





CFRU

COOPERATIVE FORESTRY RESEARCH UNIT

2005 - 2006
Annual Report

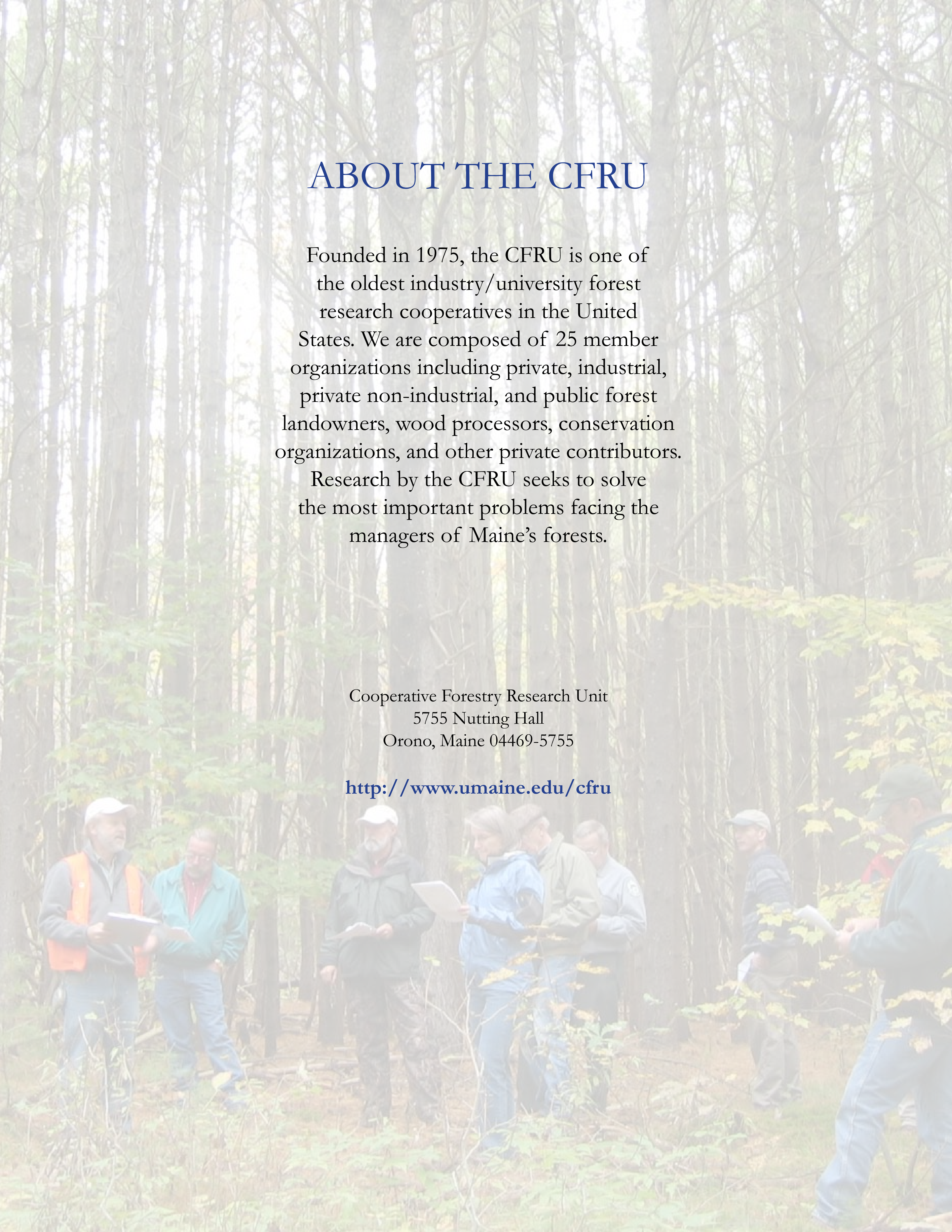
Center for Research on Sustainable Forests

COOPERATIVE FORESTRY RESEARCH UNIT ANNUAL REPORT 2005 - 2006

CFRU

1865 THE UNIVERSITY OF MAINE

Maine Agricultural & Forest Experiment Station
Miscellaneous Report 440



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

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

http://www.umaine.edu/cfru

Contents

Organization

Sometimes you need to have a look inside the trees.

Research

Silviculture

Wildlife

Biodiversity

Appendices

Introduction

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

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

Just as it has since its inception over 30 years ago, CFRU continues to conduct applied scientific research that contributes to the sustainable management of Maine's forests. Results from a variety of research projects addressing silviculture, wildlife ecology, and biodiversity conservation needs are presented in this report. Regular quarterly meetings, workshops, field tours, and conferences are sponsored by CFRU to rapidly communicate the latest research results. Publications such as, *Results*, research reports, graduate theses, and journal articles are ways we document the findings. Members have immediate access to the latest information, as well as over 30 years of past technical publications, through our web page. Technical advice and recommendations to cooperators continue to be benefits of membership and have been a hallmark of our organization since its earliest days. This report documents progress made by the CFRU during fiscal year 2005-2006.

Maine's forestland is an integral part of Maine's landscape and economy.

Highlights

ORGANIZATION

- Due to an increase in membership, CFRU acreage rose from 7.84 to 7.99 million acres in 2006 (see Financial Report).
- The Appalachian Mountain Club, The Forestland Group, LLC and Baxter State Park - SFMA joined the CFRU in 2005 (see Director's Report).
- Total CFRU revenues for 2006 reached $582,881 (see Financial Report).
- For every dollar contributed, CFRU scientists leveraged an additional $14.57 (see Financial Report).
- The CFRU became part of the Center for Research on Sustainable Forests at the University of Maine. (see Director's Report).

COMMUNICATIONS

- The CFRU implemented the *Science Spotlight* artile series to better communicate with policy makers and the public (see Activities).
- CFRU scientists, staff, and graduate students delivered more than 20 publications and 31 presentations on their latest research results (see Outreach).
- The *Research, Results and the Resource* Workshop was held to inform CFRU forest managers about the newest results from CFRU research (see Activities).

RESEARCH

Silviculture

- The sixth year of remeasurements were completed on the Commercial Thinning Research Network and preparations were made for the next thinning in the PCT stands (see CTRN).
- 5.6 million acres of CFRU member lands were mapped for the depth-to-water table. (see Depth-to-Water Table).
- A comprehensive analysis of precommercial thinning was evaluated and results suggest PCT may increase yields over a rotation (see PCT).
- The first year of the beech managment study was completed and all plots were installed and treated (see Beech Composition).
- The CFRU completed the second year of investigation into the ecology and silviculture of white cedar (see Cedar).

Wildlife Ecology

- Predictive landscape models are being developed to track umbrella species habitat change over time (see Umbrella Landscape).
- The temporal and spatial relationships between hares, lynx and habitat suggest hare densities have remained stable since 1996 and that partially harvested stands vary greatly in hare densities and stand structures (see Spatial Relationships).
- Hare densities are strong influeced by managmet and regenerating, conifer clearcuts support the highest number of hares (see Hare and Lynx).

Biodiversity Conservation

- The Biodiversity Scorecard brings together many aspects of past CFRU research by combining indicators to create a quantitate system of rating biodiversity (see Biodiversity Scorecard).
- Now in its sixth year of remeasurement, the Headwater Stream study documents the increase of stream temperature associated with harvests without buffers (see Headwater Stream).

Membership

MAJOR COOPERATORS

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

OTHER COOPERATORS

Field Timberlands
Finestkind Tree Farms
Hancock Lumber Company, Inc.
Huber Wood Products
LandVest
Peavey Manufacturing Company
Si and Lila Balch
Western Maine Nurseries, Inc.

People

Staff

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

Spencer R. Meyer
Research and Communications Coordinator

Michael R. Saunders
Forest Biometrician

Dana M. Smith
Administrative Assistant

Cooperating Scientists

Michael S. Greenwood
Professor of Forest Ecosystem Science

John M. Hagan
Manomet Center for Conservation Sciences

Daniel J. Harrison
Professor of Wildlife Ecology

Robert S. Seymour
Curtis Hutchins Professor of Forest Resources

Project Scientists

Tim McGrath
Nova Scotia Dept. of Natural Resources

Ralph D. Nyland
State University of New York ESF, New York

Andrew A. Whitman
Manomet Center for Conservation Sciences

Jeremy S. Wilson
Irving Chair for
Forest Ecosystem Management

Advisory

Officers

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

Members

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

The Advisory Committee governs all the affairs of the CFRU and ensures that ongoing and new research is conducted to the highest standards. We thank all the committee members and officers, **Kenny Fergusson** (Chair), **George Motta** (Vice-Chair), **Doug Denico** (Financial Officer), and **Mike Dann** (Member-at-Large) for their hard work and dedication over this past year.

Quarterly Advisory Committee meetings, which provide the means for direct interaction with our members, serve as a key forum for scientists and landowners to discuss research ideas and ensure that all CFRU projects are relevant, applicable, and of the highest quality. The Advisory Committee met three times this year: October 4-5, 2005, January 25, 2006 and April 26, 2006.

The October meeting included our annual fall field tour, themed "Managing the White Pine Resource" and included a stop at the University Forest in Old Town and a visit to **Robbins Lumber** operations in Searsmont, Maine. This year's theme of white pine management was stimulated by increasing discussion amongst scientists and Advisory members about white pine. To discuss future research needs and opportunities, the group first visited the white pine thinning trial at the University Forest and then toured the Robbins Lumber operations in Searsmont. Upon arrival, the group was treated to a tour of the impressive Robbins sawmill. After lunch, the group headed across the St. George River to see first hand where many of those logs grow on some of Robbins' own land. Though we had a small turnout of about fifteen folks for the day, those in attendance benefited from considerable discussion and a very cooperative exchange of ideas. CFRU Scientist, **Bob Seymour**, and Robbins foresters, **Pete Joliffe** and **Harry Potter**, led a spirited discussion about early-, mid- and late-stage pine management. Ask a dozen foresters how to grow clear pine logs and you'll get two dozen answers!

Bob Seymour touts the benefits of low density pine management in the University Forest.

Above: Bruce McLaughlin of Robbins Lumber shows CFRU members one pine grading machine. Left: Pallets of Robbins pine lumber sit ready for packaging and shipping.

COMMITTEE MEMBER CHANGES

The addition of new organizations to CFRU this year (see Director's Report) gave us the chance to welcome three new members to the Advisory Committee. We are pleased to welcome **Carol Redelsheimer (Baxter State Park, Scientific Forest Management Area)**, **David Publicover** (**Appalachain Mountain Club**) and **Brian Condon** (**The Forestland Group, LLC**) to the committee. We look forward to working with them in the coming years.

We thank **Jim Robbins** and all his family and staff for showing us their thoroughly impressive mill facility and some of their woodlands. We appreciate them opening their doors and woodlot to benefit the CFRU.

Chair Report

2006 proved to be another busy and productive year for the CFRU. It has been my good fortune to have served as Chair of the Advisory Committee during a period that the CFRU is experiencing both health and vitality. Our total enrolled area remains high, just shy of eight million acres. The CFRU has continued to include and expand the commitment of a diverse group of organizations that contribute funding, guidance and research questions. Scientists have brought forward many interesting research questions that fit the cooperators forest management needs and we are reaping the rewards of the sustained effort to keep the CFRU a meaningful and credible source of answers to forest management challenges.

This year we welcomed a number of new members: The Forestland Group, LLC (TFG), Baxter State Park, Scientific Forest Management Area (SFMA) and the Appalachian Mountain Club (AMC). We are excited to have **Brian Condon** (TFG), **Carol Redelsheimer** (SFMA) and **David Publicover** (AMC) join us around the table as their representatives. We look forward to their Advisory contributions. Engaged members providing fresh perspectives really help make the CFRU a strong organization.

One of the most meaningful parts of CFRU is the application of the results gleaned from all the research efforts. While we may never know exactly how much of this work has influenced management on the individual ownership level, one recent example of CFRU research informing policy involved questions and concerns regarding the listing of Canada lynx. Research results from CFRU-sponsored studies helped mitigate the creation of legislation around lynx habitat. This outcome was the result of many years of research from various groups with CFRU providing pivotal information to make science-based, informed decisions.

The results that have been generated from CFRU research cover a wide spectrum of topics and have been distributed through several pathways. They include articles published in scientific journals, such as the *Canadian Journal of Forest Research* and the *Wildlife Society Bulletin*; notes in *UMaine Today*; our own *Science Spotlights* articles meant to inform Maine policy makers; presentations at professional conferences; as well as postings on CFRU's wide-reaching website. These communications address subjects ranging from softwood growth and yield, to interference of hardwood regeneration, to the importance of long-term forest research, to riparian zone impacts on plant communities, to ecological relationships between snowshoe hares and Canada lynx. These publications not only inform CFRU members but also legislators and the public, and the payoff is a community better informed about ever-changing forest management challenges.

Last year I wrote, "The future is uncertain." While this remains true, the questions surrounding the structure and organization at the University have been clarified. This year saw the creation of the Center for Research on Sustainable Forests (CRSF). CFRU is now housed within the CRSF, which also includes the congressionally authorized Northern States Research Cooperative made up of Maine, New Hampshire, Vermont and New York. CRSF is led by the former dean of the College of Natural Sciences, Forestry and Agriculture, **Bruce Wiersma**, and is dedicated to understanding and providing information about the long-term sustainability of Maine's forests.

There is a great deal of energy around this new entity that may well offer additional funding opportunities for CFRU-sponsored research.

As ever, the backbone of any organization is the staff. Led by our energetic Director **Bob Wagner**, the team of **Spencer Meyer** (Research and Communications Coordinator), **Dana Smith** (Administrative Assistant), and **Michael Saunders** (Biometrician), have kept the unit on full screech (and within budget). Our current crop of cooperating scientists (**John Hagan**, **Dan Harrison**, and **Bob Seymour**) and project scientists (**Tim McGrath**, **Ralph Nyland**, **Jeremy Wilson,** and **Andrew Whitman**) continue to contribute an incredible amount of effort, thought, and time. And, finally, I would like to acknowledge **Mike Greenwood**, whose term as Cooperating Scientist ended this year after a long run through the years. Mike's thoughtful contributions greatly help our endeavors. Thank you Mike for all you have done.

With several exciting, new research projects coming out of the gates, I look forward to the coming year as the CFRU continues to work towards meeting evolving challenges in the Maine woods.

Kenny Fergusson

CFRU Advisory Committee Chair

Kenny inspects some bryophytes during a CFRU field tour.

Director's Report

I am happy to report that this was one of those years where the value of CFRU to its member organizations was much higher than usual. Two notable accomplishments (lynx research and depth-to-water-table mapping) made significant practical contributions to our members.

Foresight by CFRU members six years ago to invest in a series of research projects led by **Dr. Dan Harrison** to investigate the effects forest management practices in northern Maine on snowshoe hare and Canada lynx (see Hare and Lynx) paid large dividends this year. Results from this research clearly indicated that forest management practices are compatible with the habitat needs of snowshoe hare and Canada lynx. Using these results, the Maine Forest Products Council requested that 10,000 square miles in northern Maine be excluded from critical habitat designation by the federal government. After considering the research data on which the request was made, the U.S. Fish and Wildlife Service announced in November 2006 that it would not designate any land in Maine as critical habitat for the federally endangered Canada lynx.

The second major accomplishment came from a request last year by J. D. Irving to develop depth-to-water-table maps for CFRU member lands. A presentation by **Greg Adams** (JD Irving) at the April 2005 Advisory Committee excited members about the practical value of depth-to-water-table maps for their lands. As a result, a new one-year project was developed in collaboration with Mitchell Geographics and the University of New Brunswick to develop depth-to-water-table maps for five million acres of CFRU member lands (see Depth-to-Water Table). The maps were completed and distributed to all participating members this year, and are now being used by member organizations to improve road building and forest management decisions across the state.

Membership in CFRU remained strong this year. We were very fortunate to welcome three new members (**The Forestland Group, LLC**, **Baxter State Park - Scientific Forest Management Area** and the **Appalachian Mountain Club**) this year. We look forward to new collaborations with them.

The CFRU also changed administrative homes within the university this year. The unit was transferred from the College of Natural Sciences, Forestry, and Agriculture (NSFA) to the new Center for Research on Sustainable Forests (CRSF) that was initiated in July 2006. The CRSF includes the CFRU, Northeastern States Research Cooperative, and UMaine faculty across campus working on forest-related research. The CFRU reports to the new CRSF Director (**Dr. Bruce Wiersma**, former Dean of the NSFA College) who reports to the Vice President for Research. This new home for CFRU will strengthen our forest research focus and linkages.

The following annual report details the significant accomplishments of CFRU researchers and staff during this productive year.

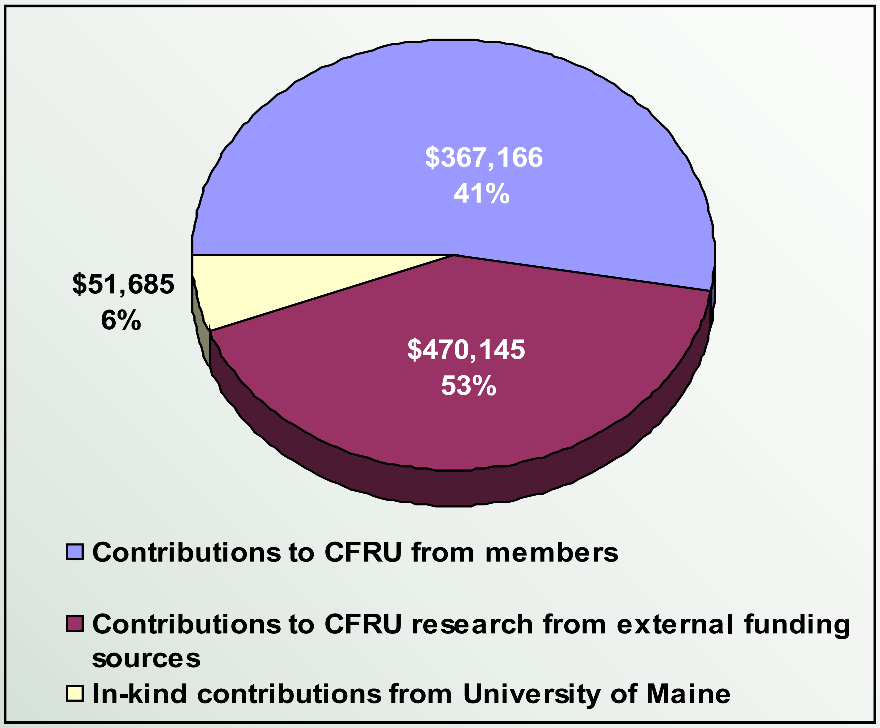
Robert G. Wagner
CFRU Director

Financial Report

Twenty-six members representing 7.99 million acres of Maine's forestland contributed $470,145 in dues to support CFRU this year (Table 1). In addition, $112,736 of additional funds were contributed by sixteen members to develop depth-to-water-table maps for 5.6 million acres of their lands (Table 2). Thus, CFRU collected a total of $582,881 from member organizations during 2005-06. We also welcomed The Forestland Group, LLC (249,153 acres), The Appalachian Mountain Club (37,093 acres) and Baxter State Park, Scientific Forest Management Area (29,537 acres) as new members of the CFRU this year.

Sound fiscal management by CFRU project scientists and staff resulted in spending $19,237 (5.2%) less than was approved by the Advisory Committee (Table 3). These savings were returned to the central account for future use on other CFRU projects. CFRU spent 52% of its budget for research projects (excluding depth-to-water-table project) and 48% for administration, including staff/scientist salaries and other expenses (meetings, field tours, web maintenance, data bank, travel, computers, safety, phones, printing, and office supplies). Research expenses were divided among five silviculture projects (33%), three wildlife ecology projects (34%), and three biodiversity conservation projects (33%) (Table 3).

Figure 1. CFRU members contributed $470,145 this year. An additional $367,166 was leveraged from external funding sources, and the University of Maine contributed $51,685 of in-kind support.



Using contributions from CFRU members, project scientists were able to leverage an additional $367,166 from other sources to support CFRU-sponsored research projects. When added to the $51,685 of in-kind contributions from the University of Maine, the total value of CFRU research during this fiscal year was $888,997 or 89% above member contributions (Figure 1). The total value of CFRU research including the depth-to-water-table mapping project was $1,001,733.

A substantial amount of leveraging comes from CFRU members pooling their resources. For exam-

Table 1. CFRU cooperator contributions during FY 2005-06.

Cooperator	2006 Reported Acres	Amount Invoiced (Jan 2006)	Amount Received	Balance
Landowner/ Manager				
Irving Woodlands, LLC	1,380,000	$74,000	$74,000	$0
Wagner Forest Management, Ltd.	1,163,887	$63,194	$63,194	$0
Black Bear Forest, Inc.	981,665	$54,037	$54,037	$0
Plum Creek Timber Company, Inc.	908,600	$50,202	$50,202	$0
Seven Islands Land Company	793,000	$44,133	$44,133	$0
Prentiss and Carlisle Company, Inc.	735,258	$41,101	$41,101	$0
Maine Bureau of Parks and Lands	385,000	$22,138	$22,138	$0
Huber Resources Corporation	362,894	$20,866	$20,866	$0
Katahdin Forest Management, LLC	299,000	$17,193	$17,193	$0
The Forestland Group, LLC[1]	249,153	$14,326	$14,326	$0
Clayton Lake Woodlands	245,000	$14,088	$14,088	$0
The Nature Conservancy	180,064	$10,354	$10,354	$0
Baskahegan Lands	101,629	$5,844	$5,844	$0
St. Aurelie Timberlands	61,605	$3,542	$3,542	$0
Frontier Forest, LLC	53,338	$3,067	$3,067	$0
Appalachian Mountain Club[1]	37,093	$2,133	$2,133	$0
Baxter State Park, Scientific Forest Management Area[1]	29,537	$1,698	$1,698	$0
Robbins Lumber Company	27,275	$1,568	$1,568	$0
Millowners				
Sappi Fine Paper		$23,125	$23,125	$0
Huber, J. M. Corporation, Wood Products		$1,500	$1,500	$0
Hancock Lumber Company, Inc.		$1,000	$1,000	$0
Other				
LandVest		$200	$200	$0
Peavey Corporation		$137	$137	$0
Field Timberlands		$100	$100	$0
Finestkind Tree Farms		$100	$100	$0
Balch, Sidney		$500	$500	$0
Total	**7,993,998**	**$470,145**	**$470,145**	**$0**

[1]New members who joined during FY 05-06.

ple, for every dollar contributed by our five largest members this year, they received $7.23 from other member contributions, $6.43 from external funding sources, and $0.90 from in-kind contributions from the University of Maine. Therefore, *every dollar contributed by the largest CFRU members leveraged an additional $14.57 to support their highest priority research projects* (Figure 2).

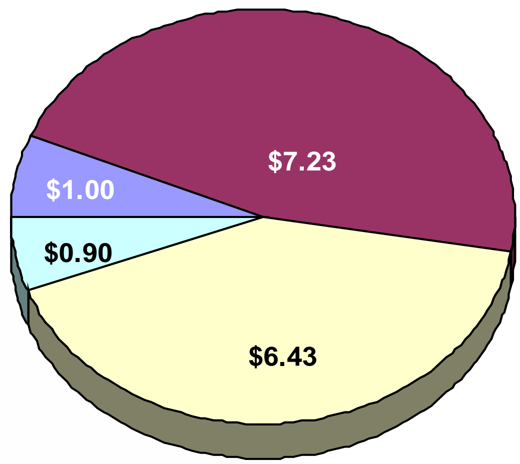


Figure 2. For every dollar contributed by one of our five largest members they received $7.23 from other members, $6.43 from external funding sources, and $0.90 from in-kind contributions by the University of Maine. Therefore, every dollar contributed by the five largest CFRU members leveraged an average of $14.57.

CFRU Landowner Member	Acres Mapped	Amount contributed
Irving, J. D. Ltd.	1,200,000	$24,000.00
Plum Creek Timberlands	908,600	$18,172.00
Seven Islands Land Company	834,000	$16,680.00
Maine Bureau of Parks and Lands	385,000	$7,700.00
Huber, J. M. Corporation	358,677	$7,173.54
Katahdin Forest Management, LLC	293,000	$5,860.00
The Forestland Group, LLC	249,153	$4,983.06
Clayton Lake Woodlands	245,000	$4,900.00
The Nature Conservancy	210,000	$4,200.00
Baskahegan Lands	101,629	$2,032.58
St. Aurelie Timberlands	61,605	$1,232.10
Timbervest	22,859	$457.18
Frontier Forest, LLC.	53,338	$1,066.76
Robbins Lumber, Inc.	28,000	$560.00
Wagner Forest Management, Merriweather	283,999	$5,679.98
Wagner Forest Management, Typhoon LLC	401,946	$8,038.92
Total Project Cost	**5,636,806**	**$112,736.12**

Table 2. CFRU participants and contributions for producing depth-to-water-table maps during FY 05-06.

Table 3. CFRU project expenditures and balances for FY 2005-06 (as of December 8, 2006).

Project	PI	Approved Amount	Amount Spent	+ / -	%
Administration	Wagner	$173,430	$165,624	$7,806	4.5%
Research **Silvculture:**					
Maine Commercial Thinning Research Network	Wagner / Seymour	$36,182	$32,770	$3,412	9.4%
Qualitative Silviculture of Northern White Cedar	Seymour	$9,500	$9,490	$10	0.1%
Hardwood Silviculture Graduate Student	Wagner	$8,000	$0	$8,000	100.0%
Agenda 2020 PCT Modeling Project	Wagner	$8,800	$8,800	$0	0.0%
Beech-Dominated Post Harvest Project	Wagner	$8,766	$8,757	$9	0.1%
Wildlife Ecology:					
Predicting responses of snowshoe hares and lynx to alternative forest harvesting scenarios across multiple spatial scales (Phase 2)	Harrison	$25,000	$25,000	$0	0.0%
Agenda 2020 future marten habitat modeling	Harrison	$6,000	$6,000	$0	0.0%
Relationships of snowshoe hares and lynx to forest harvesting	Harrison	$32,000	$32,000	$0	0.0%
Biodiversity and Riparian Zone:					
Quantifying biodiversity values across managed landscapes: Scorecard	Hagan / Whitman	$25,000	$25,000	$0	0.0%
Quantifying biodiversity values across managed landscapes: Riparian Index	Hagan / Whitman	$15,000	$15,000	$0	0.0%
Monitoring recovery of headwater stream temperature	Hagan / Whitman	$20,000	$20,000	$0	0.0%
TOTAL		**$367,678**	**$348,441**	**$19,237**	**5.2%**

A mostly clear pile of cedar logs awaits the truck to the shingle mill.

Activities

COMMUNICATIONS

Publications & Presentations

The goal of the CFRU communications program is to provide coop members with timely and pertinent research results from CFRU projects in a form that they find most useful. CFRU publications, made available on our website, have played a key role in delivering this information. Over the past year CFRU scientists, staff, and graduate students produced a variety of new publications and presentations, including eight journal articles, 12 research reports and notes, and 31 conference and public presentations, for a total of 51 published communications. Included in this list are two new CFRU *Science Spotlight* articles entitled, "Maine's Cooperative Forestry Research Unit: Understanding Tomorrow's Forests Today" and "Cool and Clear: CFRU Studies Water Quality in the Maine Woods." These articles are aimed at the general public and Maine's policy makers to inform them about the cooperative forest research of the CFRU. Also, four *Results* articles were released to cooperator managers. These articles summarize results from recent CFRU research in an attempt to get the newest information to those who are out on the ground managing the Maine Woods. See the Outreach section of this report for a complete listing of all publications and presentations for this fiscal year.

Website

After a complete redesign of the CFRU website (http://www.umaine.edu/cfru - just click on the CFRU logo at the bottom of any page in this report) in late 2005, CFRU staff have continued to develop a portal that serves the scientists, cooperators and the general public. Plans are underway to add areas for up-to-date information about each current research project while providing an archive of information for past projects. All CFRU Annual Reports and general audience publications continue to be available to any site visitor.

The much-used publications database and search engine continue to provide access to the Unit's more than 30 years of publications. This search engine is often the envy of other departments around campus.

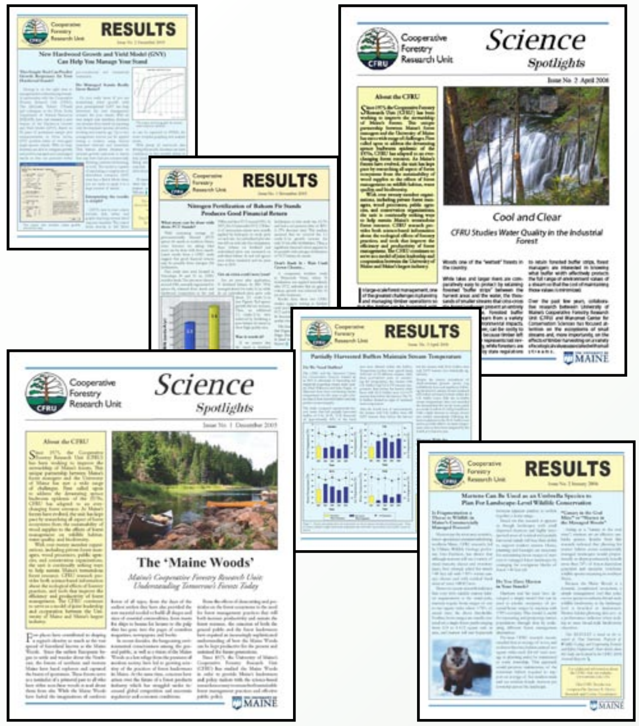
Workshop

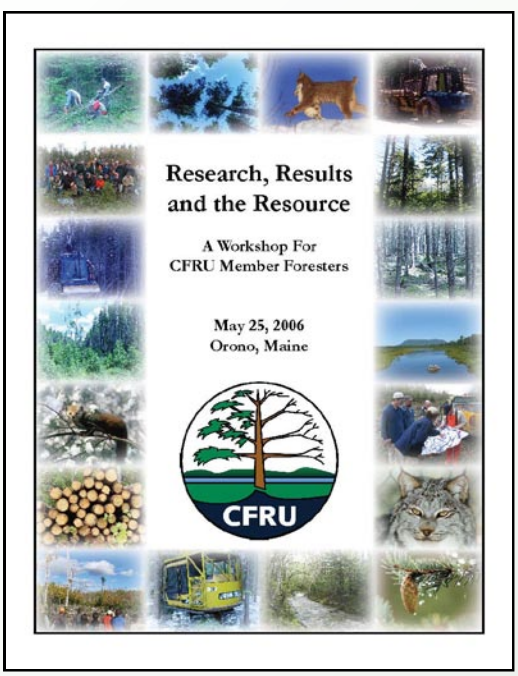
On May 25, 2006 in Orono, the CFRU held another workshop to present results from recent and current research to our cooperators. The workshop, entitled "Research, Results and the Resource" offered

Bob Seymour discusses the AFERP gap harvests with CFRU cooperators and scientists.

presentations about new information on silviculture, biodiversity, wildlife habitat, forest modeling and water quality. Scientists **Bob Wagner**, **Bob Seymour**, **Dan Harrison**, **Tim McGrath**, **Will Mitchell**, **Mike Greenwood**, and **John Hagan** all presented results from their work. A complete agenda and set of abstracts is available on the CFRU website. The morning consisted of a series of nine research presentations and in the afternoon everyone boarded buses and toured a private woodlot in Clifton where **Ralph Nyland** led segments on hardwood competition and **Andy Whitman** presented the LS Index in an older mixed-wood stand. A special "Thank You" goes to consulting forester **Bill Mahan** for showing off one of his managed parcels and helping to facilitate the tour. While most of the group was in the field in the afternoon, **Will Mitchell** led a hands-on, indoor workshop for our cooperator's GIS users to unveil the Depth-to-Water Table mapping project. In all, over 100 hundred CFRU cooperator foresters and managers took part in the day's activities. These workshops have been successful and we will continue to hold one every two years to deliver our newest information to Maine's forest practitioners.

Science Spotlights and Results articles help the CFRU communicate with the public and our Cooperatos about our research programs.





Over 100 CFRU foresters and managers attended the 2006 workshop in Orono.

FIELD AND DATA

As usual, the field season was filled with some combination of tree diameters, flat tires, hare pellets, rainy tents and of course, black flies. More than 12 summer interns and graduate students chased trees, hares, and lynx around the state, traveling greater than 10,500 miles performing research duties for various CFRU projects.

The summer students were exposed to various aspects of forest research in Maine and took home a better appreciaton for the importance of sustainable forest research. In turn, the CFRU gained from their hard work and came away from the summer with another year's data on several projects. Accomplishments of the 2006 silviculture field crew included:

1) Annual re-measurement of over 12,000 tagged trees on twelve Commercial Thinning Research Network (CTRN) study sites across the state;

2) Data processing and stand cruising in preparation for the Winter 2006-07 thinning of the PCT stands of the CTRN; and

3) Installation and complete pre-treatment inventory of 480 understory vegetation plots in the Beech Management project.

In addition, field crews led by **Dan Harrison** and **John Hagan** collected data on a variety of wildlife habitats and biodiversity conservation projects.

STAFF AND STUDENTS

In January 2006, **Michael Saunders** joined the team to take over the Precommercial Thinning (PCT) Project. After completing a Ph.D. at the University of Maine, Mike is well suited to lend his biometrics experience to the CFRU for the PCT project as well as modeling support for other projects.

The CFRU continues to fund several graduate students in the School of Forest Resources and the Department of Wildlife Ecology. This has proven to be an affective way for the CFRU to advance our scientific understanding of forest dynamics while contributing to the education of the resource managers and scientists of tomorrow. Under **Dan Harrison's** advising, graduate student **Laura Robinson** completed her M.S. thesis entitled, "Ecological Relationships Among Partial Harvesting, Vegetation, Snowshoe Hares ,and Canada Lynx in Maine." Laura's work provided much information that helped inform the U.S. Fish and Wildlife Service when it decided not to designate critical habitat for lynx in Maine. Two of Harrison's Ph.D. students, **Erin Simons** and **Kasey Legaard** continued their joint pursuit to understand the effects of landscape change on wildlife umbrella species. In addition to these wildlife pursuits, **Philip Hofmeyer** completed a second year of work on understanding the ecology and silvicultural traits of cedar in Maine. Under **Bob Seymour's** advising, Phil is nearing completion of his Ph.D. program.

Spencer Meyer continues as the Research and Communications Coordinator, managing operations for several research projects and heading up the communications effort through publications, the website, field tours and workshops. After two years as our Administrative Assistant, **Dana Smith** continues to ably manage the office and help keep things running smootly for the CFRU.

Members of the 2006 Commercial Thinning crew rest at Chimney Pond during the annual Katahdin hike.

Silviculture

Commercial Thinning Research Network

Depth to Water Table Mapping

Precommercial Thinning Modeling

Improving the Composition of Hardwood Regeneration in Beech Stands

Silviculture and Ecology of Northern White Cedar

Commercial Thinning Research Network

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

ANNUAL MEASUREMENTS AND MAINTENANCE

The CFRU Commercial Thinning Research Network (CTRN) completed its 6th season this year. 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 quantifues the growth and yield responses from the timing of first commercial thinning (i.e. now, delay 5 yrs, and delay 10 yrs) and level of residual relative density (33% and 50% relative density reduction). The second study, also established on six sites, was installed in mature spruce-fir stands without previous PCT (no-PCT) to quantify the growth and yield response from commercial thinning methods (i.e. low, crown, and dominant) and level of residual relative density (33% and 50% relative density reduction).

Seven 1-acre treatment plots with 0.20-acre measurement plots centered in each treatment plot were established on each site. All trees within the measurement plot that meet the minimum size requirement were measured for diameter at breast height (DBH), and a subset were measured for total height, crown height, and two-dimensional

Summer 2006 Crew Leader Erik Nash and graduate student Matt Olson prepare to inventory the PEF commercial thinning site.

location before the commercial thinning treatments were applied. After the thinning treatments were applied, all residual trees were tagged and are being measured periodically. In-growth and mortality also are being assessed. More than 12,000 trees are being monitored annually across the twelve sites.

Through the 2005 field season, post-treatment measurements were divided into three types:

1) intensive measurements (IM) including a complete inventory of DBH, total height, crown height, in-growth, and documentation of downed and dead trees;

2) downed tree and mortality assessments (DM) including documentation of all downed and dead trees; and

3) extensive measurement (EM) including DBH on every tree, in-growth, and documentation of all downed and dead trees.

After several years of this protocol it has become apparent that more regular measurements of some metrics and better mortality data produce a better dataset for modeling purposes. Starting with the 2006 field season, measurements have been collapsed so that we now conduct IM inventories every two years at the PCT sites with EM inventories in the between years; and IM inventories every fourth year at no-PCT sites with EM during the other years. This gives diameter data for every year and height data on a schedule more appropriate for the precision with which we can measure tree heights. Additionally, a new mortality code system is in place to allow us to better differentiate between density-dependent and wind-related mortality.

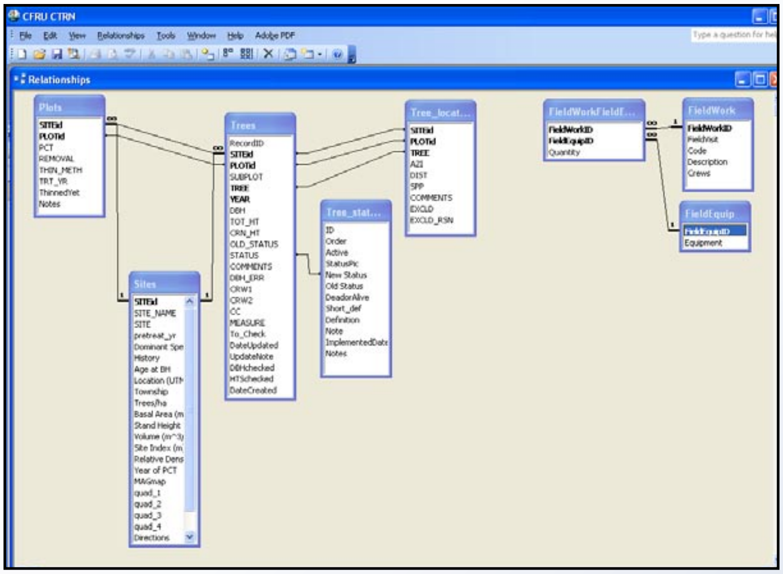


Figure 3. The CTRN database is organized in a relational database management system (RDMS) to best accomodate the complexities of multi-scale data involved in the Network.

Scale		
Sites	**Plots**	**Trees**
Directions to each site	Type of treatment applied	DBH each year
GPS locations	Year of treatment	Height each year
Stand history		Species
Site maps		Crown Class
and many other attributes		

Table 4. The CTRN database contains data attributes appropriate at each scale of the study.

DATABASE DEVELOPMENT

As with many long-term studies, the CTRN has outgrown the simplistic requirements of spreadsheets so a new database has been developed. Microsoft Access provides a relational database management system (RDMS) framework and a relatively easy user interface and is an appropriate software tool for the CTRN database. The RDMS allows multi-scale data (Figure 3 - e.g. the CTRN has site-, plot- and tree-level data) to be related in such a way as to store large quantities of data efficiently without sacrificing access to archived information. What this means for the CTRN is an organized repository for yearly data associated with the study, allowing current and

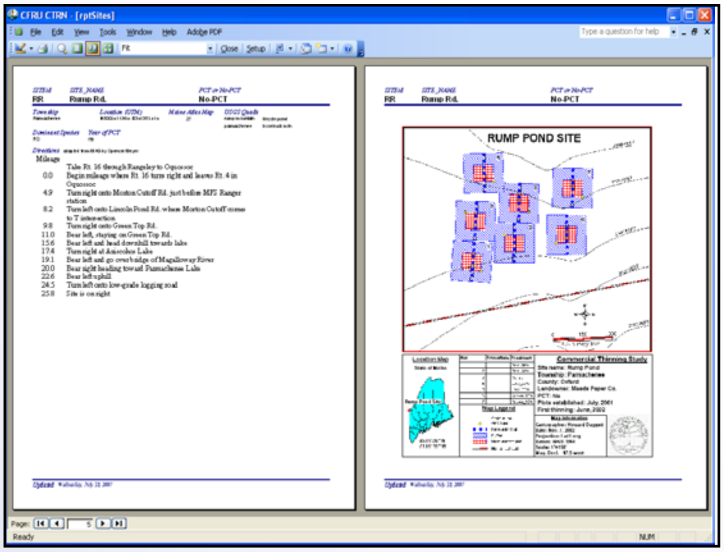


Figure 4. The CTRN database contains complete stand-level maps and directions for each site.

future researchers the ability to maintain consistency over the length of the study. Examples of attributes for each scale are included in Table 4. Even logistical information, such as maps to get to each site, are included in the database (Figure 4).

PCT STANDS SECOND ENTRY

The PCT experimental design calls for the next round of commercial thinnings to be conducted during the 2006-07 winter. After the 2006 field season data were cleaned and loaded into the CTRN database, preparations were made to apply thinning prescriptions to the six PCT sites. As part of the new CTRN relational database, a software application called StandMark (Figure 5) was developed to facilitate tree marking such that prescription targets can be met within each plot with precision. This software is loaded on a tablet PC which can be used directly in the field during marking operations. Using previous inventory data for each site, StandMark assesses the treatment assigned to each block during the experimental design process (Figure 6).

Because the relative density metric is used as part of the thinning prescription, the attributes of each tree affect the overall marking. As the forester marks a tree in the field, it is marked in this Microsoft Access-based tool (Figure 7). The software then runs iterative calculations after each update to give the user a progress report of his proximity to the target density. This tool has been field tested and will be implemented during Fall 2006 .for the actual PCT stand markings.

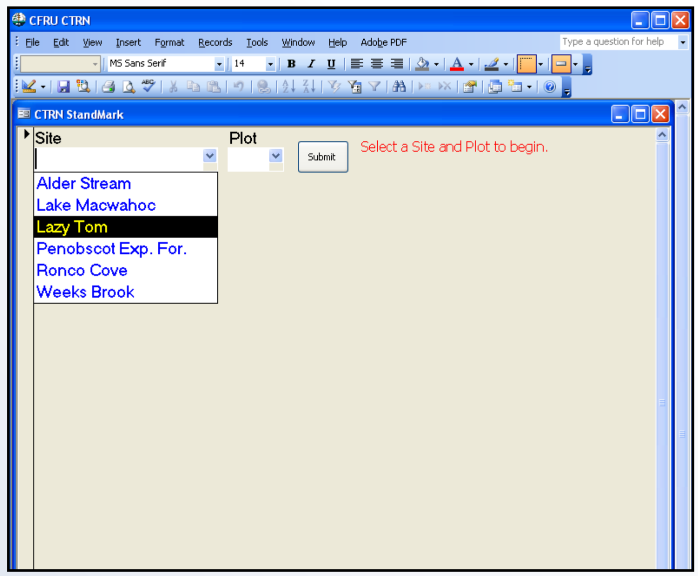


Figure 5. CTRN StandMark allows the forester to use existing inventory data to mark a stand to an exact relative density.

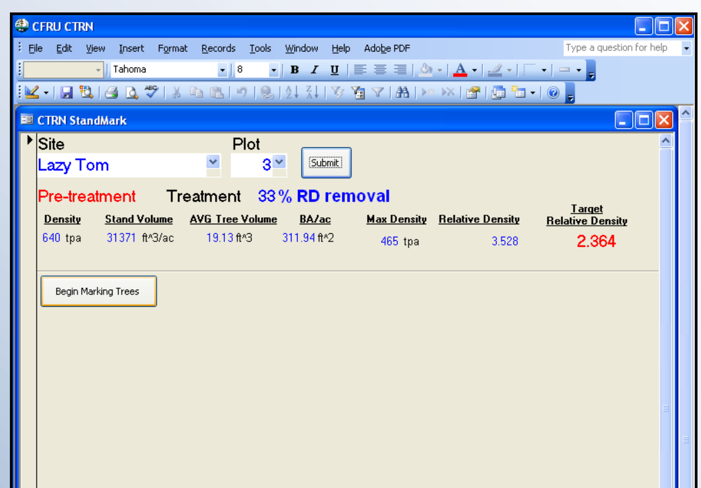
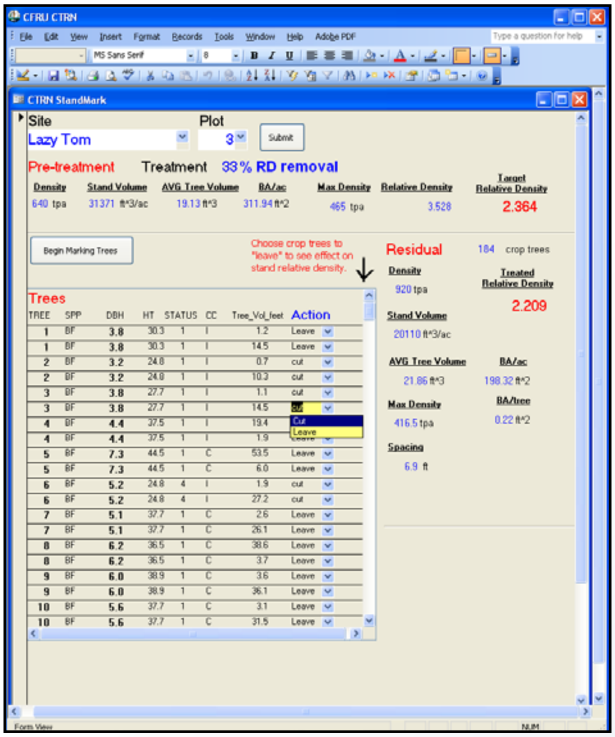


Figure 6. CTRN StandMark provides current stand structure conditions to the user in preparation for the marking.

Figure 7. The user then selects *Cut* or *Leave* for each tree and StandMark will update the progress towards a target density based on that stand's prescription.



5TH-YEAR ANALYSIS

At the April 2006 Advisory Committee meeting, members voted to fund a new CTRN proposal entitled, "Maine Commercial Thinning Research Network: Analysis of 5th-Year Growth and Yield Responses." This sub-project of the CTRN is meant to quantify all responses the stands have experienced in the first five years of post-treatment measurements. This analysis got underway this year and will be reported in the next annual report. Some highlights of the intended analyses are:

- Analysis of Variance (ANOVA) comparing stand-level responses among treatments in post-thinning basal area growth, total volume growth, and merchantable volume growth;
- quantitative comparison of diameter distributions to better understand thinning effects on growth and yield models;
- multiple regression analysis of individual-tree growth responses on pre-thinning conditiosn and post-thinning competition;
- a comprehensive mortality assessment and comparison across treatments, including windthrow, wind breakage and rotten stems; amd
- net present value (NPV) comparisons of thinning treatments based on volumes removed and residual stand values

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

A single-grip pcocessor head is used on a long boom to reach between the trees for a low-impact commercial thinning.

DEPTH-TO-WATER TABLE MAPPING FOR CFRU MEMBER LANDS

Robert G. Wagner

At the January 2005 CFRU Advisory Committee meeting, **Greg Adams (**J. D. Irving**)** presented the results of efforts by the province of New Brunswick to map the depth-to-water table across the province. Research by Paul Arp's lab at the **University of New Brunswick** (UNB) had developed a method for building these maps from digital elevation models and GIS stream layers. These depth-to-water table maps have proven to be very useful in Irving's forest operations for: 1) road layout and construction, 2) harvest layout and timing, 3) silvicultural prescriptions, 4) wetland identification, 5) soils mapping, and 6) site classification. CFRU members were excited about the possibility of developing such maps for their Maine lands and requested that **Bob Wagner** develop a proposal for the April 2005 meeting.

PROPOSAL AND TEST MAPS

Wagner searched for GIS experts with the capability of developing these maps. At the April 2005 Advisory Committee meeting, **Will Mitchell** of **Mitchell Geographics** in Portland presented a pre-proposal to map the depth-to-water table for cooperator lands. CFRU members agreed to move forward with a full proposal provided that the mapping could be completed for $0.02 per acre and that test maps could be successfully generated for two Maine townships as proof of concept. During March and April 2005, UNB and Mitchell Geographics developed depth-to-water table

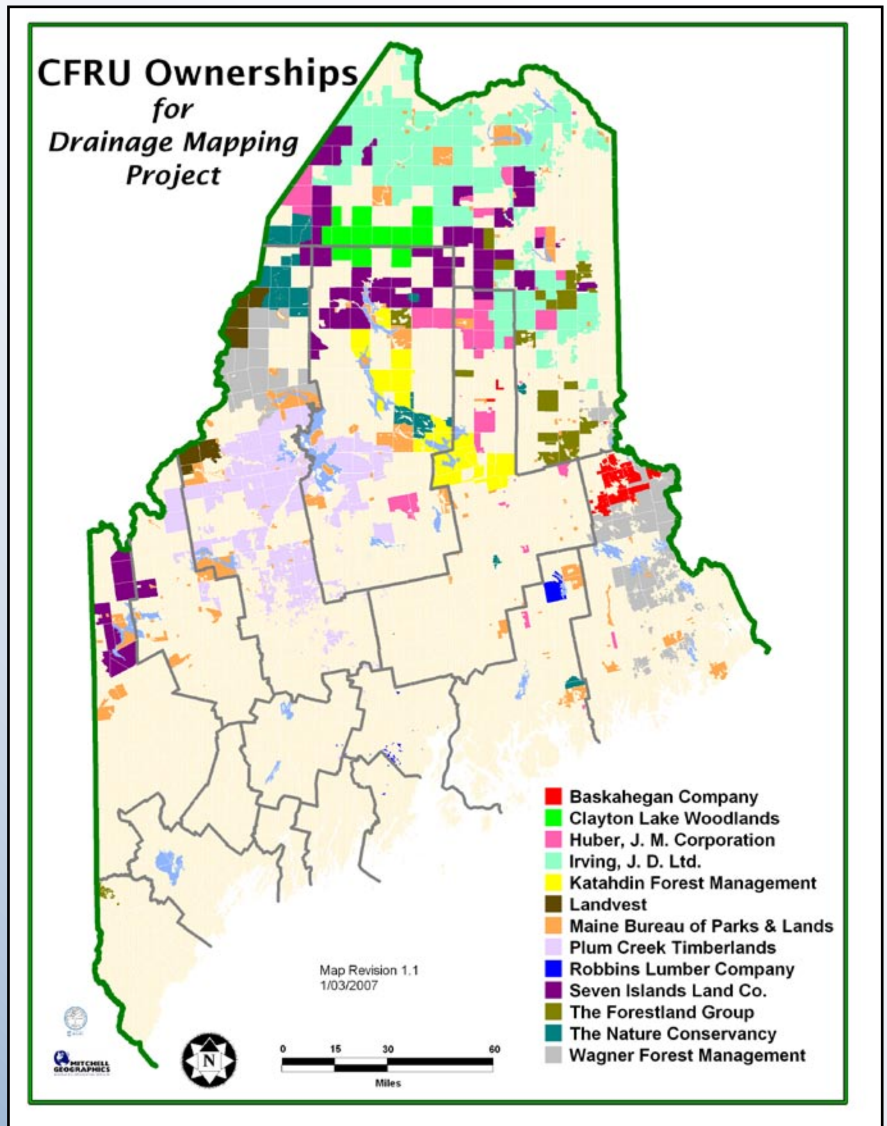


Figure 8. Extent of depth-to-water table mapping totaling 5.6 million acres of CFRU member lands.

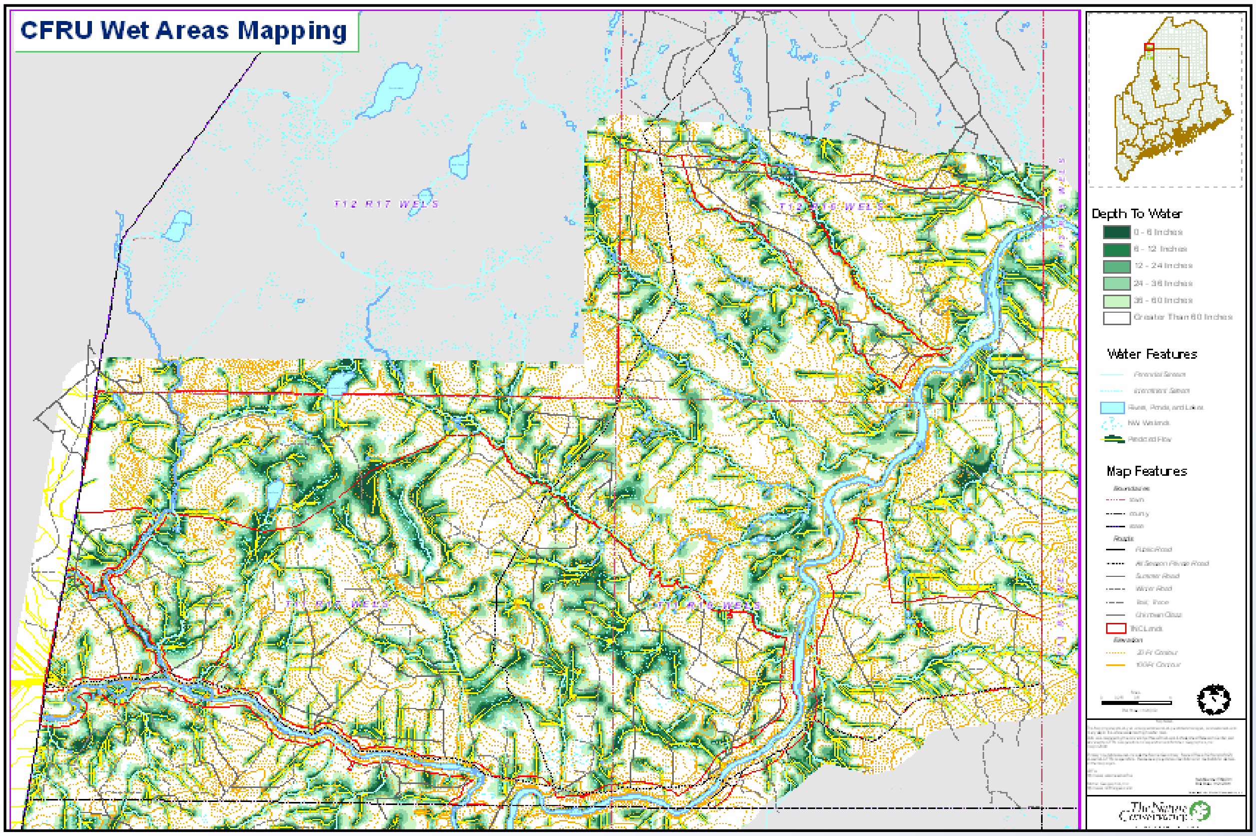


Figure 9. Example depth-to-water table map developed for a portion of The Nature Conservancy's land.

maps for two test townships: Irving Woodlands - T14 R7 and the University of Maine's Penobscot Experimental Forest. In May 2005, staff from Mitchell Geographics, UNB, and CFRU ground truthed the maps confirming predicted culvert locations and digging test holes to measure actual depth-to-water table. Results from this field testing demonstrated the accuracy of the mapping procedure and also identified the need for several refinements. Based on the successful test maps, a full proposal was submitted by Mitchell Geographics in July 2005 to develop depth-to-water table maps for all CFRU members that wished to have their lands mapped.

MAPPING

During summer and fall 2005, CFRU members were solicited as to whether they wanted to participate in the project. Fifteen members requested that a total of 5.6 million acres of their lands be mapped at $0.02 per acre (Figure 8). Since the mapping was not research, members agreed to pay for the maps above their annual dues. Participating members were invoiced a total of $112,736 (see Financials), based on the number of acres they requested to be mapped. CFRU staff administered the dispersion of funds to Mitchell Geographics as each phase was satisfactorily completed for each participating member.

Development of the maps occurred from October 2005 to April 2006. Will Mitchell and **Mark Castonguay** (UNB) presented the final report on completion of the project at the April Advisory Committee meeting. A special session also was held for GIS staff from participating CFRU member organizations by Mitchell Geographics and UNB at the May CFRU workshop. The project was completed in June 2006.

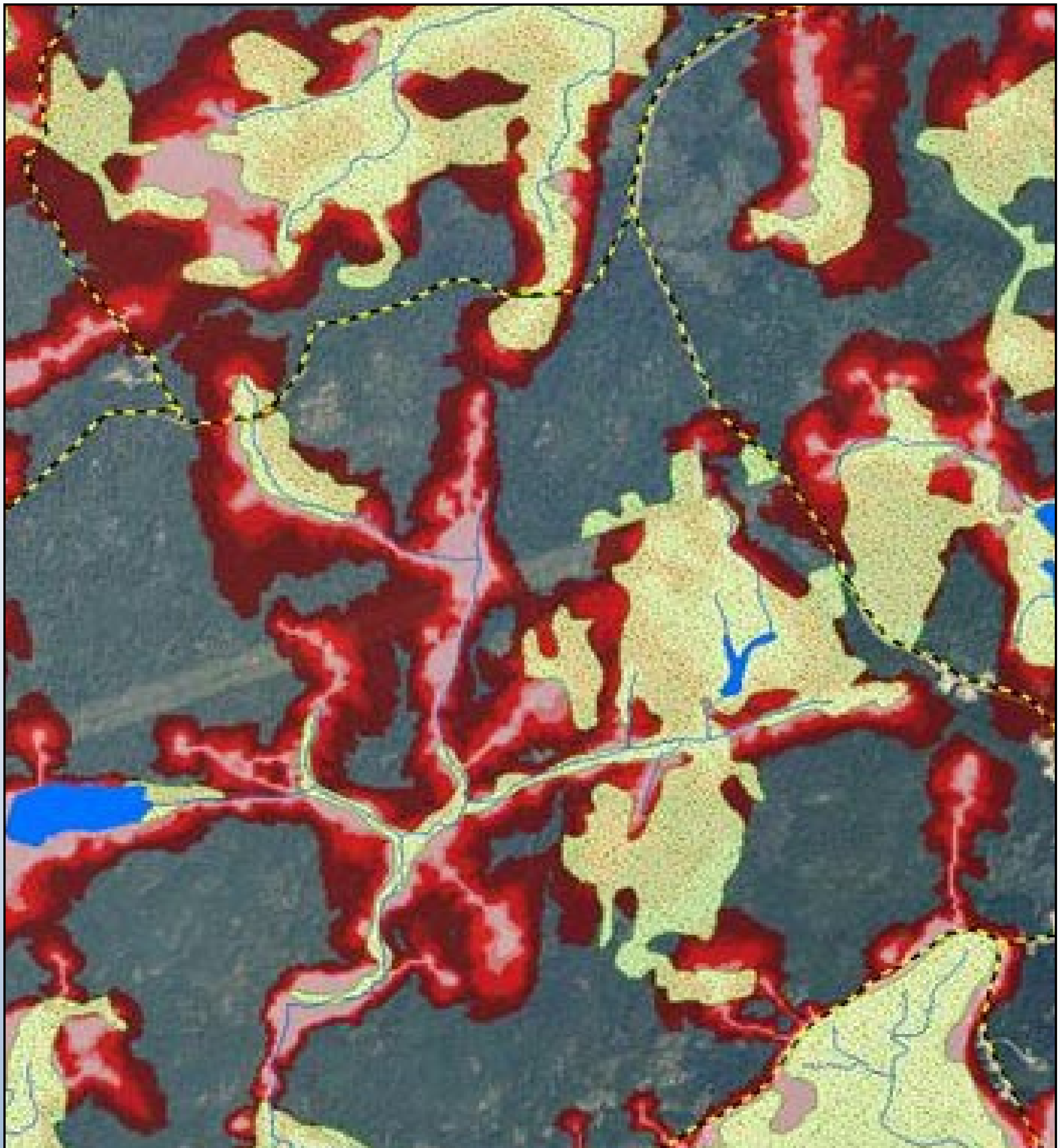


Figure 10. Example depth-to-water table map over aerial photo showing mapped wetlands and road network placement.

The completed maps (Figure 9) provide a high degree of detail that has many operational uses. The maps also can be used with aerial photos (Figure 10). An additional benefit of these maps includes an improved digital elevation model (DEM) layer. These maps also provide a new landscape approach for applying the Briggs Site Classification System for softwood sites released by CFRU in 1994.

Technical questions and requests for maps of other areas of Maine are available from Will Mitchell at will@mitchellgeo.com or toll free at 1-877-914-GEOG (4364).

Precommercial Thinning Modeling Project

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

INTRODUCTION

Natural regeneration in most softwood stands in the northeastern United States and Maritime Provinces of Canada is often prolific (Newton et al. 1992, Brissette 1996). Stands commonly are overstocked and found in mixtures with competing hardwoods; both situations lead to significant reductions in conifer growth and/or delays in final harvest. Daggett (2003), for example, reported that by 22 years after herbicide treatment, competition with hardwoods had reduced softwood volume by 68%. Zhang et al. (1998) reported that spaced plots achieved merchantable diameters sooner than overstocked control plots, thereby shortening the rotation by 10 years or more. Aerial application of herbicides and precommercial thinning (PCT) are two of the most common silvicultural tools used in softwood stands to rectify overstocking and undesirable competition (Figure 11). While the effects of herbicide on stand growth and financial yields have been well established and generally consistent (Newton et al. 1992a, Newton et al. 1992b, Daggett 2003), the response of spruce–fir stands to PCT have been inconclusive. Zhang et al. (1998) found that PCT increased average tree diameter by up to 28.3%, average stand merchantable volume by up

Figure 11. Precommercially thinned stand just after commercial thinning.

to 22.0%, and average stand value by up to 18.8% in stands harvested 35 years after PCT. Daggett (2003) also reported increases in merchantable softwood volume from PCT; however, stands without PCT or herbicides had internal rates of return (IRR) of 6.0% and those with PCT and herbicides averaged an IRR of 5.8%.

These two studies highlight the uncertainty with the growth response and financial viability of PCT in spruce–fir stands. This project seeks to clarify these relationships by modifying existing growth and yield models to describe rotation-long stand yields and financial returns from PCT across a range of residual stand densities, ages of treatment, and site classes. This work is being funded by a U.S. Forest Service Agenda 2020 grant, the CFRU, and Plum Creek Timber Company.

METHODS

Modeling Framework

A beta version of the new Northeast Variant of the Forest Vegetation Simulator (FVS) provided the "backbone" model for this project. FVS was chosen over other existing growth and yield models for northeastern forests because this model outputs tree lists that could be directly incorporated into a merchandizing model. A walk-thru of the modeling framework for this project is shown in Figure 12, and a description of two components follow.

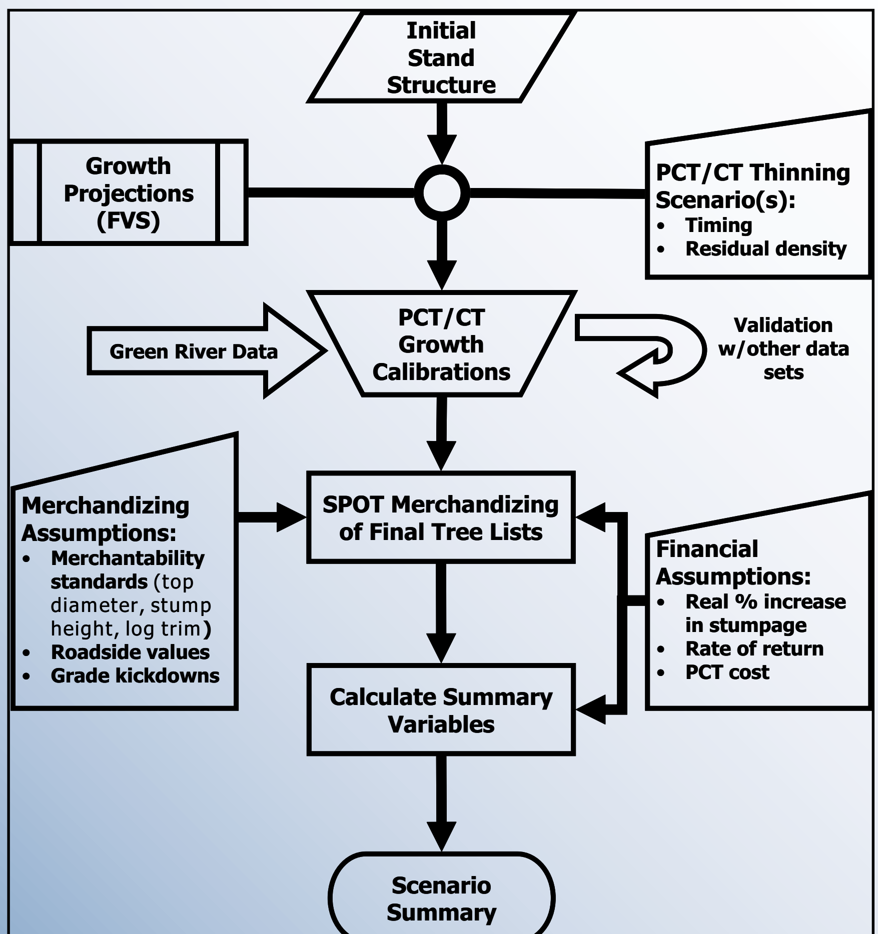
Growth Calibrations

Test runs of the base FVS model against growth and development in several PCT stands showed that the model significantly under-predicted diameter growth and overestimated height growth in early stand development. This, in turn, greatly affected the mortality estimates and final volume estimates. Therefore, FVS was calibrated using repeat measurements from a dataset for the long-term, replicated Green River PCT Spacing Study in New Brunswick that is managed by the Atlantic Forestry Centre of the Canadian Forest Service.

SPOT Merchandizing

The Stand Product Optimization Tool (SPOT) was developed to quantify the financial value of a stand of timber given a set of merchantability constraints, market conditions, and harvest and trucking costs (McConville 2003). SPOT uses the tree-level information from a stand inventory

Figure 12. Planned modeling framework for PCT project. User inputs include definition of PCT/CT thinning scenarios, merchandizing assumptions and financial assumptions. Output will include volume harvested, wood costs, harvest costs, net present values, and internal rates of return at five-year intervals following the last thinning entry.



and determines the optimal bucking of each tree to maximize mill-delivered value of the stand. Elements of the SPOT model were recoded in the language R (R Development Core Team 2005) to calculate a stand-level roadside value of any particular cut or residual tree list from a FVS simulation given a set of merchantability standards, product roadside values, and grade kickdowns (i.e., estimation of percent of grade meeting that grades's size threshold that would not meet that grades's quality threshold because of defect and would thus be moved to a lower quality grade).

Simulations

Structural Archetypes

To test this modeling framework, archetypal stand structures were created using Growth and Yield Model (GNY - NSDNR 1993) to bracket the range of the most common structural conditions observed in young spruce-fir stands. Three factors were used to define these archetypes:

1) Width of the diameter distribution could be narrow, as would happen in natural stand development after a silvicultural clearcut, or broad, as would happen when advanced regeneration was protected during harvest.

2) Composition for each distribution was varied as the proportion of the starting basal area (BA) comprised of a species. Specifically, the levels were: a) 100% balsam fir; b) 75% balsam fir and 25% red spruce; c) 80% balsam fir, 10% red maple, and 10% paper birch; and d) 60% balsam fir, 20% red spruce, 10% red maple and 10% paper birch (a cross between b and c).

3) Site index (SI_{50} = 50 years) was varied in three levels, either 50, 60, or 70 for balsam fir. SI_{50} largely controlled the rate of growth and subsequent timing of management activities.

All archetypal distributions were standardized to a total BA of 75 ft^2/ac.

Thinning Regimes

There are diverse arrays of precommercial and commercial thinning (CT) treatments that can be simulated on any particular stand. For these tests, management consisted of a single PCT and single CT:

1) PCT occurred when the dominant softwood height was 10 ft (i.e., occurring immediately on the tree lists for the various structural archetypes). Three spacings were simulated: none, 6-ft (1210 trees/ac) or 8-ft (680 trees/ac).

2) CT varied by three levels defined on the timing of entry: none or when the dominant softwood height was either 40 ft or 55 ft The simulated CT removed 10% of all trees for skid trails, all hardwood competitors, and 70% of the balsam fir greater than 8.5 in DBH. A low thin was simulated on the remainder of the distribution to a residual BA of 60% of pre-treatment, all-species BA.

For both treatments, spruce was slightly favored over balsam fir. All hardwoods were removed but allowed to resprout in FVS.

PRELIMINARY RESULTS

Precommercial Thinning

PCT had a substantial benefit to growth in stands either with or without a subsequent CT. In stands of pure fir, PCT alone was projected to increase total volume at year 70 by an average across the two starting diameter structures of 7.9 and 3.9% with 6-ft spacing and 0.1 and 5.3% with 8-ft spacing, for SI_{50} 50 and 70 stands, respectively (Figure 13). Merchantable volumes increased by 13.2% and 2.8% with 6-ft spacing and 2.1% and 2.3% with 8-ft spacing, for SI_{50} 50 and 70, respectively. Although stands with spruce and hardwood components had similar projected volume gains, PCT shifted that volume to conifer stems from hardwood stems. These over-yielding patterns, particularly for total volume, are unusual but have been substantiated by 43-year stand-level summaries taken from the Green River Study (Doug Pitt, personal communication).

Financially, PCT greatly increased the net present value of stands and shortened the financial rotation age (Figure 14). In stands of pure fir, projected net present value (NPV) at a discount rate of 4% peaked for either spacing at $530-610/ac in year 60-65 on SI_{50} 50 sites and at $1090–1200/ac in year 45-50 on SI_{50} 70 sites. Without PCT, projected NPV did not peak until later and at substantially lower values—$488/ac at year 75 and $986/ac at year 55 for SI_{50} 50 and 70, respectively. Projections of NPV for PCT stands with hardwood components had similar NPVs and rotation lengths, but the projections without PCT had even lower NPVs and more delayed rotation lengths. Averaged across all starting structures, PCT had internal rates of return (IRR) of 8.9–9.7% and 12.0–14.9% at financial rotation length on SI_{50} 50 and 70, respectively.

COMMERCIAL THINNING

Unlike for PCT, at this time the model has not been calibrated with data for the commercial thinning response. However, the uncalibrated growth models within FVS suggested that commercial thinning alone did not increase total stand volume (note parallel stand trajectories in Figure 13) compared to unthinned stands. Furthermore, CT had no effects on total merchantable yield, unless stands had a higher site index and significant hardwood component. For example, across SI_{50} 70 stands, total merchantable yield increased by 3.0-12.1% after CT in stands with a hardwood component. Used in conjunction with the 6-ft

Figure 13. Total standing volume of site index 60 stands of pure balsam fir for the nine PCT/CT thinning scenarios. Curves are averaged across the two initial diameter distributions (i.e., narrow and broad) for each scenario, lending to slightly different CT timings and the nonvertical lines corresponding to the CT entry. Note the over-yielding of the PCT'd stands (solid green and red lines) compared to the nonthinned control (solid blue line) above age 25.

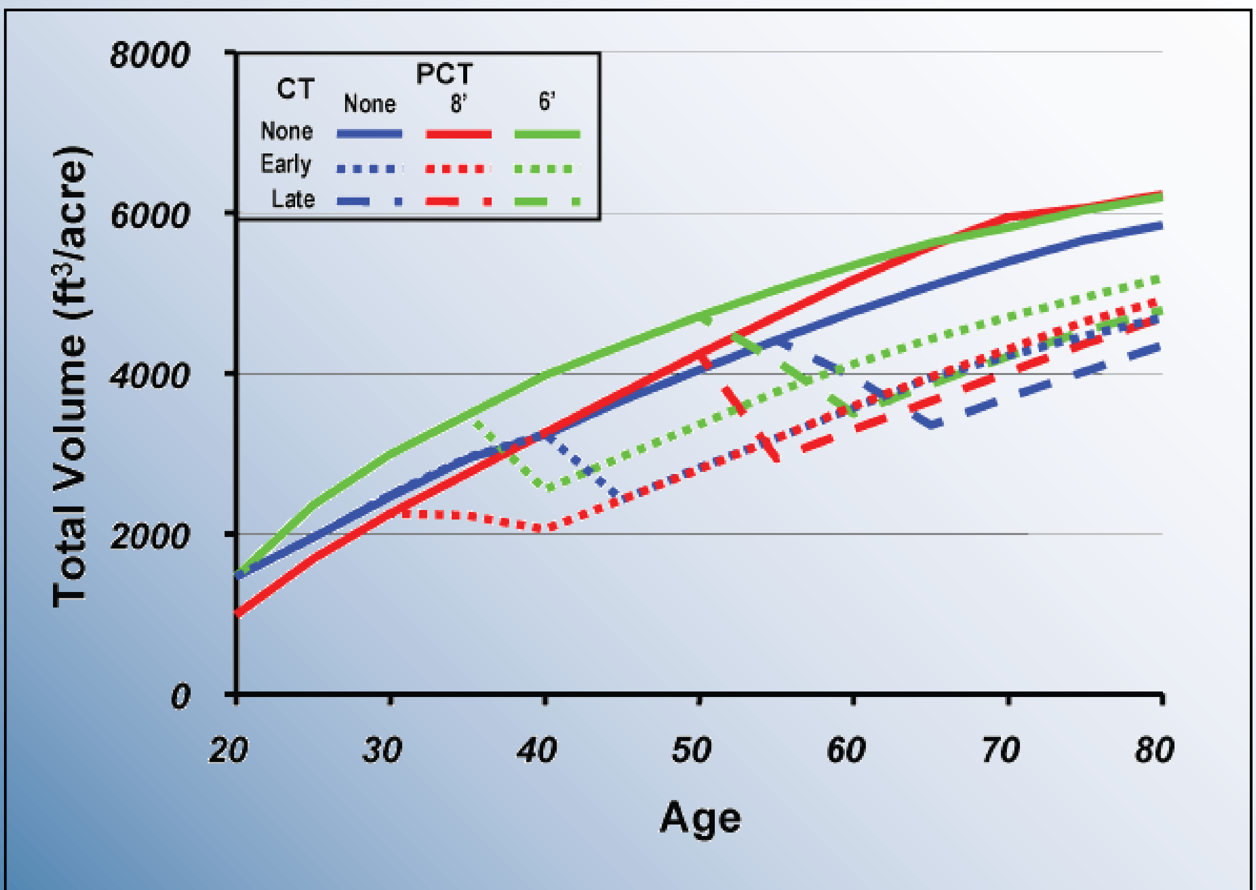
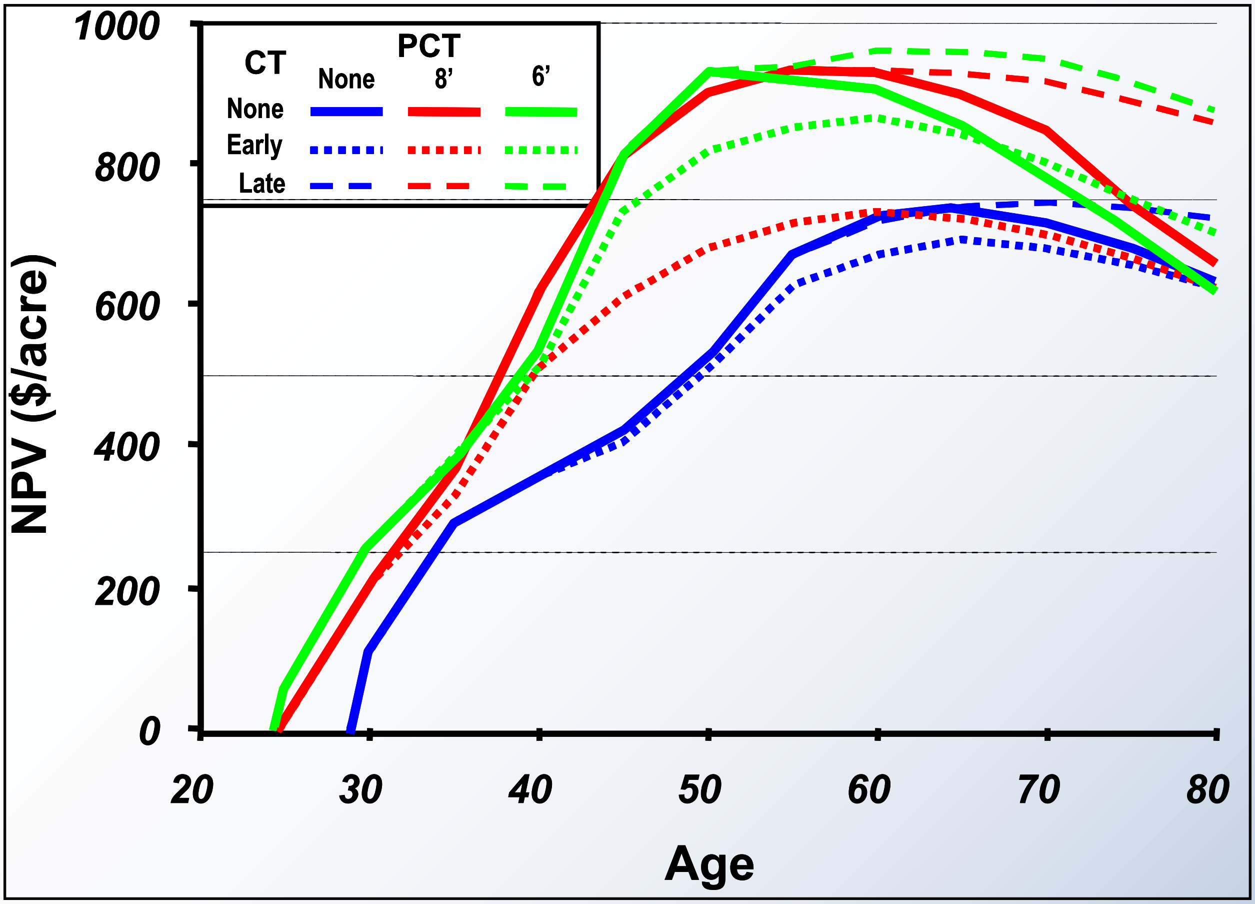


Figure 14. Net present value (NPV) in year 2000 dollars of site index 60 stands of pure balsam fir for the nine PCT/CT thinning scenarios. Financial assumptions include a 4% real rate of return, a precommercial thinning cost of $200/ac, a roadside value of $63/cord and $275/mbf (all year 2000 dollars), and a real increase of 0.7%/year and 1.4%/year in pulpwood and sawlog values, respectively. Curves are averaged across the two initial diameter distributions (i.e., narrow and broad) for each scenario. In this structure, PCT had a internal rate of return between 7-8% at maximum NPV.



spacing PCT, early CT can significantly increase total merchantable yield, by up to 16.6% in pure SI_{50} 70 balsam fir stands. Late CT performs better with the wider 8-ft spacing in most structures.

Although CT increases total merchantable yield in most cases, CT generally removes smaller, lower quality stems that do not add a great deal to the overall stand value. Financial analysis of the three CT treatments suggests that early CT entries may be detrimental by both reducing peak NPV by $50–250/ac and delaying financial rotation length by 5–10 years (Figure 14). Later CT entries do not have this deleterious effect on peak NPV and merely extend the length of the rotation by 10–15 years (Figure 14). Early CT may be appropriate, however, in stands with a significant, overtopping hardwood component that is slowing down the growth of a subcanopy of balsam fir and/or spruce. However, further calibrations of the CT growth response will be needed before these results should be used to change operational thinning regimes.

CONCLUSIONS & FUTURE ACTIVITIES

These preliminary results suggest that PCT can significantly increase total and merchantable yield over the length of a rotation. Further, and contradicting Daggett (2003), these projections suggest that PCT increases peak NPV significantly, by as much as $150-300/ac at a discount rate of 4%. PCT may also shorten the rotation by as much as 10–15 years in some stands.

Future activities in this project will include:

- calibrations of the CT response with data from the Commercial Thinning Research Network;

- calibrations of responses with significant hardwood competition;

- validation of the improved model with datasets provided by Plum Creek Timber Company, Irving Woodlands and others; and

- running a full analysis of the calibrated model with a broader array of archetypes, site qualities, and timings of the PCT entry.

We will also continue to work with the FVS group at the USFS Forest Management Office in Fort Collins, Colorado to improve performance of the NE variant of FVS. If determined necessary, we will begin to customize a version of the NE variant that would be applicable to managed spruce–fir stands in the Northeast.

More information about this project is available by contacting Bob Wagner at bob_wagner@umenfa.maine.edu or 207-581-2903.

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The Austin Pond study demonstrated the potential difference in growth between PCT and non-PCT'd trees.

Improving the Composition of Hardwood Regeneration on Beech-Dominated Sites

Robert G. Wagner

A new CFRU project was approved and established this year to develop an effective and low-cost strategy to improve the composition of hardwood regeneration after the harvesting beech-dominated sites in Maine. The project was designed in collaboration with **Ron Lemin** (UAP Timberlands) and **Maxwell McCormack** (CFRU, Retired).

PROBLEM

Thousands of acres of mid-site hardwood stands on CFRU member lands are plagued by an abundance of American beech (*Fagus grandifolia*) that generally dominates and competitively excludes more desired hardwood species after stands are harvested using shelterwood and selection methods (Figure 15). Developing a low-cost and effective treatment for improving the composition of hardwood regeneration in beech-dominated stands can help restore the quality and long-term financial value of hardwood stands across Maine.

APPROACH

A number of studies have demonstrated that beech is highly susceptible to glyphosate (Accord) and triclopyr (Garlon) herbicides. These studies also have shown that sugar maple and other de-

Figure 15. Beech-dominated hardwood regeneration within two years of harvesting a stand on Prentiss & Carlisle lands (T2 R8). Abundant sugar maple, red maple, and yellow birch are interspersed among beech. This stand is being used for this CFRU study.

EnTree 5735 surfactant (%)	Glyphosate (Accord Concentrate) application rate (lbs/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

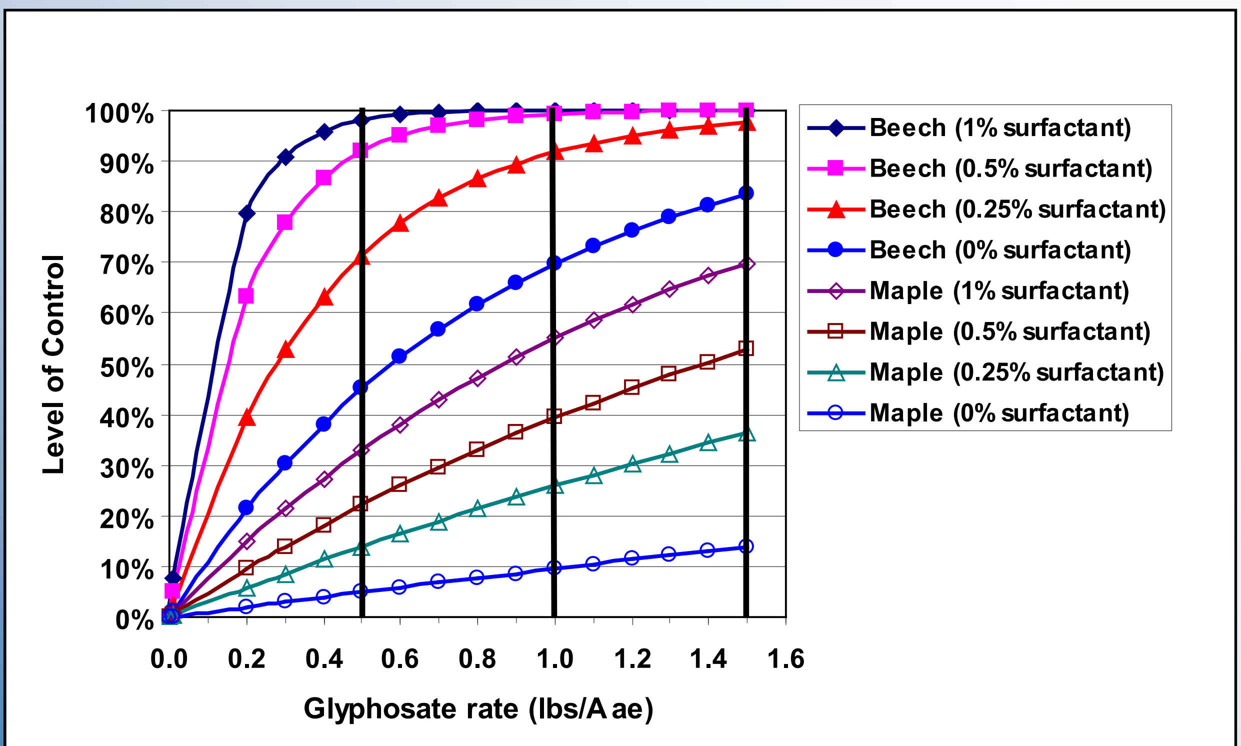
Table 5. Factorial combinations of glyphosate and surfactant being compared.

to maintain adequate stocking of hardwood regeneration while shifting dominance toward the maple and birch.

We proposed a complete factorial combination of three glyphosate (Accord Concentrate) rates and four surfactant (EnTree 5735) concentrations (12 treatments) plus an untreated control (Table 5). The objective of these treatments is to identify the glyphosate rate and surfactant concentration that maximizes control of beech and minimizes damage to maple and birch. Figure 16 depicts the conceptual approach to the problem. The rate and surfactant combination that provide the greatest degree of difference in control between beech and maple (and birch) has the greatest likelihood of achieving the management objective. The best treatment will provide effective control of beech while still maintaining adequate stocking of maple and birch regeneration.

sired hardwood species tend to be much less susceptible than beech to herbicide injury, especially from glyphosate. Therefore, we hypothesized that there may be an optimum combination of glyphosate herbicide and surfactant that can successfully control beech regeneration within several years of harvest while still preserving desired hardwoods (i.e. sugar maple, red maple, yellow birch). The goal of such a treatment would be

Figure 16. Hypothesized relationship between level of control for beech and maple (sugar and red) using various combinations of glyphosate herbicide and surfactant. Vertical lines indicate herbicide rates where observations are being made in this study. The most effective treatment combination will be the one providing adequate beech control while minimizing injury to maple.



EXPERIMENT INSTALLED

With the able help of **Carol Redelsheimer (prior to joining the Advisory Committee as a member)** and **Laura Audibert**, who were hired to lead the field portion of the study from May through July, three study sites were selected, 96 treatment plots installed, and 480 vegetation sample plots measured. Assistance from CFRU Advisory Committee members (**Kenny Fergusson**, **Dave Dow**, and **Marcia McKeague**) allowed us to use sites on Huber Resources (T2 R7), Prentiss & Carlisle (T2 R8), and Katahdin Forest Management (TA R7) lands. The final experimental design was a randomized complete block with three replications (sites serving as blocks).

Pre-treatment measurements of the sample plots revealed that beech, sugar maple, red maple, and yellow birch were present on nearly all sample plots, providing excellent conditions for evaluating treatment effects on each species. An average of 16,615 beech, 18,232 sugar maple, 12,400 yellow birch, and 6,902 red maple were found per acre before treatment. Each site had been shelterwood harvested within two years of the study being installed, thus providing a good representation of post-harvest conditions when release treatments would likely be applied.

All treatments were applied in mid-August during excellent weather (low wind and no rain). The full factorial design was applied on August 17 using

Figure 17. Bob Wagner operating a CO^2-powered backpack sprayer with a single KLC-9 flood tip nozzle on an 11-ft tall extended boom used to treat the plots. Note fine droplets that are deposited in a 25-ft wide swath behind the backpack sprayer.

a CO^2-powered backpack sprayer with a single KLC-9 flood tip nozzle on an 11-ft tall extended boom that simulates ground application using a radiarc or other hydraulic spraying system (Figure 17). The amount of spray used was measured to document the actual herbicide and surfactant rate delivered to each plot. All treatments were applied to within 2.2% of the target rate on average, with all but five of the 72 plots being applied within 10% of the target rate. Three of the treatments were replicated on other plots using a backpack mistblower application on August 22 (Figure 18). Results from these plots will be used to compare results from a mistblower with that of a hydraulic nozzle system.

Plans for the coming year involve re-measuring all the plots on the three sites to assess the first-year effect of the treatments. Current CFRU funding provides for measuring vegetation responses for three years. Longer-term measurements will be required to assess the effect on hardwood regeneration dynamics, but the results from next year's measurements should provide a good indication of whether the concept being tested in this study is feasible.

More information about this project is available by contacting Bob Wagner at bob_wagner@umenfa.maine.edu or 207-581-2903.

Figure 18. Max McCormack using a gas-powered backpack mistblower to treat a research plot. The very fine droplets from this sprayer simulate those deposited from a tractor mounted mistblower typically used to treat understory forest vegetation.

Silviculture and Ecology of Northern White Cedar

Philip Hofmeyer, Robert S. Seymour and Laura Kenefic

SUMMARY

Our investigation of northern white-cedar (*Thuja occidentalis* L.) had three objectives:

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

2) to describe early stem development and recruitment patterns; and

3) to quantify cedar leaf area to sapwood area relationships and growth efficiency.

Phil Hofmeyer cuts one of his tree discs.

Our goal was to begin filling in the knowledge gaps associated with this species' ecology, responses to silvicultural treatments, growing space utilization, and ultimately address the sustainability of recent harvesting trends in Maine. With over 60 sites throughout northern Maine on a wide range of landownership (and associated management strategies), results gleaned from this study should be applicable to cedar managers throughout Maine.

COMPARATIVE GROWTH STUDY

Sixty sites were selected throughout northern Maine to compare northern white-cedar growth to red spruce and balsam fir (Figure 19). Two soil pits were excavated at each site to determine Briggs' (1994) site class by depth to redoxymorphic features (Table 6). Five upper canopy cedar and five red spruce and/or balsam fir were selected based on outward soundness and light exposure (LE) class. LE classes are somewhat analogous to traditional crown classes; however, they tend to have a higher level of repeatability among observers and provide more information about an individual stem's ability to capture solar insolation (Bechtold 2003). A LE class of 5 is analogous to a dominant crown class and an LE class of 1 is analogous to an intermediate crown class. No overtopped (LE class 0) trees were selected for this study. Each selected tree was cored twice to the pith (perpendicular) at breast height (1.3 m). Sapwood length was marked in the field on each core. Tree measurements of diameter at breast height, total height, lowest live branch height, bark thickness and a basal area factor 10 (BAF 10) prism plot were taken in the field. Cores were dried, sanded and read using WinDendro software.

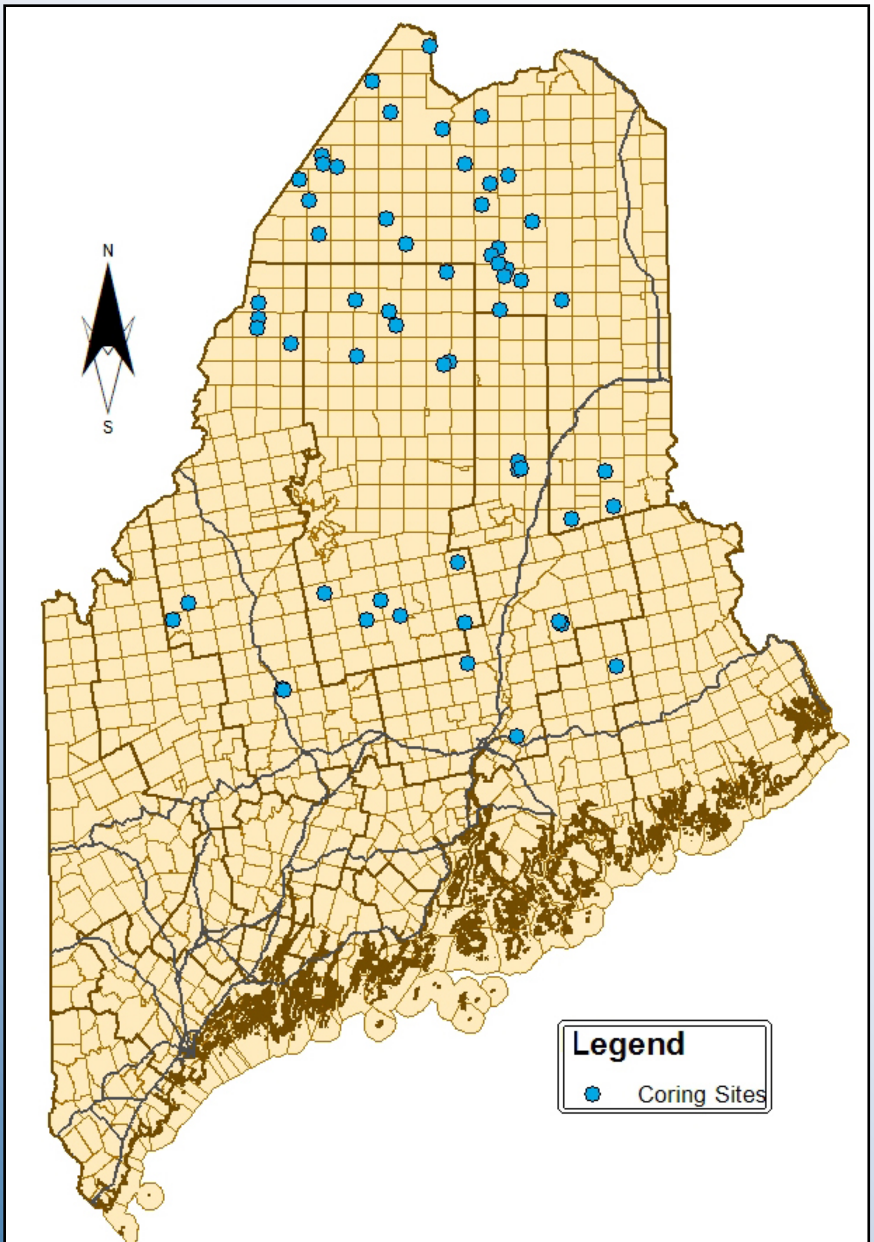
Table 6. Briggs' (1994) site class descriptions.

Site Class								
	1		2		3	4		5
Drainage Class	Well	Somwehat Excessive	Somewhat Excessive	Moderately Well	Somewhat Poorly	Poorly Drained	Excessively[1]	Very Poorly
Mottling Depth[2]	>24"	-	-	16-24"	8-16"	4-8"	-	<4"
Thickness of Loam Cap	-	>12"	8-12"	-	-	-	-	-

[1] Shallow bedrock (<12") or coarse sand and gravel

[2] Depth to seasonal high water table as indicated by low chroma mottles (or grey).

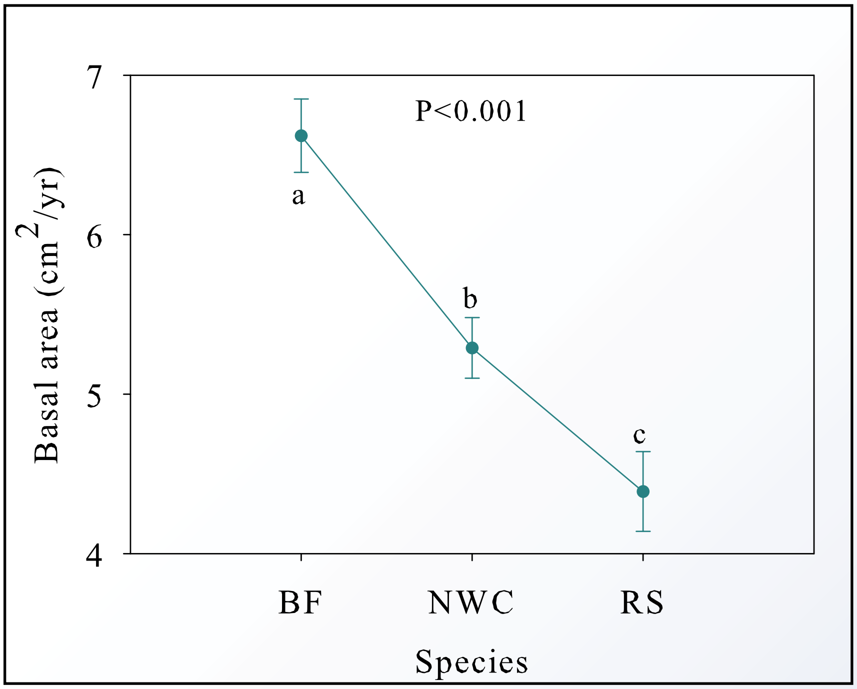
Figure 19. Sixty mixed-species study sites throughout northern Maine.



Data were collected during the summers of 2005 and 2006. Only the most recent complete five years of growth data were used for analysis. Analysis of Covariance (ANCOVA) compared basal area growth increment among species, site classes, and LE classes, using sapwood area (a surrogate for leaf area) as a covariate at an alpha of 0.05. SYSTAT version 11 was used for all analyses.

Decay was present in all species across all site classes; however, there were significant differences among species (Table 7). With such a high proportion of decay in some of the samples, it was difficult to age the increment cores. Nevertheless, we were able to detect differences in age among species. The oldest cedar observed had 222 years of readable rings at breast height, with many exceeding 150 years. The oldest red spruce was 201 years, with ages com-

Figure 20. Basal area increment least squares (LS) means by species. Means are adjusted for the sapwood area covariate for all species combined.



monly 100-130 years. Balsam fir rarely exceeded 100 years in age; the oldest individual observed was 109 years.

Basal area growth differed significantly among species when other variables were held constant (Figure 20). Sapwood area was a significant covariate ($p<0.001$) for all species in detecting differences in basal area growth. Site class was marginally non-significant when all species were included ($p=0.058$). Balsam fir was the only species that had significant differences in basal area growth among site classes ($p=0.013$) (Figure 21) and light exposure classes ($p=0.015$) (Figure 22).

Conventional wisdom in Maine is that northern white-cedar trees growing on upland sites have higher growth rates and better quality (e.g. Curtis 1941). Results from this study do not support that conclusion, at least in terms of basal area growth and soundness across site classes. A significantly lower proportion of cedars were decayed on site classes 4 and 5 than on site class 2, though decay was high in all classes. In Maine, upland sites are frequently partially cut, potentially leading to increased root and crown damage to create entry points for fungal infection. However, a study in the Adirondacks of New York comparing bog community cedar to limestone outcrop community cedar found that approximately 80% of the stems had central decay, independent of site (Harlow 1927). Partial harvesting may also have driven species selection for the present study. Because red spruce is highly sought after, it is commonly targeted for removals on accessible sites. Sparse upper canopy red spruce limited the number of sites useable for this comparative study, leading to a relatively small sample size that may not be fully representative of the red spruce population in Maine. Similarly, these results are biased to outwardly sound individuals of all species, which might have different mean growth rates than the Maine populations.

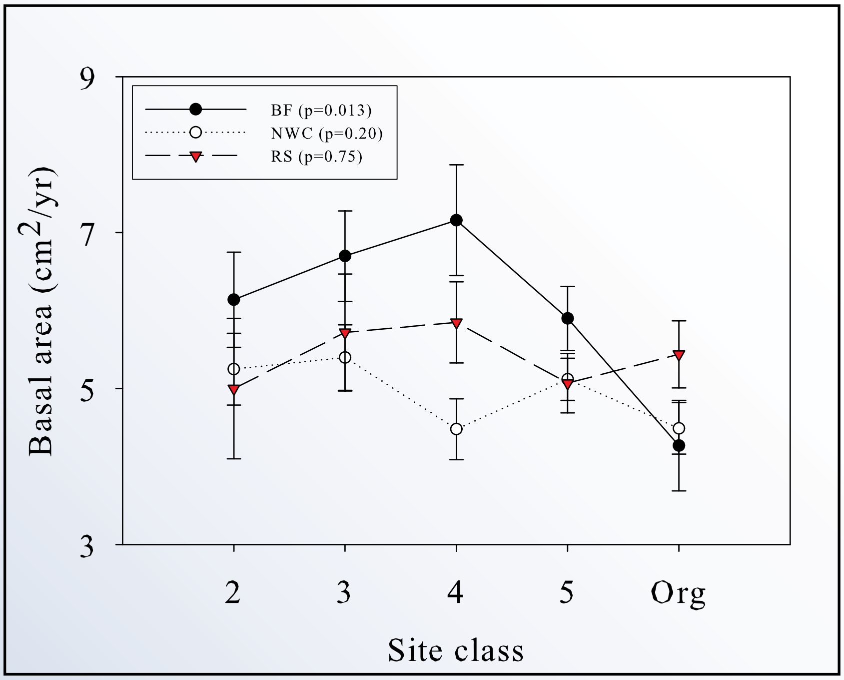
ANCOVA, using species, light exposure, site class, and sapwood area as variables, suggests that balsam fir will generally outcompete cedar and red spruce. This was not true across all site classes and light exposure classes when analysis was done

Table 7. Mean proportion of cores decayed by site class

	Proportion of sample decayed		
Site Class	**BF**	**RS**	**NWC**
2	0.57 (0.09)^{a}	0.10 (0.10)	0.97 (0.07)^{a}
3	0.40 (0.08)^{ab}	0.13 (0.08)	0.88 (0.07)^{ab}
4	0.40 (0.10)^{ab}	0.13 (0.06)	0.64 (0.06)^{b}
5	0.19 (0.06)^{b}	0.07 (0.04)	0.73 (0.04)^{b}
Organic	0.23 (0.08)^{b}	0.13 (0.05)	0.74 (0.05)^{ab}
Mean	**0.34 (0.03)^{b}**	**0.11 (0.02)^{c}**	**0.80 (0.03)^{a}**

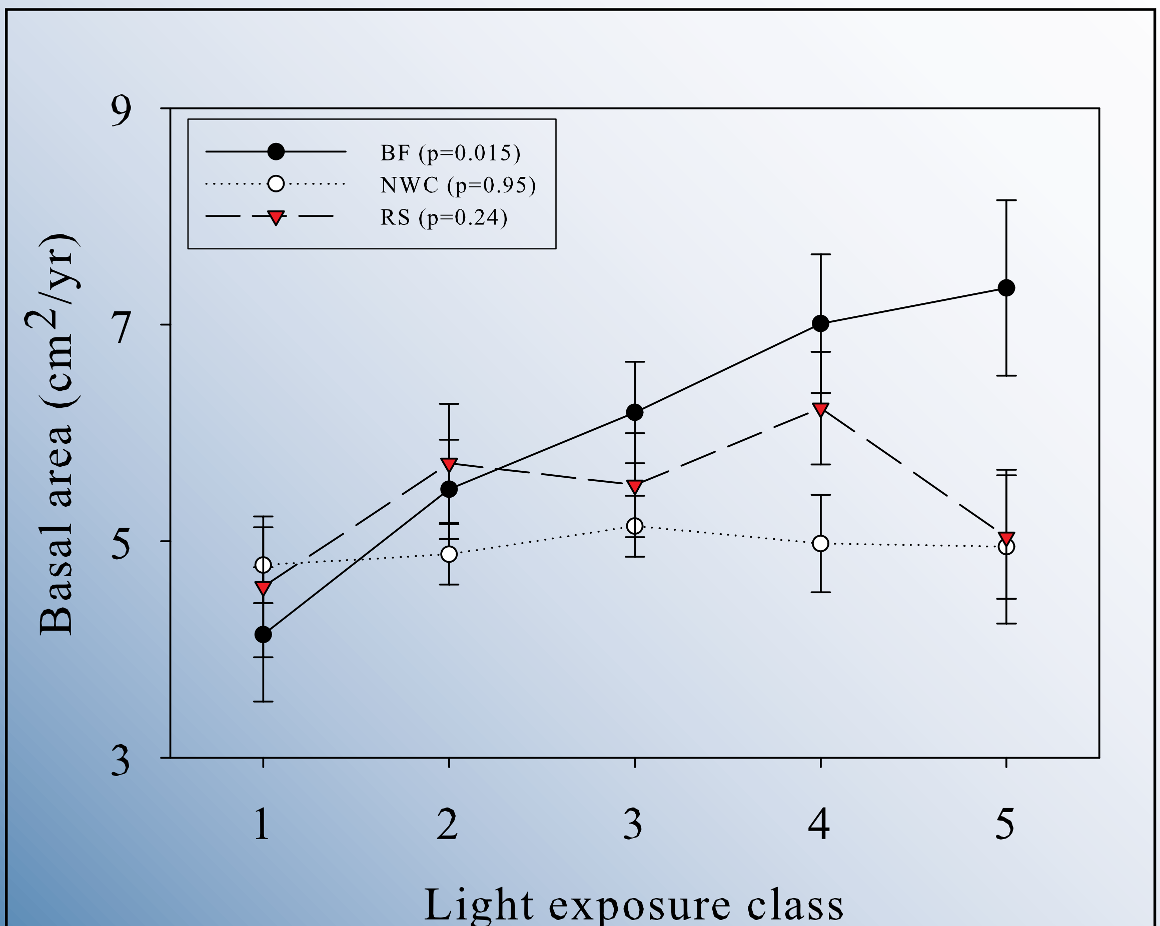
* Means of the same species followed by different letters are significantly different at $\alpha=0.05$ level. Species' means were also significantly different.

Figure 21. Basal area increment LS means by species across site classes. Species means are adjusted for species-specific sapwood area covariates.



by species (Figures 21 and 22). Additionally, cedar had a higher mean growth rate than red spruce, which was not expected. This belies the common belief that cedar has poor growth rates and thus limited management potential. Lastly, our data suggest that northern white-cedar basal area growth of non-overtopped trees is not responsive to increased crown light levels. This could have important implications for managing mixed-species stands where cedar is an important component of understory and midstory strata, and might allow foresters to take advantage of advance growth effects.

Figure 22. Basal area increment LS means by species across light exposure classes. Species means are adjusted for species-specific sapwood area covariates.



EARLY STEM DEVELOPMENT AND RECRUITMENT

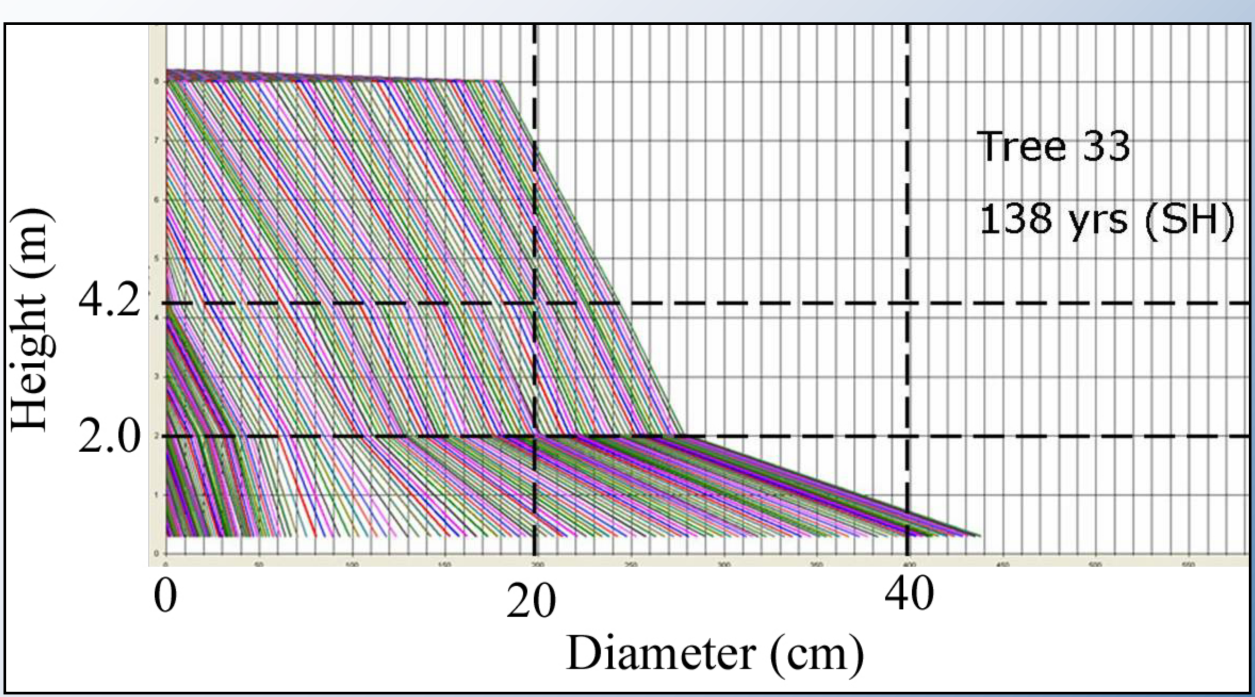
Maibec Industries, Inc. based in St-Pamphile, Quebec donated 73 sound cedar stems for early stem development analysis. Of these, 61 stems were sound to the pith allowing for complete growth analysis. Sample stems were imported from Maine into Quebec and had known stand origin, though stand history is unknown. A cross-sectional disk was taken from each sample tree at 0.3 m, 2 m, 4.2 m, and one at merchantable top diameter for a total of four disks per tree. These disks were taken at unconventional research intervals to allow the stems to be used in commercial shingle production after the samples were removed. Regardless of the intervals selected, we believe they will allow for adequate characterization of early stem development. Each disk was sanded and read using WinDendro software.

Cedars in northern Maine were found to be much older than previously considered. The mean age for the Maibec sample trees at 0.3 m is 197 years (107-356), at 2 m is 167 years (80-310), and at 4.2 m is 142 years (70-248). Though the sample is biased toward stems that are sound to the pith, the age range of the 2 m samples is consistent with the readable age range of merchantable-size stems in the comparative growth study, which was not biased to inwardly sound individuals.

A pile of mostly clear cedar wasn't easy to find for this study.

Cumulative height and radial growth will be reconstructed for each stem (e.g. Figure 23). Though this has not yet been completed for all trees, several trends are consistently observed. The first to note is the initial suppression depicted by narrow growth rings and slow height growth increment. This suggests that cedar recruitment into the main canopy often entails extended periods of slow height development and diameter growth in the lower canopy strata. The second trend is the conspicuous flaring of the stem at the butt.

Figure 23. Stem profile for sample tree 33. Each line represents one year's growth in both height and diameter.



Future analysis is aimed at describing the time periods necessary to recruit stems into the sapling and pole stages as well as the time necessary to grow out of browsing height for snowshoe hare and white-tailed deer. This information will be closely linked to regeneration and initial growth data from project cooperators in Quebec.

LEAF AREA : SAPWOOD AREA AND GROWTH EFFICIENCY

During the summer of 2006, 25 sound cedar stems were destructively sampled to quantify leaf area to sapwood area relationships and growth efficiency. This sample was stratified by site class to determine soil drainage influences (if any) on growth efficiency. Most sample trees were sound to the pith (with several exceptions) to supplement early stem development information from the stems donated by Maibec Industries. Trees with excessive forking were not sampled for this portion of the study.

Each sample tree was carefully felled to avoid excessive limb damage. Total stem height and lowest live branch height were measured to determine crown length. Three sample branches were selected from each crown and removed for later analysis. On each sample branch, five foliar sprays were removed and stored for later analysis of specific leaf area. Cross-sectional disks were removed at 1-meter intervals along the stem, with an additional disk removed at the lowest live branch (LLB) location. The sapwood-heartwood boundary was marked and measured in the field along six radii on the LLB and BH cookie. All cookies have been sanded in preparation for analysis using WinDendro software. Stored sample branches were dried to a constant weight, and separated into photosynthetic parts, non-photosynthetic parts, and cones.

Laura Kenefic inspect a cedar disc for the sapwood delineation.

Though this methodology is accepted and commonly used for conifer leaf area studies, it is more complex for northern white-cedar. Cedar architecture is best described as a continuum of axes to foliage, without discrete separations. This unique morphology adds variability and difficulty in separating branch materials. Lab analysis for this portion of the study is nearly complete and will be ready for data analysis this upcoming spring.

More information about this project is available by contacting Bob Seymour at seymour@umenfa.maine.edu or 207-581-2860.

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Wildlife

Predicting Responses of Forest Landscape Change on Wildlife Umbrella Species

Temporal and Spatial Relationships Among Hares, Lynx and Habitat

Responses of Snowshoe Hare and Canada Lynx to Forest Harvesting in Northern Maine

Predicting Responses of Forest Landscape Change on Wildlife Umbrella Species

**Erin Simons, Kasey Legaard, Daniel Harrison,
Steven Sader, Jeremy Wilson, William Krohn, and Laura Robinson**

SUMMARY OF PROGRESS DURING YEAR TWO

Two Ph.D. students (Erin Simons and Kasey Legaard) have completed their coursework and are progressing rapidly towards the completion of their dissertation objectives related to the funded project. Additionally, a masters thesis (Robinson 2006) was completed, described in the 2006 CFRU report "Responses of snowshoe hare and Canada lynx to forest harvesting in northern Maine," which developed a predictive model of lynx occurrence that will be used for evaluating trends in habitat supply for that federally threatened species. We also made significant progress on the development of a retrospective time series of forest cover maps spanning the years 1988-2004 based on Landsat Thematic Mapper (TM) satellite imagery (Section III). In 2007, we will be quantifying temporal changes in habitat supply for American marten (*Martes americana*) and Canada lynx (*Lynx canadensis*) during the period 1988-2004 by applying predictive occurrence models to year-specific forest cover maps. We are currently compiling the detailed forest condition information required for our Forest Projections analysis and have begun to construct the alternative forest management scenarios that will allow us to evaluate the effects of different timber harvesting strategies on landscape change and future habitat supply for lynx and marten.

PROJECT OVERVIEW

Since the implementation of the 1989 Maine Forest Practices Act (MFPA), changes in commercial forest management practices have resulted in substantial increases in partially harvested stands and forestland harvested annually. There have also been significant changes in timberland ownership; between 1995 and 2002 approximately 1.6 million acres changed hands from Forest Industry Ownership to Non-Industrial Private Ownership (Maine Forest Service 2003). These changes in forest policy and management practices could greatly influence the future sustainability of wildlife species in Maine, particularly those that depend on early-successional forest (e.g., Canada lynx) or intact mature forest (e.g., American marten). Lynx and marten have been proposed as umbrella species for forest wildlife conservation in Maine because together they represent a range of ecological conditions associated with habitat occupancy for >80% of forest vertebrates in northern Maine (Harrison and Hepinstall, *In Preparation*). Both of these species are area sensitive and respond to habitat change over large spatial scales.

With lynx and marten habitat conservation largely in the hands of private forest landowners in Maine, it is important that we understand the short- and long-term effects of forest management on landscape change and lynx and marten habitat. Through this understanding we can de-

Lynx is one umbrella species used to evaluate the impact of changing commercial forest management practices.

velop tools forest managers can use to manage lynx and marten habitat at the appropriate spatial and temporal scales. Evaluation of these types of ecological effects requires an accurate depiction of timber harvest patterns and their evolution over a long period of time and across large areas. Thus, we have initiated a collaborative study involving the formal endorsement and financial support of more than 20 forest companies in Maine (Maine Cooperative Forestry Research Unit), national forestry industry (National Council for Air and Stream Improvement), Maine Department of Inland Fisheries and Wildlife, U.S. Fish and Wildlife Service, U.S. Geologic Survey, The Nature Conservancy, Maine Cooperative Fish and Wildlife Unit, Maine Agricultural and Forest Experiment Station, and the University of Maine to evaluate past trends in lynx and marten habitat supply (Section III), to simulate the effects of alternative forest management scenarios on landscape change and lynx and marten habitat (Section II), and to build predictive models of species occurrence for marten and lynx and to evaluate the utility of marten and lynx as umbrella species in Maine (Predictive Modeling and Evaluating Umbrella-Species).

PRIMARY ACTIVITIES IN 2006

I. PREDICTIVE MODELING AND EVALUATING UMBRELLA-SPECIES

Models for predicting occurrence of Canada lynx and American marten in northern Maine will be applied to the forest cover maps generated under the Forest Change and Harvest Trends section of this project. The development and validation of a second generation model for predicting Canada lynx occurrence in Maine has been recently completed (Robinson 2006) and is described in the CFRU report "Responses of snowshoe hare and Canada lynx to forest harvesting in northern Maine." The marten occurrence model was developed in a previous project (Hepinstall and Harrison 2004) and was demonstrated to have a >75% accuracy for predicting home range occupancy by marten in Maine. Lynx and marten have been proposed as umbrella species for forest wildlife conservation in Maine because together they represent a range of ecological conditions associated with habitat occupancy. Hepinstall and Harrison (*In Preparation*) found that if areas in Maine with a probability of occurrence >50% for lynx, based on the occurrence model developed by Hoving et al. (2004), and >80% for marten were protected, 111 (86%) of the 130 vertebrate species that they considered would be incidentally benefited. This suggests that planning for lynx and marten habitat could accommodate the habitat needs of many of northern Maine's wildlife species. Our analysis will allow us to evaluate the effects of landscape change on the spatio-temporal dynamics of habitat quantity and distribution for lynx and marten in northern Maine over the past 17 years (1988-2004).

II. FOREST PROJECTIONS

This work will provide a means through which we can evaluate the interacting effects of past forest management legacy and future forest management under alternative management scenarios on landscape change and lynx and marten habitat. Past forest management legacy will be represented by the inclusion of a set of townships representing a gradient of past forest management intensity. We are currently working with a diverse group of landowners to acquire current spatial data sets (e.g., GIS-based stand type maps) and forest inventory information for selected townships. These data sets will allow us to compile a portfolio describing each township within the set, which will be used as the basis for simulating future conditions under a range of alternative forest management scenarios.

Forest stand projections will be implemented by Dr. Jeremy Wilson using landscape-modeling software such as the Landscape Management System (LMS Version 3.0) and Woodstock (Version 3.26) forest modeling system in conjunction with the Stanley (Version 5.0) spatial harvesting software (McCarter et al. 1998, McCarter 2001, Remsoft 2002). Scenarios will explore different strategies and tradeoffs for meeting fiber and wildlife habitat objectives. Beginning in 2007, we will be developing scenarios that will allow us to compare and contrast the current dominant form of timber harvesting in Maine (i.e., partial harvesting) to strategies that differ both in the amount of volume removed and harvest block layout. By also including a diverse array of past forest management intensities as the basis for our simulations, we will be able to evaluate the temporal persistence of the effects of forest management on landscape pattern.

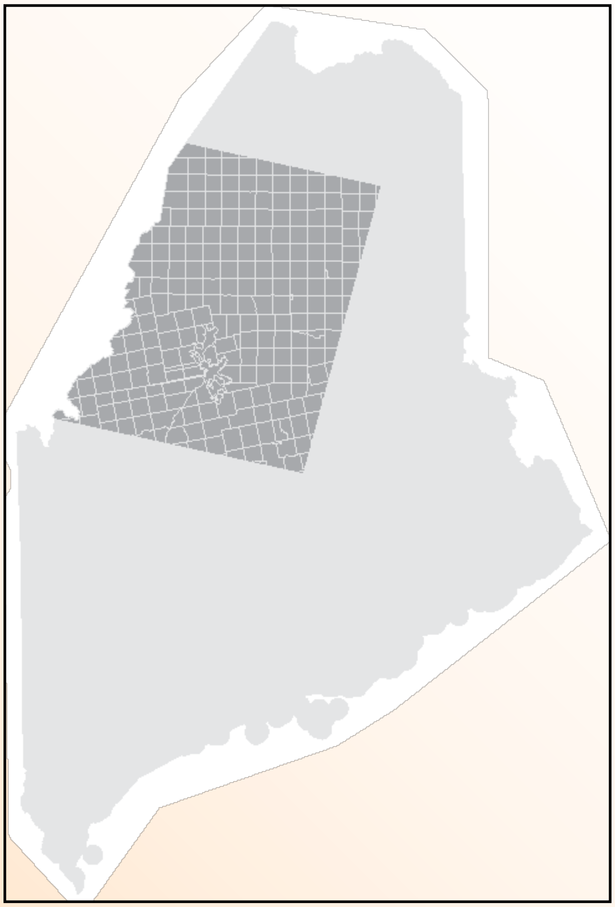
Additionally, we hope to include scenarios that reflect alternative management responses to a future spruce budworm outbreak. The most recent outbreak (1972-1986) left a lasting legacy on the age distribution and species composition of Maine's forest, which has important implications for the availability of habitat for both early successional and mid- to late-successional species. Consequently, it is important that we have plans in place to deal with the next outbreak in a way that considers habitat supply for early successional (i.e., lynx) and mid-late successional (i.e., marten) wildlife species.

III. FOREST CHANGE AND HABITAT TRENDS

In collaboration with the Maine Image Analysis Laboratory (MIAL), we have completed a retrospective time series of forest cover maps for northern Maine based on Landsat TM satellite imagery spanning the 17-year period of 1988-2004. Sampling across this time period allows us to document changes in forest harvest patterns following major changes in forest policy and ownership that have occurred since the early 1990s. The study area (Figure 24) was expanded to encompass approximately 20,000 km^2, including the greater part of 215 townships and roughly 4.5 million acres of forestland. The assortment of ownership types (e.g., industrial forest products companies, family-owned corporations, investment entities, and NGO's) within this area is broadly representative of the unorganized townships of northern Maine. Using the predictive species occurrence models, we will be able to characterize the landscape-scale effects of changes in timber harvesting practices on lynx and marten habitat and changes in the quantity and distribution of habitat over a large portion of the geographic ranges of these high-profile umbrella species across northern Maine.

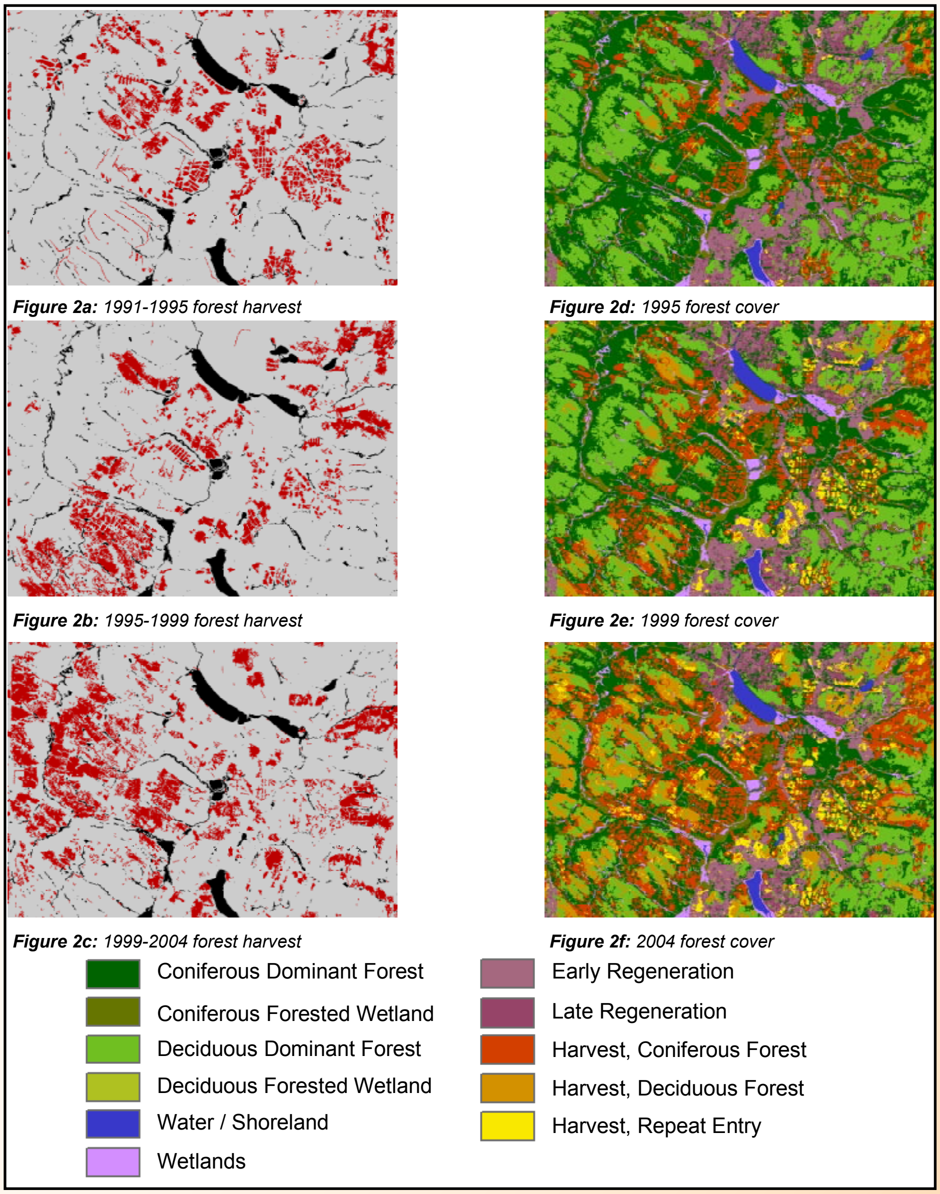
To produce a retrospective time series of forest cover and habitat maps, we have developed a means by which older digital land cover products can be updated based on established forest change detection techniques (e.g. Sader and Winne 1992, Sader et al. 2003). A harvest detection time series was assembled from individual change detection maps spanning one- to three-year time intervals between image acquisition dates. Harvested areas were mapped into two intensity classes (clearcut/heavy partial cut, light partial cut). Forest regrowth and regeneration between image acquisition dates were also mapped. Confusion between light par-

Figure 24. The study area (dark gray) for Forest Change and Habitat Trends. Study area encompasses approximately 20,000 km^2, including the greater part of 215 townships and 4.5 million acres of forestland.



tial harvests and changes induced by other factors (such as plant phenology or atmospheric effects) were resolved via extensive editing aided by visual interpretation of the TM imagery. The harvest detection time series was used to update the 1993 Maine GAP vegetation and land cover map (Hepinstall et al. 1999) to reflect cumulative changes in forest cover. Figure 25 shows the areas harvested (a-c) between the time periods 1991-1995, 1995-1999, and 1999-2004 and the corresponding updated forest cover maps (d-f) for a 1,200 km^2 test landscape in northern Maine. This series of maps demonstrates the cumulative effects of timber harvesting on landscape change over a 13 year time period. By incrementally updating the GAP land cover map, rather than creating a series of land cover products through the direct classification of each TM image, we have minimized the impact of image-to-image variation caused by factors other than changes of interest. Additionally, through the explicit detection of forest cover change between successive images, we have improved upon the accuracy of GAP harvest and forest regeneration classes. Our approach demonstrates an efficient and flexible means for producing land cover data needed to identify and document the cumulative effects of forest management on landscape structure and wildlife habitat. Our methods and preliminary results were presented at the 2006 Eastern CANUSA Conference in Quebec City.

Figure 25. Figures a-c show the areas harvested (red) between three time periods: 1991-1995, 1995-1999, and 1999-2004 for a 1,200 km^2 test-landscape. Figures d-f show the corresponding updated forest cover maps.



IV. PLANS FOR 2007

Using the retrospective time series of harvest detection and forest cover maps, we will document cumulative effects of evolving management practices, including changes in landscape pattern, forest age class distributions, forest composition, and consequent changes in lynx and marten habitat supply (i.e., completion of Forest Change and Habitat Trends). We are currently preparing the forest cover maps for use as the basis for the retrospective analysis of lynx and marten habitat to evaluate the broad-scale effects of landscape change on the quantity and distribution of lynx and marten habitat in northern Maine. In addition, we will be using various quantitative techniques, including regression models, to analyze trends in forest harvest activity apparent in the retrospective time series and to project harvest activity into the future under various alternative forest management scenarios. The township-scale analysis of the Forest Projections work will complement the broad, retrospective analysis by allowing us to describe the evolution of current conditions and to consider alternative future conditions. This will enable us to make specific recommendations to the participating landowners about alternative management strategies that will promote lynx and marten habitat, as well as general recommendations to the forest companies that participate with CFRU, the Maine Department of Inland Fisheries and Wildlife, and the U.S. Fish and Wildlife Service.

More information about this project is available by contacting Dan Harrison at harrison@umenfa.maine.edu.

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The Maine landscape has many different forest patch arrangements throughout.

Temporal and Spatial Relationships Among Hares, Lynx and Habitat

Daniel Harrison, William Krohn, Laura Robinson and Jessica Homyack

PROJECT BACKGROUND AND OVERVIEW

The snowshoe hare is the primary prey of the federally threatened Canada lynx throughout its broad geographic range in North America. Thus, effects of stand-scale forest management practices on lynx will likely be determined by changes in forest structure that influence hares. Previous research funded by the CFRU has documented that hare densities are positively associated with conifer stem densities (Robinson 2006) and negatively associated with the shading provided by large trees (Fuller 2006). Thus, hare densities were lowest in recent partial harvests and recent clearcuts, low in mature conifer- and deciduous-dominated stands, intermediate in PCT-treated stands, and highest in regenerating conifer clearcuts with a past history of herbicide application (Fuller and Harrison 2005, Robinson 2006, Homyack et al. 2007). Recent trends indicate that >96% of the acreage currently harvested in Maine annually is comprised of partial- and shelterwood-harvesting. However, little is known about hare densities and residual stand structure within stands representing the broad range of selection and shelterwood practices currently used throughout the geographic range of the Canada lynx in Maine. Further, home range-scale modeling of lynx occurrences has indicated that lynx are associated with landscapes predominated by regenerating conifer clearcuts and the correspondingly high hare densities (Hoving et al. 2004, Robinson 2006).

Clearcutting has declined to <5% of the annual forest harvests reported in Maine, which begs the question of how long the regenerating clearcuts that currently support lynx occurrence and high hare densities will remain as high quality habitat. Empirical data on the duration and trends in habitat quality for hares following forest harvesting are lacking; published speculation suggests that optimal hare densities may be supported for approximately 10-25 years following cutting and that precipitous declines in hares would be expected from 20-30 years after cutting. Therefore, a better understanding of temporal changes in forest structure after cutting is needed to evaluate and forecast future trends in habitat supply for lynx as the extensive areas of regenerating clearcuts created via spruce-budworm salvage in the 1970's and 1980's mature towards self-thinning and pole stages.

Snowshoe hares select stands with dense understory cover to avoid predators. Stands regenerating following clearcut harvesting support the highest hare densities in Maine.

Finally, hare population dynamics have been extensively studied on boreal sites in Alberta, the Yukon, Alaska, and within the intermountain forests of Montana. Despite that the largest population of Canada lynx in the coterminous U.S. occurs in the Acadian forests of Maine, there have been no long-term studies of hare population dynamics in this region. Although hare populations exhibit 9-11 year cycles, which are synchronized across vast geographic areas throughout the boreal forest region, considerable debate exists over the presence of synchrony and cyclicity within the Acadian forests. Knowledge of natural processes causing temporal and spatial changes in hares is of critical importance when evaluating the influences of short-term human-induced habitat changes (e.g., forest harvesting) on lynx and hare habitat.

The objectives of this project are to:

1) Document temporal changes in hare densities across benchmark regenerating conifer clearcut stands in the Telos and Clayton areas of northern Maine;

2) Evaluate the differences in hare densities and to evaluate the extent of population synchrony between the Telos and Clayton Lake areas;

3) Evaluate the differences in hare populations between established, regenerating partial- and shelterwood-harvested stands relative to benchmark regenerating conifer clearcut stands; and

4) Determine the relationship between number of years after clearcut harvesting and the hare densities within regenerating stands.

APPROACH

We have monitored hare densities using pellet survey protocols developed for Maine based on previous CFRU-supported projects (Homyack et al. 2006). Densities have been monitored on seven benchmark regenerating conifer clearcut stands in the Telos region since winter 1996. Further, eight regenerating conifer clearcuts stands in the Clayton Lake area have been surveyed twice-annually since 2005. Additionally, 21 partial harvest stands, including 11 selection harvests, seven conifer-dominated shelterwood stands, and three overstory removals were established and hare densities were estimated twice-annually in 2005 and 2006.

PRELIMINARY FINDINGS

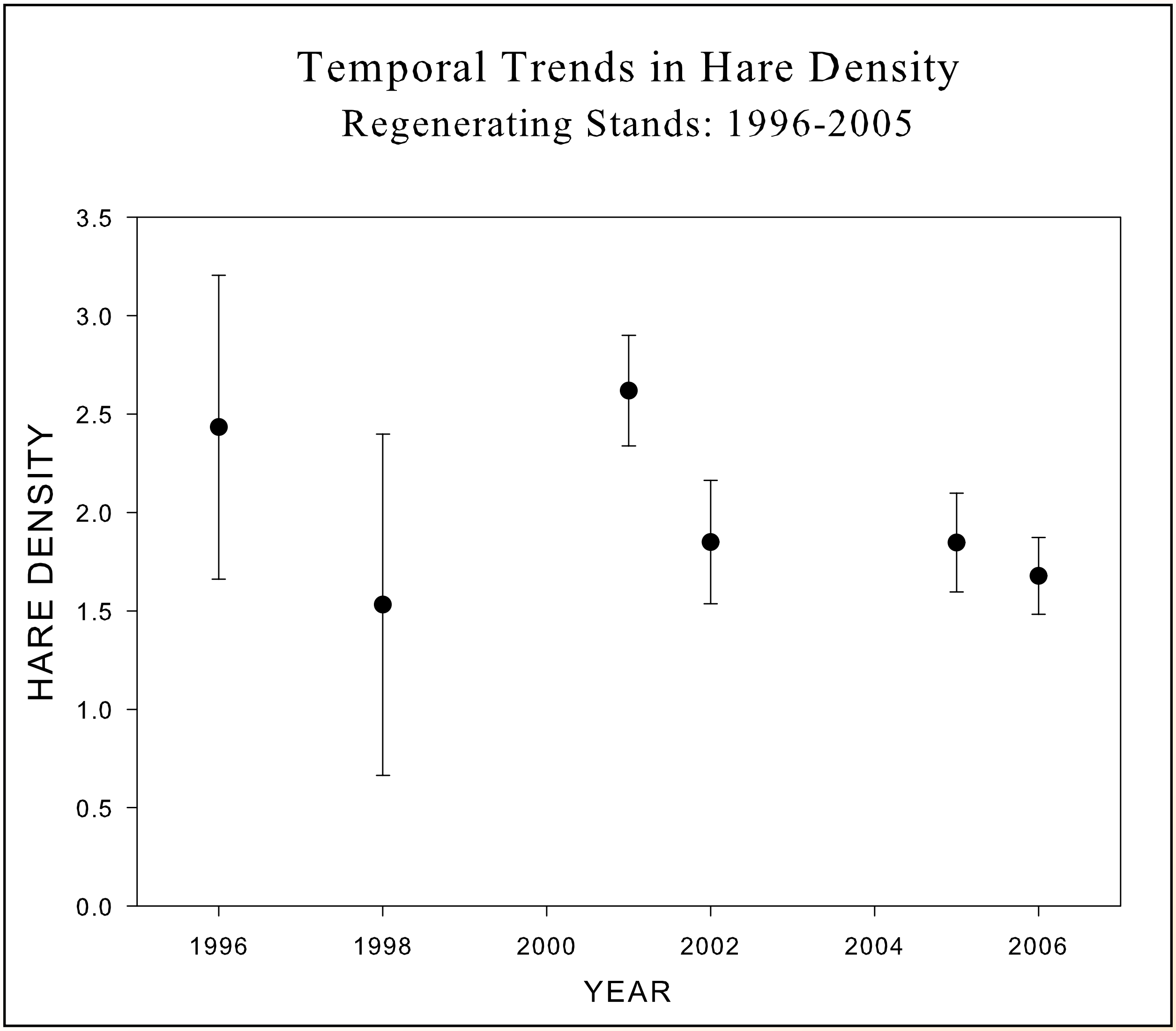
Temporal Changes in Hare Densities

Hare densities within the Telos region have remained remarkably stable since 1996 with mean hare densities in regenerating conifer clearcut stands varying from only 1.6-2.6 hares/ha during that 11-year period (Figure 26). The maximum differences between years were 1.6-fold, which is 1-2 magnitudes lower than the 5- to 25-fold fluctuations typical of boreal forest ecosystems from the low to the peak of the 10-year hare cycle. To date, our data suggest that hares may not be cycling in the Acadian forests of northern Maine.

Spatial Synchrony in Hare Densities

Over the initial two years of our study, mean hare densities within regenerating clearcut stands in the Telos area have ranged from 1.6-1.8 hares/ha during winter and from 0.6-1.9 hares/ha during summer. In the Clayton Lake area densities have ranged from 2.3-2.8 hares/ha during winter, and from 0.6-1.5 hares/ha during summer. Additional years of data will be required to determine the relative effects of latitudinal differences versus within-stand structure in determining spatial variation in hare densities and to determine whether hares fluctuated synchronously across the geographic range of lynx in Maine.

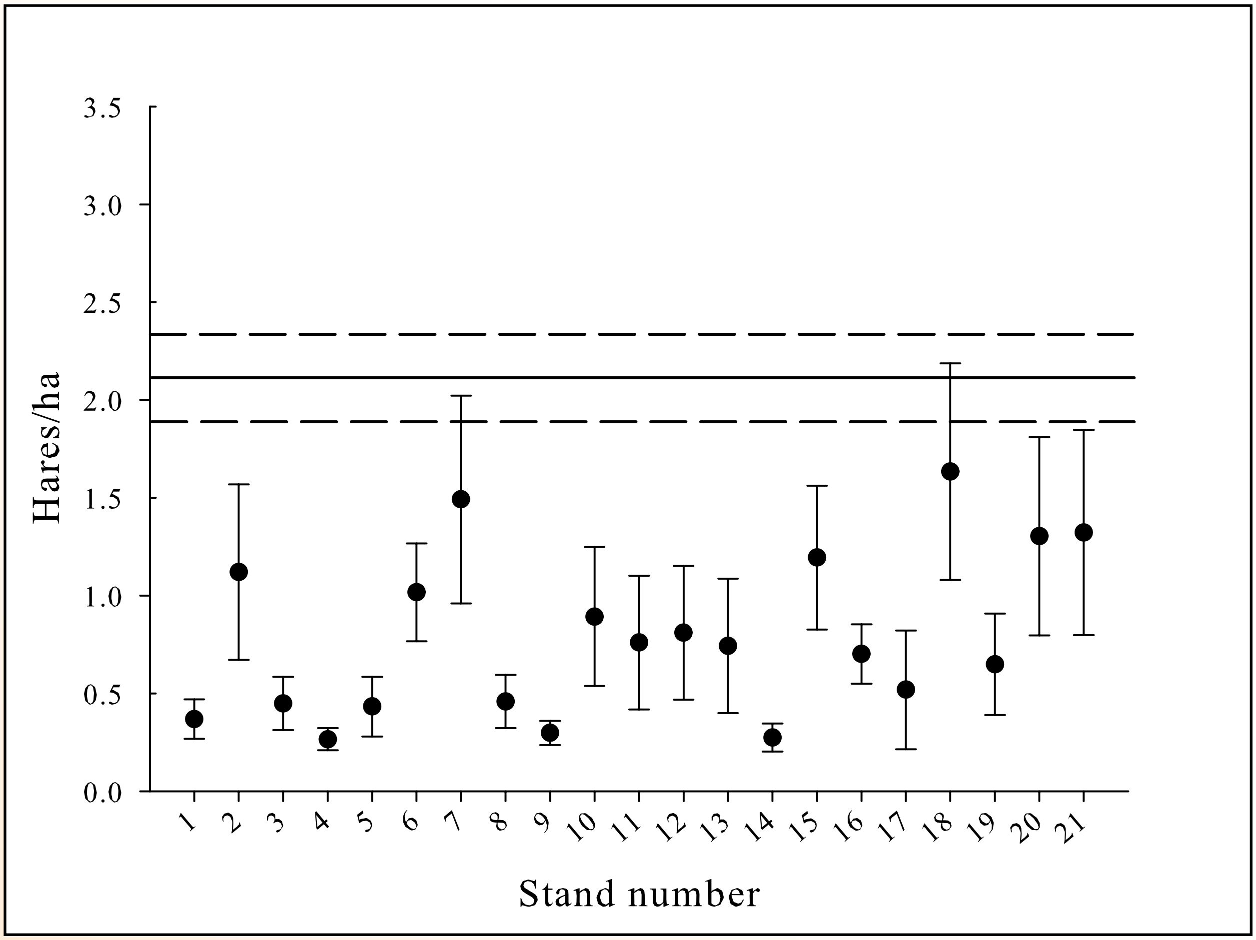
Figure 26. Temporal changes in mean hare density (± SE) across seven regenerating clearcut stands in the Telos area of northern Maine from 1996-2006. Note that only 2 stands were surveyed in 1998, which contributes to the wider standard error during that year.



Effects of Partial Harvesting on Hare Densities

Hare densities in partially harvested stands were compared to regenerating (19-32 year post-harvest) conifer clearcuts, which represent the optimal stand condition for hares in Maine (Figure 27). Results suggest that partial harvesting is associated with residual stands that vary greatly in their vegetation characteristics and snowshoe hare densities (*see* Robinson 2006). Partially harvested stands had lower conifer stem densities, higher densities of deciduous trees, and higher log densities than regenerating conifer clearcuts, which may be related to the large discrepancy in hare densities between the two harvesting approaches. Hare densities within 21 partially harvested stands ranged from 0.26-1.65 hares/ha, but all were lower than the mean hare density (2.10 hares/ha, SE 0.22) found in regenerating conifer clearcuts during the critical leaf-off season. Partially harvested stands may not support the hare densities previously hypothesized as required to maintain a viable lynx population across the landscape; however, this issue requires additional study and will be a focus of continued investigations.

Figure 27. A comparison among hare densities (+ 95% CI) in 21 partially harvested stands (stands 1-21) and the mean density (2.1 hares/ha, solid line) + 1SE (dashed lines) in 12 regenerating clearcut stands surveyed in the Telos and Clayton Lake areas of northern Maine. Data represent averages across 2 winter seasons in 2005 and 2006.



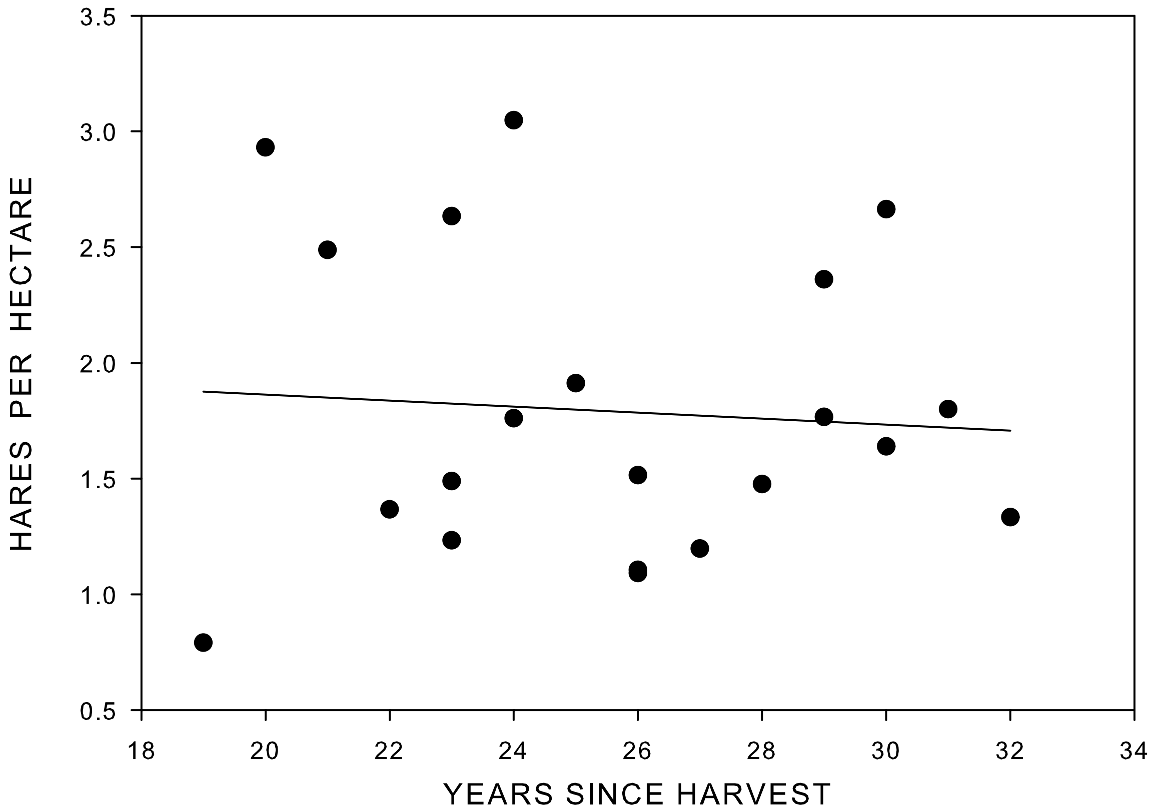
Hare Densities and Stand Succession

We monitored hare densities in regenerating conifer clearcut stands spanning a range of ages from 19 to 32 years post-harvest to evaluate the question of "how ephemeral is hare habitat?" Existing speculation in the literature has suggested that habitat quality for hares may decline drastically when regenerating conifer stands approach 25 years of age. Further, hare densities in mature stands in Maine support hare densities of only about 0.2-0.25 hares /ha, so we expected that hare densities would decline precipitously as stands progressed from regenerating into pole and mature stages. Surprisingly, hare densities have been remarkably stable with age since harvesting (Figure 28), suggesting that the window of elevated hare densities may be much wider than previously thought. Densities consistently averaged between 1.5-2.0 hares/ha across stands ranging from 19 - 32 years post-harvesting. We will continue to monitor these stands into the future to document the trajectory from the current densities of 1.5 - 2.0 hares/ha to expected densities of approximately 0.20-0.25 hares/ha in the mature stand condition.

FUTURE PLANS

We are funded for 2 additional years and plan to continue to monitor temporal and spatial trends in hare populations across our benchmark stands in the Telos and Clayton Lake areas through fall 2008.

Figure 28. Estimated hare densities in regenerating clearcut stands ranging from 19-32 years post-harvest in the Telos area of northern Maine.



More information about this project is available by contacting Dan Harrison at harrison@umenfa.maine.edu.

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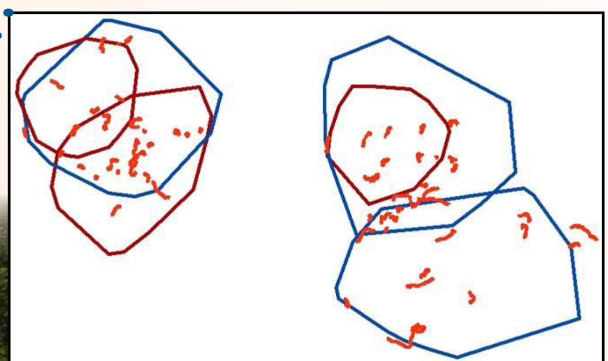
RESPONSES OF SNOWSHOE HARE AND CANADA LYNX TO FOREST HARVESTING IN NORTHERN MAINE

Laura Robinson, William Krohn, and Daniel Harrison

PROJECT SUMMARY

In August, Laura Robinson completed her M.S. under the guidance of Drs. Harrison and Krohn (Robinson 2006). A key component of her thesis research was to examine the responses of snowshoe hares (*Lepus americanus*) and Canada lynx (*Lynx canadensis*) to forest management, giving special emphasis to partial harvesting. This thesis is posted on the CFRU website and documents stand-scale hare densities by forest types, as well as presenting a map of estimated hare densities across northern Maine. The study also presents a model of stand-scale relationships between hares and vegetation, and geographic- and home range-scale habitat models for lynx in northern Maine. At the geographic-scale, lynx were negatively associated with bobcats and positively associated with hares. At the home range-scale, lynx occurrences had a strong, positive association with hare densities. Consistent with the published findings of Hoving et al. (2004), Canada lynx habitats in northern Maine are largely driven by the salvage cuts of the 1970-80s following the outbreak of the spruce budworm (*Choristoneura fumiferana*).



Tracking wildlife species tells scientists a lot about the behavior of the animals in relation to the forest habitat.

INTRODUCTION AND OBJECTIVES

The Canada lynx is a specialized predator, preying primarily on snowshoe hare, and is a federally threatened species along the southern edge of its distribution in the northern U.S.A. The dependence of this predator on one prey species makes understanding the relationship between forest management and hares a high priority. A published habitat model for Canada lynx in northern Maine showed a positive association between regenerating conifer clearcuts and lynx and a negative association with partially harvested stands (the first generation lynx model of Hoving et al. 2004). However, this model had a number of limitations. Specifically, the first generation lynx model was based on a small number of sites used by lynx and these occurrences were limited in distribution to the extreme northwestern part of the state. Furthermore, the "no-use" sites used in the model were randomly chosen, and thus could have been sites actually used by lynx. Finally, the first generation lynx model did not assess the importance of landscape-level hare densities, and was developed at a time when, compared to today, relatively little of northern Maine was partially harvested. Thus, there was a need to develop a second generation habitat model for lynx in northern Maine, based on a larger number of samples that were better distributed, sampled both occupied and unoccupied sites with a standard protocol, and represented current forest conditions.

Before developing a second generation lynx habitat model, however, we first needed to estimate hare densities across the landscape. To do this, hare densities were measured in all major forest types, and thus we were able to map hare densities across northern Maine. A current forest cover map, in GIS format, was needed as the basis for mapping hare densities throughout northern Maine. The only available GIS map of Maine forest cover available at the time was developed by the Maine Gap Analysis Project (Hepinstall et al. 1999), but it represented conditions during the mid-1990s, not current forest types. In addition to dealing with the need to update this map, we gave special attention to measuring hare densities in partial harvests because of the widespread distribution of partially harvested stands across northern Maine. Furthermore, while studies have suggested a relationship between hare populations and thick vegetative cover (e.g., Litvaitis et al. 1985), this relationship needed to be studied across a full range of hare densities within the lynx's Maine range. This was especially important because we suspected that hare densities in established partial harvests could be higher than in recent partial harvests, given that vegetative cover increases with time after cutting (up to a point).

Directly estimating hare densities is time consuming and expensive. While counting pellets is an efficient and cost-effective alternative (Homyack et. al. 2006), changing forestry practices may continue to increase the number of forest types that then need to be sampled. A possible alternative to sampling hare pellets in an ever-increasing variety of forest management stands is to determine whether or not hare densities are directly related to vegetative structure. If a strong relationships exists over a wide range of hare densities, than one needs merely to characterize vegetative structure to estimate densities of hares.

The objectives of this study were to:

1) Develop a forest cover type map for northern Maine representing 2004 habitat conditions for hares,

2) Use stand-scale hare densities to map hare densities for all major forest types across northern Maine,

3) Use hare densities and vegetation measurements to develop a habitat model for hares, and

4) Develop second generation models for lynx at both the geographic- and home range-scales based on sites occupied and unoccupied by lynx based on snow-tracking surveys.

METHODS

Occupied versus Unoccupied Sites

To understand the process (or processes) influencing the distribution of a species, one statistically compares those characteristics thought to be important on sites occupied versus sites unoccupied by the animal of interest. In the case of Canada lynx, the Maine Department of Inland Fisheries and Wildlife (MDIFW) searched 52 townships across northern Maine, 2003-2005. These searches were done 2-4 days after a snow, and a minimum of 55 km of roads were searched per township. Based on MDIFW observations of radio-collared lynx in Clayton Lake, this survey protocol had a high probability of detecting resident lynx.

Because lynx and bobcat are potential competitors, and because their tracks can be distinguished in fresh snow (i.e., lynx tracks are larger than bobcat; see Krohn et al. 2004: 123-124), careful attention was given to recording the occurrence of both species during the late winter surveys.

Updating the Maine GAP Vegetation and Land Cover Map

The base map developed for the Maine Gap Analysis Project consisted of 37 land use/land cover types, representing forest conditions as of 1993 (Hepinstall et al. 1999). In cooperation with the Maine Image Analysis Laboratory, University of Maine, a series of satellite-based change detection maps were developed to update, to conditions as of 2004, the GAP map for northern Maine (Legaard et al. 2006). The 2006 CFRU report entitled "Predicting Responses of Forest Landscape Change on Wildlife Umbrella Species" provides a brief description of the methodology used to identify areas impacted by forest management. This method was found to be superior to direct classification of a single satellite image because it permits the tracking of complex and sometimes subtle forest management changes through time across northern Maine. The updated GAP map reduced the number of classes to 32, and maintained the 30 m resolution of the 1993 map. Special attention was given to identifying and mapping those forest types known to be important to lynx (e.g., established partial harvests, Fuller 2006) or hares (e.g. regenerating conifer clearcuts, see next section).

Stand-scale Hare Densities and Other Variables

Hare densities were assigned according to types of forest stands. More specifically, northern Maine can be viewed as four classes of hare habitat as follow:

- non-hare habitats such as non-forested wetlands, developed areas, and fields (= 0 hares/ha)
- poor habitats, including recent clearcuts, mature forests, or forested wetlands (= 0.2 hares/ha)
- moderate hare habitats, such as pre-commercially thinned clearcuts (= 1.0 hares/ha) and established partial harvests (= 0.8 hares/ha)
- high hare habitats, or regenerating conifer clearcuts (= 2.0 hares/ha)

By taking these densities and applying them to the updated GAP map, the 2004 density of snowshoe hares across northern Maine was estimated and mapped. For additional details, see Robinson (2006: 96-101).

In addition to hare densities, other variables used to determine what factors most strongly influence the occurrence of Canada lynx in northern Maine were snow depth, elevation, bobcat occurrence, and fisher harvest density. For justifications as to why these variables were selected, defined, and measured, see Robinson (2006: Chapter 3).

Hare Habitat Model

Hare densities where estimated in 36 stands (15 clearcuts, 21 partial harvests) located in the Clayton Lake and Telos areas of northern Maine. Plots were cleared of hare pellets in both the fall and spring, so that estimates of hare densities could be made for the leaf-off seasons (i.e., winter), 2004-05 and 2005-06. Special emphasis was given to modeling hare habitat relations during this season as winter is the time of greatest mortality for hares, and hence vegetative characteristics would likely be related to survival and hare densities. In June and July of 2005, vegetation characteristics were measured in 20 of the 28 pellet plots at each study stand. Based on previous studies of hare habitats (e.g., Litvaitis et al. 1985), 16 vegetation characteristics were measured at each of the randomly selected plots. Fourteen models were developed to describe hare/habitat relations, and an information-theoretic approach was used to select the model that best described the association between hares and the vegetative characteristics. See Robinson (2006: Chapter 2) for additional details on methods.

Second Generation Lynx Habitat Models

To determine the relationships between a species and its habitat, one must be careful that the question being asked is appropriate for the scale being studied. It is well known that ecological processes occur at various scales, and thus what may be determining an animal's distribution (or habitat use) at one scale is probably not in play at other scales. In developing second generation habitat models for lynx in northern Maine, two key questions were asked:

1) Across the entire area of northern Maine encompassed by the snow-track surveys, what determined where the lynx placed their geographic range?

2) Within the lynx's geographic range in Maine, why did lynx locate their home ranges where they did?

The range of lynx in Maine was determined by connecting the outer-most sites of detection. The units of analysis for the geographic analysis were townships, whereas the landscape-level analysis were done based on simulated core areas used and unused by Canada lynx (based on the snow-track surveys). Simulated core areas of 3.15 km^2 were based on 50% fixed kernel home range areas of resident female radio-collared lynx monitored by the MDIFW.

RESULTS

Hare Distribution and Habitat Relationships

Figure 29 shows the estimated densities of snowshoe hares across northern Maine. Note the concentrated high density of hares near Clayton Lake, in the central part of the lynx's Maine range, the location of lynx telemetry work being conducted by the MDIFW.

Hare densities during the two leaf-off seasons were averaged, and densities in individual stands were continuously (i.e., not clumped) distributed, ranging from 0.3 to 4.2 hares /ha. Relating hare densities averaged over the two winter seasons to vegetation showed that at the stand-scale hares in northern Maine were strongly associated with conifer stem densities (+), basal area removed (+), and log density (-). These three variables explained 67% of the variation in densities, and landowners in the Acadian forest seeking to have high hare densities should manage forest conditions to produce high conifer stem densities (Figure 30), similar to those found in regenerating, herbicided conifer stands some 15-30 years post-clearcut.

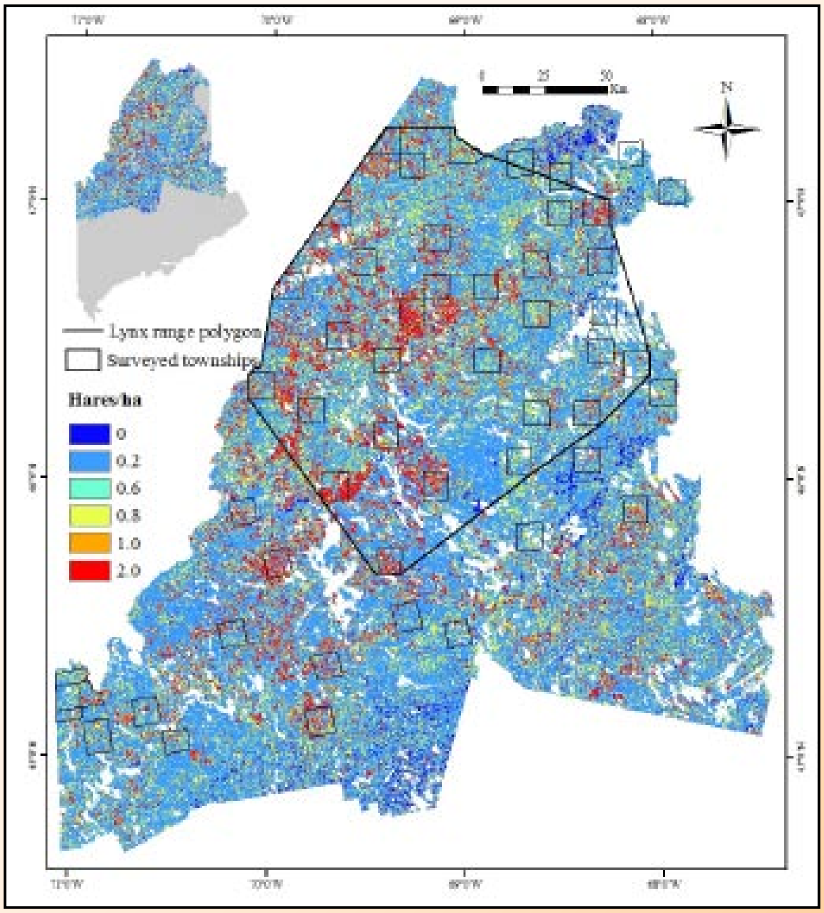


Figure 29. Estimated hare densities across northern Maine.

Second Generation Lynx Habitat Models

In addition to the map of hare densities shown in Figure 29, other variables (i.e., elevation, fisher harvest, and snowfall) used to model lynx distribution are shown in maps in Chapter 3 of Robinson (2006).

In terms of sites occupied and unoccupied by Canada lynx, Figure 31 shows the locations of the townships searched, and the sites where lynx (n = 227) and bobcats (n = 86) were found. Note how lynx occurred north of the bobcats, and that in general the two species did not occupy the same areas. This pattern is important in understanding the findings presented below.

The sample size for the geographic-scale analysis consisted of 31 townships with one or more lynx detections and 14 townships with bobcats (two townships had both species); for the home range-scale of analysis, we had 56 detection cores and 126 non-detection cores (Figure 32). At the geographic-scale, 15 models were developed with lynx being closely associated with high hare densities and negatively associated with the occurrences of bobcats. At the home range-scale, when the two townships with bobcats at the southern edge of lynx's Maine distribution are ignored, lynx occurrences are strongly associated with high hare densities. To better understand why lynx placed their home ranges where they did, we needed to better understand what was driving hare densities in northwestern Maine. To do this, a set of *post hoc* models were developed. Again, these models clearly show the importance of hare densities in home range placement, and in terms of forest management, regenerating conifer stands were the most important determinant of lynx occurrence across the landscape.

Figure 30. Conifer stem densities measured in the northern Maine study stands (n = 36). The median conifer stems density in regenerating conifers was 11,850 versus 3,350 stems /ha in the partially harvested stands.

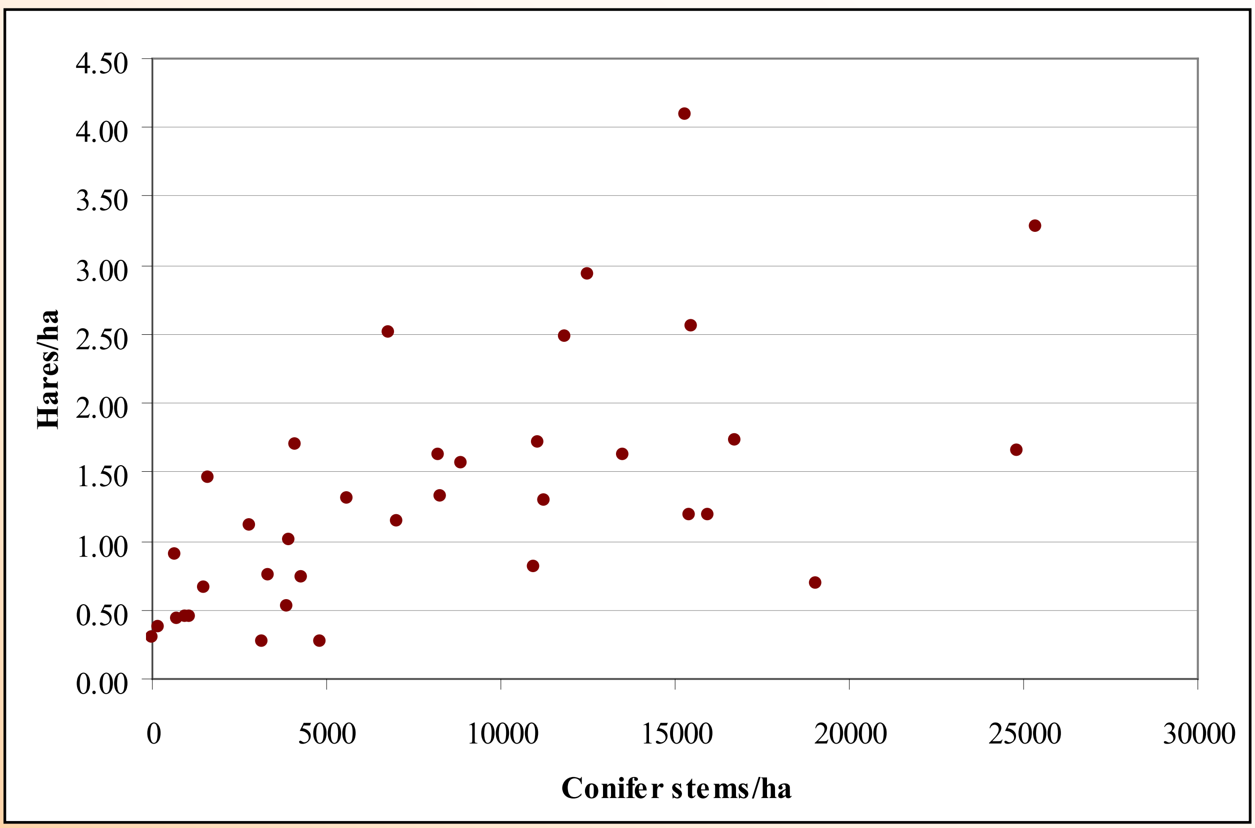
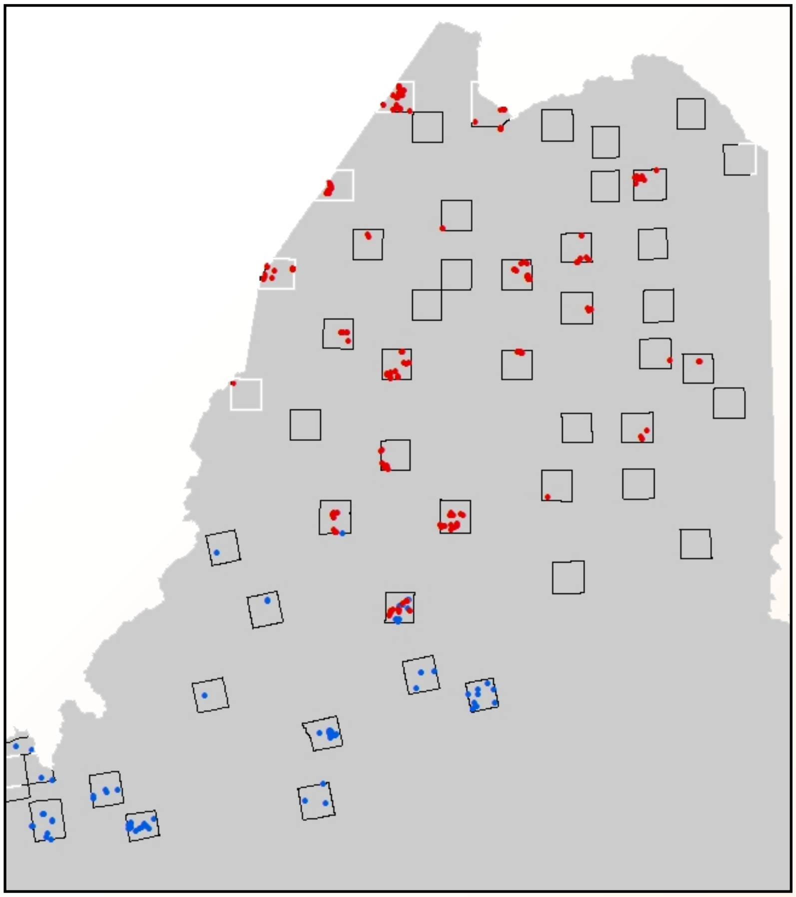


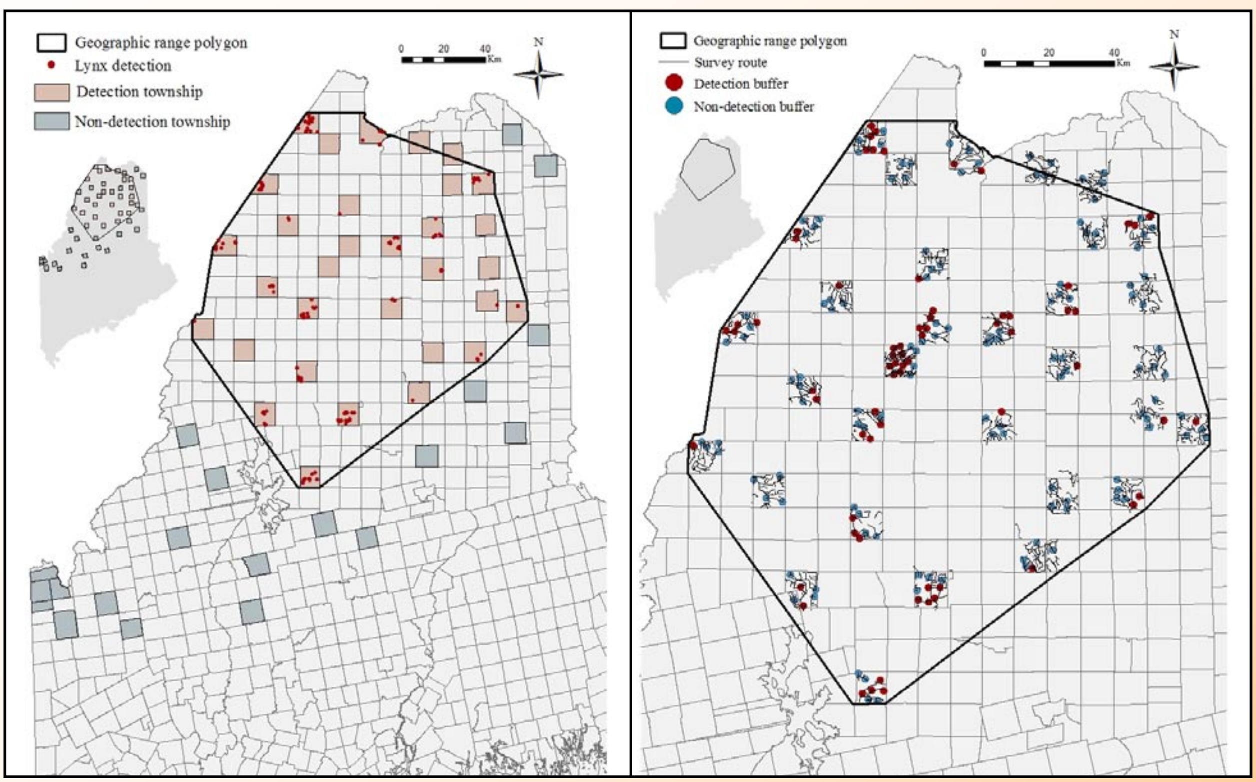
Figure 31. Locations in the searched townships where Canada lynx (red dots) and bobcat (blue dots) were found during the snow-track surveys across northwestern Maine.



CONCLUSIONS

In northern Maine, hare densities are strongly influenced by forest management, with regenerating conifer clearcuts supporting the highest densities. Across northwestern Maine, in the area covered by the MDIFW snow-track surveys, lynx occurrences were positively associated with hare densities and negatively associated with the occurrence of bobcats. Within the lynx's Maine range (as estimated from the snow-track surveys), and excluding two townships along the southern edge that overlap with bobcats, the density of hares was the predominant factor driving the occurrence of the Canada lynx. Given that es-

Figure 32. The two scales used to develop habitat models for Canada lynx under the forest conditions estimated to exist in northern Maine during 2004 (left = geographic scale; right = home range-scale).



tablished partial harvests averaged approximately 0.8 hares /ha, compared to a minimum of 2.0 for regenerating conifers, and that previous research suggests lynx need at least 1.0 hares /ha across the entire landscape, we question whether landscapes comprised of partially harvested stands will be adequate to support lynx (especially when non-hare habitats are factored into the overall landscape density). However, because established partial harvests were not negatively associated with lynx occurrences, this conclusion is preliminary and we continue to research the relative importance of clearcuts and partial cuts to snowshoe hares and Canada lynx in the extensively managed Acadian forest of northern Maine.

More information about this project is available by contacting Bill Krohn at wkrohn@umenfa.maine.edu.

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Snowshoe hare are the primary prey for Canadan lynx.

Biodiversity

Biodversity Scorecard: Integrating CFRU Wildlife and Biodiversity Research

Headwater Stream Study

The Biodiversity Scorecard:

Integrating CFRU wildlife and biodiversity research

Andrew Whitman, John Hagan, and Ethel Wilkerson

BACKGROUND

Conserving biodiversity is a fundamental goal of all major sustainable forestry programs (e.g., SFI, FSC, and ATF). However, the biodiversity element of sustainable forestry has been especially challenging to landowners because biodiversity typically is defined as "life in all its forms, from the level of the gene, to species, to whole ecosystems, including all the processes that maintain these various levels." Land managers can be challenged by the complexity of maintaining all plant and animal species (i.e. biodiversity).

The only practical approach to assessing "life in all its forms" is to measure a few components of the forest system that can inform landowners about the larger ecological system—in essence, indicators. Sustainable forestry certification programs have largely relied on policy response indicators to address the biodiversity principle, or goal. Policy response indicators reflect the implementation of certain policies and practices by a forest manager to protect a value, in this case biodiversity. While important, policy response indicators provide no information about the actual status of biodiversity. In contrast, condition indicators provide quantitative information about the status of the value of interest. Condition indicators can move sustainable forestry into the realm of defensible quantitative science and provide land managers with concrete information about the status of biodiversity. Quantitative measures also facilitate decision making about biodiversity. To this end we have created and applied a series of biodiversity indicators (collectively called a "Biodiversity Scorecard") that integrates diverse elements for managed forest landscapes in northern Maine.

THE BIODIVERSITY SCORECARD

Previous research funded through CFRU, National Council for Air and Stream Improvement (NCASI), and others have positioned Maine to be a leader in integrating biodiversity conservation with commercial forest management. Our first goal was to use this research to develop the fewest possible quantitative indicators that can provide us with the most information about the

Chestnut-sided warbler is one bird species that can indicate landscape-scale biodiversity.

different components that make up biodiversity. Our second goal was to develop simple indicators that could be calculated using existing information. We derived all indicators from information contained in existing timber inventory and/or GIS databases. The indicators are simple and affordable, but science-based and information rich. Some of the indicators are still being tested to assure that they will accurately describe ecological conditions and be practical to use.

We selected indicators to address four major components of biodiversity in northern Maine industrial forest: late-successional (LS) forest and species, early-successional (ES) species, aquatic/riparian health, and landscape configuration. These four components were selected because (1) they represent many of the biodiversity concerns held by landowners and stakeholders for private forest lands; (2) they cover many biodiversity elements that can be vulnerable to forest management; and (3) previous CFRU related research provides the scientific underpinning necessary for selecting robust yet practical indicators for these components. We developed indicators appropriate to the township scale because (1) many large landowners in Maine typically own and manage units of land at the township scale (36 square miles); and (2) except for the largest animal species (e.g., moose, etc.), most elements of biodiversity could be maintained in management units the size of northern Maine's townships.

OBJECTIVES

1) Build a practical, informative, scientifically legitimate set of quantitative biodiversity indicators (the Biodiversity Scorecard) for managed forest landscapes in northern New England.

2) Test the efficacy by applying the Biodiversity Scorecard to 17 landscape units of managed forest landscapes in northern Maine.

BUILDING THE SCORECARD

We developed nine indicators based on previous research (Table 8). Two indicators for aquatic/riparian health, Indicator 3a and Indicator 3b, were developed based on a thorough review of the literature. The remaining indicators were based on previous Manomet and UMaine (Harrison et al.) research supported by the CFRU and/or NCASI which was conducted in northern Maine.

Indicator 1a: Mean large tree density (large [> 16 in DBH] trees/ac). Large trees are a key habitat feature of many LS forest species and of LS forest as demonstrated in earlier CFRU funded work (Whitman and Hagan 2005, Whitman and Hagan In Press). Large tree density can be calculated from landowners' timber inventory data. Large trees are detected on a relatively small proportion of plots. Hence standard timber inventory methods may evaluate large tree density with such low precision that trends are difficult to assess except over very long time intervals. In a separate project, Manomet is assessing the efficacy of landowner timber inventory data for tracking this indicator.

Indicator 1b: Percent of landscape in LS forest. We assessed the amount of LS forest because some LS species may require more habitat than is provided by large trees alone (captured by indicator 1a). Indicator 1b can be calculated from standard timber stand maps based on acres of high volume stands or from a combination of timber inventory data and stand maps. We are testing two methods for calculating this indicator. Method 1 includes all acres of high-volume stands (>40 ft tall, >50% canopy closure, and most canopy stems > 9 in DBH). This is easily derived from most timber stand typing systems. Method 2 is more selective and is based on acres of high-volume stands likely to be LS stands (including moderate-volume forested wetlands but dropping out high-volume intolerant [e.g. white birch or aspen] stands). Some landowners have the necessary information in their GIS to identify over-mature LS stands for the second method. The second indicator is a more accurate estimate of LS acreage than the first method.

Table 8. Biodiversity scorecard components, sub-components, indicators, justification for each indicator, and necessary data sources.

Components Sub-components	Indicator	Justification	Data Sources Used
1. Late-successional (LS) forest			
1a. LS structure	Mean large (> 16 in DBH) tree density (trees/ ac)	A key substrate, foraging substrate, nesting and denning structure for many species	Timber inventory data
1b. LS forest	Percent area in LS forest (>16-16 in DBH trees/ ac)	Key habitat for LS species vulnerable to forest management	GIS data layers: tall, high-volume forest cover or LS forest cover
2. Early successional (ES) species			
2a. Bird habitat	Percent of landscape in ES bird habitat (< 20-ft tall)	A species group with widely declining populations elsewhere due to habitat loss	GIS data layers: ES forest cover
2b. Hare habitat	Percent of landscape in high-quality hare habitat (20-40 ft tall forest, > 50% canopy cover)	A keystone species as prey for many predators, dominant herbivore, and key prey species for Canada lynx	GIS data layers: High-quality hare habitat coverage
2c. Lynx habitat	Number of lynx potentially supported by landscape (778.4 ac [315 ha] units, 60% in high value hare habitat [>0.4 hare/ac {1.0 hare/ha}])	Federally listed as threatened species.	GIS data layers: High-quality hare habitat coverage, hexagon grid system with 778.4 ac (315 ha) cells
3. Aquatic/ riparian health			
3a. Stream sedimentation	Road crossings/ stream mile (multiple stream crossings within a 49 ft [15 m] stream length were counted once)	Focal point for sediment delivery to water bodies	GIS data layers: Mapped stream coverage, all stream coverage*, road coverage
3b. Water temperature	Percent of stream miles with a forest buffer > 20-ft tall, > 50% canopy closure, > 49 ft (15 m) wide.	Shade from buffers prevents streams from reaching lethal temperature.	GIS data layers: Mapped stream coverage, ES forest cover
3c. Peak stream flow patterns	Percent of watersheds with > 30%, < 20-ft tall forest, 12 Hydrologic Unit Classification (HUC)	Fast runoff from young forests increases the level of peak stream flows after rain storms.	GIS data layers: 12 HUC watershed coverage, ES forest cover
4. Landscape elements			
4a. Fragmentation Index	Number of marten potentially supported by landscape (500 ha units 75% in marten habitat, > 40 ft, >50% canopy closure)	Yields habitat for area-sensitive species and for most forest vertebrates.	GIS data layers: Mid-age and older forest coverage, hexagon grid system with 1235.5 ac (500 ha) cells

* The all-stream coverage was available from the Depth-to Water-Table GIS Project, a project with widespread participation from the CFRU membership.

Indicator 2a: Percent of landscape in early-successional (ES) bird habitat. Populations of many ES bird species are declining across the region or the eastern U.S. as their habitat is being lost to afforestation (Hagan et al. 1997). ES habitat created by silvicultural clearcuts may offset some habitat loss and associated regional population declines (Hagan et al. 1997).

Indicator 2b: Percent of landscape in high quality (> 1.0 hares/ha) hare habitat. Snowshoe hare is a keystone prey species and makes up a substantial portion of most carnivore diets (Homyack 2003); it is an especially important prey item for Canada lynx. As the dominant herbivore in northern forests, it also may have a key function in mediating nutrient cycles (Homyack 2003).

Indicator 2b: Number of female Canada lynx potentially supported by landscape (315 ha units, 60% in high-value hare habitat [>1.0 hare/ha]). The Canada lynx is rare in the U.S. and is federally listed as a threatened species with federal protection. Although the block size used here is much smaller than the home range of Canada lynx, it represents the area of 50% of observations of denning female Canada lynx and has been used in habitat suitability studies for northern Maine (Robinson 2005). This indicator is based on female home range size because females are key to population viability.

Indicator 3a: Stream sedimentation (road crossings/stream mile [multiple stream crossings within 15 m along a road were only counted once]). The greatest potential impact of forest management on aquatic health is through the delivery of sediment to water bodies. Roads are responsible for more sediment pollution than other forest management activities (Rothwell 1983) and permanent stream crossings are the source of the majority of sediment entering water bodies (Swift 1985, Bilby et al. 1989). Permanent stream crossings account for about 80% of the sediment delivered to streams. Hence stream crossings density is a good indicator for assessing risk levels for sedimentation due to forest management (Jones et al. 2001, Reeves et al. 2004, Hudy et al. 2006).

Two methods were used to calculate this indicator. The first method is calculated from stream crossings of streams mapped from aerial photography. These streams were 1st-order streams and larger perennial streams. The second method was calculated from a GIS coverage of streams generated by the Depth-to-Water-Table Project. The Depth-to-Water-Table Project mapped hypothetical streams wherever the water table depth was estimated to be zero. These streams include perennial streams, intermittent streams, and ephemeral streams. Because intermittent or ephemeral streams can be conduits for delivering sediment into larger water bodies, we recommend using the second method for calculating this indicator. However, land owners lacking GIS data for intermittent streams or ephemeral streams may have to rely upon the first method.

Indicator 3b: Water temperature (percent of streams with forested buffers > 20 ft tall, > 50% canopy closure, and > 49 ft wide). Removal/thinning of forest canopy increases the solar radiation reaching the stream channel (Burton and Likens 1973) and often results in increases in stream temperature (Brown and Krygier 1970). Temperature increases can reach a level that are harmful to fish and other stream fauna (EPA 1986). In Maine, previous CFRU research has shown that streams with >49 ft-wide buffers provide enough shade to prevent streams from heating to temperatures lethal to stream fauna (Wilkerson et al. 2006).

Indicator 3c: Peak stream flow patterns (percent of township acres in watersheds with > 30% 1-15 year old forest, at the 12-HUC level [Hydrologic Unit Classification]). The third way that forest management can affect water quality is by changing the hydrology of watersheds. Peak flows can increase when >30% of a watershed consists of young forest (Hornbeck 1973, Hornbeck et al. 1993). Greater peak flows can increase bank erosion (Verry 2000) and sediment transport (Morisawa 1968). In this analysis we used 12-HUC watersheds because this size is the smallest one readily available in the public domain as a GIS coverage. It would be more appropriate to use 14-HUC or 16-HUC watersheds as the impacts of increased peak flows are probably greatest in relatively small (~200 ac) watersheds (Robinson et al. 1995).

Indicator 4a: Landscape Fragmentation Index (number of marten potentially supported by landscape [1250 acre units at least 75% covered by marten habitat (> 20 ft tall, > 50% canopy closure)]). Marten were used as an "umbrella species" to identify large blocks of forest for marten and other species that prefer or require large blocks of habitat, including large-bodied woodpeckers and some birds of prey. Marten can also be used as an umbrella for many forest vertebrate species. Along with the Canada lynx indicator above, these two indicators can be used as umbrella indicators for most of Maine's vertebrate species. This indicator was derived from CFRU research (Payer and Harrison 2000).

PROJECT STATUS AND RESULTS: APPLYING THE BIODIVERSITY SCORECARD

We ran the Biodiversity Scorecard on 17 landscape units in northern Maine, ranging in size from 1,317 acres to 32,446 acres (11 of 17 units were essentially full townships; Figure 33). We used large tree density data from previous CFRU studies to score Indicator 1a (Figure 34). To score the remaining indicators, we used stand maps from multiple cooperators (Figure 34). For Indicator 3c, we also used a United States Geological Survey GIS coverage for 12-HUC watersheds. A summary of the scores follows:

- Scorecard Indicator 1a: Landscape units averaged 4.9 large (> 16 in DBH) trees/ac. This may provide adequate numbers of large trees for vertebrates that nest, den, and/or roost in large trees and exceeds some retention guidelines for Maine (e.g., Flatebo et al. 1999). This may not be adequate numbers of large trees for other species dependent on late-successional attributes.
- Scorecard Indicator 1b: The first method of estimating percent of late-successional acres/landscape unit yielded an estimate much greater than the second method: 5.3% versus 0.3%, respectively. Either estimate suggests level of LS habitat is low in many landscape units and may be inadequate for maintaining populations of species that depend on LS habitat.
- Scorecard Indicator 2a: The median percent of ES bird habitat/township was 18% and ranged from 7 to 39%. Landscape units with > 10% ES habitat likely have sufficient ES habitat to support all ES bird species native to northern Maine.

Figure 33. Size of landscape units used in the Biodiversity Scorecard analysis. Each filled circle represents the score of a single landscape unit.

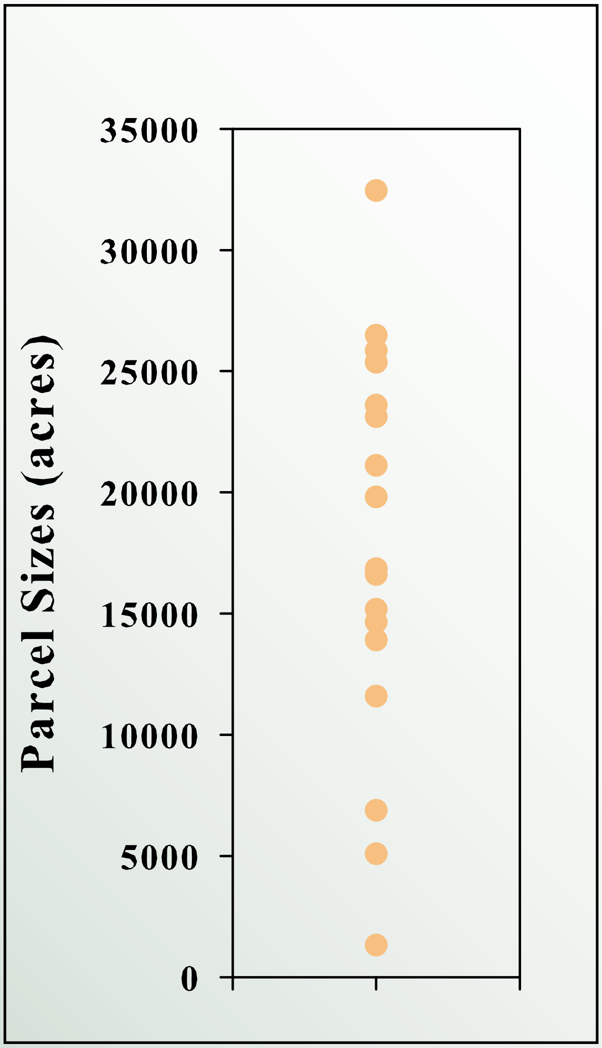
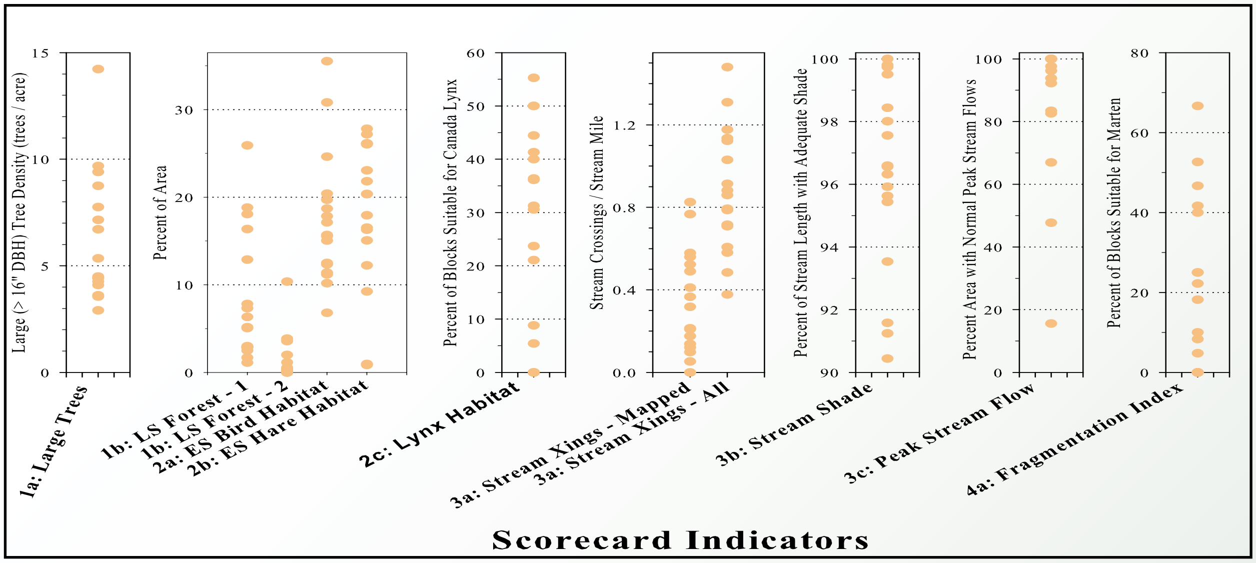


Figure 34. Summary of the Biodiversity Scorecard Indicator scores from landscape units in 17 townships in northern Maine. Each filled circle represents the score of a single landscape unit. The number-letter prefix of the X-axis labels corresponds to the indicators found in Table 8.



- Scorecard Indicator 2b: The median percent of high-quality hare habitat per landscape unit was 23% and ranged from 1 to 34%. Hares are critical for maintaining Canada lynx populations. Although it is not known how much hare habitat is required to support Canada lynx at township and larger spatial scales, landscape units > 25% hare habitat may be important areas for maintaining Maine's Canada lynx population.

- Scorecard Indicator 2c: The median percent of hexagons within a landscape unit suitable for Canada lynx was 31%. Only three of the 17 landscape units lacked any hexagons suitable for Canada lynx.

- Scorecard Indicator 3a: The median number of stream crossings per landscape unit was 0.3 crossing/mile for mapped streams, likely representing bridged as well as culvert crossings. The median number of stream crossings for all streams per landscape unit was 0.9 crossings/ mile. The difference between the two estimates is probably completely accounted for by culvert crossings for small perennial and intermittent headwater streams.

- Scorecard Indicator 3b: All landscape units had >90% of mapped streams with adequate shade, which includes a significant amount of stream miles where regulations do not require landowners to maintain shade. Streams in these landscape units probably have adequate shade to prevent stream temperature from reaching lethal levels for stream fauna.

- Scorecard Indicator 3c: Normal peak stream flows occurred across most of each parcel. Based on this indicator, for many landscape units, logging may not be substantially affecting stream hydrology and intensity of peak stream flows.

- Scorecard Indicator 4a: The median percent of hexagons suitable for marten was 18%. Five of the 17 landscape units lacked any hexagons suitable for Marten, including one township.

- Overall Summary: For the sampled landscape units, six indicators may be at levels indicating low risk to their respective biodiversity components: ES habitats and aquatic/riparian health.

For many sampled landscape units, the remaining three indicators may be at levels posing a risk to their respective biodiversity components: two LS forest indicators and one landscape indicator. The two LS indicators suggest that species dependent on large trees and LS forest might be vulnerable to current forest management. The fragmentation indicator, which is based on marten habitat area requirements, suggests that a number of landscape units may lack the spatial extent of mid-mature forest blocks necessary to support even a single marten home range.

REMAINING TASKS

The CFRU cooperator scorecard workgroup will be convened to provide feedback about the indicators and methods used for calculating each indicator.

A Manomet Forest Mosaic Note will be produced to detail this version of the scorecard.

A manuscript for publication in a peer-reviewed journal.

The Scorecard Project will continue in 2007-2009 to understand (1) how the Scorecard indicators change when multiple townships are evaluated, and (2) how future management will affect biodiversity as measured through simulations using the Scorecard as an assessment tool.

ACKNOWLEDGEMENTS

Data were anonymously provided by multiple CFRU cooperators and their GIS support staff. Dan Boss (James Sewall Company) conducted the GIS analysis that made the application of the scorecard to different townships possible. The scorecard is based on research from over a dozen projects led by Manomet and UMaine (Dan Harrison et al.). CFRU cooperators were instrumental to these past projects by providing the landbase on which to conduct field work, their staff who generously gave their time to find study areas and provide useful comments, and critical support from their GIS staff. The scorecard was possible because of support over the years from the CFRU, NACSI, Manomet Center for Conservation Sciences, Merck Family Fund, Plum Creek Timber Company, Harold Whitworth Pierce Charitable Trust, The Nature Conservancy, The National Fish and Wildlife Foundation, and the National Commission on Science for Sustainable Forestry. Lastly, this research depended on the hard field work of many graduate students and field assistants.

More information about this project is available by contacting Andy Whitman at awhitman@prexar.com.

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Manomet field worker measures large spruce tree.

Headwater Stream Study

Ethel Wilkerson and John Hagan

INTRODUCTION

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

The study was originally designed to run three years (one pre-treatment year [2001] and two post-treatment years [2002-2003]). However, because of the significant increases in stream temperature which persisted through the second post-harvest year, the CFRU continued the study to monitor timing of temperature recovery. We now have obtained a total of five years of post-harvest temperature data from the experimental streams. This report provides water temperature results for all six field seasons (2001-2006) and data on recovery (re-growth) of riparian vegetation and canopy cover (i.e., shade).

In 2006, a manuscript examining riparian plant communities along our headwater sites titled, "Do small headwater streams have a riparian zone defined by plant communities?", was published in the *Canadian Journal of Forest Research*. Another manuscript, "The effectiveness of different buffer widths for protecting headwater stream temperature in Maine," was published in 2006 in *Forest Science*. A manuscript summarizing the water quality results entitled, "The effectiveness of different buffer width for protecting water quality and macroinvertebrate and periphyton assemblages of headwater stream in Maine," has been accepted pending revisions to the journal *Freshwater Biology*. A manuscript summarizing the air temperature changes within riparian buffer zones will be submitted for publication in early 2007.

STUDY DESIGN

At the beginning of the study, in 2001, we assigned 15 headwater (1st-order) streams in western Maine to one of five study treatments (Table 9). All streams were measured for water temperature and water chemistry parameters both before harvest (2001) and after harvest (2002- 2006). In each year of the study we deployed automatic temperature recorders at 100-m intervals along a 500-m study reach in each of the 15 study streams (Figure 35).

Figure 35. Study layout.

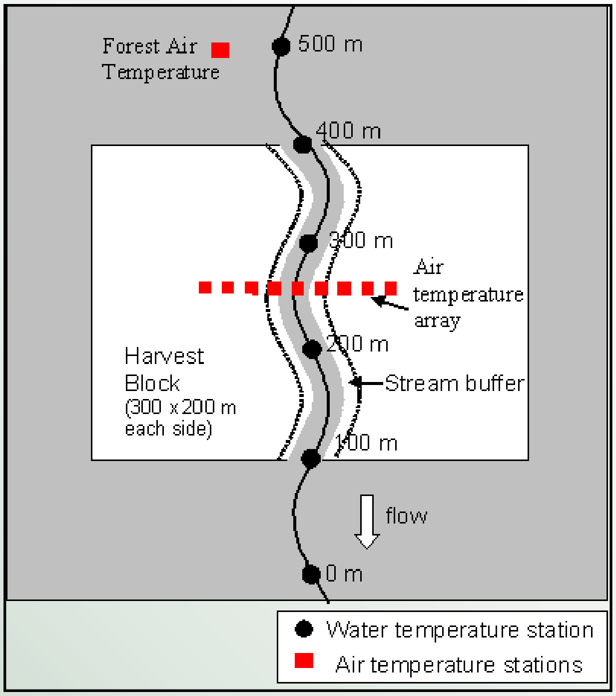


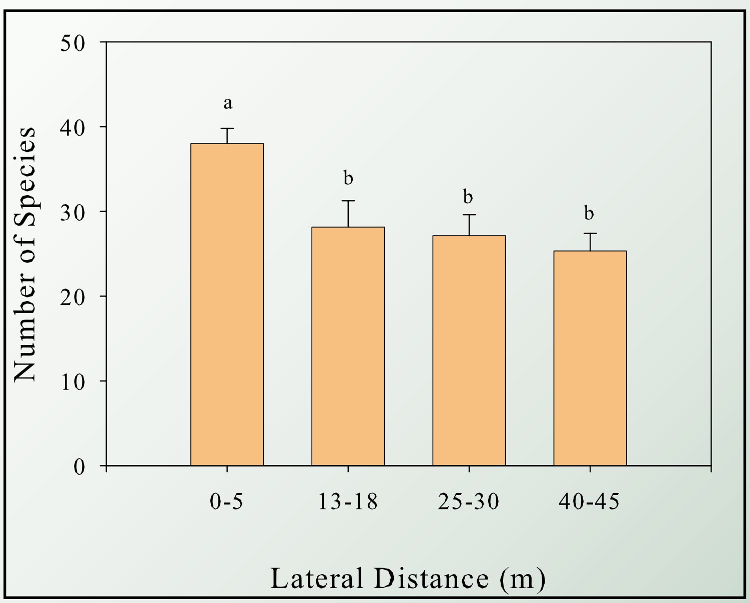
Table 9. Harvest treatments used in this study.

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

Riparian Plant Communities

Wetlands are customarily delineated by plant communities. One of our questions early on in the study was whether these small headwater streams had a riparian zone as defined by plant communities. In the pre-harvest year only (2001), we surveyed herbaceous plants in 5x50 m quadrants located perpendicular to the stream channel (0-5 m, 13-18 m, 25-30 m, and 40-45 m). The 0-5 m quadrant contained a significantly greater number of herbaceous plant species than the quadrants located further from the stream channel (Figure 36). There were 16 species of herbaceous plants found only within 5 m of the stream channel (Table 10). Of these species six were forest specialists, five disturbance specialists, four generalists, and 1 wetland generalist (Table 10). Complete analysis of the herbaceous communities determined a detectable riparian plant community adjacent to small headwater streams that is distinct from communities further away from the stream channel, suggesting that small headwater streams do have a riparian zone as defined by plant communities (see Hagan et al. 2006 for full results).

Figure 36. Mean species richness for herbaceous plants for each of the four sampling zones adjacent to study streams. Error bars represent standard error of the mean. Different letters represent significant differences ($p<0.05$) between sampling zones.



Has stream temperature recovered five years after the harvest?

Five years after harvest (2006), stream temperature remained elevated above pre-harvest levels at the downstream end of the harvest zone (Figure 35) in the no-buffer (2.7°C) and 11-m buffer (1.1°C) streams (Figure 37). We have never detected any temperature increase in the 23-m buffer, partial-cut buffer, or control stream treatments. However, for the no-buffer and 11-m buffer treatments, 2006 data suggest

Figure 37. The mean weekly maximum temperature from June 15 - August 15 in the pre-harvest year (2001) and the five post-harvest years (2002-2006). Water temperature readings were taken at the lower end of the harvest zone (100-m station). Air temperature readings were taken within intact forest, 100 m from the nearest harvesting and 50 m from the stream channel.

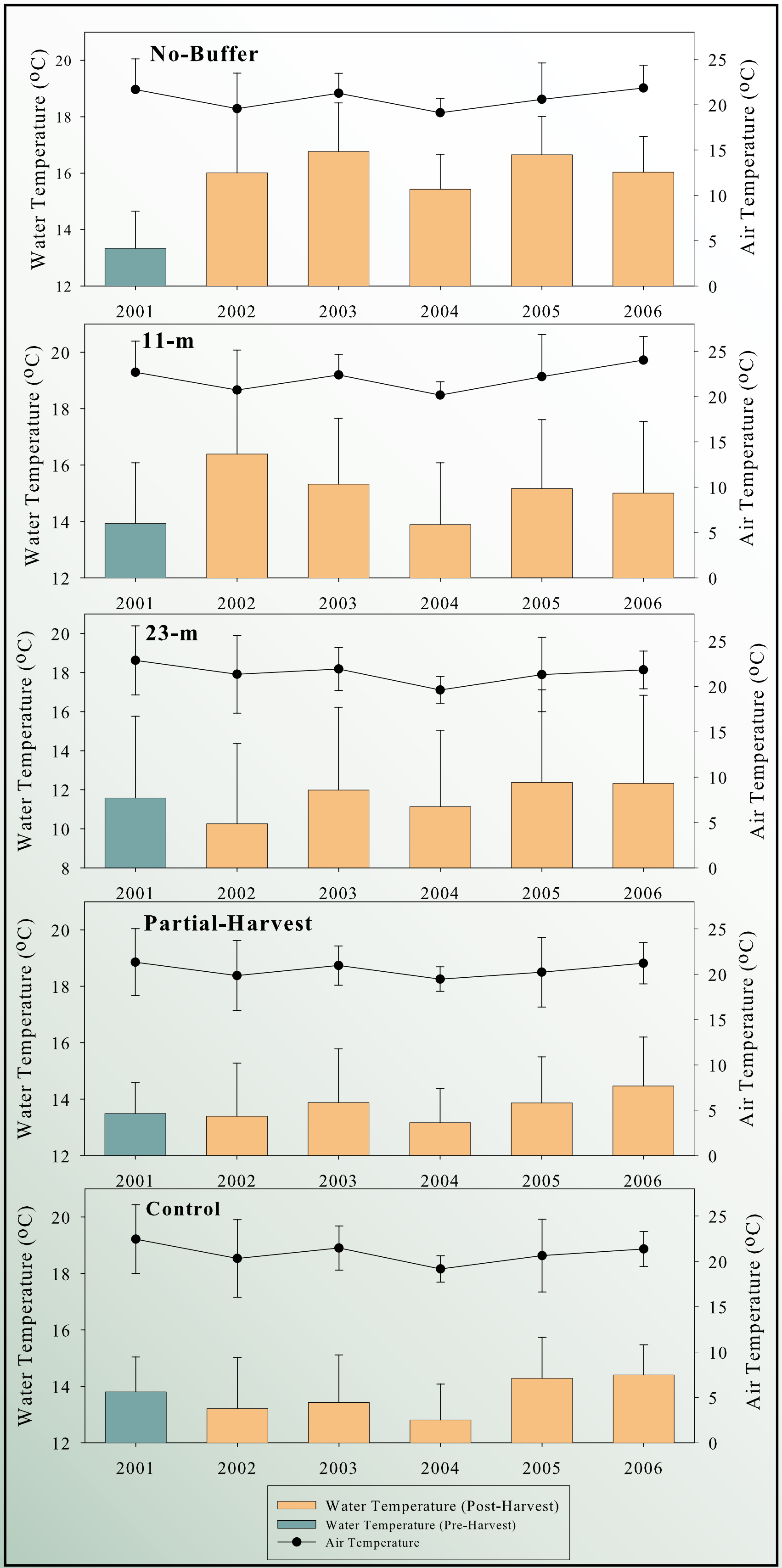


Table 10. Harvest treatments used in this study.

Scientific Name	Common Name	Habitat Type*
Prunella vulgaris	selfheal	D
Osmorhiza claytonii	bland sweet cicely	F
Pyrola minor	little shinleaf	F
Scutellaria lateriflora	mad-dog skullcap	WG
Symphiotrichum cordifolium	common blue heart-leaved aster	G
Taxus canadensis	American yew	F
Carex novae-angliae	New England sedge	F
Dryopteris carthusiana	spinulose wood fern	F
Equisetum scirpoides	dwarf scouring-rush	F
Fragaria virginiana	wild strawberry	D
Galium asprellum	rough bedstraw	G
Lycopus uniflorus	northern water-horehound	G
Polypodium appalachianum	Appalachian polypody	G
Ranunculus acris	common buttercup	D
Solidago canadensis	Canada goldenrod	D
Veronica officinalis	common speedwell	D
* F=forest specialists, G=generalists, D=disturbance species, WG=wetland generalists		

stream temperature might have finally started to moderate. In the no-buffer streams, temperature was 0.7°C cooler than in 2005 and 0.8°C below the maximum stream temperature observed in 2003. These reductions in water temperature occurred despite similar (+/- 0.3°C) summer air temperature conditions. In 2004, we observed a smaller temperature increase in the no-buffer and 11-m buffer streams (Figure 37), and all streams for that matter, because it was a cooler summer.

Over the five post-harvest years stream temperature in the 11-m buffer streams has gradually declined (excluding 2004, an abnormally cool year). In 2006, stream temperature was 1.4°C below the maximum stream temperature observed in the first post-harvest year (2002). Stream temperature in the 11-m buffer streams also cooled (-0.2°C) compared to 2005, despite a slight increase (+0.2°C) in summer air temperature. Evidence for temperature recovery five years following the timber harvest is stronger in the 11-m buffer streams than in the no-buffer streams. We will continue to monitor stream temperature in 2007.

Temperature Recovery: The importance of shade

Temperature recovery to pre-harvest norms is not expected to occur until inputs of solar radiation to the stream channel are reduced. Low vegetation (shrubs and saplings) can partially shade the stream from solar radiation and mitigate temperature impacts associated with harvesting (Feller 1981). To track potential recovery in relation to vegetation recovery, we have monitored the height of the recovering streamside understory vegetation and shade over the stream channel.

The height of the understory streamside vegetation has rapidly increased following the timber harvest (Figure 38). In 2006, the average height of all species of understory vegetation at the no-

Figure 38. Photographs of a no-buffer stream pre-harvest (2001) and in the first (2002), second (2003), and fifth (2006) post harvest years. Reference points in each photo are indicated by blue crosses.

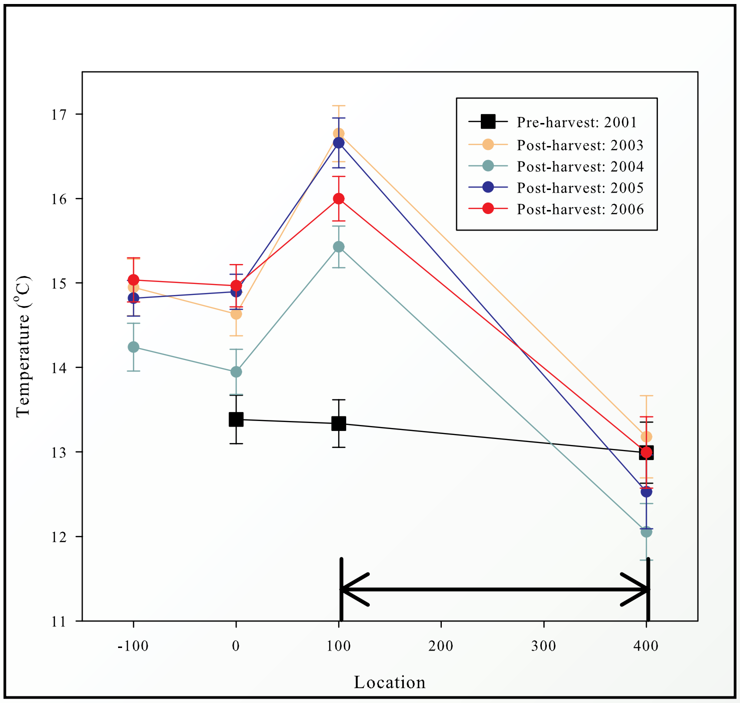
buffer streams was 0.78 m (Table 11), an increase of 0.35 m since measurements began in 2003 (the second post-harvest year). As the height of the understory vegetation has increased so have shade levels over the stream channel. Canopy closure within the harvest zone of the no-buffer streams has increased 12% in the five years following the harvest (Table 11). Despite modest gains, shade levels remain 60% below pre-harvest levels, and so far the growth of understory vegetation has done little to mitigate post-harvest increases in temperature in the no-buffer streams. However, in 2006 temperature increases were slightly smaller than in the previous year, perhaps indicating streamside vegetation regrowth is starting to shade the stream channel.

Removal of trees within and beyond the partially harvested 11-m buffer decreased shade levels by only 9% (Table 11) relative to pre-harvest shade levels. Since the second post-harvest year (2003), the height of the understory vegetation has increased 0.14 m (Table 12) and shade levels to within 1% of pre-harvest levels (Table 4). In 2006 average stream temperature remained elevated over pre-harvest levels but the overall trend of stream temperature shows continued cooling over time (Figure 37). The increased shade levels in 11-m buffer streams seem to have mitigated increases in stream temperature observed in previous years.

Downstream temperature recovery

In addition to understanding temporal temperature recovery (i.e., how many years temperature increases persist after the timber harvest) it is also instructive to understand spatial temperature recovery (i.e., temperature recovery downstream of the harvest zones). Beginning in the second post-harvest year (2003), we started measuring stream temperature 200 m below the harvest block (mi-

Figure 39. Mean weekly maximum stream temperatures in second through fifth post harvest years (2003-2006) for no-buffer streams. The 400-m location corresponds to a location above the harvest zone, 100-m is at the downstream boundary of the harvest zone, 0-m is 100 m below the harvest zone, and -100 is 200 m below the harvest zone.



nus 100-m station, Figure 35) in the no-buffer streams. We had been measuring temperature only 100 m below the harvest block until that time. Because we observed that downstream recovery was not complete 100 m below the harvest block, we added the 200 m downstream station.

After flowing through 200 m of largely undisturbed canopy below the harvest zone, stream temperatures were 1.0-1.8°C cooler than at the downstream end of the harvest zone (100-m station, Figure 39). One-hundred meters below the harvest zone, stream temperatures cooled but were still 0.9-1.7°C warmer than pre-harvest levels at that same location. The rate of cooling stabilized between 100 and 200 m below the harvest zone, probably because the stream water temperature was back in thermal equilibrium with the air (Ice 2000).

Stream Temperature and Brook Trout

In all 15 study streams average weekly maximum stream temperatures did not exceed 17°C regardless of buffer treatment (Wilkerson et al. 2006). This is well below the thermal stress criteria for brook trout (24°C, EPA 1986). Recently, the New Hampshire Fish and Game Department reported that brook trout populations are absent from streams that exceeded average daily maximum temperatures of 19.5°C during the month of July (J. Magee, personal communication). Based on this finding, the elevated stream temperatures observed in our study do not threaten brook trout populations. Temperature thresholds are not known for macroinvertebrates and other aquatic communities.

CONCLUSIONS

- Five years after harvest, stream water temperature remained elevated (2.7°C) above the pre-harvest year for the no-buffer

Table 11. Mean canopy closure taken 0.3 m above the stream channel in the pre-harvest year (2001), and first (2002) and fifth (2006) post-harvest years.

	Pre-Harvest (2001)		1st Year Post-Harvest (2002)		5th Year Post-Harvest (2006)	
Treatment	Mean %	S.E.	Mean %	S.E.	Mean %	S.E.
No-Buffer	96	0	24	4	36	5
11-m	94	2	85	3	93	3
23-m	93	1	91	1	98	1
Partial-Harvest	94	1	90	2	97	1
Control	96	0	94	0	98	0

Table 12. Average height (m) of the dominant type of understory vegetation within the harvest zone of streams in the no-buffer and 11-m buffer streams. Measurements were taken in 1 m^2 plots on both sides of the stream channel every 20m in second (2003), third (2004), fourth (2005), and fifth (2006) post harvest years.

	No-Buffers		11-m Buffers	
Year	Mean (m)	S.E.	Mean (m)	S.E.
Post-Harvest yr. 2 (2003)	0.43	0.02	0.45	0.04
Post-Harvest yr. 3 (2004)	0.69	0.04	0.65	0.04
Post-Harvest yr. 4 (2005)	0.76	0.03	0.58	0.04
Post-Harvest yr. 5 (2006)	0.78	0.03	0.59	0.03

streams despite rapid growth of understory vegetation and an increase in shade levels over the stream channel. Temperature increases declined slightly in 2006, suggesting the beginning of temperature recovery.

- Stream temperature remained elevated (1.1°C) in the 11-m buffer streams but temperature began to moderate in 2006—average temperature has gradually declined since the harvest and shade levels have returned to within 1% of pre-harvest levels.

- In no-buffer streams, temperature increased 3.0-3.6°C within the harvest zone in post-harvest years (2002-2006). Temperatures cooled (-1.0 to -1.8) after re-entry into undisturbed canopy but remained elevated above pre-harvest levels 100 m below the harvest zone.

- One more field season is presently scheduled (2007) during which we will continue to document whether stream temperature recovery is taking place.

PLANNED ACTIVITIES

This winter and spring we will be submitting several manuscripts for publication. In May, 2007, we will begin a sixth post-harvest field season. We will continue to measure water temperature, water quality, understory vegetation communities, and over stream canopy closure.

ACKNOWLEDGEMENTS

Our work in 2006 was made possible by the cooperation and support from Plum Creek Timber Co., Seven Islands Land Co., GMO, and Wagner Timberlands. We thank the CFRU, NCASI, and Manomet Center for funding this project. Comments and questions about this report are welcomed. Contact Ethel Wilkerson or John Hagan at 207-721-9040 or by e-mail at ewilkerson@prexar.com or jmhagan@prexar.com.

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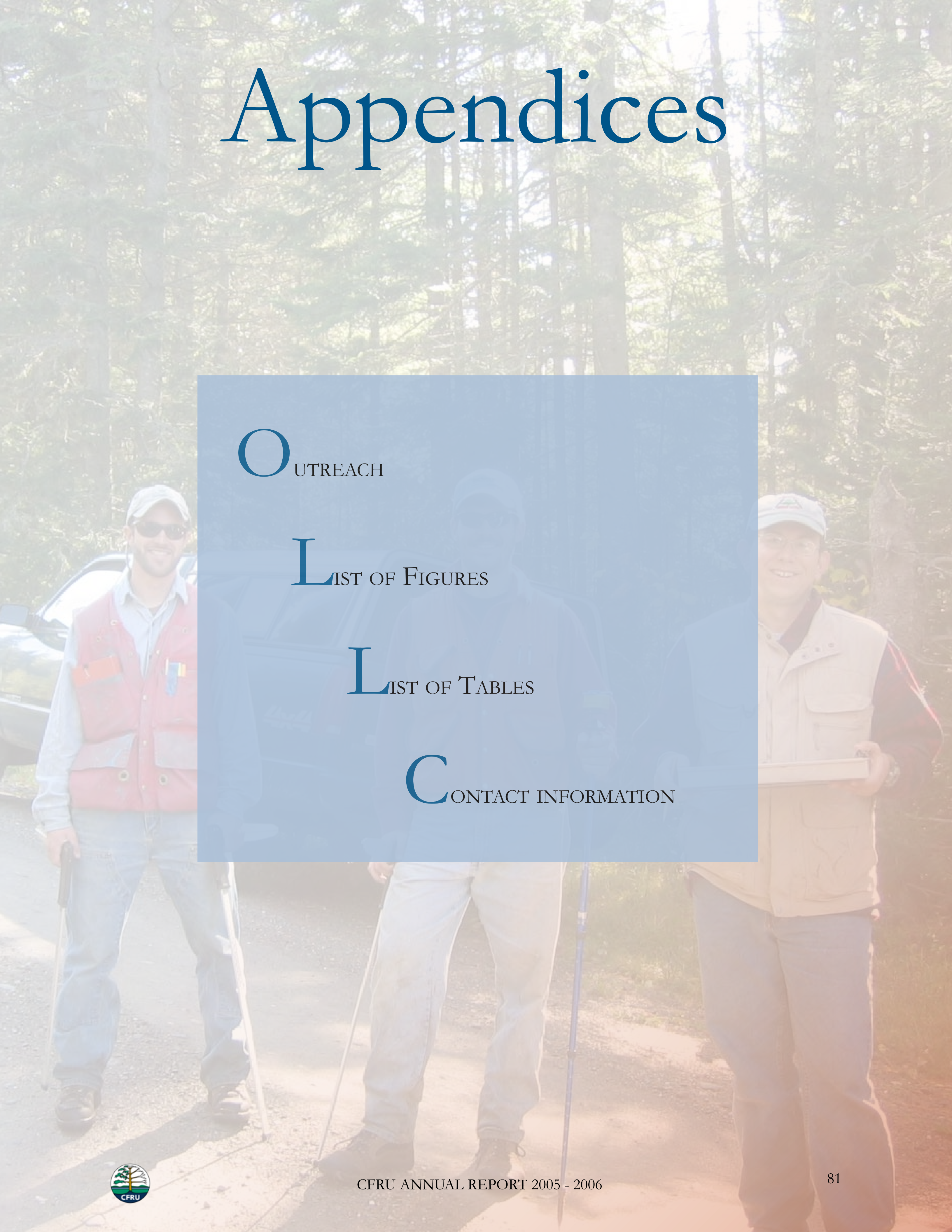

Appendices

Outreach

List of Figures

List of Tables

Contact information

Outreach

Communicating our research accomplishments to a wide audience is a critical component of the CFRU. Over the past year CFRU staff and scientists produced more than 51 new articles, theses, reports, proceedings, and presentations to state, regional, national, and international audiences.

JOURNAL ARTICLES

Etheridge, D.A., D.A. MacLean, R.G. Wagner, and J.S. Wilson. 2006. Effects of intensive forest management on stand and landscape characteristics in northern New Brunswick, Canada (1945–2027). *Landscape Ecology* 21: 509–524.

Homyack, J.A., D.J. Harrison, J.A. Litvaitis, and W.B. Krohn. 2006. Quantifying densities of snowshoe hares in Maine using pellet plots. *Wildlife Society Bulletin* 34: 74-80.

LeDoux, C. and A.A. Whitman. 2006. Estimating the capital recovery costs of alternative patch retention treatments in eastern hardwoods. *International Journal of Forest Engineering* 17: 21-30.

Little, K.M., I. Willoughby, R.G. Wagner, P. Adams, H. Frochot, J. Gava, S. Gous, R.A. Lautenschlager, G. Örlander, K.V. Sankaran and R.P. Wei. 2006. Towards reduced herbicide use in forest vegetation management. *Southern African Forestry Journal* 207: 63-80.

Wagner, R.G., and A.P. Robinson. 2006. Critical period of interspecific competition for four northern conifers: Ten-year growth and associated vegetation dynamics. *Canadian Journal of Forest Research* 36: 2474-2485.

Wagner, R.G., K.M. Little, B. Richardson, and K. McNabb. 2006. The role of vegetation management for enhancing productivity of the world's forests. *Forestry* 79(1): 57-79.

Whitman, A. and J.M. Hagan. accepted. An index to identify late-successional forests in temperate and boreal zones. *Forest Ecology and Management*

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

Foresters learn best in the woods.

RESEARCH REPORTS

Fuller, A.K. and D.J. Harrison. 2006. Ecology of red foxes and niche relationships with coyotes on Mount Desert Island, Maine. Final contract report to U. S. National Park Service, Boston, MA. 41 p.

Fuller, A.K. and D.J. Harrison. 2005. Influence of forest practices on stand and sub-stand scale selection and movements of Canada lynx. Pages 56-60 in Maine Cooperative Forestry Research Unit Annual Report, Maine Agricultural and Forest Experiment Station Miscellaneous Report 435, Orono, ME.

Fuller, A.K., D.J. Harrison, B.J. Hearn, and J.A. Hepinstall. 2006. Landscape thresholds, occupancy models, and responses to habitat loss and fragmentation by martens in Newfoundland and

Maine. Final Contract Report to Canadian Forest Service and the Western Newfoundland Model Forest. 92 pp.

Harrison, D.J. and J.A. Hepinstall. 2005. Evaluating the umbrella species approach for biodiversity conservation on commercial forestlands in Maine. Pages 64-67 in Maine Cooperative Forestry Research Unit Annual Report, Maine Agricultural and Forest Experiment Station Miscellaneous Report 435, Orono, ME.

Harrison, D., S. Sader, J. Wilson, and W. Krohn. 2006. Predicting responses of forest landscape change on wildlife umbrella species. Pages 53-59 in Maine Cooperative Forestry Research Unit Annual Report, Maine Agricultural and Forest Experiment Station Miscellaneous Report 438, Orono, ME.

Homyack, J.D. Harrison, and W. Krohn. 2005. Temporal changes in abundance of snowshoe hares in Maine: 1995-2002. Pages 61-63 in Maine Cooperative Forestry Research Unit Annual Report, Maine Agricultural and Forest Experiment Station Miscellaneous Report 435, Orono, ME.

Kittredge, D.B., D.J. Harrison, R. Smardon, and L. Blum. 2006. Final Program Evaluation of the External Review Team: Department of Natural Resources, University of New Hampshire. 31 p.

MacPhee, B. and T. McGrath. 2006. Nova Scotia Growth and Yield Model Version 2 User's Manual. Available from: http://www.gov.ns.ca/natr/forestry/reports/Report79.pdf.

Meyer, S.R., R.G. Wagner, J. Witham, S. Norton, I. Fernandez, B. Wiersma, E. Small, J. Wilson, and A. Kimball. 2006. Long-term Forest Ecosystem Studies of the Cooperative Forestry Research Unit and the University of Maine. p. 83-93 In Irland, L.C., A.E. Camp, J.C. Brissette, and Z.R. Donohew (Eds.). Long-term Silvicultural & Ecological Studies Results for Science and Management, Yale University, School of Forestry & Environmental Studies, Global Institute of Sustainable Forestry, GISF Res. Paper 005. 245 p.

Robinson, L., D. Harrison, W. Krohn, and A. Fuller. 2006. Responses of snowshoe hares and lynx to alternative forest harvesting practices. Pages 60-68 in Maine Cooperative Forestry Research Unit Annual Report, Maine Agricultural and Forest Experiment Station Miscellaneous Report 438, Orono, ME.

Wagner, R., R. Seymour, M. Saunders, J. Wilson, L. Kenefic, D. Denico, and K. Fergusson. 2006. Forest Harvest Classification System for Maine. Report by Maine Society of American Foresters Task Force.

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

CONFERENCE PRESENTATIONS

Fuller, A.K., D.J. Harrison, and B.J. Hearn. Effects of habitat loss and fragmentation on the endangered Newfoundland marten. Invited presentation at the Western Newfoundland Model Forest's Marten Habitat Workshop, Corner Brook, Newfoundland, November 1, 2005.

Fuller, A.K., D.J. Harrison, and B.J. Hearn. Modeling habitat occupancy of marten in estern Newfoundland: management and planning applications. Invited presentation to the Newfoundland Marten Recovery Team, Corner Brook, Newfoundland, November 2, 2005.

Harrison, D.J. Managing forest stands and landscapes to maintain wildlife biodiversity. Invited presentation at Research, Results and the Resource Workshop, sponsored by Maine Cooperative Forestry Research Unit, Orono, ME, May 25, 2006.

Harrison, D.J., W.B. Krohn, L. Robinson, J.A. Homyack, and A.K. Fuller. Temporal and spatial variation in hare densities within the geographic range of lynx in Maine. Invited paper presented at Symposium on Lynx Conservation in the lower 48 states, The Wildlife Society Annual Conference, Anchorage, Alaska, September 27, 2006.

McGrath, T., R. O'Keefe, and B. MacPhee. Nova Scotia Growth and Yield Model: 2005 Update. May 2006. CFRU Workshop.

Wagner, R.G. 2006. Long-term yield gains and the top 10 lessons learned from forest vegetation management research in North America. Society of American Foresters 2006 National Convention, October 25-29, Pittsburgh, PA. (Invited presentation)

Wagner, R.G. 2006. Should We Fertilize? In Proceedings of Research, Results and the Resource: A Workshop for CFRU Member Foresters, May 25, 2006, University of Maine, Orono, Maine.

Wagner, R.G. 2006. Vegetation Management: Yield gains, fibre flows, and the top 10 principles for success. p. 33-36 In Proceedings of Canadian Weed Science Society Annual Meeting, Forestry and Industrial Vegetation Management Working Group, Today's Silviculture: Tomorrow's Forest, November 29, 2006, Victoria, BC (Invited paper)

Wagner, R.G. and R.S. Seymour. 2006. What We Believe About Thinning in Maine's Spruce-Fir Stands. In Proceedings of Research, Results and the Resource: A Workshop For CFRU Member Foresters, May 25, 2006, University of Maine, Orono, Maine.

Wagner, R.G. and S.R. Meyer. 2006. The Cooperative Forestry Research Unit: 30 Years of Partnership between Maine's Forest Managers and The University of Maine. p. 135 In Proceedings of Eastern CANUSA Conference: Forest Science Across the Borders, October 19-21, Quebec City, Quebec.

Wagner, R.G. and S.R. Meyer. 2006. The Cooperative Forestry Research Unit: 30 years of partnership between Maine's forest managers and the University of Maine. Society of American Foresters 2006 National Convention, October 25-29, Pittsburgh, PA.

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Wagner, R.G., M.R. Saunders, and K.G. Kanoti. 2006. Silvicultural Intensity and Productivity of Regenerating Stands in Maine. p. 51 In Proceedings of National Workshop on Forest Productivity and Technology: Cooperative Research to Support a Sustainable & Competitive Future, November 8-9, Holiday Inn Capitol at Smithsonian, Washington, D.C. (Invited presentation)

Wagner, R.G., R.S. Seymour, and S.R. Meyer. 2006. Maine's Commercial Thinning Research Network. p. 96 In Proceedings of Eastern CANUSA Conference: Forest Science Across the Borders, October 19-21, Quebec City, Quebec.

OTHER PRESENTATIONS

Fuller, A.K., and D.J. Harrison. 2006. Stand-scale habitat relationships of lynx in northern Maine. Final contract report presentation to Maine Cooperative Forestry Research Unit, Orono, ME, January 25.

Fuller, A.K., and D.J. Harrison. 2006. Stand-scale habitat relationships of lynx in northern Maine. Invited presentation at Forestry Noontime Seminar Series, University of Maine, Orono, March 3.

Fuller, A.K. 2006. Landscape thresholds and responses to habitat loss and fragmentation by martens in Maine and Newfoundland. Ph.D. dissertation seminar, University of Maine, Orono, April 10.

Hagan, J.M. and A.A. Whitman. 2006. Selecting forest biodiversity indicators. Forest Leadership Meeting, Toronto, Ontario. March 5 (particpants: stakeholders, ON DNR staff, and scientists).

Harrison, D.J. 2006. Quantifying biodiversity values across managed landscapes in northern and western Maine. Presentation to Maine Cooperative Forestry Research Unit, Orono, ME, April 26.

Harrison, D.J. 2066. Research results and applications for management: stand and landscape management for marten and lynx on commercial forestlands in Maine. Invited presentations and field tour. Annual meeting of Foresters, Wagner Land Management Corp., Bethel, ME, May 3.

Harrison, D.J. 2006. Wildlife, forest succession, vegetation management, and biodiversity. Invited lecture in FES 435/535: Managing Forest Succession, University of Maine, Orono, Maine. April 13.

Harrison, D.J., W.B. Krohn, and J.A. Hepinstall. 2005. A landscape planning framework for northern Maine: an overview of recent research results for marten, lynx and other forest vertebrates. Maine Department of Inland Fisheries and Wildlife, Augusta, ME.December 21.

Robinson, L. 2006. Ecological relationships between partial harvesting, snowshoe hares, and lynx in Maine. M.S. thesis defense seminar, University of Maine, Orono, Maine. August 15.

Robinson, L., D.J. Harrison and W.B. Krohn. 2006. Ecological relationships between partial harvesting, snowshoe hares, and lynx in Maine. Presentation and discussion for forestry and wildlife professionals, University of Maine, Orono, August 24.

Wagner, R.G. 2006. Cooperative Forestry Research Unit: What's in it for forest landowners? Wagner Forest Management Annual Meeting, Bethel, ME. May.

Wagner, R.G. 2006. Opportunities and Challenges For Maine's Forest Landowners in the Coming BioProducts Market, Science & Technology for the Future of Maine's Forest-based Economy, University of Maine, Orono, Maine. March.

Wagner, R.G. 2006. Sustainable wood supply in a dynamic world: Where have we been, where are we going, and what do we need to know? Workshop on The Art and Science of Wood Supply Estimation, Ontario Ministry of Natural Resources, Sault Ste. Marie, Ontario. December - Invited keynote presentation

Wagner, R.G. 2006. What is CFRU? Research, Results and the Resource: A Workshop For CFRU Member Foresters, Orono, ME. May.

Whitman, A.A. 2006. The LS Index and managing for LS attributes. Biennial Training Workshop of the Cooperative Forestry Research Unit, Orono, ME. May 25.

PUBLIC PRESENTATIONS

Wagner, R.G. 2006. Opportunities and Challenges For Maine's Forest Landowners, UMaine "Paper Days" Symposium, University of Maine, Orono, Maine. April.

Whitman, A.A. 2006. The status, importance, and conservation of Maine's old forests. Southern Maine Community College, South Portland, ME. April 5.

The people make all the difference.

List of Figures

Sometimes there is even a little time leftover for some fun...

List of Tables

The secondary crop at some Commercial Thinning Research Network sites rewards a hard day's work.

Contact Information

John M. Hagan (Ph.D.)	**CFRU Cooperating Scientist,** Program Director Manomet Center for Conservation Science, Brunswick, ME (207) 721-9040; jmhagan@prexar.com
Daniel J. Harrison (Ph.D.)	**CFRU Cooperating Scientist,** Professor of Wildlife Ecology, University of Maine, Orono, ME (207) 581-2867; harrison@umenfa.maine.edu
Philip Hofmeyer	**Graduate Assistant**, School of Forest Resources, University of Maine, Orono, ME (207) 581-2878; philip.hofmeyer@umit.maine.edu
William B. Krohn (Ph.D.)	**Leader**, Maine Coop. Fish and Wildlife Research Unit, Assistant Professor of Wildlife Ecology, University of Maine, Orono, ME (207) 581-2870; wkrohn@umenfa.maine.edu
Spencer R. Meyer	**CFRU Research and Communications Coordinator**, Cooperative Forestry Research Unit, University of Maine, Orono, ME (207) 581-2861; spencer_meyer@umenfa.maine.edu
Rakesh Minocha (Ph.D.)	**Scientist**, USFS Northeast Forest Experiment Station, Durham, NH (603) 868-7622; rminocha@hopper.unh.edu
Robert S. Seymour (Ph.D.)	**CFRU Cooperating Scientist,** Curtis Hutchins Professor of Forest Resources, University of Maine, Orono, ME (207) 581-2860; seymour@umenfa.maine.edu
Dana M. Smith	**CFRU Administrative Assistant**, University of Maine, Orono, ME (207) 581-2893; dana.smith@umit.maine.edu
Robert G. Wagner (Ph.D.)	**CFRU Director,** Henry W. Saunders Distinguished Professor in Forestry, School of Forest Resources, University of Maine, Orono, ME (207) 581-2903; bob_wagner@umenfa.maine.edu
Andrew A. Whitman	**Forest Ecologist**, Manomet Center for Conservation Science, Brunswick, ME (207) 721-9040; awhitman@prexar.com
Ethel Wilkerson	**Project Manager**, Manomet Center for Conservation Science, Brunswick, ME (207) 721-9040; ewilkerson@prexar.com