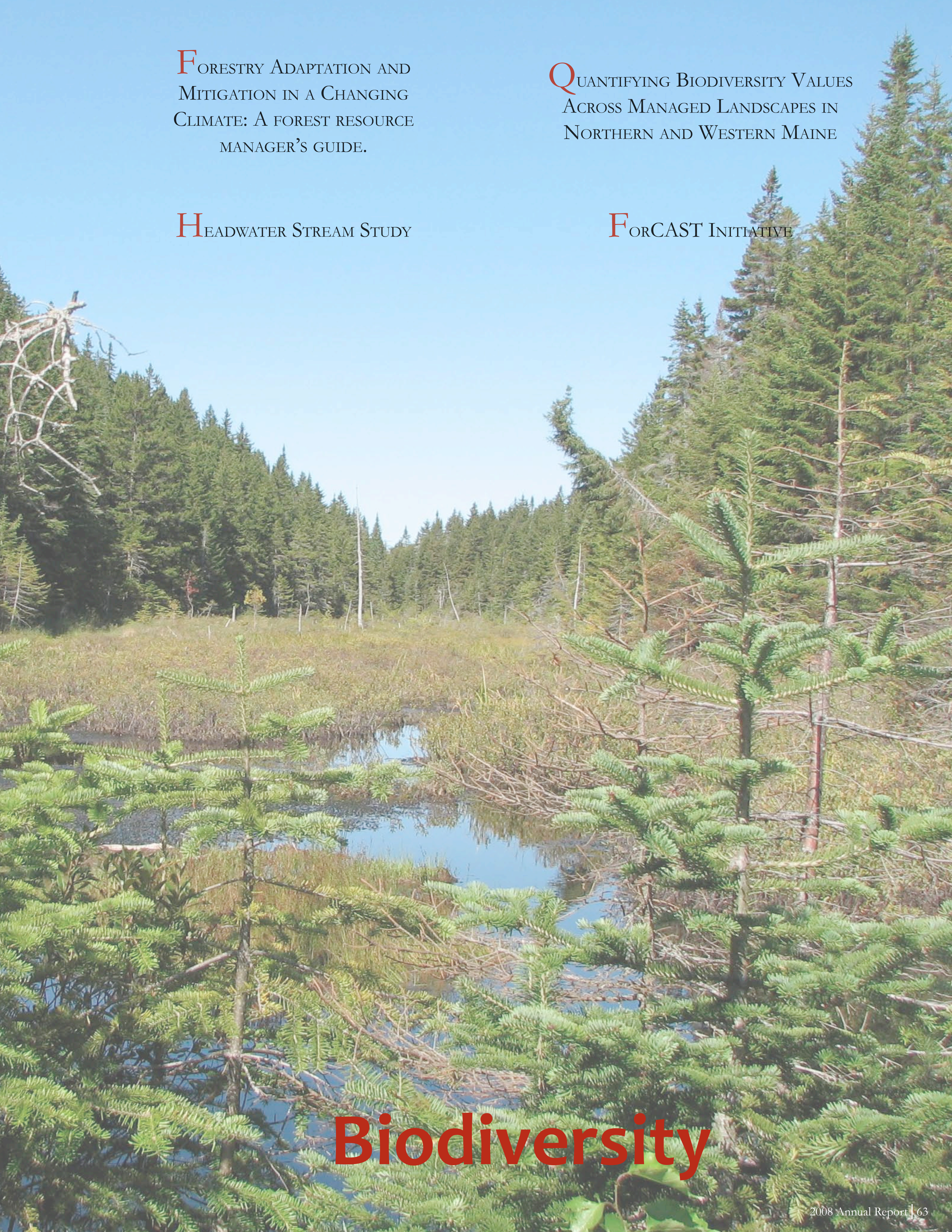
A winter severity index (WSI) that uses a combination of measurements of snow depth, sinking depth, and ambient temperature reflects the direct relationship between winter severity and the body condition, productivity, and mortality of wintering deer, and is probably the most useful tool that deer managers have to adapt and adjust annual harvest goals to address long-term deer population goals. The use of a WSI offers many advantages including annual assessments and management responses, as well as long-term data sets that should identify changes associated with climate change. These data are valuable for analyses of weather and herd response, temporal evaluation of a DWA as it ages or is harvested, and to compare biological and economic value of a DWA.

A long-term evaluation of the number of days with 50 cm snow depth and/or relative WSI scores could be useful to produce a stratified, landscape approach in managing DWAs in Maine. One possible approach is to establish habitat management zones based on differences in average winter severity and corresponding criteria for minimum crown closure (e.g., 70 % in north, 50 % in central, 30 % in south).

Land use zoning through LURC restricts timber harvesting in an effort to manage and protect DWAs. However, LURC zoning is insufficient for maintaining functional DWAs long-term because it only protects the shelter portion of a DWA. LURC zoning would be more effective if it better reflected that DWAs are larger than the shelter component, and that the dynamics of forest growth and replacement of cover and forage contributes to the viability of a DWA over time. Zoning, managing, and conserving DWAs requires accurate and continuous effort in identifying use and location of DWAs, and such work is critical to help LURC be more effective.

The traditional "expert" or authoritative approach of management is not recommended to address the DWA issue in Maine, rather, a co-managerial approach that will require shared responsibility is advocated. Given the myriad of stakeholders and their varied knowledge and attitudes, high public value and sentiment for deer, dramatic shifts in land ownerships and turnover, economic issues, and recent history of public referendums, strong and responsible leadership by one organization is needed to implement an objective and successful human dimensions approach to address deer and DWA management in Maine.

For more information about this project, please contact Peter Pekins.



Forestry Adaptation and Mitigation in a Changing Climate: A forest resource manager's guide.

Quantifying Biodiversity Values Across Managed Landscapes in Northern and Western Maine

Headwater Stream Study

ForCAST Initiative

Biodiversity

Forestry Adaptation and Mitigation in a Changing Climate: A Forest Resource Manager's Guide

Authors

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Manomet Center for Conservation Sciences

INTRODUCTION

Overwhelming evidence now exists for global warming (IPCC 2007). In 50-100 years, parts of the northern forest of Maine will have a climate more like New Jersey today (Union of Concerned Scientists 2006). Increasingly, the business sector throughout the U.S. and the world is concluding that its ability to mitigate and adapt to climate change is tied to their long-term viability (e.g., Carey 2004). Failure to take action is predicted to result in a 5-20 % reduction in global gross domestic product (GDP) (Stern 2006). The private business sector (rather than government) is providing most of the innovation on how to deal with climate change. Surprisingly, companies that are most aggressive in addressing climate change are discovering an immediate competitive financial advantage (Walsh 2007).

A considerable volume of information has been generated about climate change and the potential implication to forests and forest products. We can expect climate change impacts to be manifested in rapid changes in species distribution, and/or diebacks (Aber et al. 2001, Dale et al. 2001), and increased damage from extreme weather events (e.g., ice storms, wind, drought, insects, rain events, and fire (Irland 2000, Peterson 2000, Flemming et al. 2002). Impacts can also be positive, in terms of increased forest growth and yield for the more resilient species (Cao and Woodward 1998, IPCC 2007). At present, this information is unconsolidated and difficult to access (but see Oregon Forest Resources Institute 2006). More importantly, it is difficult for forest managers to interpret and translate this information into practical management actions, or even assess the merits of any action given the level of uncertainty about potential forest impacts (Perez-Garcia et al. 2002).

"Response will also require that growth and yield models are adjusted to reflect changing conditions and the tree species characteristics that become more prevalent."

Having climate adaptation management strategies are essential if landowners are going to have plans that help them achieve their objectives (e.g., revenue, silviculture, retain certification, etc.). A strategy is also crucial if the Northern Forest will continue to play a mitigating role in the ongoing need to address greenhouse gas (GHG) emissions buildup. Our framework is designed to help forest managers to determine what, if any, actions they may undertake to reduce the immediate and long-term risk of climate change. This framework draws largely upon recommended actions from temperate forest managers around the world. We had initially sought to catalogue current actions that forest managers are taking with climate change adaptation as a specific objective. However, the published literature currently lacks concrete examples of climate change adaptation practices relevant to temperate forest managers.

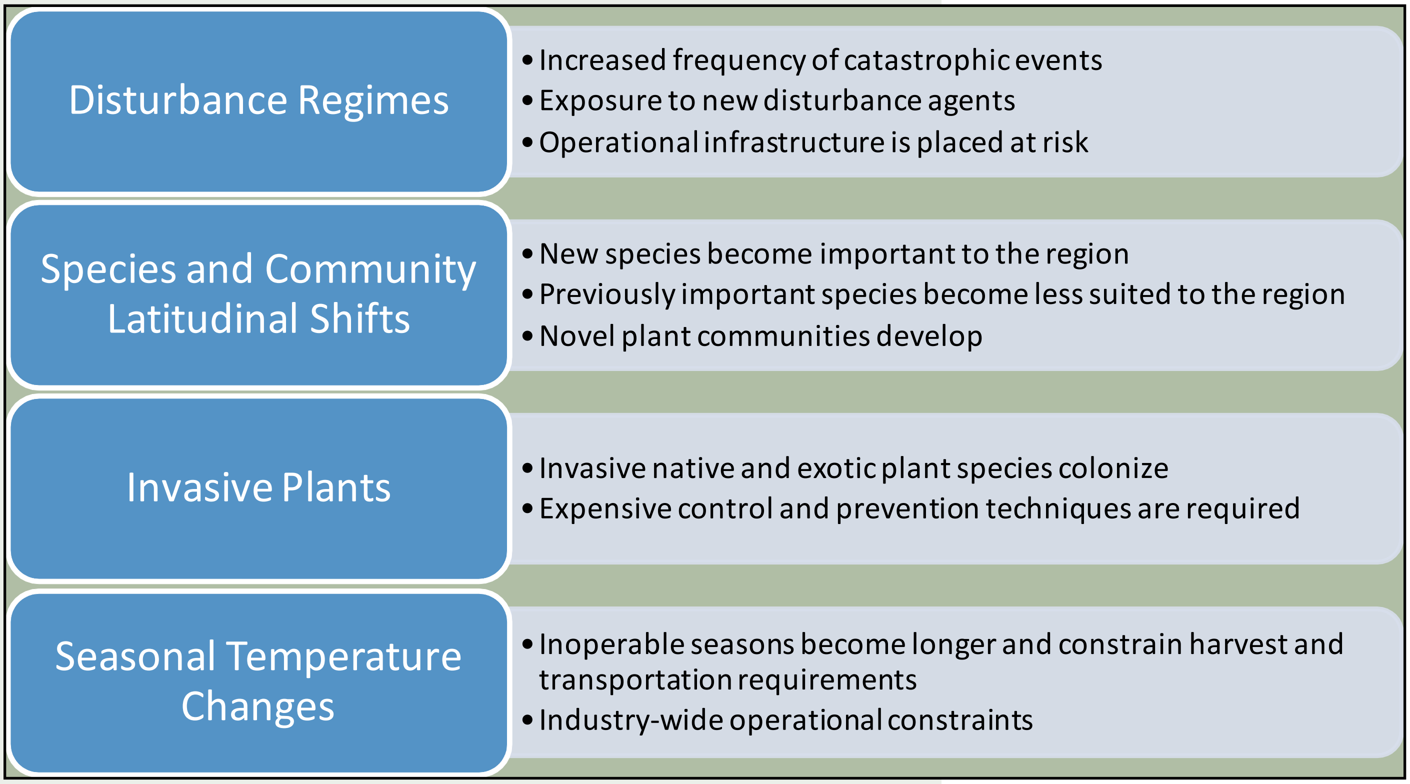

Figure 24. Primary Climate Change Stressors Relevant to Forestry

WHAT DO WE NEED TO ADAPT TO?

We know from basic ecological principles that climate shapes the broad scale distribution pattern of tree species and the assemblage of forest communities. As mentioned briefly above, natural disturbance regimes such as fire, wind, and insect outbreaks are also determined to a large degree by climate. We are now learning first-hand in New England about the adaptive properties of many invasive plant species and exotic insect pests. Forest managers have developed silvicultural and operational practices that are appropriate to the current set of conditions and disturbance regimes. In a rapidly changing climate scenario, many of these "stressors" are likely to change, potentially within the typical rotation length of a New England forest stand. With that change, our forest management strategies must also change. We have presented a forestry adaptation framework based on the assumption of the change that is likely to occur within a suite of stressors. We highlight these stressors and describe some of the relevant issues that current and future forest managers may need to address (Figure 24). We are already seeing elements of these stressors appearing in Maine and elsewhere in New England. For example, many invasive plant species such as Japanese barberry (*Berberis thunbergii*), Asiatic bittersweet (*Celastrus orbiculata*), and exotic species of honeysuckle (*Lonicera spp.*) are gaining footholds in woodlots throughout southern Maine. These invasive species present challenges to regenerating desirable commercial species (Burke and Grime 1996). Other stressors are more speculative at this time, but addressing them requires significant forethought and strategies that anticipate change. With species latitudinal shifts, for example, it is difficult to predict how fast and which species will be most affected by changes in climate. However, several credible models do predict significant change in store for many of today's primary commercial species in Maine (Iverson et al. 2008). A quick review of the top six

Figure 25. Adaptation Toolbox

harvested species in Maine reveals that five of those six are likely to decline in abundance and distribution within the state in most climate change scenarios.

FORESTRY ADAPTATION FRAMEWORK

We present a toolbox approach that incorporates three broad strategies of *Resistance, Resilience,* and *Response* after Noss (2001), Millar et al. (2007), Spittlehouse and Stewart (2003), and Spittlehouse 2005). Figure 25 summarizes these concepts and fundamental management actions. A key fourth element to the framework is the inclusion of mitigation strategies that promote carbon sequestration through practice changes and long-lived wood product storage.

Resistance can be seen as a short-term strategy for primarily high-value resources such as plantations or stands near financial maturity. Specific actions include maintaining adjacent mature stands for protection against wind events or taking early defensive actions against pest species such as the hemlock wooly adelgid (*Adelges tsugae*).

Resilience can be seen both as a short-term and a long-term strategy. Resilience refers to the capacity of a stand or community to recover from a disturbance and return to a reference state (Noss 2001). Since forest communities are most vulnerable to invasion and significant species shift following a disturbance, a strategy that promotes resilience at the stand establishment phase will be important to deliberately maintain desired commercial species. Particularly if climate change results in more frequent stand replacing disturbance types in New England. Resilience strategies must pay particular attention to invasive plant species and maintaining vigorous and diverse communities at the landscape scale.

Enabling Maine's forests to respond to climate change requires an acceptance of a great deal of uncertainty around how quickly change will occur. The primary concept is to facilitate the movement of species over time. Many of the strategies proposed to maintain diversity and landscape connectivity will be appropriate in this case as well. The long-term approach to facilitate response may also include the planting of adapted species and shortening rotation lengths to allow for more frequent modification of genotypes. Response will also require that growth and yield models are adjusted to reflect changing conditions and the tree species characteristics that become more prevalent. This strategy is clearly the most costly and requires acceptance of a level of uncertainty that many landowners will likely not choose (Figure 26).

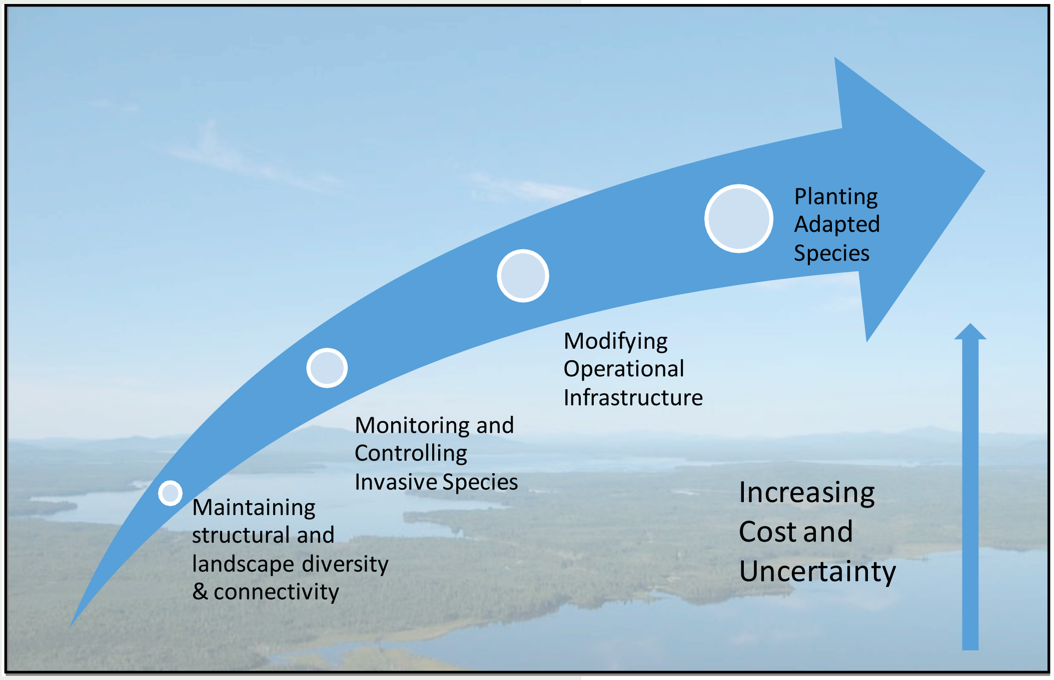

Figure 26. Relative costs of adaptation practices

Many of the management actions we propose under these three strategies have significant overlap with ecological forestry concepts (e.g., Elliot 1999, Lindenmayer and Franklin 2002, Keeton 2007). Our report also describes other operational concerns such as peak flow and watershed assessments that are new to Maine and the Northern Forest but may likely be necessary in a changing climate. The full report and the subsequent abbreviated *Natural Capital Note* identify specific actions that can and should be taken by forest Managers in Maine to adapt commercial forestry in a changing climate. We also make recommendations for a GHG mitigation strategy for carbon-accumulating practices and discuss the relevance of forest product storage of carbon to this strategy.

PRODUCTS

We are finalizing a detailed report and an executive summary for the forestry community which will be released by the end of 2008. We have conveyed our results in an Ecological Forestry Workshop held in October where more than 20 foresters and ecologists were in attendance from the US and Canada. Pending future funding, Manomet will conduct another adaptation workshop in 2009.

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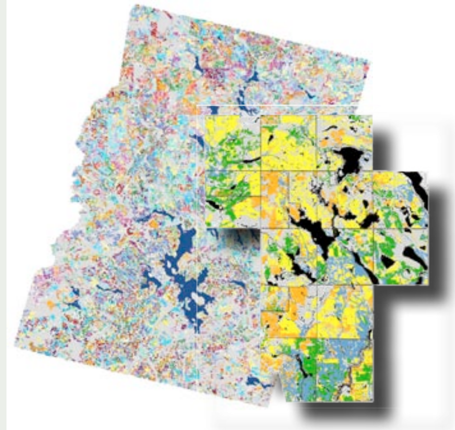
For more information about this project, please contact John Gunn.

Quantifying Biodiversity Values Across Managed Landscapes in Northern and Western Maine



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PROJECT OVERVIEW

Sustainable forestry certification programs require forest managers to monitor and manage the environmental impacts of management activities in order to maintain biodiversity. Landowner efforts for evaluating forest management outcomes and conserving biodiversity could be improved. Landowners often look to current regulations that are aimed at protecting specific landscape features (e.g., bald eagle nesting areas, deer wintering areas, or shoreland zones) as a starting point, but these regulations do not provide the necessary tools for protecting biodiversity at large. Management guidelines and tools are necessary to ensure that, for example, the habitat requirements of early-successional species are also incorporated into long-term forest management planning.

Previous research funded by the CFRU and others has positioned Maine to be a leader in developing methods to assess and monitor landscape-scale biodiversity conservation on certified forestlands. Specifically, the CFRU has funded previous projects to quantify *condition* indicators for managed forests in Maine at the stand-scale (i.e., late successional index, early-successional bird index, snowshoe hare habitat index, and riparian indices) and landscape-scale (i.e., predictive occurrence models for area-sensitive umbrella species, American marten and Canada lynx). These condition indicators are designed to assess the status or current condition of biodiversity. These indicators contrast with indicators of certification programs which only describe landowners' policies, practices, and institutional capacity to protect biodiversity. These indicators can also be integrated into a landscape-scale conservation planning, biodiversity management, and performance scoring framework, which may serve to simplify and standardize landowner efforts to conserve biodiversity.

"Research by the CFRU and others has positioned Maine to be a leader in developing methods to assess and monitor landscape-scale biodiversity conservation on certified forestlands."

We have proposed to apply and evaluate a set of biodiversity indices (collectively called the "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.

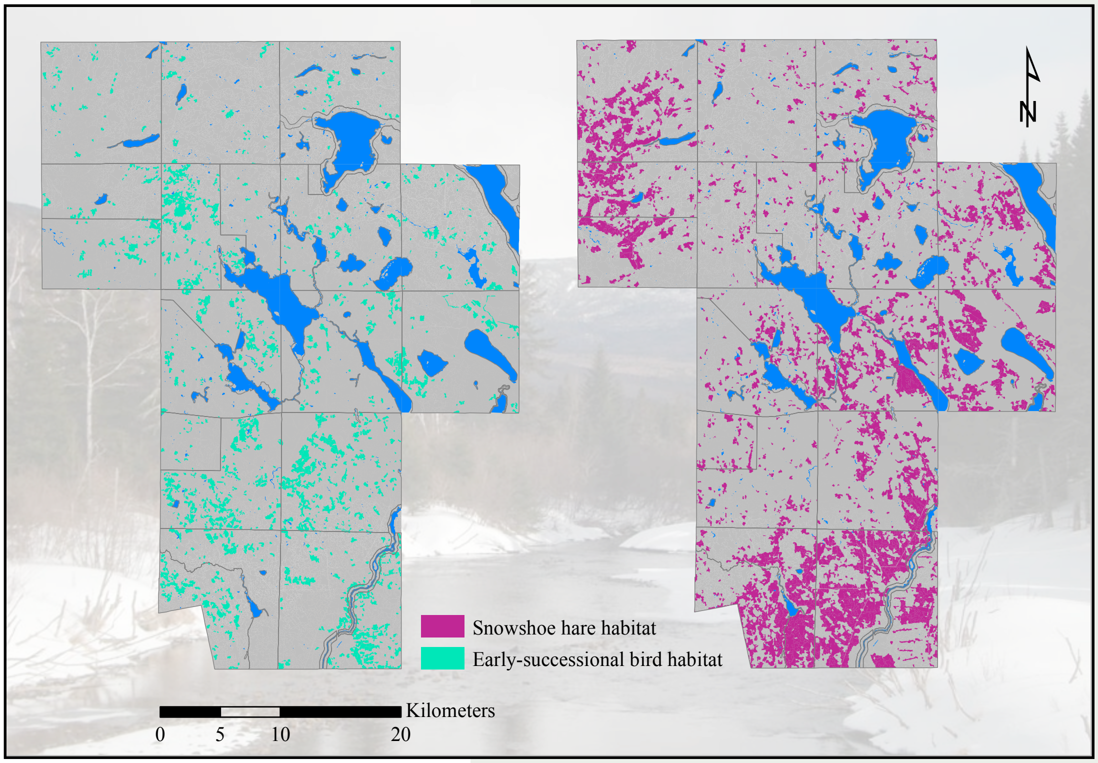

Figure 27. Early-successional bird habitat (*left*) and snowshoe hare habitat (*right*), as modeled based on current stand conditions.

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: i) natural succession, ii) continuing recent forest management trends for included ownerships, and iii) 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 1-8 townships.

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

SUMMARY OF PROGRESS DURING YEAR 2

In the first year we selected 14 townships in north-central Maine that are representative of the variety of forest management legacies that have been created since the 1970s spruce budworm outbreak, including: 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. These townships form a contiguous area (344,034 ac) in north-central Maine and are composed of 27 ownership parcels that include a representative mix of owner types. We used satellite-derived products to create stand-level coverages because a common land cover data set was essential for being able to simulate future forest conditions under the alternative forest management scenarios.

During the second year, we completed the development of the stand-level data for the 14 townships, including harvest history, overstory composition, and estimations of stand size class and stocking density. We than used these data to map and quantify current (ca. 2007) conditions for four of the Scorecard metrics: snowshoe hare habitat index, early-successional bird index, and lynx and marten indices. The snowshoe hare index was calculated as the percent of the landscape in high-quality hare habitat (conifer or mixed, 16-35 year-old regenerating forest) and the early-successional (ES) bird index was calculated as the percent of the landscape in ES bird habitat (< 20-ft tall forest). The lynx and marten indices were calculated as the number of adult, resident animals potentially supported by the landscape using spatially-explicit predictive models developed in northern Maine, the results of which are described in "Predicting responses of forest landscape change on wildlife umbrella species" in the 2007 CFRU Annual Report.

In addition, we completed our assessment of the utility of satellite-derived stand-level data for mapping late-successional (LS) forest. We visited 115 random points located in areas with no harvest history 1970 to 2007 within the 14 township study area, and applied the LS index (Whitman and Hagan 2007) to identify the presence of LS forest structure. Results indicated that 37 % of the random points occurred in LS forest.

PRELIMINARY RESULTS

Based on the snowshoe hare and early-successional bird (Figure 27) index there were 58,488 ac and 22,984 ac of habitat, respectively, distributed broadly across the 14 townships. High-quality snowshoe hare habitat occurred in areas with a history of salvage logging during the 1970s and 80s spruce budworm outbreak. It is estimated that the study area has the potential to support an overall density of 0.21 martens/km^2, which is comparable with marten densities observed previously in north-central Maine in areas with extensive timber harvesting and where martens are trapped (Payer 1991). The study area also has the potential to support an overall density of 2.23 lynx/100 km^2, with areas of higher local density occurring in areas where high-quality hare habitat is aggregated (Figure 27).

PLANS FOR 2009

In the third year we will complete our evaluation of current conditions for the Scorecard metrics included in our analyses (Objective 1) and also evaluate the scalability of each of the included metrics (Objective 2). We will also use the stand-level data to simulate future forest conditions over the next 25 years (2007 to 2032) under the alternative forest management scenarios (Objective 3) to quantify the change in Scorecard metrics. Forest stand projections will be implemented using Woodstock (Version 3.26) forest modeling system in conjunction with the Stanley (Version 5.0) spatial harvesting software. Finally, we will attempt to quantify changes in maximum allowable cut associated with biodiversity planning (Objective 4).

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For more information about this project, please contact Dan Harrison.

Headwater Stream Study

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"Timber harvests near streams should retain a minimum of 40 % shade measured at breast height above the stream surface or 60 % measured one foot above the stream channel."

INTRODUCTION

The Headwater Streams Project was designed to evaluate the effectiveness of different stream buffer widths for protecting water temperature, water chemistry, and other 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 to 2003]). However, because of significant increases in stream temperature that persisted through 2003, the CFRU and NCASI continued to support research to assess the timing of stream temperature recovery. In 2008 we collected our 7th year of post-harvest temperature data from a subset of the original 15 study streams. Data collection was limited to the no-buffer and control treatment groups. This report summarizes water temperature results for all eight field seasons (2001 to 2008) and data on recovery (re-growth) of riparian vegetation and canopy cover (i.e., shade) on streams harvested without a buffer.

STUDY DESIGN

At the beginning of the study (2001) we assigned 15 headwater (1st-order) streams in western Maine to one of five study treatments (Table 8). Streams were measured for water temperature both before harvest (2001), and after harvest (2002- 2008). In each year of the study we deployed automatic temperature recorders at 100-m intervals along a 500-m study reach (Figure 28). Stream temperature data for this report comes from the downstream boundary of the harvest zone (Figure 28). Within the 300-m harvest zone, we measured overhead shade levels using a concave spherical densiometer and height of understory vegetation within 1-m^2 plots adjacent to the stream channel.

RESULTS

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

In 2008, seven years after the harvest, water temperatures in the streams harvested without a buffer returned to pre-harvest levels (Figure 29). At the downstream boundary of the harvest zone (Figure 28) these streams had significantly elevated stream temperatures (2.0-3.4 ^{o}C) in

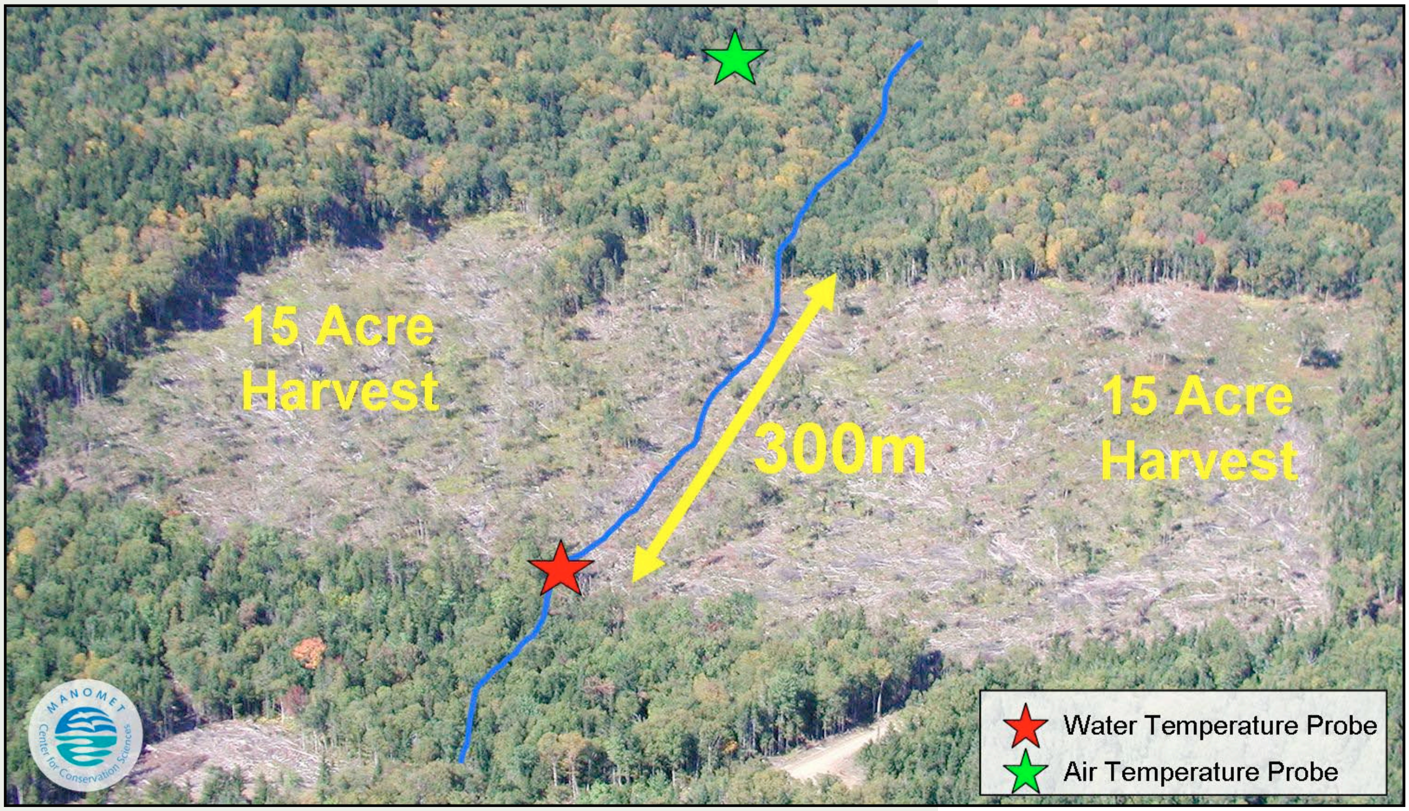


Figure 28. Experimental layout of temperature sensors through harvest zones, in relation to the stream.

the first five years following the harvest (Figure 29, Wilkerson et al. 2006). In the sixth post-harvest year (2007), stream temperatures began to moderate and temperatures returned to pre-harvest levels in 2008.

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 re-growth of vegetation, we 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 2008, the average height of understory was 1.12 m (Table 9), an increase of 0.69 m since measurements began in 2003 (the second post-harvest year).

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 harvest 23-m buffers, both sides	3
Partial Harvest	Partial cuts with no designated buffer	3
Control	No harvesting	3

Table 8. Harvest treatments.

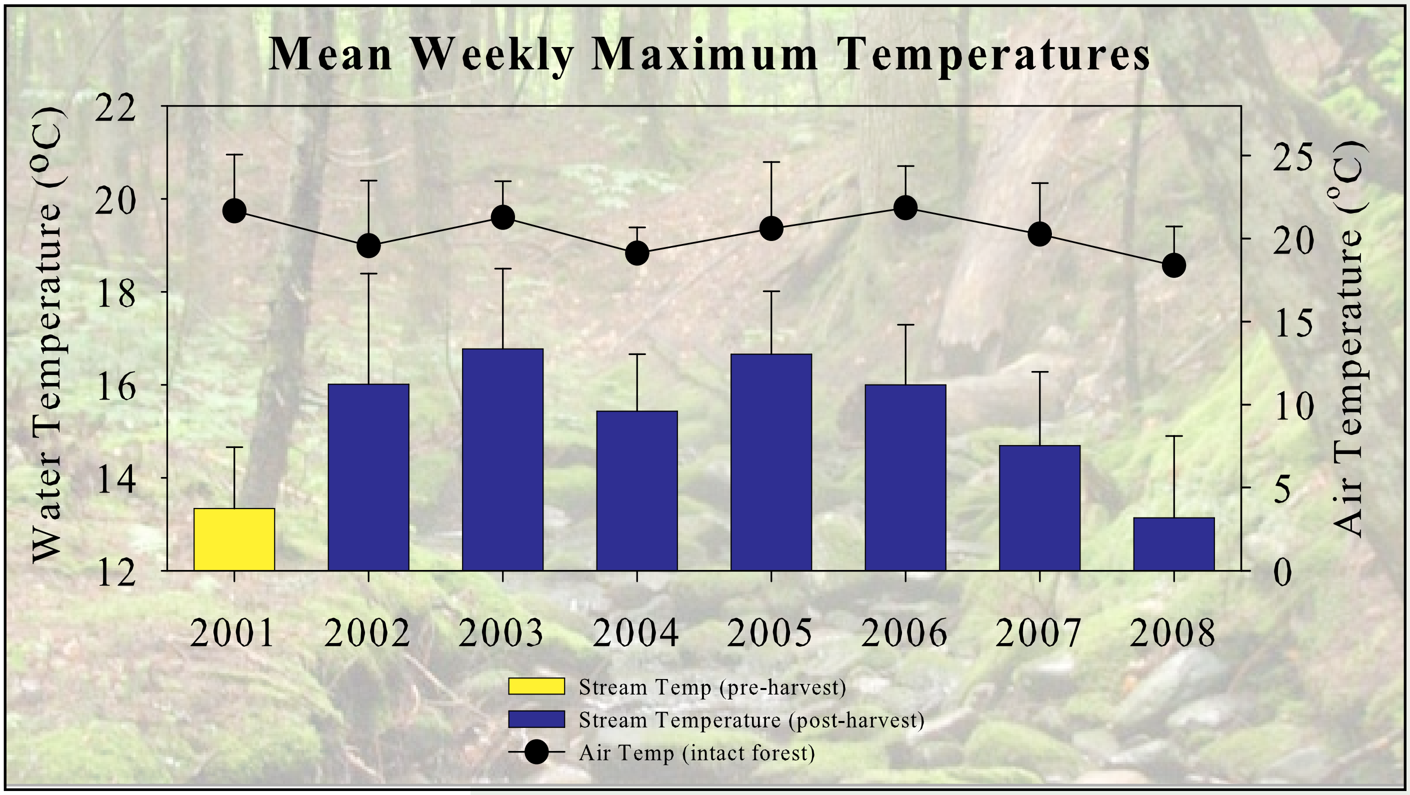


Figure 29. The mean weekly maximum temperature from June 15 - August 15 in the pre-harvest year (2001) and the seven post-harvest years (2002 - 2008). Water temperature readings were taken at the downstream end of the harvest zone. Air temperature readings were taken within intact forest, 100 m from the nearest harvesting and 50 m from the stream channel. Different letters represent significant differences ($p<0.05$) between sampling years.

As the height of the understory vegetation increased, so did shade levels over the stream channel. Immediately after the harvest, shade decreased 66-68 % in the no-buffer treatment group (Figure 30). In 2008, average shade level 0.3 m above the stream channel was 62 %. Shade measured at the traditional height (1.4 m) was 44 % (Figure 30). Shade levels were higher closer to the water's surface because the re-growing streamside vegetation was ≤1 m tall. The recovery of stream temperatures in 2008 to pre-harvest levels suggests that these shade levels are effectively protecting the stream channel from solar radiation. Timber harvests near streams should retain a minimum of 40 % shade measured at the traditional height of 1.4 m above the stream surface or 60 % measured 0.3 m above the stream channel.

Case Study: Stream Temperature and Cold Water Fisheries

Stream temperatures are influenced not only by shade but by site specific variables including stream size (Brown and Krygier 1967), geographic aspect (Kochenderfer and Edwards 1991), and inputs of groundwater (Sullivan et al. 1990). One study stream in the no-buffer treatment group exhibited the largest temperature increases in the study. This stream had a southeastern aspect and the high level of solar radiation resulted in large post-harvest temperature increases. By examining the hourly tem-

Year	Mean (m)	S.E.
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
Post-Harvest yr 7 (2008)	1.12	0.05

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 to 2007 (second through seventh post-harvest years).

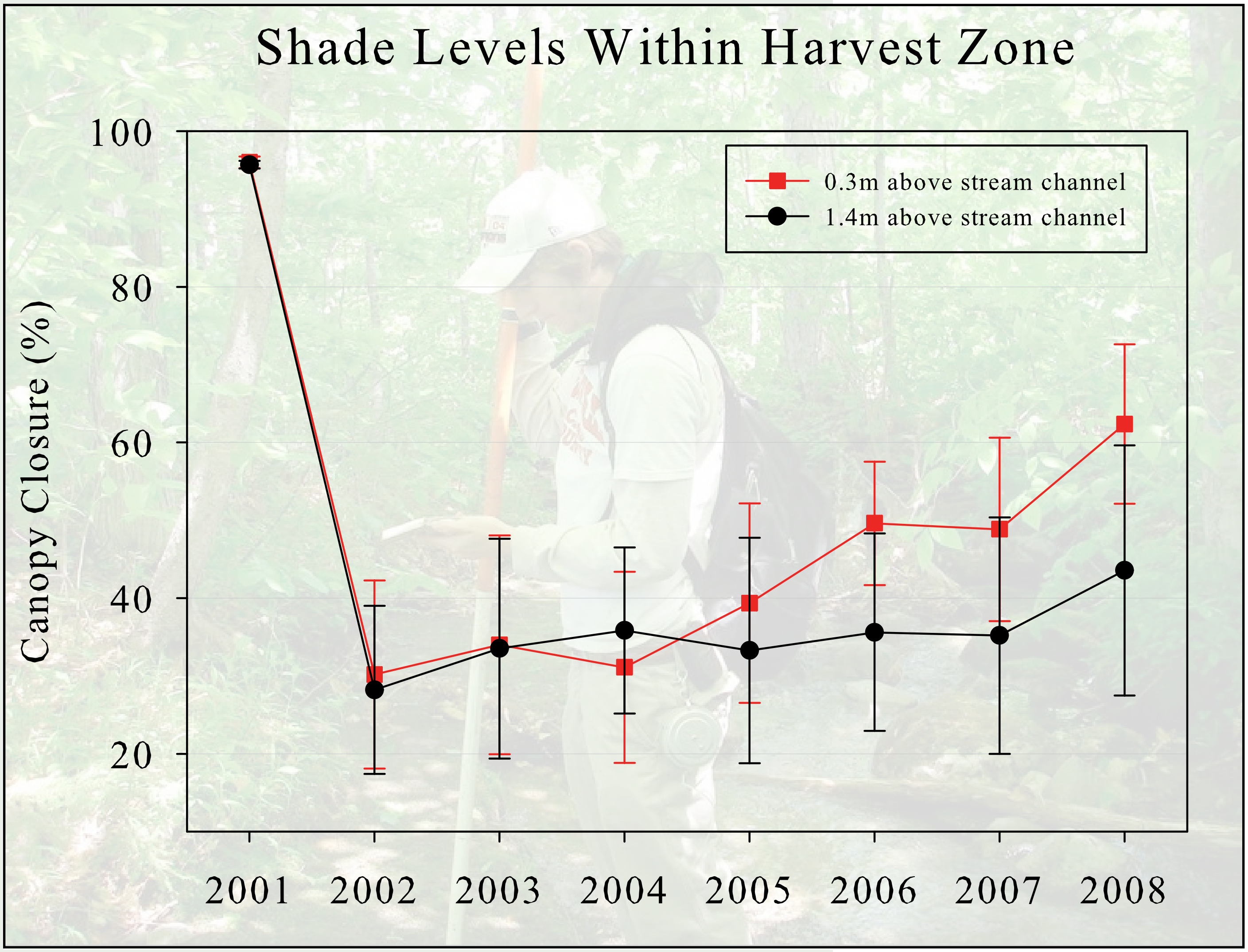
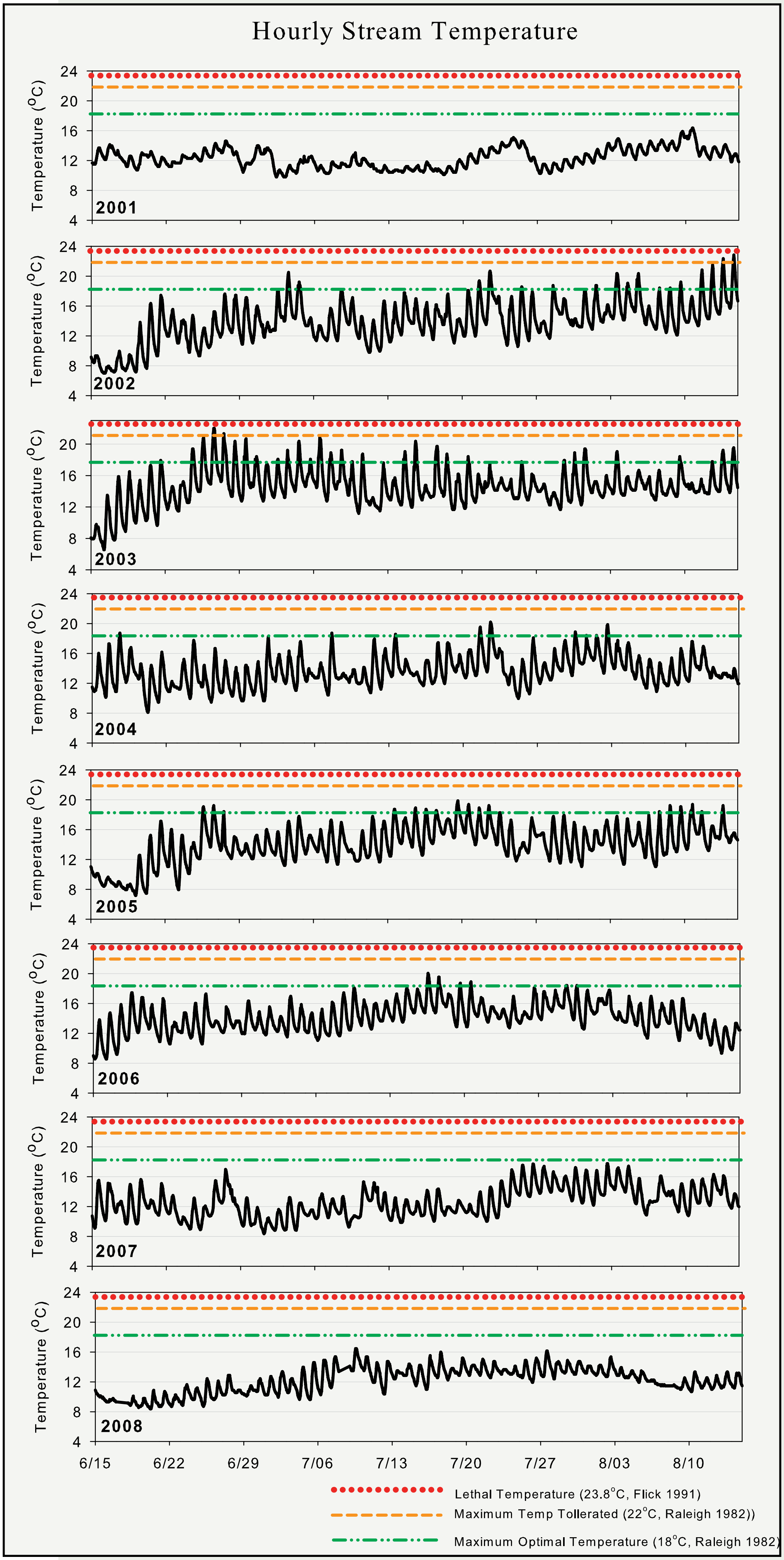


Figure 30. Average shade levels within the harvest zone of the streams without a buffer in the pre-harvest (2001) and six post-harvest years (2002 to 2007). Shade levels were measured at approximately 0.3 m and 1.4 m above the stream channel.

perature readings of this stream for each year of the study (2001 to 2008) we can better understand post-harvest temperature changes and how they relate to habitat requirements of brook trout. Following the harvest, both the maximum temperature and daily temperature range increased (Figure 31). The increase in temperature was greatest in the first two years following the harvest (2002 to 2003). In both these years stream temperatures exceeded 22 °C, the maximum water temperature tolerated by brook trout (Raleigh 1982). In the first 5 years following the harvest (2002 to 2006) water temperature within the harvest zone exceeded 18.3 °C, the maximum optimal temperature for brook trout (Raleigh 1982). However, despite the observed temperature increases stream temperatures never reached 23.8 °C, a temperature considered to be lethal to brook trout (Flick 1991). In 2007 to 2008 (6-7 years after the harvest) stream side vegetation began to shade the stream channel and temperatures remained within the optimal range for brook trout (Figure 31). These data represents an extreme harvest prescription, one that is not commonly applied in Maine. However, it shows the importance of maintaining stream side shade, particularly on southern and southeastern aspects.

Figure 31. Hourly stream temperature within the harvest zone from June 15-August 15 in pre-harvest (2001) and seven post-harvest years (2002 to 2008). The green line represents the maximum extent of the optimum temperature range for brook trout (18 °C, Raleigh 1982). The orange line is the maximum temperature tolerated by brook trout (22 °C, Raleigh 1982) and the red line shows the lethal temperature for brook trout (23.8 °C, Flick 1991).



CONCLUSIONS

In 2008, seven years after the timber harvest, stream temperatures recovered to pre-harvest levels. Streamside vegetation in the unbuffered streams has grown to an average height of 1.12 m in the seven years following harvest. This vegetation contributes to a 60 % shade level near the water's surface. The recovery of stream temperatures in 2008 suggests the streamside vegetation is effectively protecting stream channels from solar radiation.

Streams on southeastern aspects are susceptible to large temperature increases. Harvesting without retaining a buffer or adequate shade can result in stream temperatures that exceed the optimal temperature range of brook trout.

ACKNOWLEDGEMENTS

The Headwater Streams Project was supported by Plum Creek Timber Company, Seven Islands Land Company, Black Bear Forest, Inc., and Wagner Forest Management. Special thanks to many foresters including: John Ackley, Aaron Boone, Frank Cuff, Gordon Gamble, Steve Gettle, Pete Johnson, Dan Lamontagne, Mark Leathers, Kirk MacDonald, and Bryan Savoy who played a key role in making this project a success. We thank the CFRU, NCASI, and Manomet Center for Conservation Sciences for funding this project. Comments are questions about this report are welcomed.

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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.

For more information about this project, please contact Ethel Wilkerson.

The ForCAST Initiative

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"Individual research programs continue to make great strides and we believe the future forest will be best understood by integrating our research efforts."

INTRODUCTION

A new research program is underway in the Center for Research on Sustainable Forests (CRSF; also the home of the CFRU) at the University of Maine. ForCAST, or Forest Conditions, Assessment, Status and Trends is an interdisciplinary research effort that bridges the divide between several forest-related research areas. Several research groups in the U. Maine's School of Forest Resources (SFR), Maine Image Analysis Lab (MIAL), CFRU and Department of Wildlife Ecology have partnered under the direction of the CRSF Director, Dr. Bruce Wiersma to integrate future forest modeling and communication efforts.

An interdisciplinary effort, ForCAST focuses on the following questions about our forests:

1) How will changing ownership of Maine's forest affect harvest patterns and future wood supplies?

2) How will suburban sprawl and land parcelization affect the future of central Maine and pressures on the north Maine woods?

3) How will climate change and pollution affect the future composition and productivity of Maine's forests?

4) How will an emerging bioenergy/bioproducts industry affect Maine's forest and wildlife habitat?

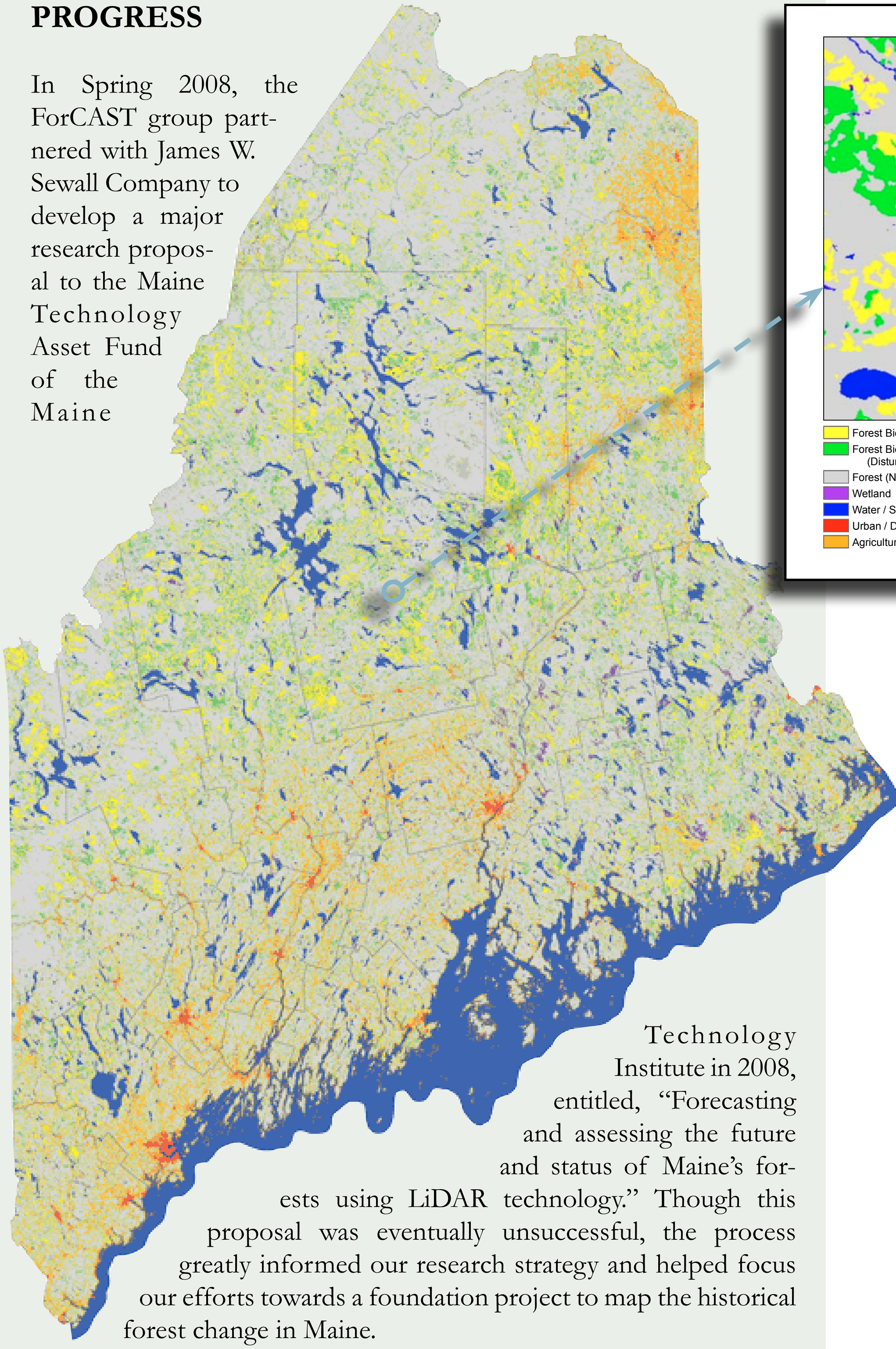
5) How will forest fragmentation affect keystone wildlife species and forest biodiversity?

6) How will exotic and invasive pests affect the future of Maine's forests?

We believe the answers to these questions will drive the future of Maine's forests for products, services and general societal value. Through compiling forest inventories, geographic information systems (GIS) and other long-term databases, ForCAST is building a library of long-term knowledge about our forests with which we will be able to answer these questions. Individual research programs continue to make great strides and we believe the future forest will be best understood by integrating our research efforts. This idea has led us to a truly interdisciplinary approach to ForCAST. The research team currently includes forest ecologists, wildlife biologists, foresters, environmental scientists, remote sensing scientists, biometricians, GIS specialists, and technology and communications experts.

PROGRESS

In Spring 2008, the ForCAST group partnered with James W. Sewall Company to develop a major research proposal to the Maine Technology Asset Fund of the Maine Technology Institute in 2008, entitled, "Forecasting and assessing the future and status of Maine's forests using LiDAR technology." Though this proposal was eventually unsuccessful, the process greatly informed our research strategy and helped focus our efforts towards a foundation project to map the historical forest change in Maine.



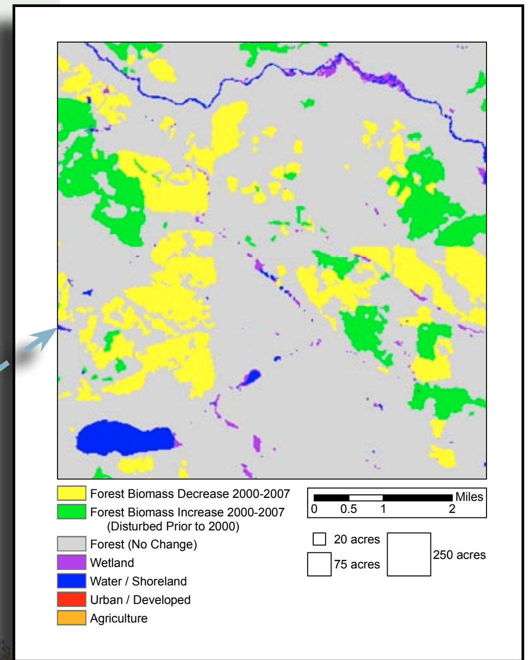


Figure 32. (*Left*) This map depicts the satellite-derived forest cover change in Maine from 2000-2007. (*Above*) This inset map includes an approximately 36 sqare mile area depicting actual stand change.

In May 2008, ForCAST brought Dr. Peter Bettinger of the University of Georgia to the University of Maine to talk to the ForCAST group about his involvement in a major interdisciplinary research effort named Coastal Landscape Analysis and Modeling Study (CLAMS). This program, conducted at at Oregon State University by Dr. Bettinger serves as an interesting and relevant model for ForCAST researchers to look to for guidance as we develop the ForCAST program.

In June 2008, Bruce Wiersma visited the USDA Forest Service Northern Station to discuss ForCAST with Station Director Michael Rains and then traveled to Washington, D.C. to meet with a group of National Program Leaders at the USDA's CSREES headquarters, also to discuss

MAINE ForCAST TOMORROW'S FOREST

ForCAST. The project was enthusiastically supported in both instances and the broad geographic and temporal scope of the ForCAST program is getting attention well beyond the borders of Maine.

In November 2008 ForCAST hosted its first stakeholder seminar to update our funders and partners on the two major projects being carried out (wildlife habitat analysis and forest cover change). The coordinated presentation by ForCAST post-doctoral researcher Dr. Erin Simons and Associate Scientist Kasey Legaard was entitled "Evaluating broad-scale changes in timber harvesting patterns, forest landscape structure, and wildlife habitat supply for umbrella species in Northern Maine."

The first major deliverable from the ForCAST group was completed at the end of this year. The Forest Cover Change map of Maine (Figure 32) is the result of ForCAST team members Kasey Legaard and Dr. Steve Sader, both of the Maine Image Analysis Lab (MIAL). Years of work at MIAL on remote sensing and change detection technology has culminated in ForCAST's ability to show a forest change time series and begin to inform our future modeling efforts. This map and the underlying data will serve as the foundation for relating many forest-related metrics to temporal change and will allow the ForCAST team to be able to predict developments of many metrics, including wildlife habitat dynamics, wood supply analysis, land ownership patterns, spruce budworm vulnerability, and climate change related forest dynamics.

FUTURE PLANS:

With the forest cover change data now available to ForCAST researchers, several other important forest change metrics are being assessed. Most notably, Associate Scientist Dr. Erin Simons is using the past and predictive power of this dataset to investigate future wildlife habitat in Maine. Combined with her work over the last several years with Dr. Dan Harrison, with funding from the CFRU (see Quantifying Biodiversity), Dr. Simons is able to combine temporal forest change and wildlife habitat data to evaluate the future potential of Maine's forests to support important wildlife species, such as lynx and marten.

In Fall 2009, the ForCAST group will host another outreach event to connect with our stakeholders.

For more information about this project, please contact Spencer Meyer.

ACKNOWLEDGMENTS

We thank our many partners in this program, including University of Maine's Vice President for Research, the Cooperative Forestry Research Unit, the Forest Bioproducts Initiative, and the Nature Conservancy. In addition, we have benefitted from the engagement of many other stakeholders and we hope to continue to development these partnerships in the coming years of the ForCAST Initiative.

Outreach

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Contact Information

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OUTREACH

JOURNAL PUBLICATIONS

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

Greenwood, M.S., C.L. O'Brien, J.D. Schatz, C.A. Diggins, M.E. Day, G.L. Jacobson, A.S. White and R.G. Wagner. 2008. Is early life cycle success a determinant of the abundance of red spruce and balsam fir. Canadian Journal of Forest Research. 38: 2295-2305.

Saunders, M.R. and R.G. Wagner. 2008. Height-diameter models with random coefficients and site variables for tree species of central Maine. Annals of Forest Science 65(2): 203.

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Seymour, R.S. 2007. Low-density management of white pine crop trees: a primer and short-term research results. Northern Journal of Applied Forestry: 24(4):301-306.

RESEARCH REPORTS

Beane, J.L., J.M. Hagan, A.A. Whitman, and J.S. Gunn. 2008. Forest Carbon Offsets: A Scorecard for Evaluating Project Quality. Manomet Center for Conservation Sciences Report MCCS NCI 2008-1, Brunswick, Maine; available on-line: www.manometmaine.org.

Fuller, A.K, D. J. Harrison, B. J. Hearn. Application and testing of models to predict probability of occupancy and density of endangered Newfoundland martens. Final Contract Report to Natural Resources Canada, Newfoundland-Labrador Wildlife Division, and Western Newfoundland Model Forest, Corner Brook, Newfoundland. 75 pp.

Meyer, S.R. 2008. We Found the Sweet Spot: 2nd Year Results Confirm Beech Can Be Controlled. CFRU Results Series #6. 1 p.

Meyer, S.R. 2008. Control the Beech, Grow the Maple. CFRU Results Series #5. 1 p.

Saunders, M.R., R.G. Wagner, R.S. Seymour. 2008. Thinning Regimes for Spruce-Fir Stands in the Northeastern United States and Eastern Canada. Final Report Submitted to the USFS Agenda 2020 Program. Cooperative Forestry Research Unit, University of Maine, Orono, ME.

Perry, T.E., R.S. Seymour, and R.G. Wagner. 2008. Assessment of Harvest Characteristics and Silvicultural Outcomes Survey: A Component of the Maine Forest Service Multi-Resource Harvest Assessment Protocol. Final Report submitted to the Maine Forest Service. University of Maine, School of Forest Resources, Orono, ME.

CONFERENCE PROCEEDINGS

Briedis, J., J. Wilson, R. Wagner, and J. Benjamin. 2008. Logging residue quantities on sites in Maine following integrated whole-tree harvests of biomass and roundwood. pp. 71 In Proceedings of Eastern CANUSA Conference, October 17-19, Orono, ME.

Coup, C., J. Benjamin, and R. Wagner. 2008. An assessment of residual stand damage following whole-tree biomass harvesting in central Maine. pp. 73 In Proceedings of Eastern CANUSA Conference, October 17-19, Orono, ME.

The CFRU continually strives to communicate the results from our research with all our stakeholders, including our members, the scientific community, policy-makers and the concerned public. We publish articles in peer-reviewed journals, CFRU Research Reports, Results briefs, conference proceedings and in popular media.

In addition to published research, CFRU scientists and staff routinely present research findings to many audiences, including scientific conferences, field workshops for members and others, industry forums, stakeholder meetings and public forest awareness events.

LeDoux, C.B and Wilkerson E. 2008 Assessing the ecological benefits and opportunity costs of alternative stream management zone widths In: Deal, R.L., tech. ed. Integrated restoration of forested ecosystems to achieve multiresource benefits: proceedings of the 2007 National Silviculture workshop; 2007 May 7-10; Ketchikan, AK. Gen. Tech. Rep. PNW-733. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 193-209.

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Meyer, S.R. (Ed.) 2008. Conference Proceedings: ECANUSA Forest Science Conference. Orono, Maine. October 17-18, 2008. 105 pp.

Nelson, A.S., and R.G. Wagner. 2008. Spatial patterns of natural regeneration in northern hardwood stands in Maine. pp. 87 In Proceedings of Eastern CANUSA Conference, October 17-19, Orono, ME.

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Olson, M.G. and R.G. Wagner. 2008. Long-term study on the influence of silvicultural intensity and composition objectives on the productivity of regenerating forest stands in Maine. pp. 88 In Proceedings of Eastern CANUSA Conference, October 17-19, Orono, ME.

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Seymour, R.S. R.G. Wagner, and S. Meyer. 2008. Commercial thinning in pole-sized spruce-fir stands: 6-year results from the CFRU thinning study. pp. 56 In Proceedings of Eastern CANUSA Conference, October 17-19, Orono, ME.

Zellers, K.E. R.S. Seymour, W. Livingston, and R.G. Wagner. 2008. Patterns of regeneration of eastern white pine (Pinus strobus L.) as influenced by large isolated crop trees and precommercial thinning. pp. 103 In Proceedings of Eastern CANUSA Conference, October 17-19, Orono, ME.

Zellers, C., R.S. Seymour, A.R. Weiskittel, J.G. Benjamin. 2008. Growth, Log Characteristics, And Financial Maturity Of Isolated Archetypal Eastern White Pine (Pinus Strobus L.) Trees. Eastern CANUSA Forest Science Conference (Poster Session). University of Maine. October 17-18.

Each summer, CFRU field crews take a break from their hard work and enjoy a hike somewhere in the Maine Woods. In this photo, crew members Alex Small and Tom Perry hike up the Helon Taylor Trail on Katahdin.

PRESENTATIONS

Benjamin, J.G. 2008. Guiding Principles of Biomass Harvesting in Maine. Invited Presentation for The Northern Forest Alliance 2008 Annual Meeting. Crawford Notch, New Hampshire. October 22, 2008.

Benjamin, J.G. 2008. Biomass Harvesting: How Much is Enough? Invited presentation for SAF – Maine Division Spring Field Tour. May 30.

Benjamin, J.G. 2008. Biomass Harvesting: More Questions Than Answers. Invited presentation for Wagner Forest Management – Forester Training Workshop. Saddleback, ME. May 6.

Fuller, A. K., D. J. Harrison, and B. J. Hearn. 2008. Application and testing of models to predict probability of occupancy and density of endangered Newfoundland martens. Presentation to Newfoundland Marten Recovery Team, Corner Brook, Newfoundland. January 4, 2008.

Fuller, A. K., D. J. Harrison, and B. J. Hearn. 2008. Application and testing of models to predict probability of occupancy and density of endangered Newfoundland martens. Presentation to Newfoundland Marten Recovery Team, Corner Brook, Newfoundland. January 4.

Fuller, A. K., D. J. Harrison, and B. J. Hearn. 2008. Spatial responses to habitat loss in two isolated populations of forest martens. Invited talk in the Ecology, Evolution, and Behavior seminar series. Virginia Tech. University, Blacksburg. February 1.

Fuller, A. K., D. J. Harrison, and W. B. Krohn. Landscape planning initiative for northern Maine using area sensitive umbrella species. Invited presentation at USDA Natural Resources Conservation Service and U.S. Fish and Wildlife Service workshop on the Healthy Forest Reserve Program in Maine, Bangor, Maine. July 1.

Fuller, A. K., D. J. Harrison, B. K. Hearn, and J. A. Hepinstall. Spatial responses to habitat loss in 2 populations of forest martens. Paper presented at The Wildlife Society 15th Annual Conference, Miami, Florida. November 11.

Fuller, A. K., D. J. Harrison, and W. B. Krohn. Applications of lynx and marten models to operational forest management. Invited presentation at Lynx on the landscape: workshop and fall field tour, Cooperative Forestry Research Unit, Greenville, Maine. October 28.

Harrison, D. J., W. B. Krohn, and A. K. Fuller. Long-term monitoring of snowshoe hare populations to inform stand- and landscape-scale forest management and recovery planning for Canada lynx in Maine. Presentation to Advisory Committee, Maine Cooperative Forestry Research Unit, Orono. April 9.

Harrison, D. J., A. K. Fuller, and E. Simons. Trends in habitat supply for wildlife species whose habitat requirements are not addressed using coarse-filter umbrella species approaches, with a focus on deer wintering areas. Presentation to Advisory Committee, Maine Cooperative Forestry Research Unit, Orono. April 9.

Harrison, D. J., W. B. Krohn, S. Scott, A. K. Fuller, and L. Robinson. Stand-scale management to increase hare and lynx populations. Invited presentation at Bridging Science and Stewardship Workshop, Maine Cooperative Forestry Research Unit, Brewer, Maine. May 14.

Harrison, D. J., A. K. Fuller, J. A. Hepinstall, and E. Simons. Forests, forest carnivores, and fragmentation: Wildlife-habitat relationships in the Acadian forests of Maine, USA. Invited seminar, Department of Ecology and Natural Resource Management, Norwegian University of Life Sciences, As, Norway. September 16.

Harrison, D. J., A. K. Fuller, J. A. Hepinstall, and E. Simons. Forests carnivores as a tool for landscape conservation: Case studies focusing on American martens and Canada lynx. Seminar presented at Grimso Wildlife Research Station, Lindesberg, Sweden. September 19.

Harrison, D. J., A. K. Fuller, J. A. Hepinstall, E. Simons, B. J. Hearn, and D. Payer. Forests, forestry, and forest martens: a landscape perspective. Invited presentation at conference titled: Pour une sylviculture adaptee a al feret irreguliere et sa faune, Faculty of Forestry, University of Laval, Baie Comeau, Quebec. October 8.

Krohn W. B., D. J. Harrison, S. A Scott, L. L. Robinson, C. L. Hoving, A. K. Fuller, and E. M. Simons. Variation in snowshoe hare densities as related to Canada lynx and forest management in eastern North America. Presentation at Eastern CANUSA Forest Science Conference, Orono, Maine. October 17.

LeDoux C.B., and E. Wilkerson. 2008. A method for quantifying and comparing the costs and benefits of alternative riparian zone buffer widths. 16th Central Hardwood Forest Conference; 2008 April 8-9; Lafayette, IN.

Meyer, S.R. From the Lab to the Lands: Four Decades of CFRU Research. A presentation to School of Forest Resources. Orono, Maine. November 7, 2008.

Meyer, S.R. Building Partnerships for Forest Research in Maine. A presentation to the USFS Northern Research Station Director. July 10, 2008.

Meyer, S.R. CFRU: A Partnership for Sustainable Forest Management. A presentation to the management and foresters of Wagner Forest Management. Rangeley, Maine. May 6, 2008.

Scott, S., D.J. Harrison, and W. B. Krohn. Partial harvests: contributing to foraging habitat?. Presentation at Lynx on the Landscape Workshop, Maine Cooperative Forestry Research Unit , Workshop. Greenville, ME. October 28.

Simons, E. M., D. J. Harrison, W. B. Krohn, K. R. Legaard, and S. Sader. Trends in American marten habitat on the commercial forestlands of northern Maine. Presented at Impact of Wildlife on the Forest Industry Workshop, New England Regional Council on Forest Engineering, University of Maine, Orono. March 10.

Forest pathologists, entomologists and other scientsts listen to a presentation in the field at a recent CFRU workshop.

Simons, E. M., D. J. Harrison, W. B. Krohn, K. R. Legaard, and S. Sader. Predicting responses of forest landscape change on wildlife umbrella species. Presentation to the Maine Cooperative Forestry Research Unit Advisory Committee, Orono. April 7.

Simons, E. M., D. J. Harrison, W. B. Krohn, K. R. Legaard, S. Sader, and J. S. Wilson. Landscape indicators of forest biodiversity: application of American marten, Canada lynx, and snowshoe hares. Presentation at Bridging Science and Stewardship Workshop, Maine Cooperative Forestry Research Unit, Brewer. May 14.

Simons, E. M., D. J. Harrison, W. B. Krohn, K. R. Legaard and S. A. Sader. Ecological factors associated with landscape-scale occurrences of Canada lynx in northern Maine. Invited Presentation at Lynx on the Landscape: What You Need to Know Workshop and Field Tour, Maine Cooperative Forestry Research Unit, Greenville, Maine. October 29.

Simons, E. M., D. J. Harrison, W. B. Krohn, K. R. Legaard, and S. A. Sader. Retrospective changes in habitat supply for Canada lynx and snowshoe hares resulting from timber harvesting: Implications for lynx recovery? Paper presented at The Wildlife Society 15th Annual Conference, Miami, Florida. November 9.

Simons, E. M., K. R. Legaard (Co-Presenters), D. J. Harrison, W. B. Krohn, and S. Sader. Evaluating broad-scale changes in timber harvesting patterns, forest landscape structure, and wildlife habitat supply for umbrella species in northern Maine. Invited presentation at Friends of ForCAST, Center for Research on Sustainable Forests, Orono. November 20.

Wagner, R.G., Silviculture research tour of long-term studies on Penobscot Experimental Forest, Project Learning Tree Workshop for Maine high school teachers, August 14, 2008, Orono, ME (Aug 08).

Wagner, R.G., Latest research in forest management and forest bioproducts, Project Learning Tree Workshop for Maine high school teachers, August 12, 2008, Orono, ME (Aug 08).

Wagner, R.G., Sustainability of a Maine Forest Bioenergy/Bioproducts Industry?, Gravure Association of America Environmental Workshop, June 17-19, 2008, Atlantic Oakes Resort, Bar Harbor, ME. (Jun 08)

Wagner, R.G., Forest Bioproducts Initiative Update, Board of Advisors, Maine Forest Products Council, Augusta, ME. (May 08)

Wagner, R.G., Maine Forest Service harvest Classification System, Board of Advisors, Maine Forest Products Council, Augusta, ME. (May 08)

Wagner, R.G., Improving Species Composition of Hardwood Regeneration in Beech-Dominated Understories: First-Year Results. CFRU Research Workshop, May 14, 2008, Brewer, ME (May 08)

Wagner, R.G., Maine Forest Service Multi-Resource Harvest Assessment: Silvicultural Outcomes Component. CFRU Research Workshop, May 14, 2008, Brewer, ME (May 08)

Wagner, R.G., Principles of Vegetative Competition in Young Forest Stands. Conference on Sustainable Forests: The Role of Vegetation Management with Herbicide, April 10 - 11, 2008, Hilton Garden Inn, Saskatoon, SK (Invited Keynote) (Apr 08)

Wagner, R.G., The Role of Vegetation Management for Increasing Productivity and Conservation of the World's Forests. Conference on Sustainable Forests: The Role of Vegetation Management with Herbicide, April 10 - 11, 2008, Hilton Garden Inn, Saskatoon, SK (Apr 08)

Wagner, R.G., Sustainability, Economic Viability, and Social Acceptability of a Forest Bioproducts Industry in Maine, Northern Forest Forum, Maine Division of Society of American Foresters, Caribou, ME (Apr 08)

Wagner, R.G., Sustainability of a Maine Forest Bioproducts Industry?, Project Learning Tree Training Session, Schoodic Point, ME (Mar 08)

Wagner, R.G., Overview of CFRU, Center for Advanced Forestry Systems Annual Meeting, Portland, OR (Feb 08)

Wagner, R.G., Sustainability, Economic Viability, and Social Acceptability of a Forest Bioproducts Industry in Maine, Northern Forest Alliance meeting, Augusta, ME (Jan 08)

Whitman, A.A. 2008. Late-successional attributes in stands of differing silvicultural treatments in northern hardwoods & upland spruce-fir forest. 4th Biennial Eastern CANUSA Forest Science Conference, University of Maine, Orono, ME. Oct 17th – 18th, 2008.

Whitman, A.A., J. Gunn, and E. Wilkerson. 2008. Ecological Forestry. Field training workshop for field foresters, Stratton, ME. October 15, 2008 (15 participants: foresters and land managers).

Wilkerson, E. 2007. A Biodiversity Scorecard. Maine Water Conference, Augusta, Maine. March 21, 2007.

Wilkerson, E. and A. Whitman. 2008. Aquatic Coarse Woody Debris: Implications of past and present management practices. Maine Water Conference, March 19, 2008.

Wilkerson, E. 2008. Forest Management Considerations for Riparian Biodiversity. CFRU Spring Forester's Workshop, Brewer, ME, May 14, 2008.

OTHER

Meyer, S.R. 2008. A Friendly, Working Relationship Keeps Landowners and Recreationalists Happy. Bangor Daily News, Experience Maine, Winter Edition. December 4, 2008.

Meyer, S.R. 2008. From the Lab to the Land: Maine Landowners Partner for Sustainable Forestry Research. Bangor Daily News, Forest Products Week Supplement. October 23, 2008.

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CFRU Advsiory members (l to r: Carol Redelsheimer, unknown, Marcia McKeague, Dave Wilson and graduate student Andrew Nelson) discuss harvest operations during a tour to the Baxter State Park Scientific Forest Management Area.

CFRU Contacts

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