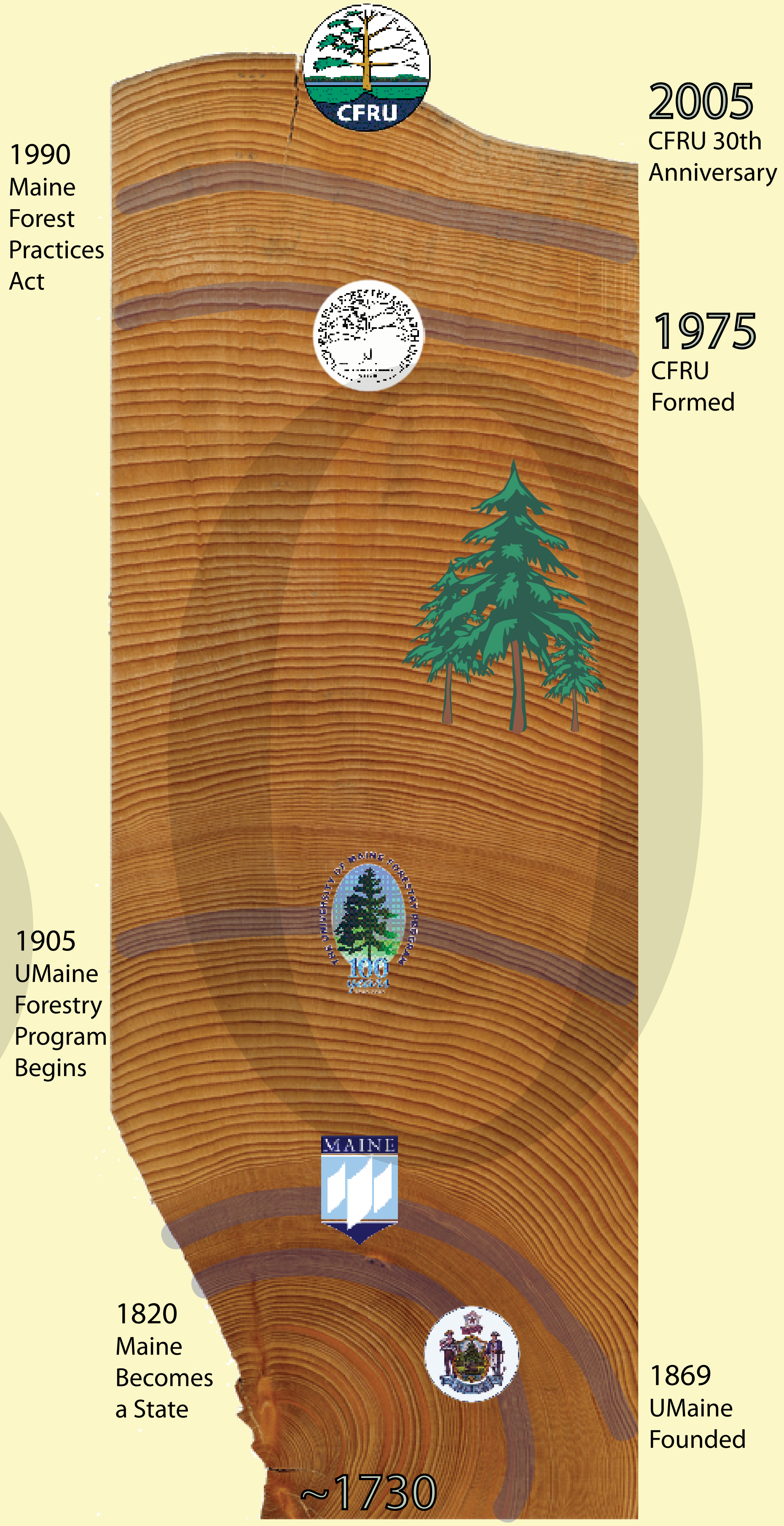
# COOPERATIVE FORESTRY RESEARCH UNIT

30th ANNIVERSARY

2004 - 2005

Annual Report




MAFES

Miscellaneous

Report 438

1865 THE UNIVERSITY OF MAINE

# COOPERATIVE FORESTRY RESEARCH UNIT ANNUAL REPORT 2004 - 2005

CFRU

1865 THE UNIVERSITY OF MAINE

Maine Agricultural & Forest Experiment Station
Miscellaneous Report 438

## *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**

Cover Photograph:

A cross-section from a 275 year-old spruce from Baxter State Park Scientific Forest Management Area (compliments of Bob Seymour)

# Contents

## Organization



*The spruce budworm was in part responsible for the formation of the CFRU and continues to leave its mark on Maine's forest landscape.*

## 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 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. Research *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 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. As well as documenting progress made by the CFRU during fiscal year 2004-2005, this report takes a retrospective look at our 30-year history of forest research in Maine. Throughout the report the reader will notice images from years past. These images serve as a reminder of the contributions of the cooperators, scientists, and others along the way who have made the CFRU a success.

*CFRU conducts research on all aspects of forest ecosystems.*

# Highlights

## ORGANIZATION

- Due to an increase in membership, CFRU acreage rose from 5.25 to 7.84 million acres in 2005 (see page 8).
- Wagner Forest Management and Black Bear Forest, Inc. joined the CFRU in 2005 (see page 8).
- Total CFRU revenues for 2005 reached $415,812 (see page 14).
- For every dollar contributed, CFRU scientists leveraged an additional $13.06 (see page 14).
- The CFRU celebrated its 30-year anniversary (see page 20).

## COMMUNICATIONS

- The CFRU developed a new communications plan that includes general audience *Spotlight* articles on key CFRU research and *Results* articles (see page 18).
- CFRU scientists, staff, and graduate students delivered more than 15 publications and 39 presentations on their latest research results (see page 18).
- The CFRU launched its new website to serve as a better interface with the public while providing additional functionality to its members (see page 18).

## RESEARCH

### Silviculture

- Five years of remeasurements were completed on the Commercial Thinning Research Network (CTRN - see page 34).
- A complete, web-based Establishment Report was developed for the CTRN to provide a framework for tracking the progress of the Network as it continues to develop and provide results to the CFRU (see page 35).
- Spatial analysis of commercial thinning suggests that for the older, non-PCT sites the type of thinning contributes to the variability in both growing space and diameter structure (see page 42).
- Physiological chemicals may provide early indicators of thinning-induced stress (see page 47).
- The CFRU completed the first year of investigation into the ecology and silviculture of white cedar (see page 49).

### Wildlife Ecology

- Predictive landscape models are being developed to track umbrella species habitat change over time (see page 53).
- Lynx selected for tall mid-successional clearcuts and established partially harvested stands over short mid-successional clearcuts, recent partially harvested stands, and mature second-growth stands (see page 60).

### Biodiversity Conservation

- After four years of post-harvest monitoring, streams with partially harvested buffers of 11-m showed signs of temperature moderation (see page 70).
- Late-succesional (LS) harvest treatments in northern hardwood stands reduced logging impacts, maintained removals of sawlog and better trees, and retained large trees and LS Index score (see page 76).

# Membership





## Major Cooperators

Baskahegan Company
Black Bear Forest, Inc.
Clayton Lake Woodlands
FraserPapers, 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
Ste. Aurelie Timberlands Company
Sappi Fine Paper
Seven Islands Land Company
The Nature Conservancy
Wagner Forest Management

## Other Cooperators

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

# Membership

**MEMBERSHIP UPDATE**

After a significant loss of membership over the past five years due to unprecedented sales of Maine forestland (see 2003 and 2004 Annual Reports), we are happy to report a major turnaround in CFRU membership this year. Efforts during 2005 to encourage membership by the new institutional investor owners of Maine's forestlands yield membership by **Wagner Forest Management, Ltd.** and **Black Bear Forest, Inc.** Wagner brought 1,165,615 acres of membership from several of their clients and Black Bear brought 1,000,000 acres of lands formerly owned by International Paper Company. In addition, **Prentiss & Carlisle**, who are long-standing members of CFRU, were successful in bringing an additional 644,306 acres of their client land base as new members. The net result was an increase in CFRU member acres of 2.8 million acres, increasing overall membership from 5.25 million in 2004 to 7.84 million in 2005 (a 49% increase). We welcome Wagner Forest Management and Black Bear Forest to the CFRU and look forward to working with your organizations to help achieve your forest management goals. We also thank Prentiss & Carlisle for their diligent efforts at bringing their extensive client base into the CFRU.

Despite our success with attracting new members this year, CFRU experienced the loss of one of its long-standing and highly valued members. **Fraser Papers** left the CFRU mid-year after the sale of all of their Maine lands (238,000 acres). We wish to thank **Kevin Topolniski** and **Don Tardie** for their tremendous support over the years. We will sorely miss their leadership on Maine forestry issues and their valued advice about forestry research needs.

The financial impact of the new members and loss of Fraser Papers mid-year is presented in the Financials section of this report.

During the coming year, our goal is to further increase CFRU membership by pursuing other institutional investors, larger private landowners, and wood processors. As a result of our success in attracting new members this year, efforts to develop a Maine Forest Research Commission (described in the 2004 Annual Report), as a means to develop a stable funding base for landowner-sponsored forest research, was terminated this year. We sincerely thank **Peter Triandafillou** (Huber Resources), **Steve Schley** (Pingree and Associates), **Jim Robbins** (Robbins Lumber), **Alec Giffen** (Maine Forest Service), **Roger Milliken** (Baskahegan Corp.), and **Bob Wagner** (CFRU) for their considerable efforts at addressing the challenges of maintaining a stable source of CFRU funding during a very dynamic period of forestland sales.

*CFRU members on the 30th Anniversary Fall Field Tour.*

# People

## Staff

Robert G. Wagner
Director and Professor of Forest Ecosystem Science

Spencer R. Meyer
Research and Communications Coordinator

Robert F. Keefe
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
Professor of Forest Ecosystem Science

## 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

*CFRU cooperators, scientists and staff pose during the 30th Anniversary Field Tour at the Penobscot Experimental Forest in October 2005.*

# Advisory

## Officers

| | |
|---|---|
| Hugh Crammond (Chair) | Irving Woodlands, LLC |
| Kenny Fergusson (Vice Chair) | Huber Resources Corporation |
| Doug Denico (Financial Officer) | Plum Creek Timber Company |
| Mike Dann (Member-at-Large) | Seven Islands Land Company |

## Members

| | |
|---|---|
| Greg Adams | JD Irving, Ltd. |
| John Brissette | USFS Northeast Forest Experiment Station |
| Tom Charles | Maine Bureau of Parks and Lands |
| Steve Coleman | Frontier Forest, LLC |
| David Dow | Prentiss & Carlisle Co., Inc. |
| Gordon Gamble | Wagner Forest Management |
| Brian Higgs | Baskahegan Corporation |
| Carl Jordan | Sappi Fine Paper |
| Marcia McKeague | Katahdin Forest Management |
| George Motta | Black Bear Forest, Inc. |
| Nancy Sferra | The Nature Conservancy |
| Bill Sylvester | Clayton Lakes Woodlands |
| Kevin Topolniski | Fraser Papers, Inc. |
| Paul Van Deusen | National Council for Air & Stream Improvement, Inc. (NCASI) |
| G. Bruce Wiersma | The University of Maine, College of Natural Sciences, Forestry and Agriculture |

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, **Hugh Crammond** (Chair), **Kenny Fergusson** (Vice-Chair), **Doug Denico** (Financial Officer), and **Mike Dann** (Member-at-Large) for their hard work and dedication.

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 high quality. The Advisory Committee met three times this year: January 26, April 13, and October 19-20, 2005. The October meeting featured our 30th Annivesary celebration dinner and **Field Tour of the Penobscot Experimental Forest.**

The theme of this year's annual field tour was "55 Years of Long-Term Research on the Penobscot Experimental Forest" and was hosted by the **University of Maine** and the **US Forest Service (USFS).** Advisory member **John Brissette (USFS)** and **USFS** scientist **Laura Kenefic** presented results from the long-term commercial clearcut and three-stage shelterwood compartments and showed silvicultural and financial comparisions between selection and diameter-limit systems. **CFRU** Scientists **Bob Wagner**, **Bob Seymour**, and staff member **Spencer Meyer** presented preliminary results from the **CFRU** Commercial Thinning Research Network study. **Bob Wagner** and **UMaine** graduate student **Mike Saunders** showed cooperators the Agenda 2020 vegetation competition study. **UMaine** professor **Mac Hunter** and graduate students **Sean Blomquist** and **Sean Patrick** showed the **Land-use Effects on Amphibian Populations (LEAP)** study. **Bob Wagner**, **Bob Seymour**, **Mike Saunders**, graduate student **Shelly Thomas** and **Mac Hunter** showed the results of the first phase of gap harvests in the **Forest Ecosystem Research Program (FERP)** study.

More than 50 CFRU members participated in the tour. We thank the hosts, speakers, and CFRU staff for making the tour a great success.

## COMMITTEE MEMBER CHANGES

The addition of new organizations to CFRU this year (see Membership) allowed us to welcome two new members to the Advisory Committee. We welcome **Gordon Gamble** (**Wagner Forest Management**) and **George Motta** (**Black Bear Forest, Inc.**) to the committee. We look forward to working with them in charting the future course of CFRU.

*Fall Field Tour participants eat lunch near the Agenda 2020 vegetation competition study on the Penobscot Experimental Forest.*

# Chair-Elect Report

This year we have been celebrating the 30th Anniversary of the founding of the Cooperative Forest Research Unit (CFRU). In October we held an anniversary dinner during which remembrances were made about the life and times of the CFRU. The list of achievements was long and the smiles were wide. The story of the CFRU's development across the decades is one of continued success in delivering practical forestry knowledge. It is also one of frequent changes and adroit maneuvering to cope with developments in both sides of our partnership (land managers and academic researchers). These changes have wrought an efficient organization that produces answers to the complex questions that surround forest management in Maine (and the rest of the world). During 2005 there was a rebound in acres enrolled in CFRU. We moved from 5.25 million to 7.84 million acres. This is a great endorsement for everyone who has worked so hard to make this organization a leader in applied forestry research.

The future is uncertain. **Bruce Wiersma**, a staunch and pro-active supporter of the CFRU, is stepping down as Dean of the College of Natural Sciences, Forestry and Agriculture. However, a restructuring of the forestry faculty at the college is ongoing and Bruce will remain active at least for a few years. Maine forest ownership maps are outdated before the ink is dry, and forest products businesses continue to face serious restructuring pressures. Social, environmental, and political pressures on forest practices continue to increase.

All of these uncertainties force us to examine the value that the CFRU provides. With this in mind I would like to draw attention to the research highlights of 2005, where progress has been made in many areas. Projects reported in this publication include analysis of commercial thinning (Wagner and Seymour), growing space allocation (Wagner and Keefe), silviculture and ecology of white cedar (Seymour and Hofmeyer), the effects of commercial thinning on physiological stress (Rakesh Minocha), the response of landscape change on wildlife umbrella species (Harrison et al.), the response of hare and lynx to silvicultural practices (Harrison et al.), impacts on headwater streams (Hagan), and the identification of late successional forest attributes (Whitman and Hagan). All of these studies exemplify how the CFRU is continuing to provide world class scientific results that address important issues affecting forest management in Maine.

In closing, I would like to acknowledge the people who make the CFRU successful. Cooperating Scientists, **Mike Greenwood**, **John Hagan**, **Dan Harrison**, and **Bob Seymour** and the Project Scientists, **Tim McGrath**, **Ralph Nyland**, and **Andrew Whitman** continue to contribute an incredible amount of effort, thought, and time. **Spencer Meyer** (Research and Communications Coordinator) and **Dana Smith** (Administrative Assistant) provide exceptional staff support. **Rob Keefe** (Forest Biometrician) has left the CFRU but he deserves many thanks for his contributions. **Michael Saunders** who has recently joined the merry crew, is a very welcome addition. **Bob Wagner** (CFRU Director) is at the hub of the unit. Bob is always working to make us successful and the accomplishments of the unit would not have been possible without his leadership and dedication.

Kenny Fergusson
CFRU Chair-Elect

# Director's Report

After a long period of upheaval from the unprecedented sale of Maine forestlands and the corresponding loss of CFRU members, this year saw a substantial turnaround with the return of 2.8 million member acres. I am very pleased to welcome **Wagner Forest Management, Ltd.** and **Black Bear Forest, Inc.** as new CFRU members representing the institutional investors that are now managing much of Maine's forest. I thank **Tom Colgan** and **George Motta** for their confidence and vision for how landowner-sponsored forest research can serve the needs of their clients. I also thank **Don White** of **Prentiss & Carlisle** who made a bold and successful effort to bring a wide array of their clients into the CFRU this year. I look forward to the new perspectives that will come from having these new forestland owners working with us at the Advisory Committee table. The CFRU will be substantially stronger as a result.

These gains in membership would not have been possible without the dedication, leadership, and hard work of **Peter Triandafillou** (Huber Resources), **Steve Schley** (Pingree and Associates), **Jim Robbins** (Robbins Lumber), and **Alec Giffen** (Maine Forest Service) who worked with landowners and government over the past year to pursue a variety of options for finding more sustainable funding options for CFRU.

The quality of CFRU research in this annual report, as always, comes from the dedication of our scientists. I extend a special thanks in this regard to our cooperating scientists (**Drs. Mike Greenwood**, **John Hagan**, **Dan Harrison**, and **Bob Seymour**) for their continued dedication to the CFRU mission and excellent work. We have an excellent Administrative Assistant in **Dana Smith** and I look forward to working with **Spencer Meyer** as he works to develop a new communications profile for the unit.

The success of the CFRU relies on the participation of it member organizations through our Advisory Committee. I thank **Hugh Crammond** (Irving Woodlands) for his guidance and support as Chair during the past two years. I look forward to working with **Kenny Fergusson** (Huber Resources) as the incoming Chair, and **Mike Dann** (Seven Islands) who serves as our Member-at-Large.

Robert G. Wagner

Robert G. Wagner
CFRU Director

# Financials

Twenty-four members representing 7.8 million acres contributed $415,812 to support CFRU activities this year (Table 1). This amount was $112,420 (34%) more than was invoiced due to the addition of two new members and a substantial acreage addition of another. We welcomed Black Bear Forest, Inc. (1.0 million acres) and Wagner Forest Management (1.2 million acres) as new members of the CFRU this year. In addition, Prentiss & Carlisle, a long standing member of CFRU, generously brought 644,306 new acres of their client lands into the CFRU. The net result was a 2.8 million acre or 54% increase in CFRU member acres relative to 2004. Due to the sale of their lands mid year, Fraser Papers left the CFRU, reducing anticipated income by $6,843. Even with this 238,000 acre loss, CFRU will move into 2006 with a 7.6 million acre land base. The net result of these membership changes was a 30% ($94,907) increase in income above last year.

Sound fiscal management by CFRU project scientists and staff resulted in spending $13,389 (3.8%) less than was approved by the Advisory Committee (Table 2). These savings were returned to the central account for future use on other CFRU projects. CFRU spent 51% of its budget for research projects and 49% 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 four silviculture projects (50%), two wildlife ecology projects (16%), and two biodiversity conservation projects (34%) (Table 2).

Using contributions from CFRU members, project scientists were able to leverage an additional $266,068 from other sources to support CFRU-sponsored research projects. When added to the $50,407 in-kind contributions from the University of Maine, the total value of CFRU research during this fiscal year was $732,287 or

Figure 1. CFRU members contributed $415,812 this year. An additional $266,068 was leveraged from external funding sources, and the University of Maine contributed $50,407 of in-kind support.

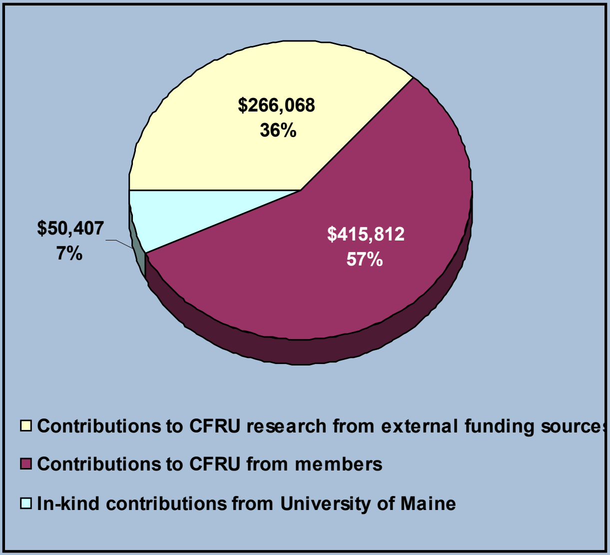
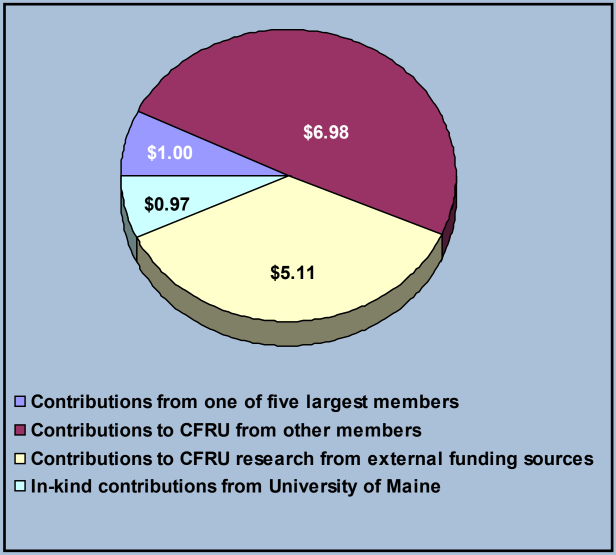



Figure 2. For every dollar contributed by one of our five largest members they received $6.98 from other members, $5.11 from external funding sources, and $0.97 from in-kind contributions by the University of Maine.



76% above member contributions (Figure 1). Substantial leveraging comes from CFRU members pooling their resources. For example, for every dollar contributed by our five largest members this year, they received $6.98 from other member contributions, $5.11 from external funding sources, and $0.97 from in-kind contributions from the University of Maine. Therefore, every dollar contributed by the largest CFRU members leveraged an additional $13.06 to support their highest priority research projects (Figure 2).

*A forester considers his options.*

*The Weymouth Point study is one of only three long-term watershed research areas in the Acadian forest.*

Table 1. CFRU cooperator contributions during FY 2004-05.

| Forest Landowner / Manager Members: | 2005 Reported Acres | Amount invoiced (Jan 2005) | Amount Paid | Balance |
|---|---|---|---|---|
| Irving Woodlands, LLC | 1,200,000 | $65,000 | $65,000 | $0 |
| Plum Creek Timberlands | 908,600 | $50,202 | $50,202 | $0 |
| Seven Islands Land Company | 880,000 | $48,700 | $48,700 | $0 |
| Prentiss and Carlisle * | 735,258 | $5,230 | $41,556 | $36,326 |
| Maine Bureau of Parks and Lands | 385,000 | $22,138 | $22,138 | $0 |
| Huber, J. M. Corporation | 362,000 | $20,815 | $20,815 | $0 |
| Katahdin Forest Management | 293,000 | $16,848 | $16,848 | $0 |
| Clayton Lake Woodlands | 245,000 | $14,088 | $14,088 | $0 |
| The Nature Conservancy | 180,064 | $10,354 | $10,354 | $0 |
| Fraser Papers ** | 238,000 | $13,685 | $6,843 | -$6,843 |
| Baskahegan Lands | 101,629 | $5,844 | $5,844 | $0 |
| Ste. Aurelie Timberlands | 61,689 | $3,547 | $3,547 | $0 |
| Frontier Forest, LLC | 53,338 | $3,067 | $3,067 | $0 |
| Robbins Lumber Company | 28,000 | $1,610 | $1,610 | $0 |
| | | | | |
| **New Members:** | | | | |
| Black Bear Forest, Inc. | 1,000,000 | $55,000 | $55,000 | $0 |
| Wagner Forest Management, Ltd. *** | 1,165,615 | $21,094 | $21,094 | $0 |
| **Forest Landowner / Manager TOTAL** | **7,837,193** | **$357,219** | **$386,702** | **$29,484** |
| | | | | |
| **Wood Processor Members:** | **2005 Reported Tons** | | | |
| Sappi Fine Paper | 2,053,802 | $25,673 | $25,673 | $0 |
| Huber, J. M. Corporation, Wood Products | | $1,500 | $1,500 | $0 |
| Hancock Lumber Company, Inc. | | $1,000 | $1,000 | $0 |
| **Wood Processor TOTAL** | | **$28,173** | **$28,173** | **$0** |
| | | | | |
| **Other Members:** | | | | |
| Landvest | | $200 | $500 | $300 |
| Peavey Corporation | | $137 | $137 | $0 |
| Field Timberlands | | $100 | $100 | $0 |
| Finestkind Tree Farms | | $100 | $100 | $0 |
| Western Maine Nurseries, Inc. | | $100 | $100 | $0 |
| **Other Member TOTAL:** | | **$637** | **$937** | **$300** |
| **GRAND TOTAL:** | | **$386,028** | **$415,812** | **$29,784** |

* Prentiss & Carlisle added 644,306 new acres of their client lands.

** Left CFRU mid-year due to sale of land.

** Membership prorated for final quarter of FY04-05.

Table 2. CFRU project expenditures and balances for FY 2004-05 (as of March 13, 2006).

| Project | Principal Investigator(s) | Amount Approved | Amount Spent | Balance | % |
|---|---|---|---|---|---|
| **Administration** | **Wagner** | **$169,395** | **$169,257** | **$138** | **0.1%** |
| | | | | | |
| **Silviculture Research** | | | | | |
| Maine Commercial Thinning Research Network | Wagner/ Seymour | $72,427 | $68,846 | $3,581 | 4.9% |
| Factors affecting the regeneration and early growth of balsam fir and red spruce | Greenwood | $4,000 | $4,000 | $0 | 0.0% |
| Quantitative silviculture of northern white-cedar | Seymour | $9,500 | $9,001 | $499 | 5.3% |
| Influence of precommercial thinning on long-term stand growth and financial returns in northeastern spruce-fir stands * | Wagner | $15,000 | $6,653 | $8,347 | 55.6% |
| **Silviculture TOTAL** | | **$100,927** | **$88,500** | **$12,427** | **12.3%** |
| | | | | | |
| **Wildlife Effects Research** | | | | | |
| Predicting responses of snowshoe hares and lynx to alternative forest harvesting scenarios across multiple spatial scales (Phase 2) | Harrison | $25,000 | $24,738 | $262 | 1.0% |
| Predicting responses of forest landscape change on wildlife umbrella species ** | Harrison | $5,000 | $4,981 | $19 | 0.4% |
| **Wildlife TOTAL** | | **$30,000** | **$29,719** | **$281** | **0.9%** |
| | | | | | |
| **Biodiversity Conservation Research** | | | | | |
| Using the Late-Successional Index of biodiversity to document biodiversity contributions to sustainable forestry *** | Hagan/ Whitman | $20,000 | $20,000 | $0 | 0.0% |
| Continued monitoring of the recovery of headwater stream water temperature following prescribed harvesting, and development of a riparian index of biodiversity **** | Hagan/ Whitman | $40,000 | $40,000 | $0 | 0.0% |
| **Biodiversity & Riparian Zone TOTAL** | | **$60,000** | **$60,000** | **$0** | **0.0%** |
| **GRAND TOTAL** | | **$360,322** | **$347,476** | **$12,846** | **3.6%** |

* Project was jointly supported by USFS Agenda 2020 and Plum Creek Timber. Only expenditures from Plum Creek Timber contribution to CFRU are shown. No CFRU funds spent this fiscal year.

** Project was jointly supported by USFS Agenda 2020, USGS, NCASI, TNC, International Paper Co., and USFWS. Only CFRU expenditures are shown.

*** Project was jointly supported by NFWF and Merck Family Fund. Only CFRU expenditures are shown.

**** Project was jointly supported by NCASI. Only CFRU expenditures are shown.

# 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 seven journal articles, nine research reports and notes, and 39 conference and public presentations, for a total of 54 published communications. See the Outreach section of this report for a complete listing of all publications and presentations for this fiscal year.

### Website

After a thorough redesign process, the Unit launched its new website at the end of 2005. The website (http://www.umaine.edu/cfru - just click on the CFRU logo at the bottom of any page in this report) was designed with a sharp public image and better overall usability in mind. Brief descriptions of CFRU research portray the broad forest research interests of the Unit. Public visitors are drawn to first of the CFRU Spotlight series, and have access to Annual Reports and older technical publications.

*Bob Seymour discusses the FERP gap harvests with CFRU Cooperators and Scientists.*

In addition to the new public side of the CFRU website, the Members Only section has been redesigned to adopt the same design of the new public site. The publications database and search engine have been overhauled to give co-operators better access to the Unit's 30 years of publications. We think the new CFRU website reflects the dynamic, professional, research-driven focus that remains the cornerstone of our organization.

## FIELD AND DATA

Our successful summer student internship program that began in 2003 continued to develop this year. We hired six outstanding students from several universities around the nation, including one from University of Maine. Students left with a better appreciation for the importance of sustainable forest management and research in Maine. We also gained from their enthusiasm, hard work, and attention to detail. As this internship program continues to develop, the CFRU is able to offer a rewarding educational opportunity to college students while instilling the importance of forest research. Accomplishments of the 2005 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) Annual re-measurements of regeneration plots on CTRN sites characterizing vegetation on over a thousand vegetation sample plots; and

(3) Remeasurement of chemical strip-thinning trial plots from the 1980s on **Clayton Lake Woodlands** and **Katahdin Forest Management** lands.

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

## STAFF CHANGES

We experienced a significant staff change this year with hiring of a new Research and Communications Coordinator for the unit. After a national search that drew 35 excellent candidates, we hired **Spencer Meyer** to fill the position. Spencer recently completed a MS degree in forestry from the University of Maine where he worked on a thesis research project supported by CFRU. His research project focused on using leaf area as a predictor of spruce and fir growth on the CFRU Commercial Thinning Research Network sites (see report). He also worked previously for the University of Maine as the crew leader for the CFRU Commercial Thinning Research Network and for the Forest Ecosystem Research Program. Before coming to Maine, Spencer had experience working as a research assistant with both the Yale School of Forestry and Harvard Forest. In 2002, Spencer received a BA degree in environmental studies from Dartmouth College.

At the end of this year **Robert Keefe** left his position as biometrician for the CFRU. Rob was originally hired to conduct a spatial analysis of growing space allocation on the commercial thinning research plots (see latest report). Over the year, we were able to extend Rob's position with the funding of a new precommercial thinning modeling project. Rob moved back to New Hampshire to pursue other career opportunities. We conducted a national search for a new biometrician to work on the precommercial thinning modeling project during fall 2005. We were fortunate to hire **Michael Saunders** on a two-year position to work on the project. Mike is completing a PhD at the University of Maine where he has been modeling changes in forest structure under different silvicultural regimes in a long-term US Forest Service study on the Penobscot Experimental Forest. Mike has a MS degree in forestry from the University of Minnesota and a BS in forestry and wildlife from Iowa State University. Mike will begin work in January 2006.

# 30th Anniversary

*CFRU Scientists, past and present, get together at the 30th Anniversary dinner in October, 2005. From left to right: Bob Wagner, Robert Shepard, Bob Seymour, Fred knight, Mike Greenwood, Max McCormack, and Dan Harrison.*

# Cooperative Forestry Research Unit: The First 30 Years (1975-2005)

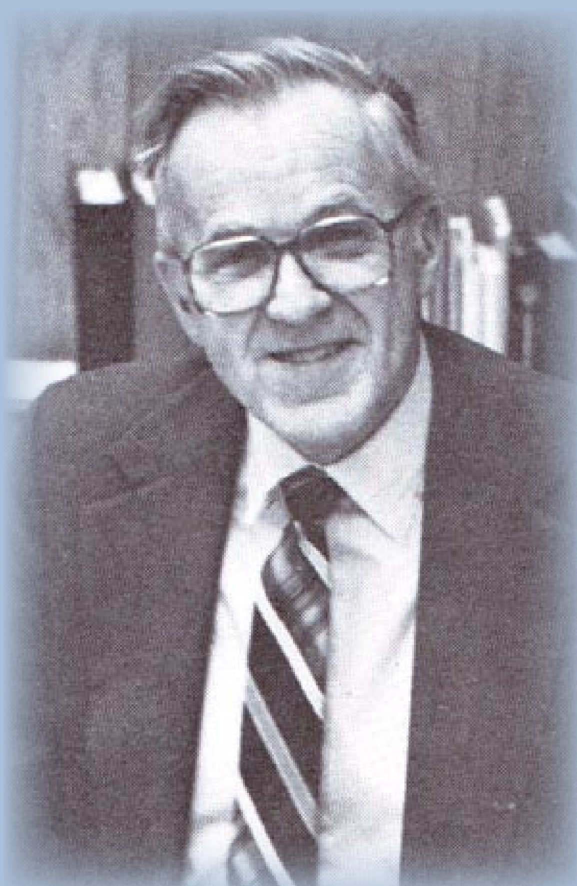
**Fred B. Knight, Maxwell L. McCormack, Jr., and Robert G. Wagner**

As the Cooperative Forestry Research Unit (CFRU) celebrates its 30th anniversary, we have an opportunity to review how it started, who was involved, and what was accomplished. The CFRU is worthy of review for several reasons. First, the Unit is one of the oldest industry and university forestry research cooperatives in the United States. Second, this unique partnership has increased knowledge about the sustainable management of Maine's tremendous forest resource in a way that would not have occurred otherwise. Third, CFRU research has been responsible for averting several potential forestry controversies that could have devastated Maine's largest industry. Lastly, a few of the principal founders and participants are still around to tell the story.

## THE BEGINNING

During the mid 1970s much of northern Maine's spruce-fir forest was being devastated by a severe outbreak of the spruce budworm. Forest landowners and managers throughout the state were being criticized for failing to participate in research to deal with the crisis. In addition, there was clearly a need to develop more research on the basic management problems facing landowners. Many were concerned about low levels of productivity in Maine's forest, and it was generally believed that the growth rates and intensity of management were far below optimum. The forest industry was clearly interested in developing a joint research effort, but how could these diverse landowners join together to conduct research without running into anti-trust violations? The problem was brought to the School of Forest Resources at the University of Maine.

Fred Knight had been appointed Director of The School of Forest Resources and Dwight B. Demeritt Professor in late 1971. Upon his hiring, Dean Bruce Poulton of the College of Life Sciences and Agriculture charged him with the responsibility of expanding the forestry research program, continuing to graduate top quality professionals, and increasing opportunities for interdisciplinary research cooperation. Malcolm Coulter had just succeeded in developing a PhD degree program for the School of Forest Resources and cooperative research efforts were in progress among several departments in three other colleges.



*CFRU's founding Director, Fred Knight.*

A key factor that made it possible for the School to consider expanding its forest research effort was the landmark 1962 McIntire-Stennis Act that had expanded forestry research programs at Land Grant universities and colleges across the US. This legislation was written by Maine's Representative Clifford McIntire in close co-operation with Director Albert Nutting of the School of Forest Resources. As a result, the School had received a substantial increase in its base funding that made it possible to recruit the talented research and teaching faculty that were present in the School by the early 1970s.

**A Forest Research Cooperative?**

The idea for a cooperative research effort between Maine's forest landowners and the University of Maine was first suggested in 1973 by an ad-hoc Committee of landowners that had been meeting with Director Knight. Many ideas were advanced about ways to fund such a cooperative. Director Knight worked with Dean Kenneth Wing and Vice-President Frederick Hutchinson to incorporate the ideas and policies of the university into the process.

UMaine President Howard Neville provided the School with the directive when he made the following statement on January 28, 1974:

> "We will establish a Center for the Advanced Study of the Forest Industries which will draw from current faculty of the University and from technical and management staffs in forest products industries the multi-disciplinary research teams necessary to address the interrelated technological, economic, environmental and management problems of industry."

This mandate was directed to the School of Forest Resources and the College of Life Sciences and Agriculture Experiment Station. The ad-hoc committee on cooperative research continued to meet. The School of Forest Resources next requested that a formal research advisory committee be appointed and composed of people with diverse connections to the forest resource.

**Forest Resources Research Advisory Committee**

In April 1974, President Neville appointed members to the new Forest Resources Research Advisory Committee (FRRAC) with the following statement: "I would hope that in time the Committee will significantly influence the University in setting priorities to assure that our research efforts will truly meet the needs of the State." The 12-member Committee was organized with George Weiland (Dead River Co.) as its first Chairman. The appointments were for two year terms with re-appointments expected for most members. The first members were Richard Anderson (Maine Audubon), Samuel Butcher (Bowdoin College), Barton Blum (US Forest Service), George Carlisle (Prentis & Carlisle), Fred Holt (Maine Forest Service), Donaldson Koons (Colby College), Maynard Marsh (Maine Fish & Wildlife), Keith Miller (Acadia National Park), Henry Saunders (Saunders Brothers), John Sinclair (Seven Islands Land Co.), and Morris Wing (International Paper Co.). There also were five ex-officio members from the UMaine.

The FRRAC Committee appointed a sub-committee to continue working on the idea of a research cooperative and to develop research priorities. The sub-committee included: Robert Bartlett (Great Northern Paper Co.), Barton Blum, Harold Klaiber (Scott Paper Co.), James Robbins (Robbins Lumber Co.), John Sinclair, Morris Wing, George Weiland, and Fred Knight.

**CFRU is Born**

Early in 1975, Director Knight assisted in the preparation of a first draft of a proposal for a Cooperative Forest Research Unit (CFRU). The final proposal was adopted in August 1975 after much negotiation both internally and with members of forest industry. The Great Northern Paper Company had previously advised Director

Knight that they were ready to increase their support for research in the School of Forest Resources and it was the first company to provide funds when the cooperative was approved.

*CFRU's first Three Scientists: David Field, Mark Houseweart, and Maxwell McCormack, Jr.*

The university's standard overhead charge on research quickly became a sticking point that required considerable discussion. Industry representatives felt that UMaine should charge no overhead, while the university administration expected the full overhead rate to be charged. After considerable negotiation, all parties agreed to a 10% overhead rate (which persists to this day) so that the plan could move forward. Annual funds were needed from cooperative members to support research and the large landowners agreed to a dues assessment of three cents per acre per year. They also agreed to support the fledgling CFRU for a minimum of five years. Increases in the dues rate would be negotiated as needed. The School of Forest Resources was fortunate to have the full support of Dean Wing and Vice President Hutchinson in all negotiations.

Within one year (1975), the idea was developed and support guaranteed for a new cooperative effort to conduct forestry research in Maine. Great Northern Paper Company brought in a check for the first year, and International Paper Company followed within days. Funds continued to be added as more cooperators received authorization to expend funds for cooperative research in CFRU. By the beginning of 1976, over $180,000 per year (or more than 6 million acres) of member participation had been assured. The review of research priorities developed by the sub-committee based on a survey of land managers had revealed three major research areas to pursue: Protection (including spruce budworm and other insect problems, fire research, diseases, animal damage and weather effects), Management (including spruce-fir silviculture, hardwood silviculture, conifer silviculture, regeneration, tree improvement, wildlife habitat management, and fertilization), and Utilization (harvesting and transportation, erosion control, economics and marketing, wood products, and non-wood products).

## RESEARCH AND PEOPLE: LATE 1970s

### Three Scientists

The university next advertised for three scientists to work on the three priority areas of research. After their hiring, the FRRAC sub-committee would become responsible for receiving and reviewing research proposals from these scientists. The first three scientists included: Drs. David Field (Associate Research Professor of Utilization and Marketing, 7/1/76), Mark Houseweart (Assistant Research Professor of Forest Protection, 7/1/76), and Maxwell McCormack, Jr. (Research Professor of Silviculture, 8/1/76). The Unit also hired three research technicians (Ellis Sprague, Paul Messier, and Rob Lawrence) and a secretary.

During the fall of 1976, the new CFRU scientists traveled around the state to meet the cooperators and develop proposals for research projects. They were given the responsibility for preparation of literature reviews and research proposals for review in early spring 1977. These documents became the bases for the project work through the early years of CFRU. The first fieldwork under the new CFRU began that summer. Maxwell McCormack also designed the CFRU logo that incorporated many of the ideas under which the coop would conduct research.

Within the first year the "three scientists" became a celebrated trio. Forest industry leaders quickly assumed an outspoken pride of ownership in their new CFRU research team. The industry took pleasure in being directly involved in getting the research priorities established and related projects underway.

Throughout the profusion of landowner-endorsed projects in these early years was the constant aura of the spruce budworm. During the summers of the early years, as many as twelve people could be found counting budworm egg masses in the CFRU laboratory in Nutting Hall. In 1977, a different insect gained attention as the first CFRU Graduate Research Assistant (Wayne Dixon) initiated his studies on life tables and fall feeding behavior of white pine weevils.

**Other Scientists and Industry Collaborators**

The talents of other UMaine researchers also were tapped. Early in 1976 CFRU funds were used to support ongoing research projects of interest to Cooperators. Early collaborators included: Marshall Ashley (remote sensing), Dave Canavera (tree improvement), Robert Shepard (forest fertilization), Tom Brann (spruce budworm growth impact), and Harold Young (biomass). Supporting research of other scientists working on relevant topics would become a standard CFRU practice for the next thirty years. In 1978, Ellis Sprague (Assistant Forest Technologist) supervised and coordinated the construction of the 22 x 56 ft CFRU Building on the University Forest, which remains a valuable asset for the Unit.

In addition to the Advisory Committee, forest industry personnel regularly interacted with the three scientists and kept them in touch with the "real world" of forestry operations. Industry participants included: Robert Cope (St. Regis Paper Co.), Pat Marceau (J.D. Irving), Tony Filauro and Ed Chase (Great Northern Paper Co.), Al Leighton (Seven Islands Land Co.), John Hartranft (Boise-Cascade Corp.), David Clement and Wayne Jackson (S.D. Warren), Henry Saunders (Saunders Brothers), Robert Chadbourne (Chadbourne Lumber), Carl Forrest and Jim May (Prentiss & Carlisle), and Temple Bowen and Peter Lammert (Maine Forest Service).

**First Research Projects**

The 1978 Annual Report was a testimonial to the wide array of research projects that were initiated by CFRU during the early years. In the area of silviculture, thinning spruce and spruce-fir stands was the topic of Frank Conlon's MS thesis. PhD student Tattersall Smith (now Dean

*The original CFRU logo (left) was redesigned (right) in 2003 to reflect the entire renage of CFRU research.*

of the Forestry Faculty at the University of Toronto) developed a study proposal to evaluate the effects of mechanized harvesting on site quality that would form the basis for what would become the Weymouth Point Watershed Study. Aerial application of herbicides to suppress undesirable vegetation and promote softwood regeneration in Maine forests was addressed in several studies, one of which became the Austin Pond Study.

In the Forest Protection program, Jim Rea and Rob Lawrence maintained the spruce budworm growth impact study. Research on the white pine weevil continued. Evaluation of fall insecticide applications was conducted with faculty entomologists John Dimond and Eben Osgood. In cooperation with Dan Jennings (US Forest Service), spruce budworm work included egg mass parasitism, kairomones, trap nesting wasps, ground invertebrate inventories, budworm pheromones, mite parasites of adult moths, dispersal of larvae, and budworm antifeedants.

Seven projects were being conducted in the area of marketing, utilization, and economics, including evaluating the potential for a Maine hardwood charcoal industry, simulation of regional timber markets, and models for forestry investment analysis. The economics of spruce-fir management and a problem analysis of economic losses from degradation of spruce budworm-damaged timber received significant attention. Public benefits from private forestland ownership and management in Maine also were considered.

By the end of 1979, the FRRAC sub-committee had become the CFRU Advisory Committee. Several personnel changes had occurred; Bart Harvey replaced Bartlett, Charles Webb replaced Wing, and Clifford Swenson replaced Sinclair. Three additional members joined the Committee: Richard Griffith (St. Regis Paper Co.), Oscar Selin (Georgia-Pacific Corp.), and Dwight Newman (representing Christmas tree growers and small woodlot owners).

## RESEARCH AND PEOPLE: 1980s

The second five-year period for CFRU began in 1981. All CFRU members (now numbering an impressive 79 organizations and contributors) expressed their confidence in the work of the Unit by signing up for an additional five years.

### First Staff Changes

Successes of the CFRU logically provided new opportunities for its scientists. David Field was appointed to the Giddings Chair of Forest Policy within the School, where he would eventually retire in 2006 after 30 years of outstanding contributions to forestry education and research at UMaine. Robert Seymour replaced Dave Field in November 1981. Seymour immediately began working on a problem analysis of timber management and harvesting, and initiated a major effort on long-term timber supply forecasting for the state of Maine. The hardwood research program was established when William Ostrofsky joined the staff as an Assistant Scientist in Forestry in August 1982. Katherine Carter replaced Dave Canavera as the geneti-

*Bob Seymour begins his more than 20-year involvement with the CFRU*

*CFRU scientists, cooperators, and chefs alike, participate in a field tour at Weymouth Point.*

cist on the UMaine forestry faculty. The School became the College of Forest Resources in 1983 and Gregory Brown was appointed Dean, and became Director of the CFRU scientists, staff, and programs.

**Shifting Research Needs and a New Scientist Trio**

With the support and encouragement from Paul McCann (Great Northern Paper Co.), the first CFRU effort to study forestry and wildlife interactions was initiated in 1984. David Santillo began his MS thesis research on the effect of herbicides on small mammals to address public concerns that had developed about the practice.

By 1986 the spruce budworm and the corps of entomologists had vanished from the scene. Mark Houseweart left the CFRU and Robert Seymour was selected as the Curtis Hutchins Professor of Quantitative Silviculture in the College in 1987. Shortly thereafter, Russell Briggs joined McCormack and Ostrofsky to form a new trio of scientists. Briggs devoted his research efforts to evaluations of forest productivity.

By the close of 1986, Fred Knight became Dean of the College and returned to his duties as Director of CFRU. The annual dues rate for members was increased by the Advisory Committee to 4.5 cents per acre. The composition of the Advisory Committee also became more dynamic and increased in size as research needs and forestland ownerships began to change in the early 1990s.

**Notable Long-Term Studies Established**

In addition to the many short-term research projects that CFRU completed, two long-term studies would become signature forestry research efforts of the Unit during the 1980s. The first was the Austin Pond Study which was initiated in August 1977 to evaluate competition release methods that promote spruce-fir regeneration. This project was stimulated by the need for improved softwood regeneration methods following the extensive clearcutting that resulted from the budworm salvage harvesting of northern Maine forests. The herbicide technology developed from this provided the basis for operational release treatments across the industrial forestlands of Maine and the surrounding region. Between 1981 and 2000 over one million acres of forest land were treated with prescriptions that originated from the Austin Pond Study. This study would go on to provide data and insight into post-release vegetation dynamics and interactions with precommercial thinning that are unprecedented in the region.

Prompted by long-term nutrient cycling concerns associated with full-tree harvesting methods, the Weymouth Point Watershed Study was established in 1979. This paired watershed study was the first of only three watershed-scale studies to be established in the state and provided an opportunity to study nutrient cycling and other factors associated with mechanical clearcutting in northeastern spruce-fir forests. This study became a model of cooperation between landowners, logging crews, US Forest Service personnel, and the university research community. Results from Weymouth Point have contributed to over 50 scientific publications that have addressed a wide range of topics, including harvesting impacts, acid rain, nutrient cycling, water quality, and the environmental fate of herbicides. The Weymouth Point Study helped to support the evolution of harvesting technologies that are more ecologically sound with regard to stand disturbance and the disposition of harvesting residues.


*Interests in the impacts of harvesting on site quality spawned the Weymouth Point Study in 1979.*

## RESEARCH AND PEOPLE: 1990s TO PRESENT

### Silviculture Research Accomplishments Continue

Through the 1990s the CFRU continued its silvicultural research emphasis under Director Bill Ostrofsky. Ostrofsky focused on ways to manage beech infected with beech bark disease. Max McCormack continued his focus on developing vegetation management strategies to promote spruce-fir regeneration. Earlier collaborations between Max McCormack and Mike Newton of Oregon State University also led to the publication of three significant journal articles about the ten-year results from the Austin Pond Study. One of these articles focused on the effects of herbicide use on moose browse, encouraging CFRU to initiate additional wildlife research projects.

Research by Robert Shepard examined the effects of papermill sludge and wood ash application on soil chemistry and tree growth. Negative results from this work eventually discouraged landowners from adopting forestland application as a means of sludge and ash disposal. During the mid 1990s, Robert Seymour continued his work refining understanding about forest growth and wood supplies resulting from various kinds of silviculture in Maine's forests. Mike Greenwood and Kathy Carter continued their efforts with tree improvement. Much of this effort focused on fast-growing hybrid larch which was being planted by several cooperators in response to future wood supply concerns.

At the same time, Russell Briggs began to lay the groundwork for developing a site classification system for spruce-fir sites across Maine. This effort would lead to the 1994 publication of the Site Classification Field Guide, or Briggs Site Classification as it became commonly known. This guide would eventually become among the most requested CFRU publications. Briggs also maintained and developed new research projects using the Weymouth Point site. Shortly thereafter, Briggs left Maine for a faculty position in New York and was replaced by Jim McLaughlin. McLaughlin also worked on the Weymouth Point Study, continueing the site classification work of Briggs by developing a Hardwood Site Classification Field Guide for Maine in 2000.

After a long and distinguished career building the CFRU from its inception, Max McCormack retired to Deer Isle, Maine in 1997. The following year, the CFRU hired Bob Wagner, a silviculture and vegetation management researcher, to replace Max. Shortly after his arrival, Wagner relocated plots and measured the 22-year growth responses on the Austin Pond Study, which was now the longest running study examining the effects of herbicides and PCT in the region.

By the late 90s, the highest priority area of research for CFRU members was developing a better understanding about how to commercially thin Maine's spruce-fir stands. To address this need, Bob Wagner and Bob Seymour initiated the Commercial Thinning Research Network in 2000. The network included a dozen study sites where a variety of commercial thinning treatments were applied. Following from earlier wood supply analyses conducted by CFRU, a 1998 analysis by the Maine Forest Service prompted Wagner and Seymour to also conduct a follow-up analysis of Maine's wood supply to identify most of the fruitful areas of silviculture research for the Unit.

*Public concerns over herbicide use turns the CFRU onto wildlife research in what will become one of the key scientifiic focuses of the Unit.*

**Cooperators Expand Wildlife Research Interests**

Prompted by public concerns about possible negative effects of herbicide use on moose and other wildlife, the early 90s also saw CFRU develop a wildlife research effort. Fred Servello and several graduate students began detailed investigations focused on herbicide effects on habitat and nutritional ecology of moose and deer. Results from this research revealed that forest herbicide use was compatible with efforts to maintain high-quality browse and cover for moose in Maine's forest. Thus, forest managers were able to continue using herbicides to increase reforestation success for spruce and fir across the state.

CFRU wildlife research continued with the initiation in 1994 of what would become some of the Unit's most significant research. Concerns about the American marten and their perceived need for old-growth forest structures potentially threatened the future of forestry practices in the state. As a result, research by Daniel Harrison and his graduate students began studying the effects of timber harvesting and trapping on marten population characteristics and habitat selection. Harrison and his students found that stand-level habitat needs by marten were generally compatible with current forestry practices, but that managers need to pay close attention to landscape scale fragmentation of forest habitat. As with CFRU herbicide effects research, Harrison's decade-long marten research that was sponsored by CFRU and other organizations likely helped Maine forest landowners avert a major wildlife habitat crisis such as that experienced with the spotted owl in the Pacific Northwest during the 1990s.

By the late 1990s, concerns about habitat needs for the Canada lynx arrived on the doorstep of Maine forest landowners. In March 2000, the US Fish and Wildlife Service listed the Canada lynx as threatened under the Endangered Species Act. Since Maine has the only verified population of resident lynx in the Northeast, a better understanding about the relationships between lynx, habitat, and forestry practices was needed. Of particular concern was the impact of the widespread use of precommercial thinning on snowshoe hare, a primary prey species of the lynx. Since 2000, Harrison and his graduate students have conducted several CFRU-sponsored research projects to examine various aspects of forest management impacts on lynx and hare. Initial results from this work have revealed that forestry practices in Maine are compatible with the habitat needs of the Canada lynx.

**Re-organization Needed**

By the late 1990s, the three-scientist model under which the CFRU had been operating for 25 years was becoming severely strained from past financial decisions by its members. During the 1970s and 80s, the CFRU had deliberately built up a substantial financial reserve. Around 1990, the Advisory Committee became uncomfortable with having such a large balance in a university account. As a result, a decision was made by the Advisory Committee to draw down this reserve and not increase annual dues. By the end of the 90s, the financial reserve had been reduced substantially, and the salaries and benefits of the seven full-time employees (three scientists, three technicians, and one secretary) were consuming nearly all of the annual member dues (now 5 cents per acre per year). As a result, there were few operating funds remaining to conduct new research projects. It became clear to CFRU members and the university that a drastic financial or organizational re-structuring was needed if the Unit was going to survive.

A re-structuring committee was formed during 1998-99 to develop a re-structuring plan for the CFRU. The committee included: Peter Triandafillou (Huber Resources, Chair), John Cashwell (Seven Islands Land Co.), Dave Field (University of Maine), Tony Filauro (Great Northern Paper Co.), Mike Greenwood (UMaine), Carl Haag (Plum Creek Timber Co.), Daniel Harrison (University of Maine), Brian Higgs (Baskahegan Co.), and Bob Wagner (UMaine). The final plan included a complete organizational re-structuring of the unit. The three-scientist funding model was replaced by a project-based "virtual unit" model. The new CFRU would have: 1) a project-based approach to funding research, 2) a scientific "staff" that was employed by other organizations and could change with changing research priorities, 3) a part-time Director appointed from the university's faculty, and 4) two full-time employees to coordinate research and communication activities. The new Unit also would change its former policy of not pursuing outside funding to seeking financial leveraging on research projects where possible.

Although it was a painful time for all those associated with the unit, the seven CFRU employees each quickly found other jobs and the Unit was able to make a relatively smooth transition into

*Third-party forest certification systems helped garner much interest in research on forest structure and landscape biodiversity.*

the new model. A new five-year prospectus was developed that defined the research priorities and organizational structure and procedures under which the Unit would operate. Bob Wagner became the CFRU Director in 1999. By the end of 2005, the CFRU had completed five successful years under the virtual unit model (Table 3) and was preparing the 2006-2010 Prospectus.

### Forest Certification and Biodiversity

During the late 1990s, the rising interest in forest certification systems (Sustainable Forestry Initiative and Forest Stewardship Council) became important to CFRU members. Most large forestland owners in Maine were in the process of certifying their lands. Since supporting research that will advance forest management practices is a major requirement of the certifiers, the CFRU provided its members with an excellent vehicle to satisfy this requirement.

In addition, certification required that forest landowners have plans for managing biodiversity. The re-structuring of the CFRU at this time provided an opportunity to increase the unit's emphasis on research in biodiversity conservation. As a result, a formal relationship was developed between CFRU and John Hagan (Manomet Conservation Sciences) who had been developing a strong research effort in this area. Research projects developed with Manomet from 2000 to 2005 included the effect of buffer strips on water quality and aquatic biodiversity, developing biodiversity indicators, and the ecological value of patch retention.

### Unprecedented Forestland Sales

A major challenge facing CFRU from 2000 to 2005 was the unprecedented sale of forestlands across the state. During the first 25 years of its existence, the CFRU had benefited greatly from a stable pattern of forestland ownership. By 2000, however, the situation had changed drastically. The giants of Maine's traditional forest industry began to leave the state. The sale of Georgia Pacific, Great Northern Paper, International Paper, and MeadWestvaco lands to institutional investors reduced CFRU member acres from 8.6 million in 1998 to 5.3 million in 2004. This 3.3 million acre loss represented a

Table 3. This list includes CFRU personnel from 1975 through 2005.

| Program Leaders | Cooperating and Project Scientists | Technical Support | Administrative Support |
|---|---|---|---|
| Russell Briggs | Marshall Ashley | Stephanie Arnold | Margaret Colman |
| Dave Canavera | Thomas Brann | Peter Caron | Eleanor Heinz |
| David Field | Katherine Carter | Richard Dionne | H.E. (Chip) Griffin |
| Mark Houseweart | Catherine Elliott | Charles Gadzik | Lynn Lavoie |
| Maxwell McCormack | Brad Griffith | R.A. Lautenschlager | Amy Morin |
| James McLaughlin | Michael Greenwood | Robert Lawrence | Joanna Silva |
| William Ostrofsky | John Hagan | Ronald Lemin | Julie Kahler |
| Robert Seymour | Daniel Harrison | Dan McConville | Dana Smith |
| Robert Wagner | William Krohn | Paul Messier | |
| | Tim McGrath | Spencer Meyer | |
| | Ralph Nyland | Gregory Reams | |
| | Fred Servello | Michael Saunders | |
| | Robert Seymour | Frank Spizuoco | |
| | Robert Shepard | Ellis Sprague | |
| | Dale Solomon | James Steinman | |
| | Alan White | | |
| | Andy Whitman | | |

38% reduction in annual CFRU funding within five years. To address the loss of income, CFRU members voted for the first time in more than a dozen years to increase the annual dues rate from 5 cents per acre to a 3-tiered system (5.75, 5.25, and 5.0 cents per acre) based on total land ownership. In addition to this significant financial loss, was the loss of dedicated cooperators (e.g., Tony Filauro, Si Balch) who served on the Advisory Committee for many years and helped to build CFRU.

Despite CFRU's more adaptable organizational structure and significant financial leveraging, the loss of more than a third of its member acres presented a significant challenge to the long-term survival of the Unit. The new investor owners of these forestlands had significantly shorter planning horizons than the previous owners and it was unclear whether supporting forestry research would be an attractive proposition. During 2005, however, the Unit was able to attract these new owners and their land managers (Black Bear Forest, Frontier Forest, Heartwood Forestland Fund, Katahdin Forest Management, Prentiss & Carlisle, Wagner Forest Management) and bring 2.8 million acres back into the Unit, thus increasing total member acres from 5.3 million to 7.8 million. The CFRU is now once again back on a stable course and developing ways to meet the research needs of the new owners of Maine's forestlands (Table 4).

Table 4. The CFRU has made many notable contributions to forest management and sicence throughout its history.

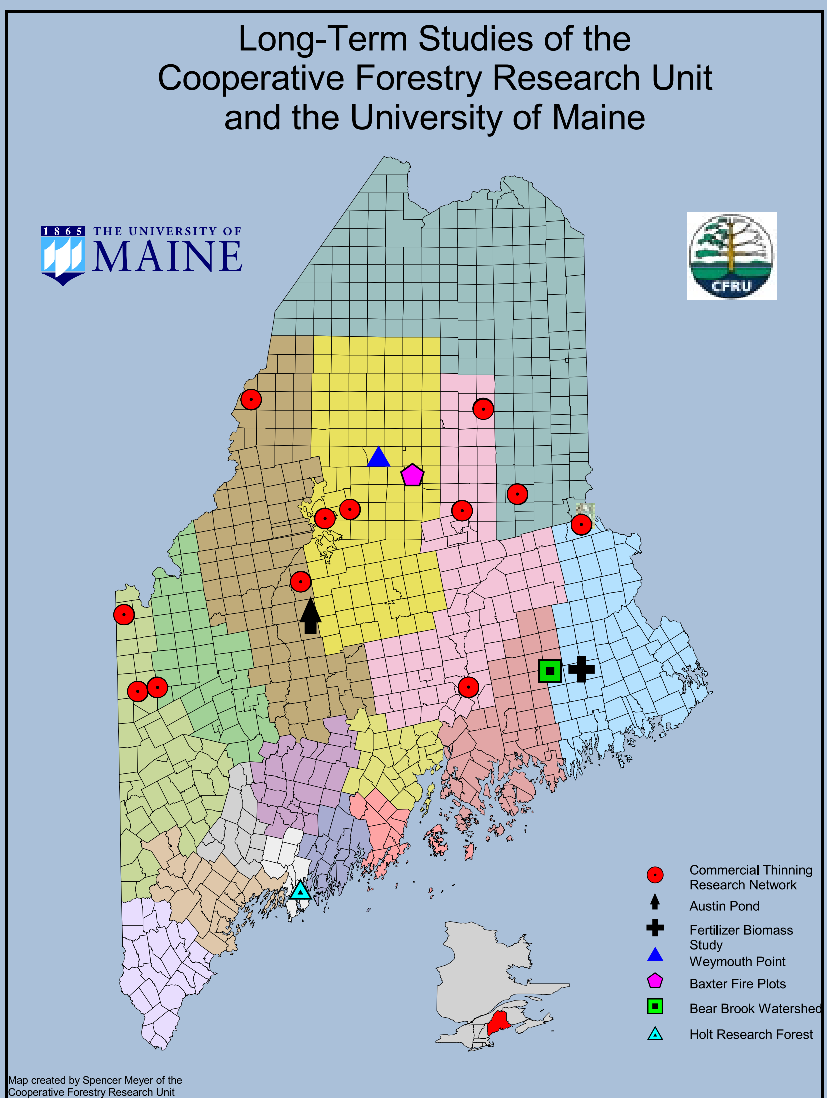
| Hightlights of CFRU |
|---|
| **Identified habitat needs for American marten** |
| Identified key habitat needs for marten that are being used for forest management across the state. |
| **Developed forest site classification systems** |
| Developed the widely used site classification systems for spruce-fir (Briggs system) and hardwood stands. |
| **Monitored nutrient losses from forest harvesting** |
| Provided key scientific data about the influence of whole-tree harvesting on nutrient cycling in Maine's northern forest using a long-term watershed study (Weymouth Point). |
| **Documented effect of herbicides on moose, deer, songbirds, and small mammals** |
| Demonstrated that the use of glyphosate herbicide did not damage moose and deer habitat, or pose a threat to songbirds and small mammals. |
| **Improved wood supply and growth & yield assessment** |
| Provided critical wood supply analysis for Maine during mid-1980s that influenced forestland management decisions and financial investments by the state's forest industry. |
| **Advanced silviculture for spruce-fir** |
| Introduced a wide variety of vegetation management tools that improved reforestation success, stand density-management diagrams to better manage stocking, and better information about wood quality. |
| **Increased forest protection** |
| Provided key recommendations for managing spruce-fir stands damaged by the spruce budworm during the 1970s and 80s, as well as how to better manage beech bark disease. |
| **Documented gains from forest fertilization** |
| Demonstrated that applying wood ash and paper mill sludge does not increase forest growth, and that nitrogen fertilizer can only increase the growth if stands have been previously thinned. |

**CONCLUSION**

During its first 30 years, the CFRU has made extraordinary contributions to the people and forests of Maine. Research conducted by the Unit has 1) improved the management of Maine's forests, 2) increased understanding about the ecology of northern forest ecosystems, 3) helped Maine forestland owners avoid potentially devastating controversies over forestry practices, 4) trained scores of undergraduate and graduate students on key forestry issues, and 5) published hundreds of scientific papers. Had the state's forest landowners and university never developed the CFRU, Maine's forest resource would certainly be less well managed and understood.

The CFRU also has improved the university by making it more relevant to the needs of forest landowners and managers across the state.

Despite some substantial challenges over the past three decades, the core objective of CFRU founders to develop a long-term partnership between the state's forest landowners and University of Maine has persisted with great success. As increasing population and globalization of the forest industry bring new pressures to the state's forest resources, the need for CFRU will be at least as great or greater than its has been for the past 30 years. The CFRU is clearly poised to adapt to these changing needs during the coming decades




*Current and recent long-term studies of the CFRU and the University of Maine.*

# Silviculture

Commercial Thinning Research Network

Growing Space Allocation to Residual Stands Following Commercial Thinning

Effects of Commercial Thinning on Physiological Stress in Balsam Fir and Red Spruce

Silviculture and Ecology of Northern White Cedar

# Commercial Thinning Research Network

Robert G. Wagner and Robert S. Seymour

Silviculture

## ANNUAL MEASUREMENTS AND MAINTENANCE

The CFRU Commercial Thinning Research Network (CTRN) completed its 5th 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) to quantify the growth and yield responses from timing of first commercial thinning (year 1, year 6 and year 11 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 to quantify the growth and yield response from commercial thinning method (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 are established on each site. All trees within the measurement plot that meet the minimum size requirement were measured for DBH, and a subset were measured for total height, crown height, and two-dimensional 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.

All sites were visited and scheduled measurements made during the 2005 field season. These measurements included the fourth round of intensive post-treatment measurements (IM) at each of the PCT sites and four of the non-PCT sites. The intensive measurement (IM) cycle includes a complete re-measurement of tree diameter, and measurements of total height, and crown height on every other tree, as well as an in-growth and mortality assessment. At two of the six non-PCT sites, we completed downed tree and mortality assessments (DM) and an extensive measurement (EM) that included measuring DBH on every tree, measuring in-growth, and documenting all downed and dead trees.

At the April 2005 Advisory Committee meeting, members voted to continue annual measurement of CTRN plots as scheduled for the next several years.

## ESTABLISHMENT REPORT

Efforts this year focused on development of a web-based establishment report for the CTRN studies. The new CTRN Establishment Report developed by Spencer Meyer was released on the CFRU web site in spring 2005 (Figure 3). The Report includes all available information about the background of the CTRN, experimental methods used, study site maps and descriptions, results of auxiliary studies, interim results, publications, and access to the complete data base. Figures 4-7 show examples of the online CTRN Establishment Report. The Report is intended to be a living document that will be continually updated as the CTRN progresses. The Establishment Report is available only to CFRU members behind the password-protected portion of the CFRU web page.

Figure 3. Introductory screen of web-based Establishment Report for the Commercial Thinning Research Network.

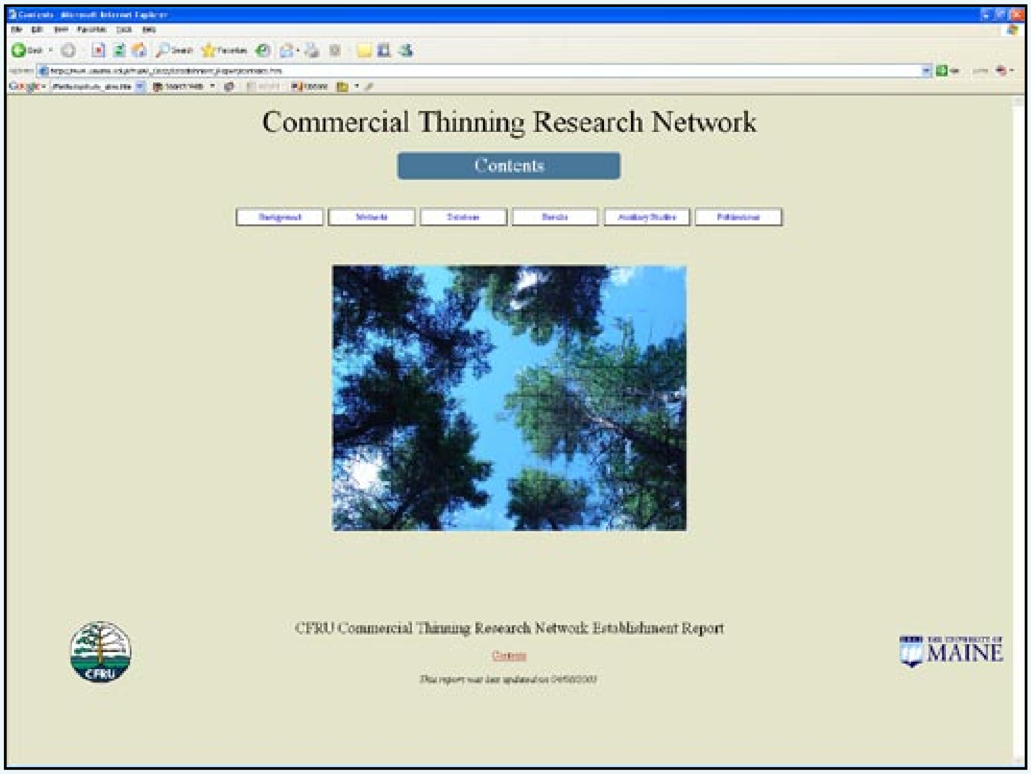



Figure 4. Establishment Report screens showing locations of CTRN study sites with site description information and plot map for one of the CTRN study sites.

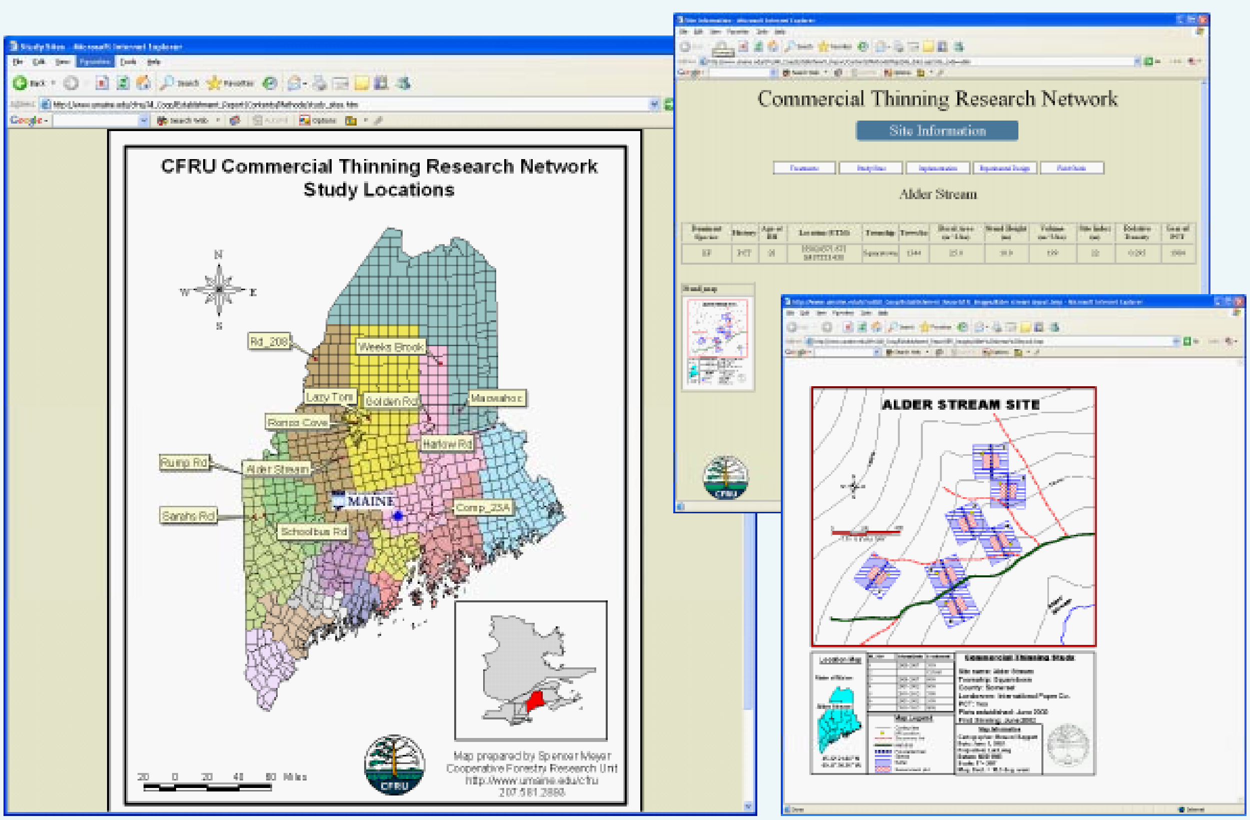


Figure 5. Establishment Report screens showing stand visualizations of plot conditions for one of the CTRN study sites.

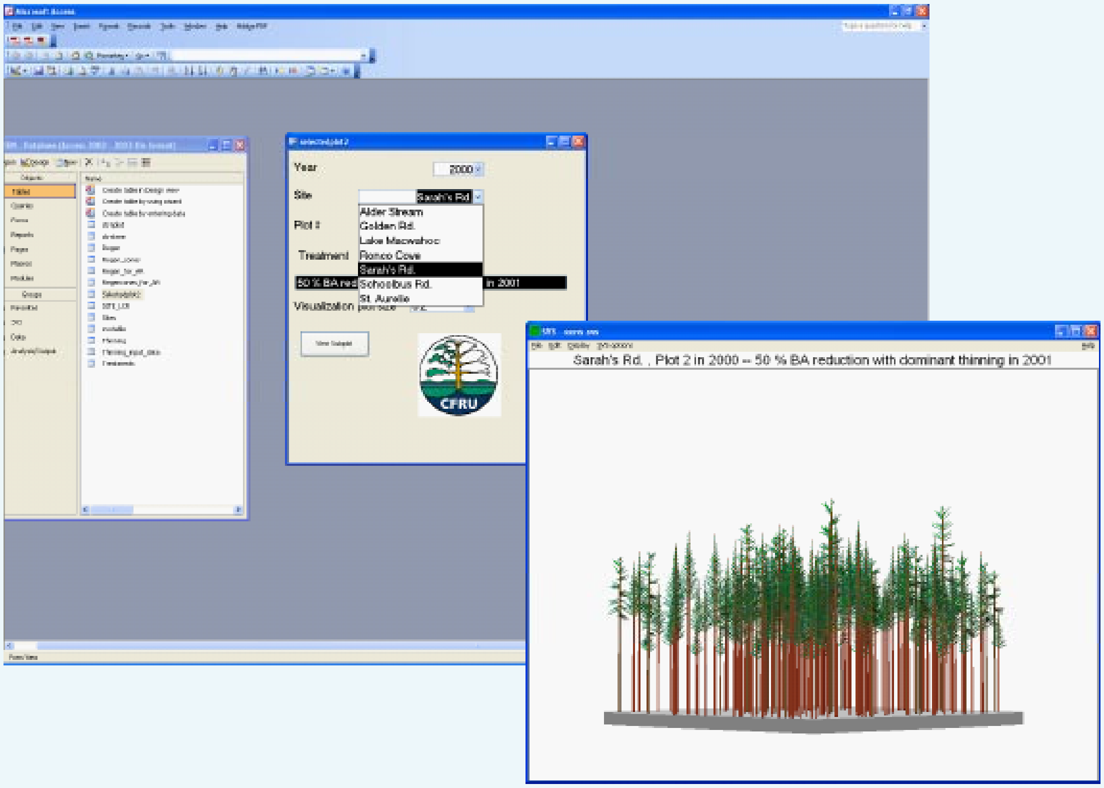



Figure 6. Establishment Report screen showing the database available from annual measurements for each of the CTRN study sites.

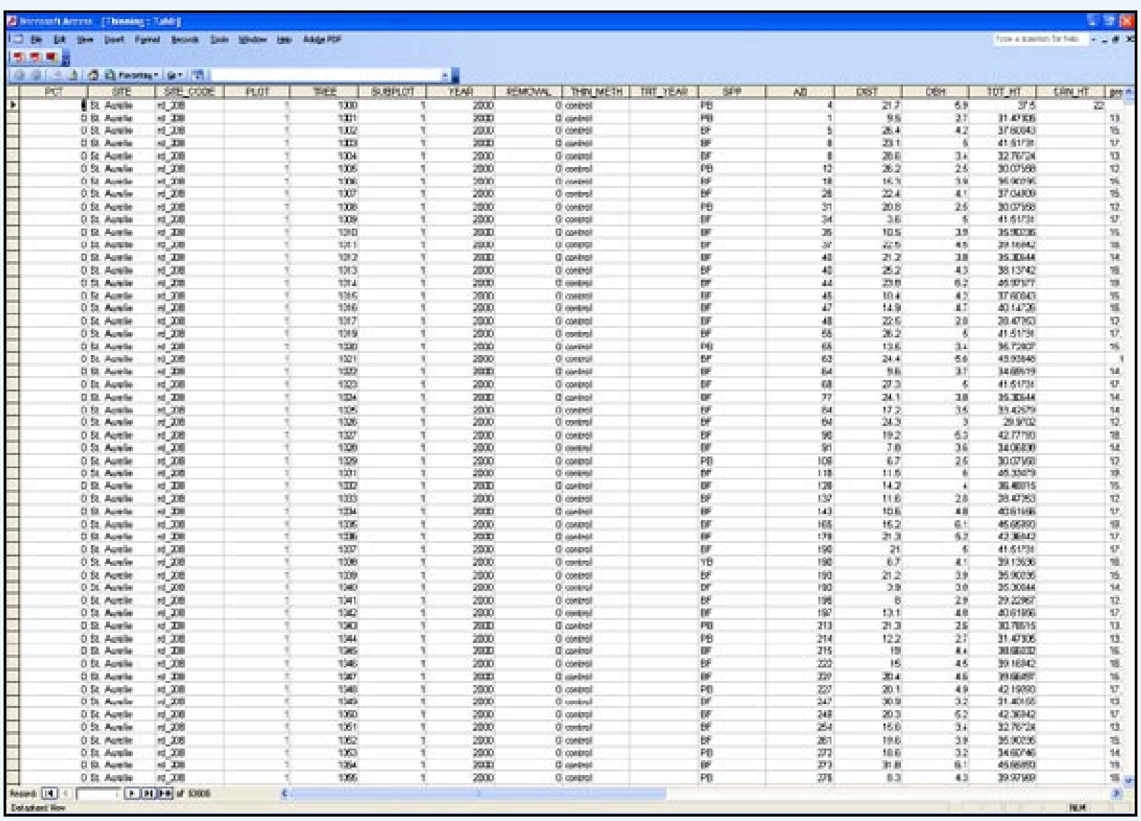
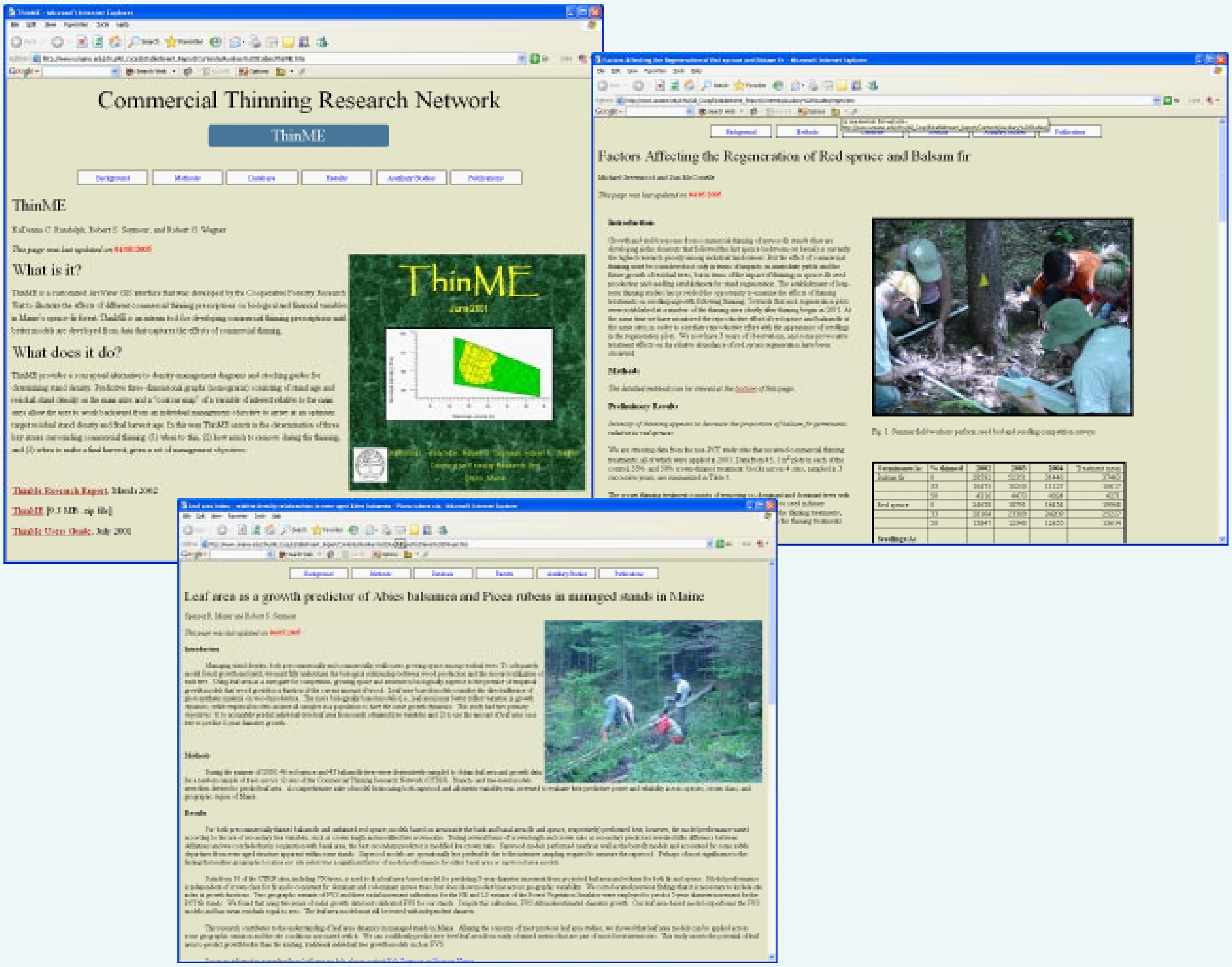


Figure 7. Establishment Report screen showing descriptions of several auxiliary studies conducted on CTRN study sites.

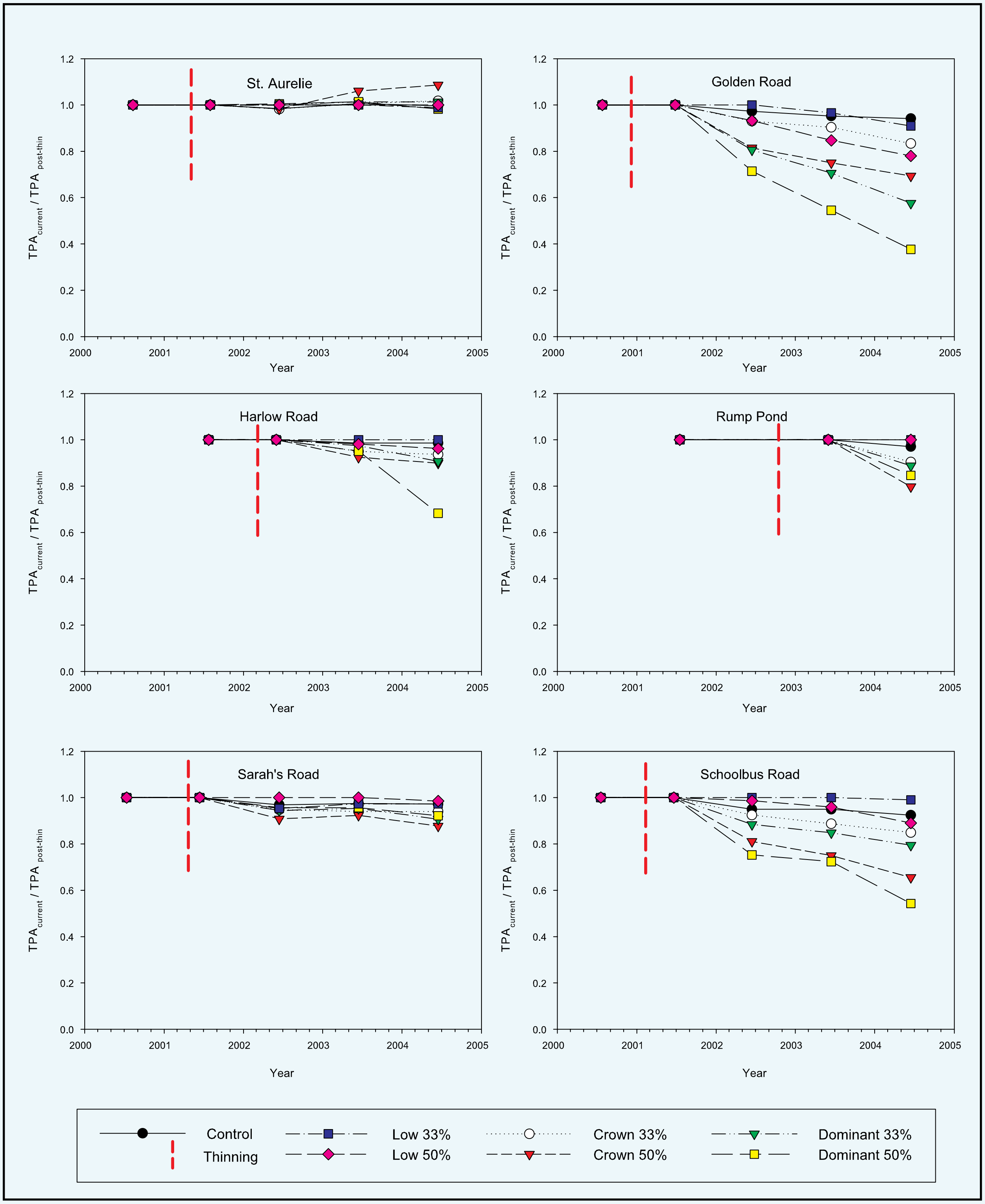



## RESIDUAL STAND MORTALITY FOLLOWING HEAVY COMMERCIAL THINNING FROM ABOVE

One of the most dramatic and important findings of the CTRN this year has been tree mortality from windthrow and other causes for some of the commercial thinning treatments on several of the study sites. The pattern of loss is most striking on sites with 40-70 year-old spruce-fir stands that had never received precommercial thinning. When expressing the proportion of trees surviving from the stand that remained after thinning, dominant thinnings resulted in a substantial loss of the residual stand on four of the six sites (Figure 8). From 20 to 60% of the trees were lost in the 50% dominant thinning treatments on the Golden Road, Schoolbus Road, Harlow Road, and Rump Pond sites. The 33% dominant thinning also caused substantial mortality on three of the sites. The 50% crown thinning treatment also caused significant losses on three of the sites. Tree losses have been increasing annually since the plots were thinned. Sites with the highest losses tended to be older stands dominated by spruce, which are on more poorly drained soils. Tree losses from the low thinning treatments have remained low on all study sites. We also have not seen any mortality from commercial thinning treatments in the younger fir stands on the six sites that had previously received PCT.

So, observations from CTRN sites to date indicate that windthrow and other tree mortality losses following commercial thinning will be highest in older spruce-fir stands on poorly drained soils that are thinned from above and at

Figure 8. Proportion of trees lost to mortality after seven commercial thinning treatments in 40-70 year-old spruce-fir stands on six sites that have never received precommercial thinning.

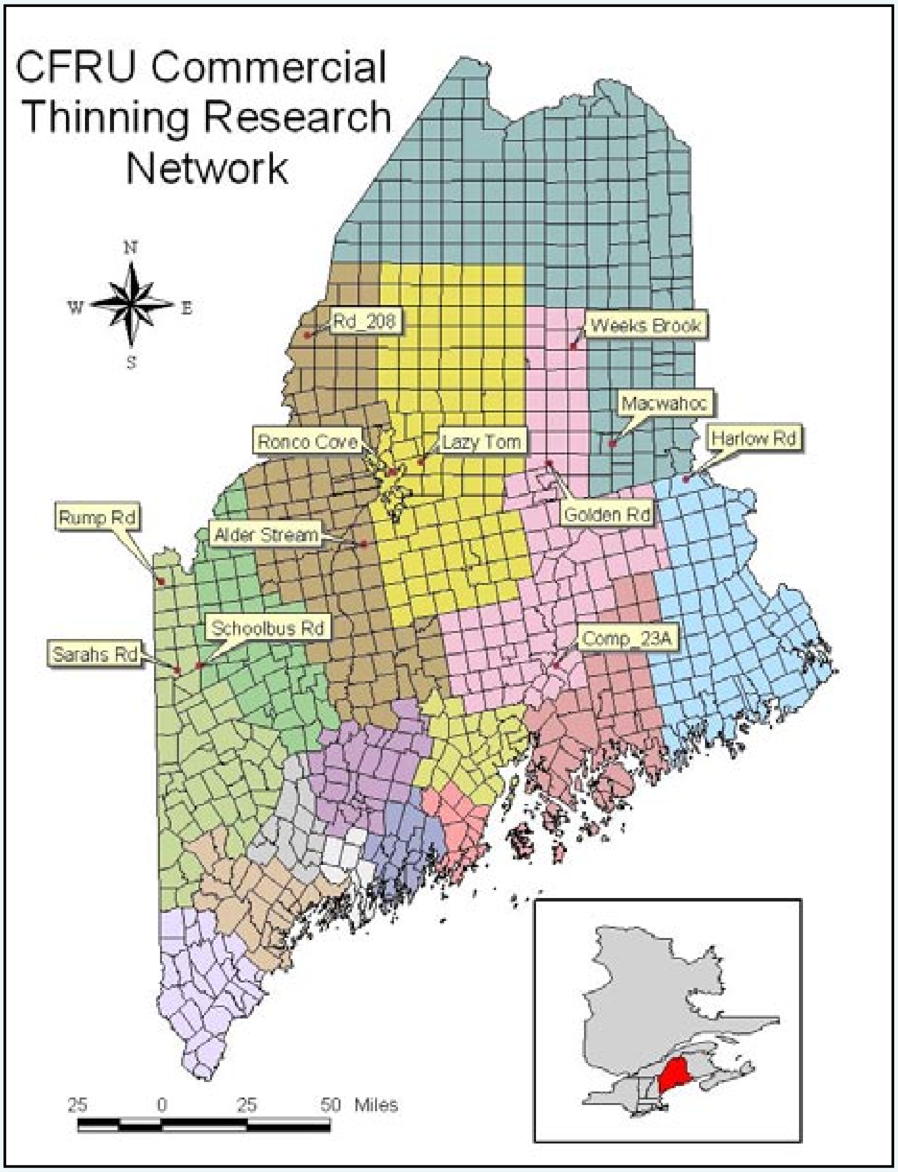


density reductions greater than one third. We are currently analyzing the mortality trends in more detail to gain better insight into the individual tree and stand conditions that may put residual stand stability at greater risk.

**GROWTH RESPONSE FOLLOWING THINNING**

In addition to mortality losses, we have been steadily tracking stand growth and yield responses following each of the commercial thinning treatments. Figure 9 shows the effects of various commercial thinning treatments on the basal area growth of the 40-70 year-old spruce-fir stands that had never received precommercial thinning. For most of the low and crown thinning treatments, basal area growth after thinning has been paralleling that of the unthinned controls. Mortality losses following the dominant thinnings, however, has caused a steady decline in basal area after thinning for the Golden Road, Harlow Road, Schoolbus Road, and Rump Pond sites. In some cases, standing basal area three years after commercial thinning is less than 50 ft$^3$/A.

The younger PCT stands that received commercial thinnings to either 33% or 50% relative density reduction have been relatively windfirm. On all six sites in this study, post-thinning basal area growth has paralleled that of the unthinned controls (Figure 10).




*The Commercial Thinning Research Network includes 12 sites throughout Maine.*

Plans call for the five-year thinning treatments to be applied to the next set of plots during 2006-07.

For more information about the Commercial Thinning Research Network please contact Bob Wagner at 207-581-2903 or bob_wagner@umenfa.maine.edu, or Bob Seymour at 207-581-2860 or seymour@umenfa.maine.edu.

Figure 9. Basal area development in 40-70 year-old spruce-fir stands following seven commercial thinning treatments on six sites that have never received precommercial thinning.

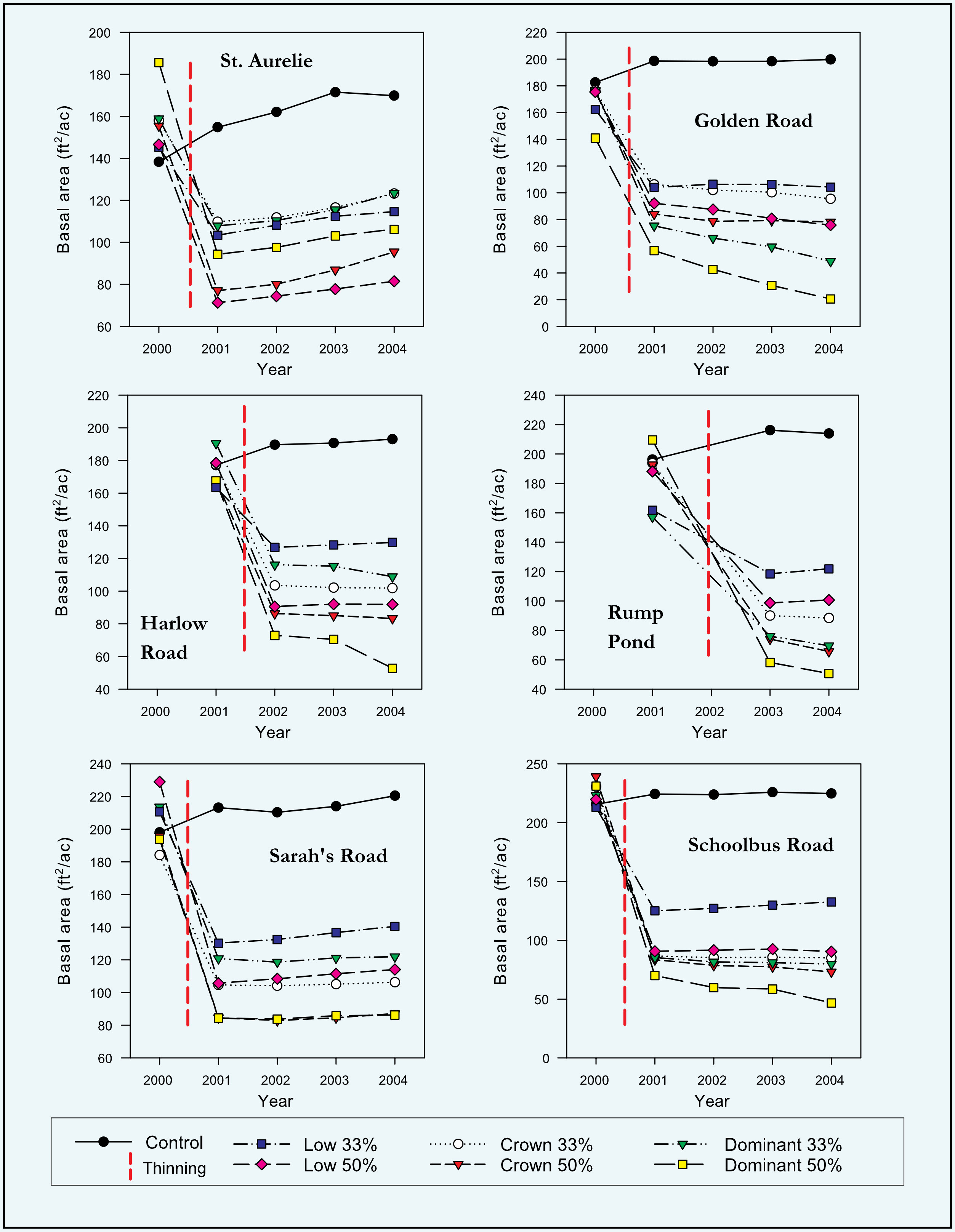



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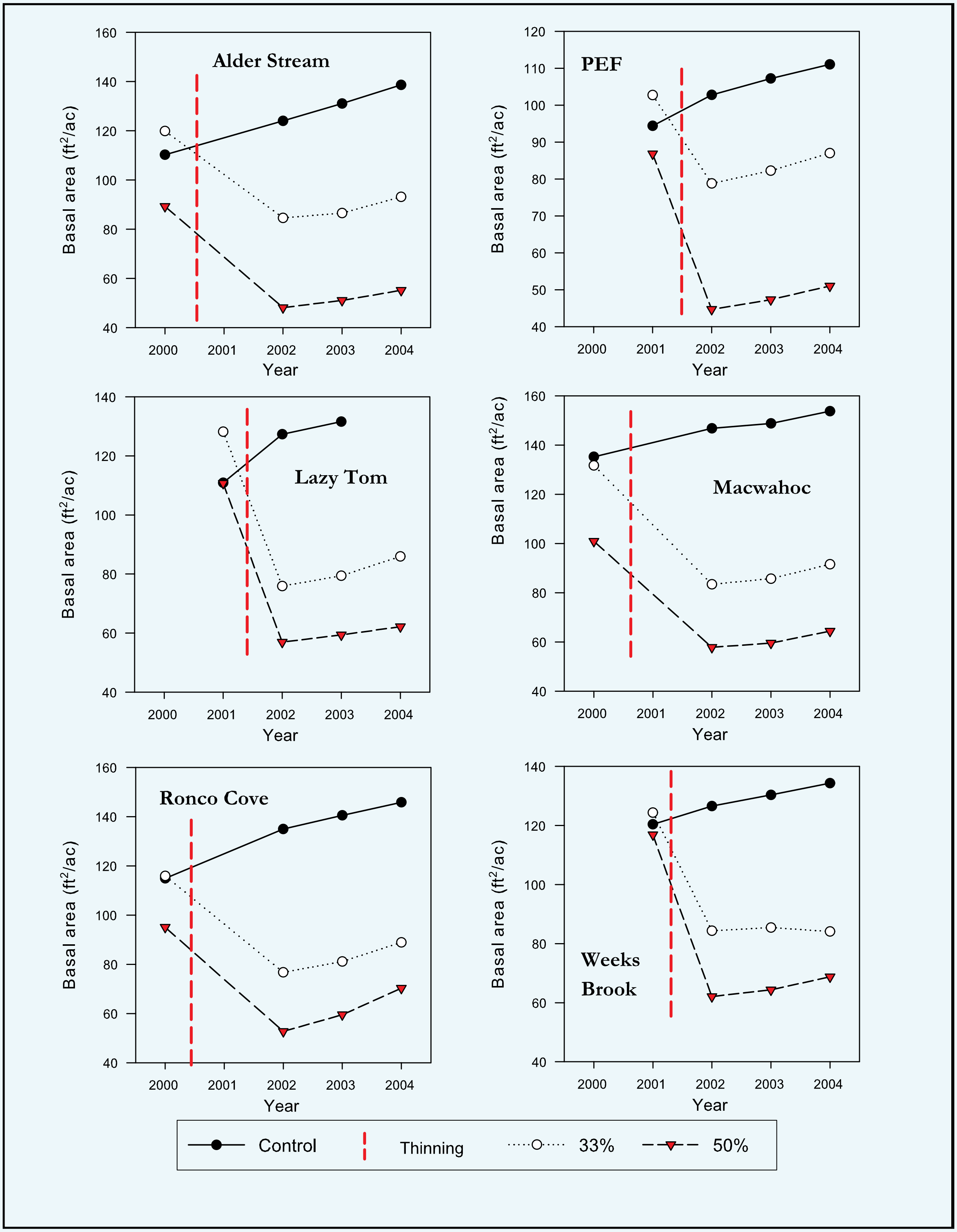
Figure 10. Basal area development in 25-40 year-old fir stands following 33% and 50% relative density removals from commercial thinning on six sites that had previously received precommercial thinning.



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# Growing Space Allocation to Residual Stands Following Commercial Thinning Treatments

Robert G. Wagner and Robert F. Keefe

A primary objective of commercial thinning is to optimize redistribution of growing space among individual trees in the residual stand to increase their volume growth and future financial value. The more than 12,000 tagged trees on 84 plots across 12 study sites, the CFRU Commercial Thinning Research Network (CTRN) provide an excellent opportunity to examine how effectively growing space was reallocated following a wide range of commercial thinning treatments in spruce-fir stands. Commercial thinning prescriptions are generally made with the objective of achieving specific spatial targets, including reducing the density of the residual stand, evenly spacing residual trees, and reducing height differences among residual trees. In addition, specific tree species and quality selections are made for retention or removal. Achieving these spatial targets is influenced by the pre-harvest distribution of trees, amount of density reduction, method of thinning, and the harvest system selected. All of these factors are likely to interact in various ways to influence the pattern of growing space reallocation to the residual stands following commercial thinning.

Understanding these effects requires a spatial analysis of the stand before and after thinning. Stem maps of trees on the CTRN plots measured before and immediately after thinning were used to compare three measures of growing space occupancy before and immediately after the commercial thinning treatments were applied. The measures include: 1) Hegyi's competition index, 2) area potentially available (APA), and 3) the square of DBH. Hegyi's Competition Index (HCI) is an index of competition around an individual tree based on the distance and relative DBH of neighboring trees. Area Potentially Available (APA) is the area of an irregular polygon around an individual tree based on the distance to the nearest neighboring trees. The square of DBH ($DBH^2$) is an indirect measure of growing space occupied by a tree based on its size.

*Thinned crowns in the Commercial Thinning Research Network stands provide ample growing space for residuals to respond.*

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These analyses were conducted for trees in both CTRN studies: 1) six sites with 25-40 year-old stands that were previously precommercially thinned (PCT) and 2) six sites with 40-70 year-old stands that were not previously precommercially thinned (Non-PCT).

## EFFECT OF COMMERCIAL THINNING ON GROWING SPACE REALLOCATION

Preliminary results from our analysis demonstrated how allocation of growing space changed from pre- to post-thinning conditions for each of the three measures of growing space availability (Figures 11 and 12). The greatest increase in growing space allocation to the residual stand occurred with the low thinning treatments on Non-PCT sites (Figure 11). The Low 50 treatment (low thinning to 50% relative density) produced the greatest change in APA, HCI, and $DBH^2$ among the treatments in Non-PCT stands. Crown thinnings produced the next largest change in APA, followed by dominant thinnings which produced little change in the APA. HCI was reduced by all thinning treatments with relatively little difference occurring among thinning methods. $DBH^2$ increased following both low and crown thinnings, and was reduced by dominant thinnings. As expected, the 50% relative density (RD) reductions had a larger influence on growing space allocation than the 33% RD reductions for all thinning methods. For

Figure 11. Effect of commercial thinning treatments on the mean of one non-spatial measures of growing space ($DBH^2$), one spatial measure of growing space (APA) and one spatial measure of competition (Hegyi's competition index, HCI) in mature, naturally regenerated spruce-fir stands.

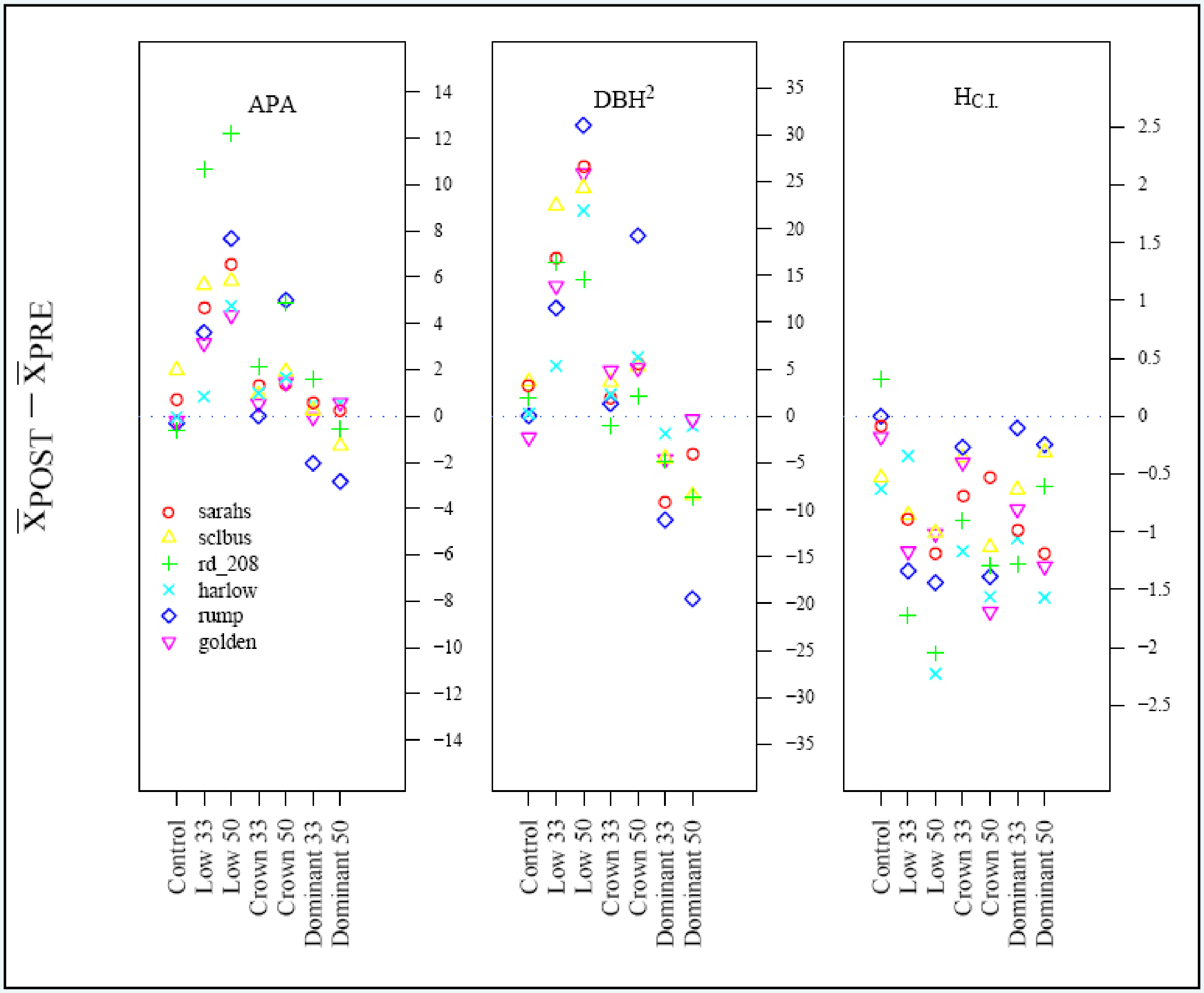


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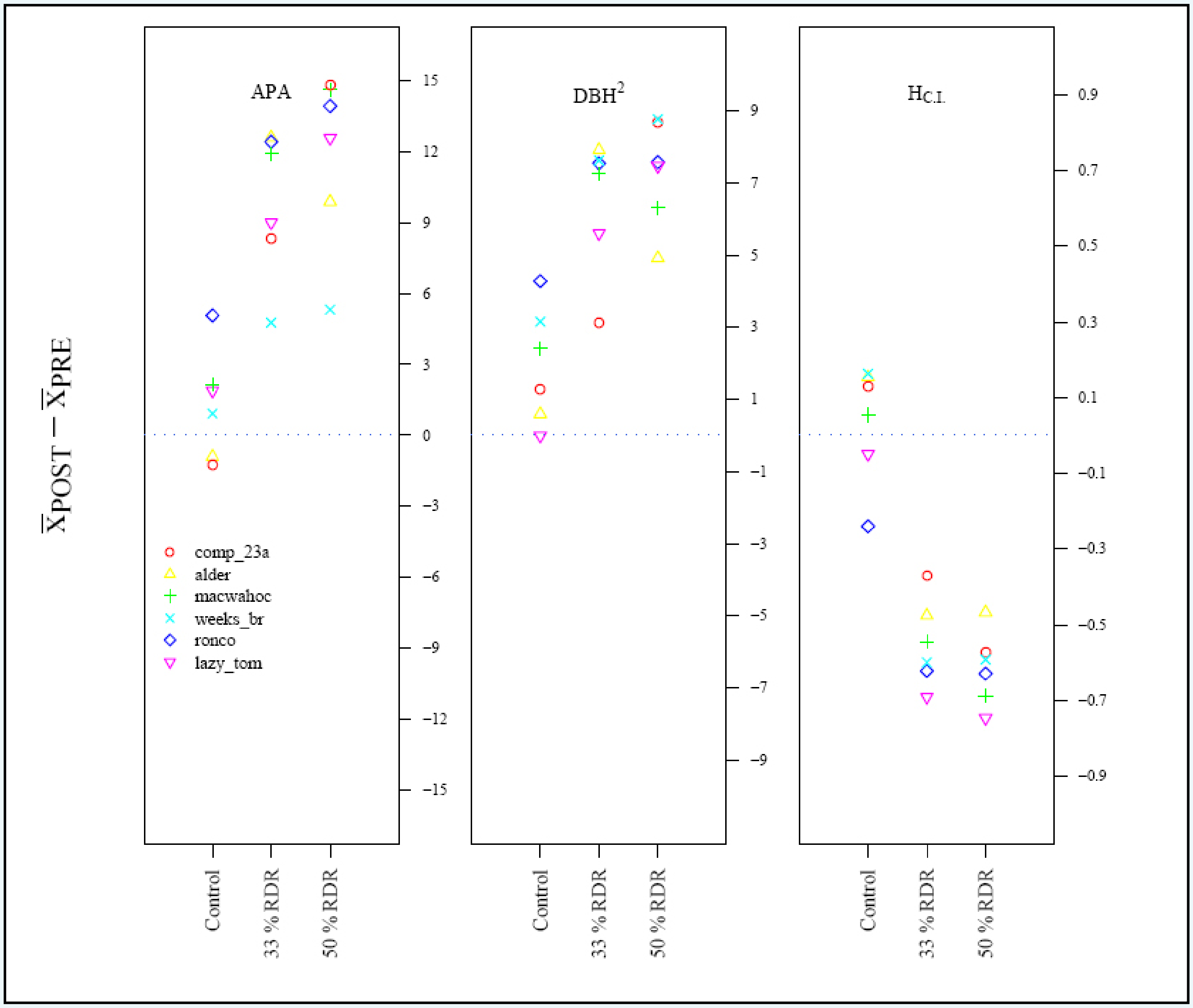
Figure 12. Effect of % relative density reduction on the mean of one non-spatial measure of growing space (DBH²), one spatial measure of growing space (APA) and one spatial measure of competition (Hegyi's competition index, HCI) in young pre-commercially thinned spruce-fir stands.



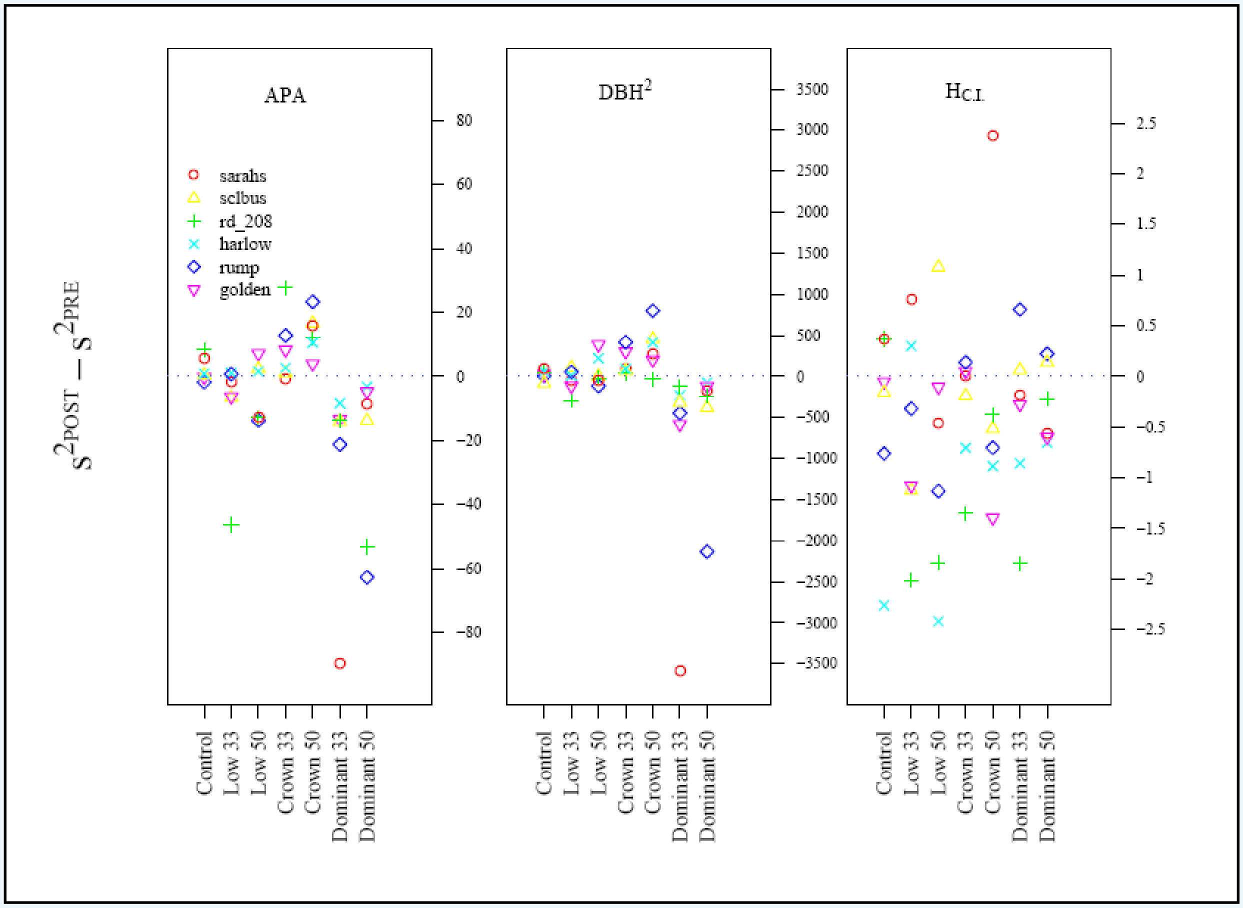

the PCT study, 50% RD reductions also had a slightly larger influence on growing space allocation than the 33% RD reductions (Figure 12).

## EFFECT OF COMMERCIAL THINNING ON VARIABILITY IN GROWING SPACE ALLOCATION

The inherent objectives of commercial thinning are not only to increase the amount of growing space available to each tree in the residual stand, but also to more equally distribute available growing space among individual trees in the residual stand. One measure of the uniformity of growing space allocation following thinning is the variation in growing space allocation among individual trees in the residual stand. To compare changes in the variation of growing space allocation among the commercial thinning treatments, we compared the change in variance for the three measures of growing space (HCI, APA, and DBH$^s$) from pre- to post-thinning conditions for all the commercial thinning treatments.

Our analysis of commercial thinning treatments in the Non-PCT sites indicated that the dominant thinnings, which removed trees in the largest diameter classes, reduced variation in APA among individual trees (Figure 13). In contrast, the crown thinnings, which removed trees in the middle diameter classes, slightly increased varia-

Figure 13. Effect of commercial thinning treatments on the variance of one nonspatial measure of growing space ($DBH^2$), one spatial measure of growing space (APA) and one spatial measure of competition (Hegyi's competition index, HCI) in mature, naturally regenerated spruce-fir stands.

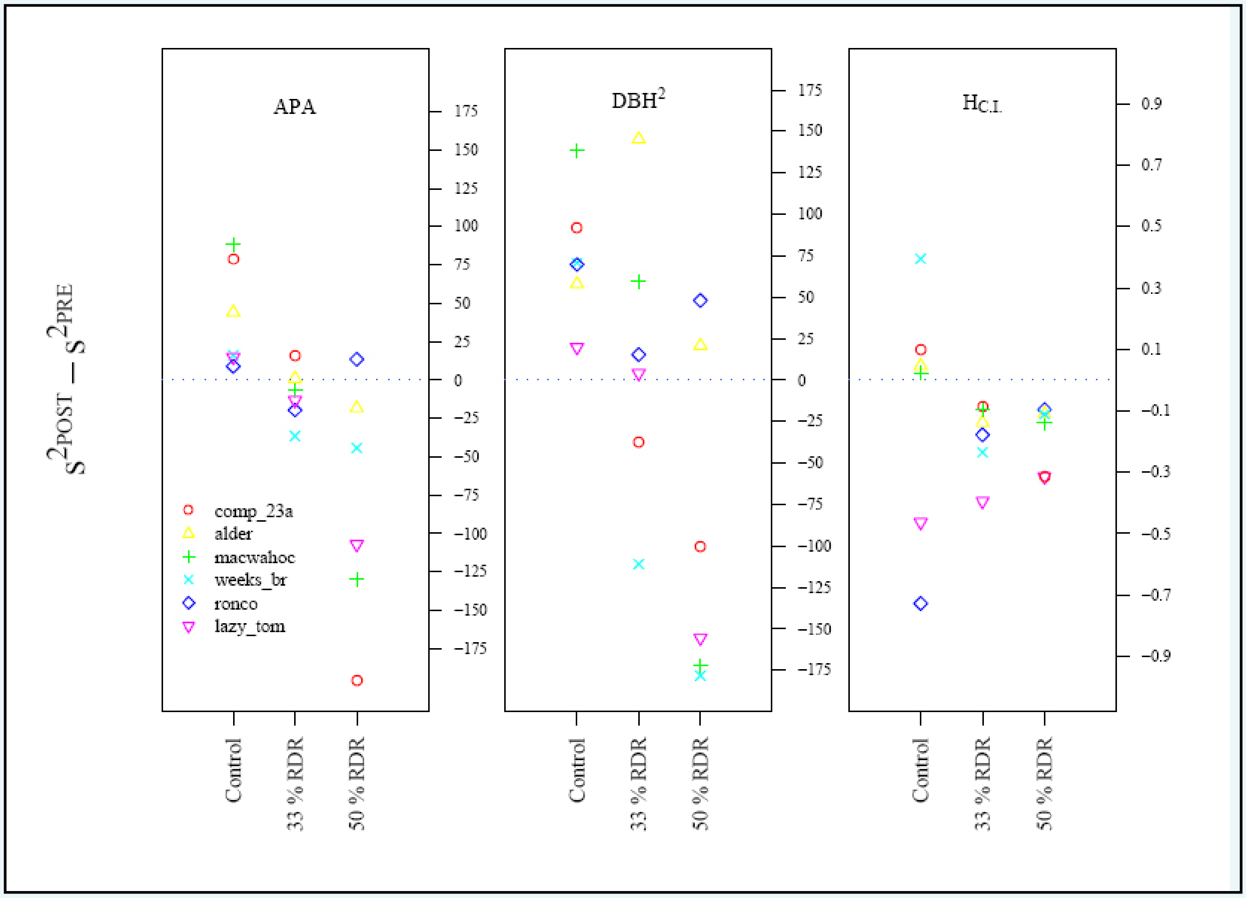



tion in APA. Thinning from below (low thinning) had relatively little influence on variation in APA before and after thinning on most sites. The degree of RD reduction appeared to have only a minor, if any, influence on variation in the APA among methods of thinning. Changes in variation of the HCI differed so much among study sites that it was difficult to draw any conclusions about the effect of thinning treatments using this metric. Changes in the variation of $DBH^2$ were similar to that of APA, with dominant thinnings generally reducing variation, crown thinning increasing variation, and low thinnings producing little change in variation. As with APA, degree of RD reduction had relatively little effect on the change in variation for $DBH^2$.

Based on this preliminary analysis, it appears that thinning from above (dominant thinning) tended to decrease variability in growing space allocation (APA and $DBH^2$) among trees in the residual stand. Crown thinning, designed to release dominant trees from other dominant and co-dominant trees, tended to increase variability in growing space allocation. Thinning from below (low thinning) tended to have relatively little influence on the variability of growing space allocation in the residual stand. The degree of density reduction (at least up to a 50% reduction in relative density) appeared to have less influence on variability in growing space than the method of thinning (low, crown, or dominant).

Results from commercial thinning in the PCT study (Figure 14), which includes younger stands of largely balsam fir that have been previously thinned, suggested that commercial thinning to 50% RD reduced variability in APA, HCI, and $DBH^2$. The 30% RD reduction treatment appeared to have little influence on reducing

Figure 14. Effect of % relative density reduction on the variance of one non-spatial measure of growing space ($DBH^2$), one spatial measure of growing space (APA) and one spatial measure of competition (Hegyi's competition index, HCI) in young, pre-commercially thinned spruce-fir stands.




variability in growing space. We are currently investigating why variation in the growing space measures appeared to increase in the untreated controls.

Ongoing work in this analysis is investigating how the forwarder trails affected the allocation of growing space, how thinning influenced other point-process measures of growing space, and how well the growing space measures are correlated with post-thinning growth. When completed, results from this work will provide CFRU members with a better understanding of 1) how commercial treatments reallocated growing space, 2) which treatments reallocated growing space most effectively, and 3) how the pattern of growing space reallocation affected post thinning growth of individual trees and the overall stand.

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

*Commercial thinning allows managers to caputre mortality and reallocate resources to more desirable stems.*

# Effects of Commercial Thinning on Physiological Stress in Balsam Fir and Red Spruce

**Rakesh Minocha, Stephanie Long, and Robert G. Wagner**

Work continued this year examining the feasibility of using the presence of specific biochemical compounds in the foliage of spruce and fir trees as indicators of stress and/or changes in growth pattern following commercial thinning at two additional new sites. Previous research indicates that putrescine (a common polyamine) and arginine in tree foliage can be used as early indicators of physiological stress caused by environmental stresses such as chronic nitrogen fertilization or acid deposition, and may be a precursor to reductions in growth, crown deterioration, or tree death (Minocha et al. 1997, 2000). Changes in a few specific amino acids and spermidine (also a common polyamine) along with changes in putrescine also may indicate increases in growth. Study sites from the CFRU Commercial Thinning Research Network (CTRN) are being used to test whether commercial thinning can produce changes in these compounds and if their presence is correlated with subsequent tree growth. Funding for this project is being provided by the U.S. Forest Service Agenda 2020 program.

Foliage samples were collected during July 2003 from the Lake Macwahoc and Golden Road study sites and in 2004 from Harlow Road and

*Separating foliage by age class can be meticulous.*

*A USFS shooter gathers foliage for analysis.*

Comp 23A (Penobscot Experimental Forest) in 2004. These samples were analyzed in 2004 and 2005 respectively. Up to 25 spruce and fir trees were sampled per plot at Golden Road and 20 fir sampled per plot at Macwahoc. For 2004 samples 15 or more trees per treatment were collected. Shotguns were used to collect foliage from the upper canopy of each tree. The samples were frozen and taken back to the laboratory in Durham, NH. In the lab, extracts were taken from the foliage to assess the presence of inorganic ions, amino acids, polyamines, chlorophyll, and soluble proteins. Results from this analysis indicate that levels of putrescine and spermidine in the current year foliage of balsam fir and red spruce are influenced significantly by thinning. Levels of both compounds increased relative to those found in unthinned stands for red spruce in most thinning treatments at Golden Road (2004 Annual Report). Patterns for balsam fir at Golden Road were less clear, but spermidine levels appeared to increase with thinning treatment. Putrescine and spermidine levels increased with the degree of commercial thinning in younger balsam fir stands, especially

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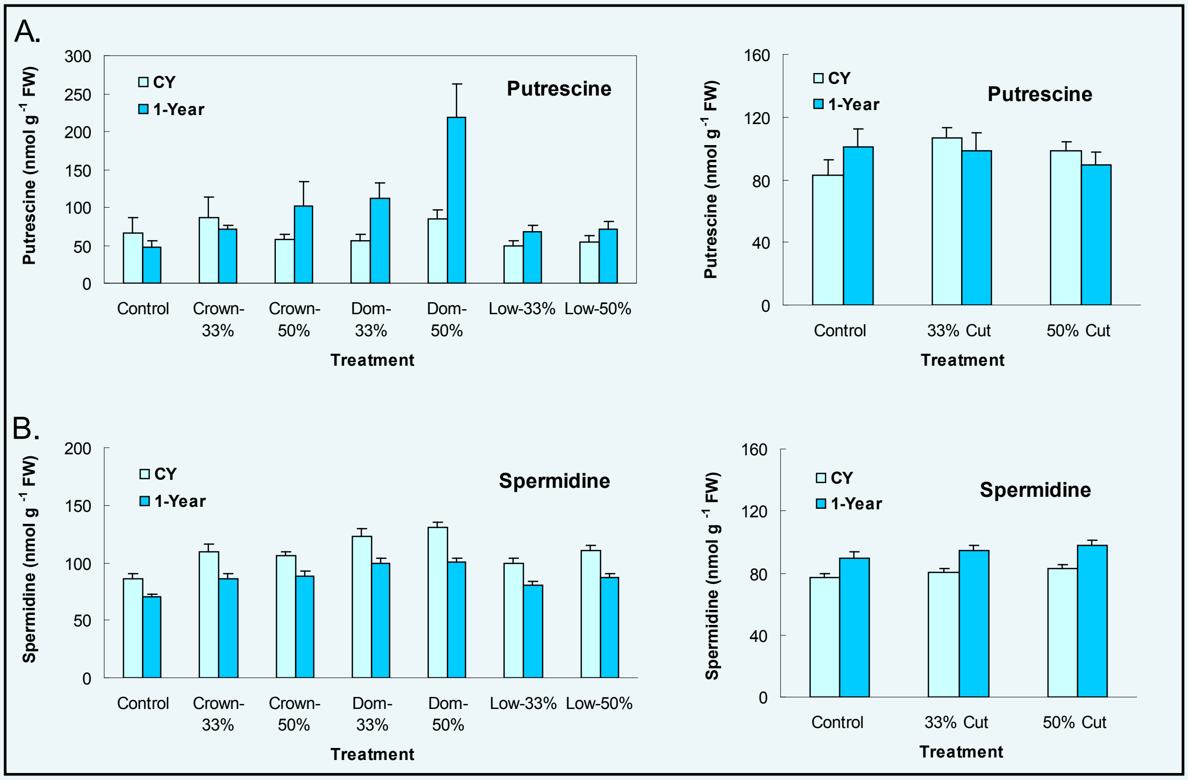
Figure 15. Levels of polyamines (putrescine and spermidine) in current year (CY) and 1-year-old needles of red spruce at the Harlow Road site (A) and balsam fir at the Comp 23A (Penobscot Experimental Forest) site (B).




in current year foliage. The results of 2004 from Harlow Road for red spruce and Comp 23A for balsam fir showed trends similar to the ones seen in 2003 for the other two sites (Figure 15). We are currently examining whether post thinning growth response of the sample trees is correlated with levels of these polyamines or other compounds. Preliminary examination of post thinning growth rate data in relation to polyamine data shows that slowing of the growth in the first few years may be tied with relative changes in N metabolism. A spermidine to putrescine ratio of close to one or higher seems to be related to higher RBA. There is a need to follow these changes for longer term because of high variability associated with relative basal area change data at this point. Based on the encouraging results from the 2003-2004 samples, the trees at study sites of 2003 were re-sampled in 2005. These samples are being analyzed and results will be reported next year.

For more information about the study contact Rakesh Minocha at 603-868-7622 or at rminocha@fs.fed.us.

## REFERENCES

Minocha R., W.C. Shortle, G.B. Lawrence, M.B. David, and S.C. Minocha. 1997. Relationships among foliar chemistry, foliar polyamines, and soil chemistry in red spruce trees growing across the northeastern United States. Plant Soil. 191: 109-122.

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Minocha, R., J. Aber, S. Minocha, and R.G. Wagner. 2003. Effects of commercial thinning on physiological stress, carbon and nitrogen metabolism in trees, and their relationship to forest productivity. p. 35 In Cooperative Forestry Research Unit, 2003 Annual Report, Maine Agriculture and Forest Experiment Station, Miscellaneous Report 2684. 73 p.

# Silviculture and Ecology of Northern White Cedar

**Philip Hofmeyer, Robert S. Seymour, Laura Kenefic**

The study of ecology and silviculture of northern white-cedar (*Thuja occidentalis* L.) in Maine is off to a good start thanks to a successful field season this summer. We made a number of excellent contacts with foresters and resource managers representing the wide collection of those interested in the sustainability of cedar on their land base (Table 5). We focused on covering as much geographic area as possible to get a wide sample of the growing conditions of mixed-species stands with cedar, spruce and fir as components. Figure 16 shows the study sites visited this past summer.

At each stand, five upper canopy cedar and five each of spruce or fir were double-cored to the pith at breast height (4.5 ft.). If rot did not allow the core to reach the pith, the location of rot was noted on the core. The sapwood boundary was noted on each core for later analysis of sapwood-leaf area relationships within each species. Each cored tree was measured for total height, height to the base of the live crown, height to lowest live branch, and diameter. A variable radius plot was centrally located to ascertain the density at which the sample trees are currently growing. Two soil pits were excavated at each site to observe soil conditions through variables such as drainage class, percent coarse fragments, depth to root restriction, slope, and depth of organic horizon. A GPS point was taken in each stand for relocation. The cores have been dried and are being sanded for analysis in the upcoming weeks. Raw data collected in the field have been entered into Excel worksheets to be manipulated for initial statistical analysis.

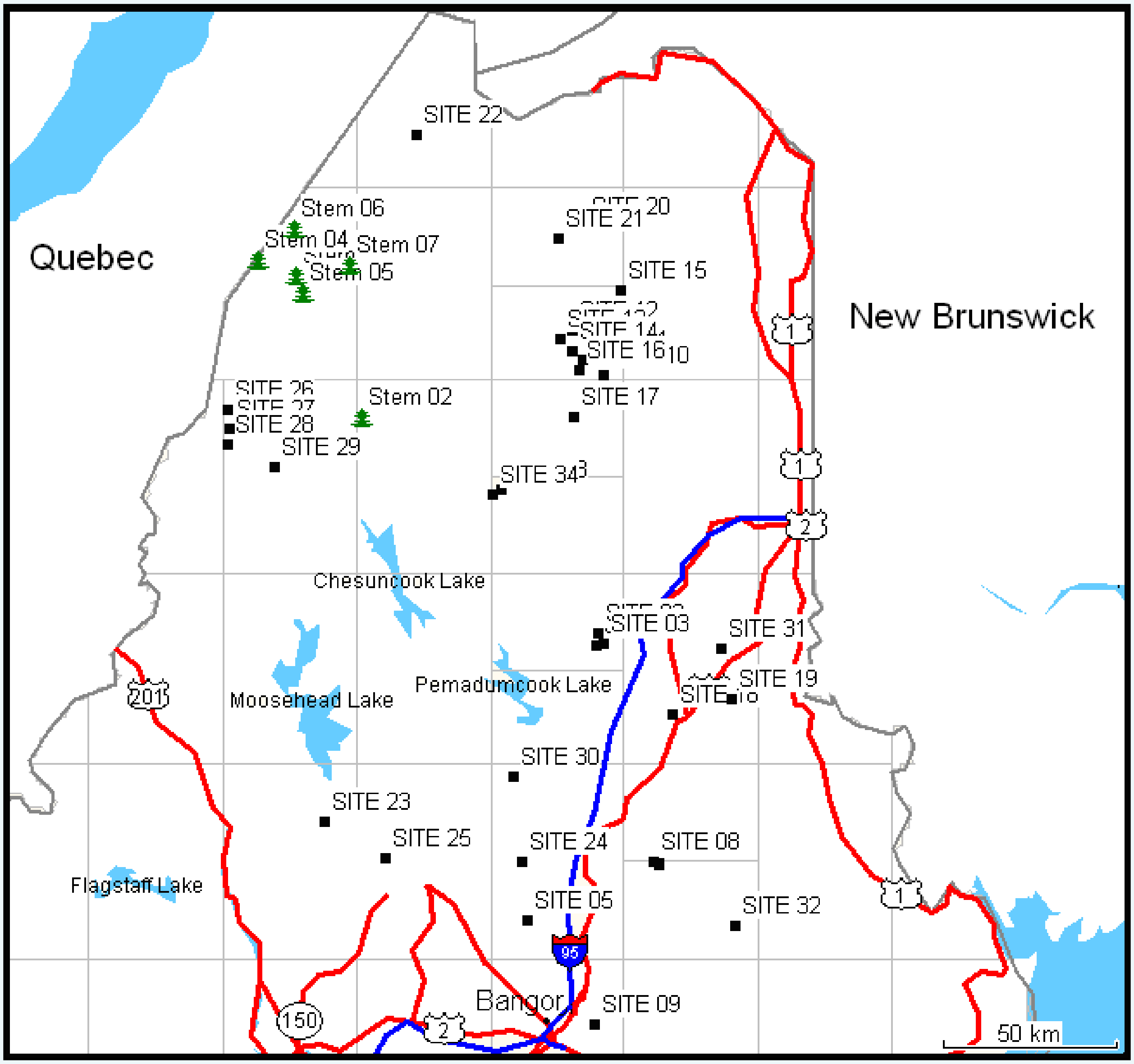
The objectives for this portion of the study are twofold: 1) quantify age-size relationships, growth rates, and recruitment rates using stem analysis, and 2) compare incremental radial growth rates for balsam fir, red spruce and northern white-cedar on a range of sites. Due to the high rate of butt rot, stem analysis of sound cedar from the Maibec mill yard in St-Pamphile, Quebec will be extremely important in quantifying growth and recruitment rates of younger individuals. Seventy-two sound cedar stems were sampled by removing tree cookies at four intervals along the stem (12", 80", 164", and a top height cookie) during October, 2005. The cookies are currently being dried and are scheduled to be sanded and analyzed during winter, 2006. This analysis will enable us to determine early stem development recruitment time periods.

*Graduate Student Phil Hofmeyer holds one of his white cedar discs.*

Potential field sites for next summer are being located, with an aim to increase the sample size in northwestern Maine, west of Moosehead Lake, and along Route 1 in the northeastern corner of the state. These sites will be added to the current study sites (Figure 16) for core analysis in the beginning of the 2006 field season. Destructive sampling of sound cedar located in the coring study for stem analysis and leaf area – growth efficiency will commence during July and conclude in August of 2006. This information will help resource managers to better understand growing space occupancy, site restrictions on growth, and growth potentials for associated species.

Preliminary observations in the field suggest that soils may be far more important to cedar growth and development than initially expected (particularly in terms of stem quality). These differences are potentially chemical in nature and impossible to characterize in the current study. A proposal for an incoming Master of Science student to rigorously investigate the soils on these sites is being drafted for review. The hope is that physical and chemical analysis of this nature will produce easily-observed trends that practitioners will be able to incorporate into future cedar management.

Figure 16. Study sites throughout northern Maine for the northern white cedar study as of October, 2005. Sites labeled "Stem" are locations from which the Maibec millyard trees were harvested. Study sites will be added during the field season of 2006. A selected subset of these sites will be used for stem analysis and leaf area, as dictated by stem quality and site availability.



## STUDY TIMELINE (FROM PRESENT)

### Winter 2005 – Spring 2006

1) Continue to analyze cores from initial 34 sites
2) Analyze Maibec mill yard stems
3) Preliminary statistical analysis of study sites
4) Locate stands for summer sampling
5) Create proposal for incoming Master of Science student for cedar soil-site relationships

### Summer 2006

1) Sample remaining stands to complete dataset for the initial phase of the study
2) Revisit a subset of stands with sound cedar to destructively sample for detailed stem and foliar analysis

### Fall 2006

1) Leaf Area Index and growth efficiency analysis of destructively sampled cedar stems
2) Read cores collected during summer; enter raw data

### Winter/Spring/Summer 2007

1) Statistical analysis of all data
2) Determine study conclusions and future opportunities for research
3) Writing technical reports for CFRU and Maibec; prepare journal manuscripts

For more information about this study contact Bob Seymour at 207-581-2860 or seymour@umenfa.maine.edu.

Table 5. Cooperators associated with this project.

| **Industrial Cooperators for Summer 2005** | |
|---|---|
| Company | Contact |
| Huber Resources Corp. | Ken Fergusson, Ted Shina |
| J.D. Irving, Limited | Jon Cole |
| Sustainable Forest Technologies | Mike Howie |
| Maine Bureau of Parks and Lands | George Ritz, Doug Reed |
| Seven Islands | Ken White |
| Baxter Scientific Forest Management Area | Jensen Bissell |
| The Nature Conservancy | Jim O'Malley |
| **Additional Cooperators Expected for Summer 2006** | |
| Huber Resources Corp. | Joel Philbrook |
| Plum Creek | Mark Doty |
| Bureau of Parks and Lands | Vernon Labbe, Dave Pierce |
| J.D. Irving, Limited | Gaeton Pelletier |
| Seven Islands | Francois Quirion, Bill Brown |
| Maine Forest Service | Gordon Moore |

*Complex leaf morphology makes white cedar leaf area work challenging.*

# Wildlife

**Predicting responses of forest landscape change on wildlife umbrella species**

**Responses of Snowshoe Hares and Lynx to Alternative Forest Harvesting Practices**

Wildlife

# PREDICTING RESPONSES OF FOREST LANDSCAPE CHANGE ON WILDLIFE UMBRELLA SPECIES

**Daniel Harrison, Steven Sader, Jeremy Wilson, William Krohn**

## SUMMARY OF PROGRESS DURING YEAR 1

Three PhD students (Kasey Legaard, Mauricio Moreno, Erin Simons) have been selected, initiated their programs of study, made significant progress on course-work, and have worked with faculty advisory committees to formulate and revise research protocols. Fieldwork needed to provide input data for lynx models (hare density estimation on 31 research grids and snow-track surveys for lynx across 61 townships) were completed during year 1 of the project. Satellite imagery required for retrospective analyses of habitat supply have been acquired, cataloged and cover types are being categorized using previously published change detection methodologies.

## PROJECT OVERVIEW

Since the implementation of the 1989 Maine Forest Practices Act (MFPA), commercial timber harvesting has shifted away from clearcutting. Partial harvests now account for approximately 96% of the annual harvest in Maine (Maine Forest Service 2004), which has resulted in an increase in the number of forestland acres being harvested annually. There have also been significant changes in timber-land 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 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). Thus, it is increasingly important that we understand the short- and long-term effects of forest management on landscape change and future habitat supply for focal wildlife species.

Dan Harrison's lab has developed predictive oc-currence models for the marten (Hepinstall and Harrison in preparation) and the lynx (Hoving et al. 2004, 2005), which together represent a range of ecological conditions spanning early to mid/late successional forests. Both of these species have large spatial requirements and respond to habitat change at large spatial-scales. Thus, ongoing efforts are evaluating marten and lynx as complementary focal species that may serve as planning "umbrellas" to assist forest managers in maintaining future vertebrate diversity across the Acadian forest. With lynx and marten con-servation largely driven by forest management, it is important to understand factors influenc-ing habitat supply and to develop tools forest

*Research shows that the Canada lynx depends largely on early-successional forest.*

W i l d l i f e

managers can use to manage lynx and marten habitat at the appropriate spatial and temporal scales.

*Marten may be used as an umbrella species for managing wildlife habitat at the landscape level.*

We have initiated a collaborative study with the formal endorsement and financial support of the CFRU, 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 University of Maine. Overall, the objectives of this effort are to 1) evaluate past trends in lynx and marten habitat supply (Forest Change and Habitat Trends Module), 2) simulate the effects of alternative forest management scenarios on landscape change and lynx and marten habitat (Forest Projections Module), and 3) further evaluate the utility of marten and lynx as umbrella species in Maine (Wildlife-Habitat Relationships, Predictive Modeling, and Umbrella-Species Module). The specific objectives for this research are:

1) Predict, map, quantify and simulate the future densities of martens and lynx, and the vertebrates that are included under their broad habitat umbrellas, across landscapes under alternative forest management regimes and with different past legacies of management for 50 years into the future; and
2) Evaluate trends in habitat supply for marten, lynx, and other forest vertebrates using Landsat TM imagery for a time series spanning 17 years (1988-2004).

## STATUS OF PROJECT MODULES

### Wildlife-Habitat Relationships, Predictive Modeling, and Umbrella-Species Modules

We are currently developing a second generation model for predicting landscape-scale occurrence of lynx in Maine. This work expands and improves earlier published modeling work (Hoving et al. 2004). The presence/absence dataset that will be used in the development of a logistic regression-based model to predict lynx occurrence has been completed. In cooperation with the U.S. Fish and Wildlife Service, the Maine Department of Inland Fisheries and Wildlife (MDIFW) conducted snow-track surveys in 61 townships throughout the historical range of Canada lynx in Maine during the winters of 2003-2005. Townships were selected on the basis of predicted lynx occurrence probability based on Hoving et al. (2004). These surveys were conducted on snowmobile and covered ≥55 km of roads within 24 to 72 hours after a snowfall (Vashon et al. 2005). This protocol was developed by the MDIFW in the study area where they are monitoring radio-colored lynx, and thus the survey method is known to have a 90% chance of detecting a lynx if a resident animal is present (Vashon et al. 2005). The number of townships surveyed in 2003, 2004, and 2005 were 20, 19, and 22, respectively. During those surveys, lynx presence was detected in 26 townships, yielding 204 geo-referenced point occurrences of lynx tracks crossing the survey transects. Point occurrences will be used to delineate "used" areas and similarly sized areas where no lynx were detected during surveys will be the "unused" areas. Parallel to the methods

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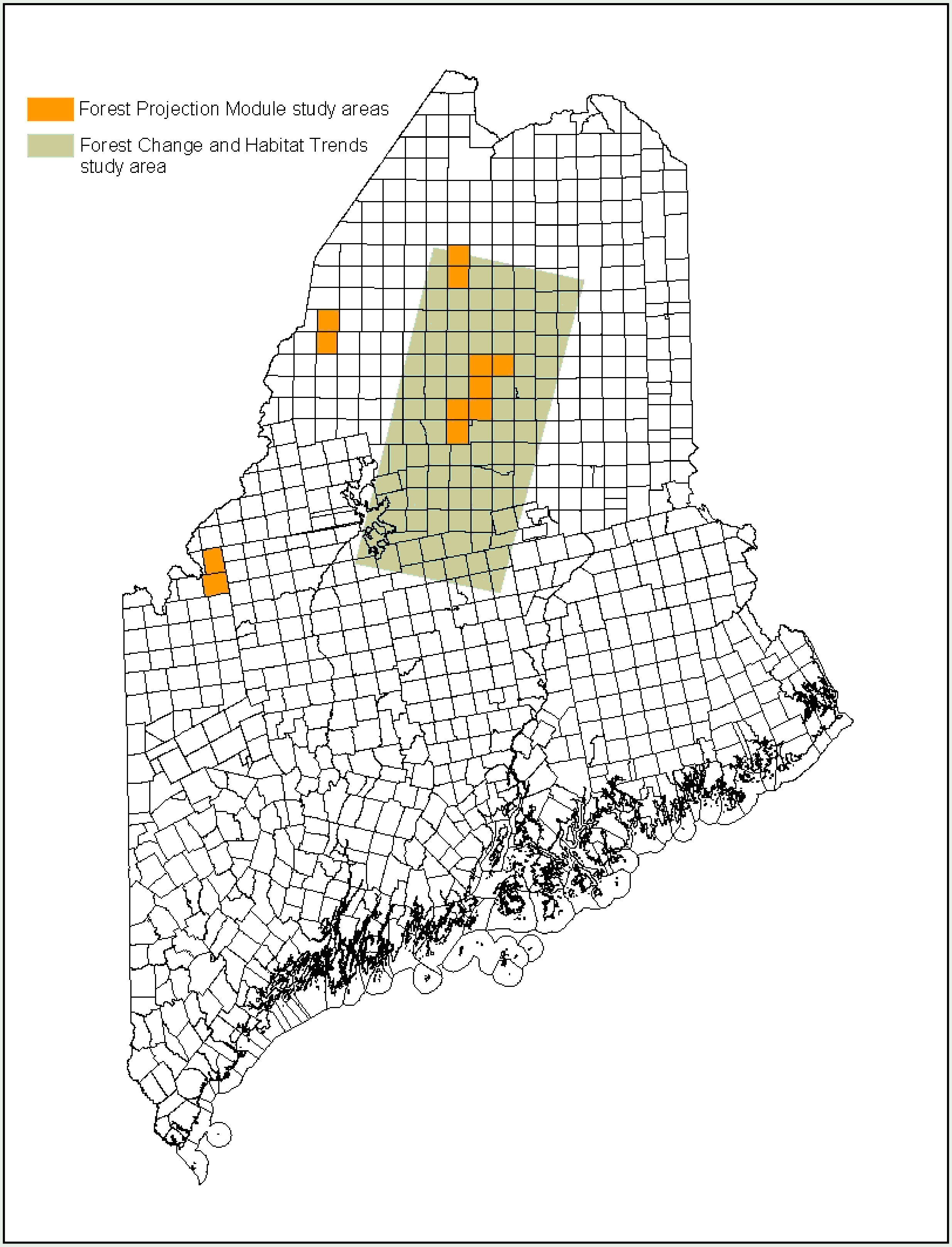
Figure 17. Study areas for the Forest Change and Habitat Trends and Forest Projections Modules. Shaded area represents the overlapping region between two Landsat TM scenes, representing ~10,000 km$^2$ of commercial forestlands in Maine. Townships colored orange are the set of six paired townships that will serve as the foundation for the forest stand projections.



of Hoving et al. (2004), hypothetical models will be developed and used to compare habitat conditions at used and unused sites within an information-theoretic framework.

Based on the modeling work of Hoving et al. (2004), we feel we have a reasonable first-cut understanding of the habitat variables (e.g., forest cover type) important to Canada lynx in eastern North America. Lynx are prey specialists on the snowshoe hare (*Lepus americanus*), and their selection of forest cover type appears to be tied to snowshoe hare densities (Hoving et al. 2004). Consequently, we will include hare densities by major forest cover type as model variables in the lynx predictive model. Of special importance is what we will use for a land use/land cover map of Maine, and how this map gets reduced to major forest cover types of interest. We are in the process of developing a land cover map generated by updating the 1993 Maine GAP land cover map (Hepinstall et al. 1999), using a change detection technique developed in the University of Maine's Maine Image Analysis Laboratory (MIAL) (Sader and Winne 1992), to reflect 2004 land cover types. The update process will be similar to methods used in the Forest Change and Habitat Trends Module.

We have already developed and validated a model for predicting landscape-scale marten occurrence in Maine based on landscape characteristics (Hepinstall and Harrison in preparation). The validation dataset indicated that the model predicts individual home range occupancy with >75% accuracy. This marten occurrence model and the second generation lynx occurrence model described above will be applied to land cover maps generated under the Forest Change and Habitat Trends Module of the project by Erin Simons (PhD student). This will allow us to evaluate the spatio-temporal dynamics of habitat supply for lynx and martens on ~10,000 $km^2$ of commercial forestlands in Maine (Figure 17) over the past 17 years (1988-2004). By applying the occurrence models to the simulated landscapes created in the Forest Projections Module, we will be able to compare alternative forest management scenarios on the basis of their effect on marten and lynx habitat supply.

Hepinstall and Harrison (2004) also evaluated the utility of using marten and lynx as umbrella species for forest wildlife conservation. Umbrella species have been proposed as a tool for simplifying biodiversity conservation by focusing on a few species that are representative of a particular habitat association (e.g., late-successional or early successional forest) and are area-sensitive (i.e., have large spatial requirements). Lynx and marten together represent a range of ecological conditions associated with habitat occupancy across millions of acres of commercial forestlands in Maine. Maine has the largest population of marten in the lower 48 states and the only verified lynx population in the northeastern U.S. Using the Hoving et al. (2004) lynx occurrence model, Hepinstall and Harrison (2004) found that if areas in Maine with a probability of occurrence >80% for lynx and >50% for marten were protected, 61% of the 111 forest vertebrates they considered would be disproportionately benefited (relative to the focal species) and an additional 25% would be proportionately benefited. This suggests that planning for marten and lynx habitat futures could accommodate habitat needs for 86% of the vertebrate wildlife species in northern Maine.

**Forest Projections Module**

The forest projections module will simulate and evaluate the effects of past forest management and future forest management under alternative scenarios on landscape change and lynx and marten habitat supply. To represent the current distribution of forest structures, we have selected a spatially stratified set of six paired townships to serve as the foundation for our forest stand projections (Figure 17). Paired townships will provide enough area (~200 $km^2$) for lynx and marten habitat management and represent a spatial scale upon which forest managers manage forest landscape units in Maine. The current forest structures within the paired townships represent different forest management legacies.

These "legacies" vary as a result of interactions between ownership goals, past harvests, natural disturbance history, and site conditions. We are acquiring both spatial datasets (e.g., GIS-based stand type maps) and forest inventory plot information from landowners to compile a portfolio describing each township within the set.

Jeremy Wilson and Mauricio Moreno, who began his PhD in the Department of Forest Management in September 2005, have initiated the township portfolios and will be projecting and mapping future forest conditions under alternative forest management scenarios for a set of six paired townships. Forest stand projections will be implemented 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). A range of alternative management scenarios will be simulated. We are developing, for example, scenarios that include increased reliance on partial cutting, increased reliance on clearcutting, establishment of no harvest reserve areas, and variations of harvest block layout (e.g., aggregated vs. dispersed clearcuts). In addition, we are considering simulating scenarios that reflect management responses to a spruce budworm outbreak.

The simulations will provide input to the marten and lynx occurrence models. Results from those models will allow us to evaluate and compare forest management strategies on the basis of their long-term effect on marten and lynx habitat and probability of occurrence. For each township pair, we will compare the temporal trends in probability of lynx and marten occurrence across scenarios, and on the basis of specific harvest characteristics (e.g., total harvest area, rotation length, percent overstory removed) within an ANOVA framework (Gustafson et al. 2001). We will also compare other forest characteristics that develop under alternative management scenarios and expose potential trade-offs that may arise. Additional characteristics will include disturbance vulnerability (e.g., wind and spruce budworm damage [MacLean and Porter 1994, Wilson et al. 1998, MacLean et al. 2000, Wilson and Baker 2001, Wilson 2004]) and economic consequences (e.g., harvest volumes).

**Forest Change and Habitat Trends Module**

In collaboration with the Maine Image Analysis Laboratory (MIAL), we are in the process of developing a retrospective time series of habitat maps for north-central Maine based on Landsat Thematic Mapper (TM) satellite imagery. The study area is approximately 10,000 $km^2$ in size, defined by the overlapping area between two Landsat TM scenes (Figure 17). Steve Sader and Kasey Legaard, who began his PhD degree in the Department of Forest Management in January 2005, have assembled a leaf-on time series of cloud-free TM images spanning the 17-year period of 1988-2004. Sampling across this time period will allow us to document changes in forest harvest patterns following major changes in forest policy and ownership that occurred in the 1990s. Research conducted in the MIAL has documented a decrease in clearcut patch size and number, and a corresponding increase in partial harvest patch size across a ~3,000 $km^2$ study area in northwest Maine following the implementation of the Maine Forest Practices Act in 1991 (Sader et al., 2003). Recent research demonstrates that harvest intensities across northwest Maine have been affected by changes in forest ownership, most notably the sale of large tracts of forestland by industrial owners to real estate investment trusts and institutional investors (Jin 2005). Using the second-generation lynx occurrence model developed under the Predictive Modeling Module, we will be able to characterize the landscape-scale effects of changes in timber harvesting practices on lynx habitat quantity and distribution over a large portion of the lynx's geographic range in Maine.

The classification scheme used to develop the retrospective time series of habitat maps is based on the methodology used to develop the Maine GAP land cover map (Hepinstall et al., 1999). Using the GAP land-cover class statistics as the basis for land cover discrimination, we will classify the oldest available (i.e., 1988) TM image. Using forest change detection techniques developed in the MIAL (e.g. Sader and Winne 1992, Sader et al. 2003), a harvest detection time series will be assembled from individual change detection maps spanning short time intervals (1-3 years) between image acquisition dates (Jin and Sader, 2005). The 1988 land cover map will then be updated according to this harvest detection time series to reflect incremental changes in land cover occurring over the 17-year study period. By incrementally updating the 1988 land cover map rather than creating a series of land cover maps through the direct classification of each TM image, we will minimize the impact of image-to-image variation caused by factors other than the land cover changes of interest. Finally, the relative accuracy of the retrospective time series of land cover maps will be assessed by comparing the final land cover map derived from the 1988 classification to a direct classification of the 2004 imagery based on GAP land-cover statistics, and to the 2004 Maine Land Cover Dataset, developed under contract for the state of Maine and scheduled for completion in early 2006.

We are currently exploring the use of logistic regression and multinomial regression models as means of analyzing patterns and trends in forest harvest activity observed in TM imagery. Harvest probability functions fit to the harvest detection time series will allow us to quantify and compare changes in forest harvest trends that may be related to changes in forest management policy, forest ownership, or other factors. This modeling effort will also serve as the basis for projecting harvest activity 50 years into the future under alternative forest management scenarios. Simulations of landscape change and consequent changes in marten and lynx habitat supply at this broader scale will complement stand-scale projections developed under the Forest Projections Module.

## TIMELINE

All aspects of the project are on schedule without significant deviations. The funding timeline for all collaborative modules associated with this project is October 2003 - September 2007. Funding received from Agenda 2020 will span October 2004 - September 2007; all products will be delivered by December 2007. Field work necessary to proceed with lynx-habitat modeling was completed on August 11, 2005. Modeling of lynx occurrences will be completed by May 31, 2006 and retrospective analyses of lynx habitat supply from 1988-2004 will be completed by August 31, 2006. Forest projections analyses will be completed by September 30, 2007.

## COLLABORATIONS

Maine Cooperative Forestry Research Unit ($17,000 total for 2005-2007), USDA Forest Service Agenda 20/20 Program (Dr. Robert Bridges) ($124,000); USGS – Science Support Partnership Program (Dr. William Krohn) ($85,533); USFWS ($15,000 plus in-kind; Dr. Mark McCollough); National Forest Industry Support (NCASI; Dr. T. Bentley Wigley) ($30,000); Maine Department of Inland Fisheries and Wildlife (in-kind support for lynx surveys; Dr. Walter Jakubas); The Nature Conservancy ($15,000, Nancy Sferra); McIntire-Stennis funding for additional graduate student support ($35,000), and academic-year salary support for P.I.'s through Maine Agricultural and Forest Experiment Station and University of Maine. This project involves formal collaborations among several scientists housed at The University of Maine, including Dr. Daniel Harrison, who leads a research lab focusing on forest wildlife-habitat relationships; Dr. Jeremy Wilson, who has extensive experience with modeling and projecting forest landscapes into the future; Dr. Steven Sader, who leads the Maine Image Analysis Laboratory which focuses on remote sensing and change detection of forests; and Dr. William Krohn, who leads the USGS Cooperative Fish and Wildlife Research Unit.

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# Responses of Snowshoe Hares and Lynx to Alternative Forest Harvesting Practices

**Laura Robinson, Daniel Harrison, William Krohn, and Angela Fuller**

The federally threatened Canada lynx (*Lynx canadensis*) is a wide-ranging felid occupying the boreal forest of North America. The range of the lynx extends throughout Canada, but only a few populations currently exist in the United States, with Maine having the only verified population east of Minnesota. This study attempts to describe biological factors that influence habitat use by lynx in northern Maine. Results from this study can be used by forest managers to develop conservation strategies for this rare carnivore.

The Canada lynx is a specialist predator on the snowshoe hare (*Lepus americanus*). Hare density acts as a regulating factor for lynx populations as evidenced by several characteristics of lynx ecology. In almost all studies of lynx diet, hares were the primary food item in all seasons and throughout the hare cycle (Saunders 1963; van Zyll de Jong 1966; Staples 1995; O'Donoghue et al., 2001). During hare declines in the northern boreal forest, lynx survival decreases and recruitment falls to near zero at hare lows (Brand and Keith 1979; Poole 1994; Krebs et al. 2001). Home range sizes are larger during hare declines and the number of dispersing individuals in a lynx population increases during hare declines (Poole 1994,1997; Slough and Mowat 1996; Krebs et al., 2001). In addition, snowshoe hare and lynx ranges overlap extensively today and did so to an even greater degree historically (Seton 1928,1929).

The cyclic nature of the populations of these two species is a direct result of the regulatory effect of hares on lynx. The lynx-hare cycle is an 8-11 year cycle with lynx populations lagging behind hare populations by one to three years (Brand et al., 1976; Slough and Mowat 1996; Krebs et al., 2001); however, evidence for a hare cycle in populations on the southern edge of the lynx and hare ranges is inconclusive (Hodges 2000a). The current weight of evidence in Maine suggests that hare populations fluctuate, but do not exhibit the 5-25 fold changes in density that characterize cycling populations in the northern boreal forest (Homyack et al., unpublished report).

Hares are prey for many carnivores in northern Maine including martens, fishers, foxes, coyotes, and bobcats; in many studies predation has

*Lynx is a forest specialist that preys on snowshoe hare and requires large ranges of primarily early-successonal forest.*

been documented as the main cause of mortality for hares (Krebs et al., 2001; Hodges 2000b). Because predation is the most limiting factor for hare survival, escape cover from predators can be considered a habitat requirement. Dense understory with high stem densities, generally associated with early successional forest, provides hares with thermal cover in the winter and escape cover from predators (Litvaitis et al. 1985). Hare densities in the northeast are strongly associated with understory cover and stem densities (Orr and Dodds 1982; Pietz and Tester 1983; Litvaitis et al. 1985; Monthey 1986). Early successional conditions occur naturally in the northern boreal forests after large fires and in the northeastern United States, after windstorms and insect infestations from species like the eastern spruce budworm (*Choristoneura fumiferana*) (Blais 1983; Mowat and Slough 2003).

Early successional conditions associated with high quality habitat for hares can be produced artificially through forest management practices, and are representative of regenerating clearcuts approximately 12 to 25 years after cutting and herbicide application (Litvaitis et al., 1985; Homyack 2003).

Today, young (10-30 years after cutting) regenerating stands as large as 5,000 ha are common throughout Maine as a result of past clearcutting in response to the widespread eastern spruce budworm outbreak of the late 1970s and early 1980s. However, the Maine Forest Practices Act of 1989 placed disincentives on clearcuts larger than 35 acres (119$^{th}$ Maine State Legislature 2000), and three forestry referenduma during the 1990s contributed to a shift in forest management away from clearcuts in favor of partial harvest cuts in various forms throughout northern and western Maine. Selection harvests and shelterwood cuts now constitute 96% of the forest acreage harvested annually in Maine (2002 Silvicultural Activities Report 2003). Thus, to understand the relationship between forest harvesting and wildlife habitat it is important to understand how partial harvesting and clearcutting comparatively affect vegetative characteristics, how vegetation changes over time within these stands, and how snowshoe hares and lynx respond to changes in forest conditions following partial harvesting.

In addition to hare density, other factors influence habitat use by lynx. Forest cover type, snowfall, bobcat density, and fisher density may be important variables in predicting lynx occurrence in northern Maine. A predictive model of lynx occurrence in the Northeast showed that a high probability of lynx occurrence was positively associated with snowfall >268 cm/year and negatively associated with mature deciduous cover (Hoving et al., In Press). But within northern Maine, lynx occurrence was best predicted by regenerating forest and was negatively associated with recent clearcuts, partial harvests, and forested wetlands (Hoving et al., 2004). Because lynx are adapted to using areas with deep snow that potentially allows them to outcompete bobcats for prey, snowfall may act as a surrogate variable to describe areas where competition between these two species is minimized. We are comparing home-range sized areas simulated around areas of documented lynx occurrences with areas without lynx detections to better understand broader-scale factors influencing lynx distribution in Maine.

We are also utilizing radio-collared lynx, coupled with continuous line mapping of lynx trails to better understand the stand-scale responses of lynx to various forest management practices. In addition to documenting preference and avoidance of various forest management activities, we are evaluating whether lynx select for stands with highest densities of snowshoe hares, for stands with intermediate hare densities where hare are more vulnerable to predators, or mature stands where hare density is low but thermal and escape cover is maximized.

## OBJECTIVES

This study was designed to understand how forest management, vegetation, and forest succession affect hare density and how hare density and other biological and physical components of the habitat influence occupancy and selection of space by Canada lynx in northern Maine.

Our objectives are to:

1) Document hare densities in a variety of conifer- and deciduous-dominated partial harvest stands and to evaluate changes in hare densities in these stands as understories develop.
2) Evaluate the effects of vegetative characteristics on hare densities in partially harvested and regenerating conifer stands.
3) Develop and test a model for discriminating habitat characteristics important in describing habitat use by Canada lynx in northern Maine based on systematic snowtracking surveys conducted by the Maine Department of Inland Fisheries and Wildlife (MDIFW).
4) Evaluate stand-scale habitat selection of radio-collared lynx via snowtracking and continuous line sampling of track-trails.

## STUDY DESIGN

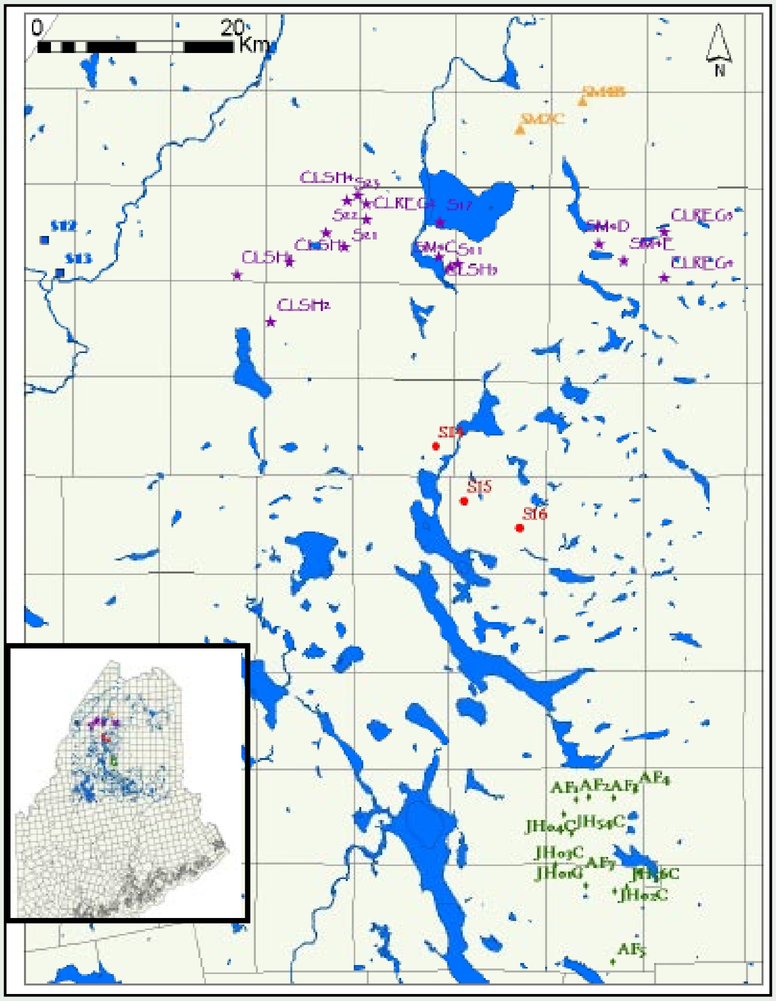
We used pellet plots to estimate hare density in partially harvested and regenerating conifer forest stands in northern Maine. Pellet counts are a reliable method for estimating hare densities based on a linear regression model developed for northern Maine (Homyack 2003). We cleared plots before leaf-off in the fall of 2004 and counted pellets before leaf-on in the spring of 2005 to obtain pellets/ha/day which was converted to hares/ha according to the linear regression equation:

hares/ha = 0.145 + 0.00015 (pellets/ha/month).

We estimated 2004-2005 overwinter hare density in 15 regenerating conifer stands and 21 partial harvest stands (Figure 18) that were distributed across holdings of five forest landowners in northern Maine (Table 6). We placed four parallel transects 360 m long and 65 m apart in forest stands and counted pellets in 5.0 m x 30 cm randomly oriented plots every 60 meters for a total of 28 pellet plots per stand.

In each stand where we counted pellets, we also measured vegetation characteristics thought to be correlated with hare density. We randomly selected 20 of the 28 pellet plots in each stand and measured vegetation characteristics in these 20 plots to describe overall vegetation characteristics for the stand. We used 10 $m^2$ circular plots in stands where total stems (<7.6 cm DBH, >1.0 m tall) were expected to exceed

Figure 18. Location of snowshoe hare and vegetation sampling grids distributed across lands held and managed by five different forest landowners (Table 6) throughout northern Maine.



20,000/ha and 20 m$^2$ circular plots elsewhere. We counted conifer, deciduous, and dead stems (<7.6 cm DBH) at >1.0 m height and at >1.5 m height to calculate stem cover units as described by Litvaitis et al. (1985), Homyack (2003), and Fuller (1999). We measured total basal area using a 2 m$^2$/ha prism and percent overhead canopy closure using a spherical densiometer at 1 m height. We counted coniferous, deciduous, and dead trees (≥ 7.6 cm DBH) and measured their DBH in addition to counting stumps and measuring their diameter. We counted the number of logs at least 1 m inside the plot (≥ 7.6 cm DBH). We measured visual obstruction as a continuous variable using a cover pole with alternating red and white 10 cm bands as the distance at which >25% of the bands were obscured by vegetation. We measured visual obstruction and canopy cover in 11 partial harvest stands both before and after leaf-on, but only after leaf-on in all other stands.

To build a logistic regression model of lynx occurrence, we will be using results of snowtracking surveys conducted over three years in different ecoregions of northern Maine by the MDIFW. The MDIFW conducted surveys from snowmobiles and spatially referenced the occurrence of lynx tracks throughout 61 townships in northern Maine from January through March during 2003, 2004, and 2005. Pilot studies conducted by the MDIFW indicate that a minimum of 55 km per 100 km$^2$ must be surveyed to detect at least one radiocollared lynx and 80 km of roads should be surveyed to detect all radiocollared lynx in the township (Vashon et al., unpublished report).

Lynx detections cannot be considered independent observations; therefore, we are developing a distance criterion to increase the probability that tracks represent individual animals. Using ArcGIS, we will create buffers around each point representing the average 75% kernel home range size for males and females. Of the buffered points, we will select only those that do not overlap to create a group of buffered points that represent "independent" lynx home ranges. We will randomly select out 20% of these buffered points to serve as a reserve dataset to validate model predictions. These final buffers will serve as "detection" home ranges for the logistic regression model. All descriptive variables will be intersected with these buffers to provide values for each predictor variable for each simulated home range.

We will generate "non-detection" home ranges by creating random points along the survey route where lynx tracks were not detected. We will then follow the same procedure that we used for the "detection" points. We will choose descriptive variables to include in the model based on results of habitat studies of lynx across North America. These variables will likely include forest cover type, hare density (based on field estimates in different forest cover types), snowfall, bobcat occurrence, an index to fisher density, and elevation.

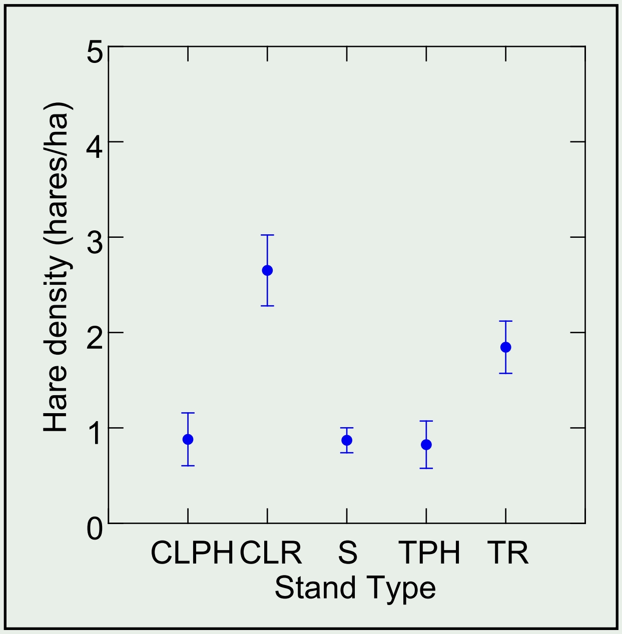
We are investigating habitat use by lynx to evaluate selection or avoidance of regenerating clearcuts, road edges, partially harvested stands and uncut mature stands. The habitat types that we considered were short (3.4-4.3 m tall) and tall (4.4-7.3 m tall) mid-successional (11-26 years since cutting) regenerating clearcuts, recent (1-10 years post-cut) and older established (11-21 years) partially harvested stands, mature (>40 years) second-growth stands (coniferous, deciduous, and mixed coniferous-deciduous), and road edge (30 m buffer on both sides of road). Radiocollared adult lynx (3 female, 3 male) were snowtracked for 65.5 km during winters 2002 and 2003. This study evaluated habitat selection at the scale of the forest stand by comparing the distance traveled by lynx in each overstory type to the percent of those overstory types within the 90% adaptive kernel home range of each lynx. Log-ratio selection indices were calculated as ln(use/availability) where use was defined as the proportional distance traveled by an individual lynx in a particular overstory type and availability was defined as the total percent of that overstory type within the home range.

Table 6. Characteristics, location and ownership of 36 grids where winter 2005 density of snowshoe hares was surveyed (pellet counts conducted during spring 2005) and where forest structural characteristics were measured in summer 2005, northern Maine.

| Stand ID | Forest Type | Township | Landowner |
|---|---|---|---|
| JH01C | 1982 conifer clearcut, herbicided in 1988 | T4R11 | Great Northern/ Nexfor |
| JH02C | 1979 conifer clearcut, herbicided in 1983 | T4R11 | Great Northern/ Nexfor |
| JH03C | 1981 conifer clearcut, herbicided in 1984 | T4R11 | Great Northern/ Nexfor |
| JH04C | 1983 conifer clearcut, herbicided in 1988 | T5R11 | Great Northern/ Nexfor |
| JH05C | 1976 conifer clearcut, herbicided in 1985 | T4R11 | Great Northern/ Nexfor |
| JH54C | 1974 conifer clearcut, herbicided in 1982 | T5R11 | Great Northern/ Nexfor |
| JH56C | 1976 conifer clearcut, herbicided in 1983 | T4R11 | Great Northern/ Nexfor |
| AF1 | 1994-1995 mixed selection harvest | T5R11 | Great Northern/ Nexfor |
| AF2 | 1994-1995 mixed selection harvest | T5R11 | Great Northern/ Nexfor |
| AF3 | 1995 mixed selection harvest | T5R11 | Great Northern/ Nexfor |
| AF4 | 1995 mixed selection harvest | T5R11 | Great Northern/ Nexfor |
| AF5 | 1992,1995 mixed selection harvest | T4R11 | Great Northern/ Nexfor |
| AF7 | 1994 mixed selection harvest | T4R11 | Great Northern/ Nexfor |
| SM2C | 1982 conifer/hardwood clearcut | T12R12 | Irving LLC |
| SM4B | 1980s conifer/hardwood clearcut | T12R11 | Irving LLC |
| SM4C | 1983 hdwd/cnfr salvage, herbicided in 1987 | T11R12 | Clayton Lake Woodlands |
| SM4D | 1985 conifer clearcut, herbicided in 1992 | T11R11 | Clayton Lake Woodlands |
| CLREG1 | 1976 conifer clearcut, herbicided in 1997 | T11R13 | Clayton Lake Woodlands |
| CLREG2 | 1975 conifer clearcut, herbicided in 1994 | T11R13 | Clayton Lake Woodlands |
| CLREG3 | 1984 conifer clearcut, herbicided in 1988 | T11R10 | Clayton Lake Woodlands |
| CLREG4 | 1984 conifer clearcut, herbicided in 1988 | T11R10 | Clayton Lake Woodlands |
| S11 | stage 1 shelterwood* | T11R12 | Clayton Lake Woodlands |
| S12 | stage 1 shelterwood | T11R17 | TNC |
| S13 | stage 1 shelterwood | T11R17 | TNC |
| S14 | stage 1 shelterwood | T9R13 | Seven Islands Land Co. |
| S15 | stage 1 shelterwood | T8R12 | Seven Islands Land Co. |
| S16 | stage 1 shelterwood | T8R12 | Seven Islands Land Co. |
| S17 | stage 1 shelterwood | T11R13 | Clayton Lake Woodlands |
| S21 | stage 2 shelterwood** | T11R14 | Clayton Lake Woodlands |
| S22 | stage 2 shelterwood | T11R14 | Clayton Lake Woodlands |
| S23 | stage 2 shelterwood | T11R14 | Clayton Lake Woodlands |
| CLSH1 | 1995 mixed selection harvest | T11R14 | Clayton Lake Woodlands |
| CLSH2 | 1996 mixed selection harvest | T10R14 | Clayton Lake Woodlands |
| CLSH3 | 1995 mixed selection harvest | T11R14 | Clayton Lake Woodlands |
| CLSH4 | 1996 mixed selection harvest | T11R14 | Clayton Lake Woodlands |
| CLSH5 | 1996 mixed selection harvest | T11R13 | Clayton Lake Woodlands |

* Stage 1 shelterwood refers to a harvesting method that includes at least one entry and leaves a significant portion of the conifer canopy intact.
**Stage 2 shelterwood refers to a harvesting method that includes at least two entries and removes at least 75% of the conifer canopy trees.

Figure 19. Density (mean + SE) of snowshoe hares during winter 2005 across two study areas and three forest harvesting treatments in northern Maine (CLPH = partial harvest stands on the Clayton Lake study area, CLR = regenerating clearcuts on the Clayton Lake study area, S = shelterwood stands, TPH = partial harvest stands on the Telos study area, TR = regenerating clearcuts on the Telos study area).




## PRELIMINARY RESULTS AND DISCUSSION

Hare densities ranged from 0.26-1.64 hares/ha in partial harvest stands and from 1.09-4.17 hares/ha in regenerating conifer stands. Mean densities of hares supported in the Clayton Lake and Telos regions were similar (Figure 19). Mean hare densities were between 0.8 and 0.9 hares/ha in established (>10 years since harvest) partial harvests and shelterwood cuts. The highest hare densities were observed in the regenerating clearcut stands (15-30 years post-harvesting) on the Clayton Lake (mean = 2.65 hares/ha) and Telos (mean = 1.85 hares/ha) study areas.

Townships that were formally surveyed for lynx occurrence with >55 km of survey effort numbered 17 in 2003, 17 in 2004, and 13 in 2005 (Figure 20). A total of 227 lynx tracks were observed in those 47 towns. Home range-sized areas are being simulated around occurrence and non-occurrence points and non-overlapping areas will be compared using logistic regression models during 2006.

Based on our snowtracking studies of radio-collared individuals, lynx selected tall mid-successional clearcuts (4.4-7.3 m, 11-26 years post-harvest) and established partially harvested stands (11-21 years post-harvest) and they selected against short mid-successional clearcuts (3.4-4.3 m, 11-26 years), recent partially harvested stands (1-10 years), and mature second-growth stands (>40 years, coniferous, deciduous, and mixed coniferous-deciduous) (Figure 21). We documented the observed and expected number of hare kills by lynx across the six forest stand types that we studied. More hares than expected were killed in mid-successional short and tall regenerating clearcuts. Fewer kills than expected were observed in recent partial harvest and in mature stands, and in road edges (Table 7). The complexity of foraging paths was greater in established (>10 years since harvest) partial harvest and in mid-successional tall stands than in recent partial harvest and mid-successional short stands (Table 7). Detailed results and interpretations from this work will be presented to the CFRU Advisory Committee at their upcoming January 2006 meeting.

Figure 20. Lynx locations (red dots) found during ecoregional surveys (routes in black lines) conducted by the Maine Department of Inland Fisheries and Wildlife during the winters of 2003-2005 in northern Maine.

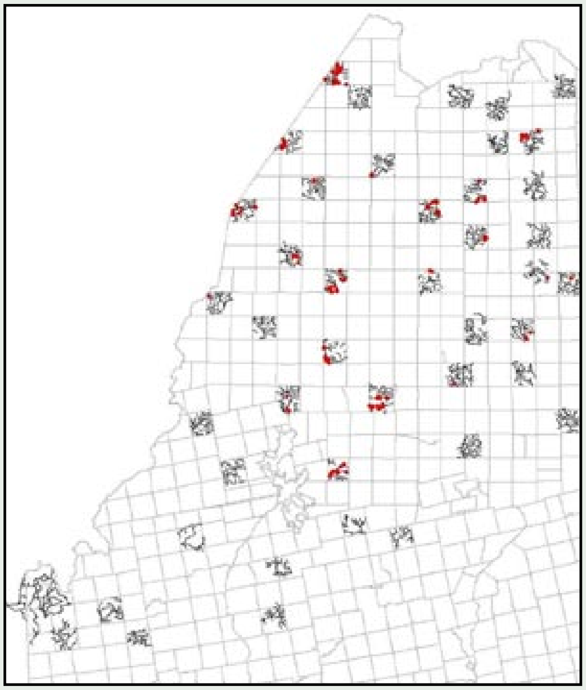
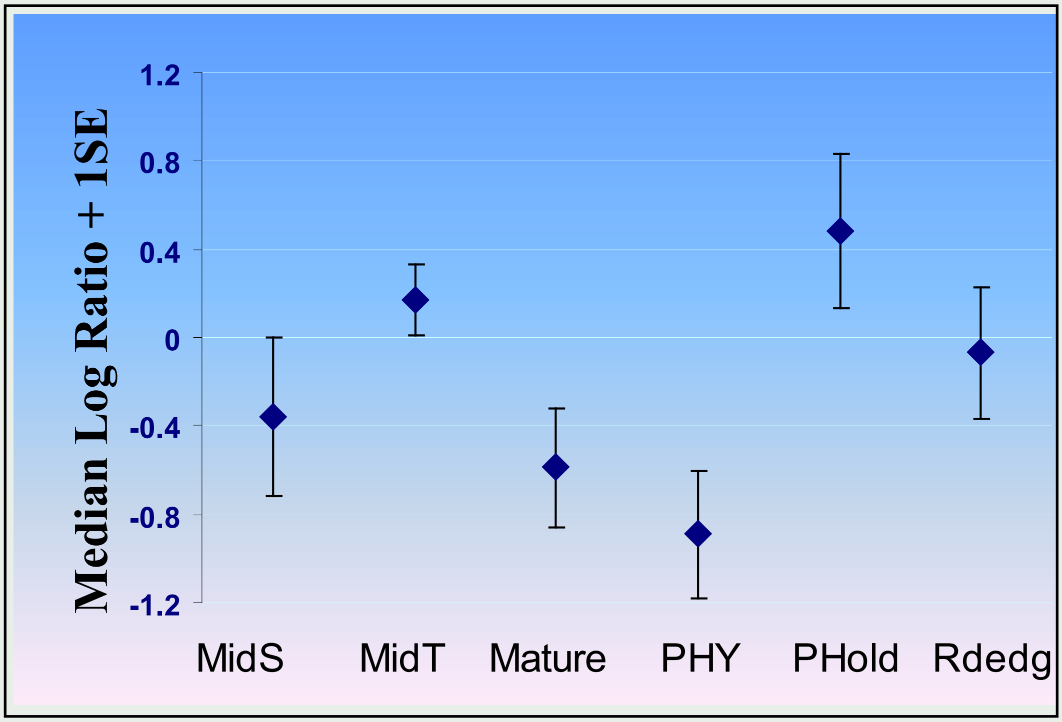


Figure 21. Stand-scale habitat selection by six radio-collared lynx (3 males, 3 females) as revealed by back-tracking in the snow. Values greater than zero indicate positive selection, and values less than zero indicate avoidance of a stand type (MidS = short regenerating clearcuts, MidT = tall regenerating clearcuts, mature = uncut second-growth stands, PHY = recent partial harvests, Phold = established partial harvests, Rdedg = road edge).




## PROJECT STATUS AND TIMELINE

We will use Analysis of Variance (ANOVA) to determine if hare densities in regenerating conifer stands are statistically different from those in partial harvest stands and if hare densities change over time in these two stand types. We will use Principle Components Analysis (PCA) to identify correlated vegetation variables and will use multivariate statistic methods to determine which vegetation variables are important in predicting hare density. We will then use an information-theoretic approach to select models that best describe hare density in terms of important vegetation variables. We will use logistic regression and Akaike's Information Criteria (AIC) to identify biological variables that are important in describing lynx occurrence in northern Maine and will validate this model with reserve data. Finally we will use model outputs to predict and map the probability of lynx occurrence throughout northern and western Maine. We have completed field work and expect to finish modeling and data analysis by May, 2006.

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Table 7. Mean fractal dimension of movement paths and observed and expected number of snowshoe hares killed by Canada lynx in northern Maine during winters 2002 and 2003.

| Habitat Type[b] | Snowshoe Hare Kills[a] # Observed | # Expected | Fractal Dimension Males | Females |
|---|---|---|---|---|
| **Mid-successional short** | 5 | 3.2 | 1.06 | 1.11 |
| **Mid-successional tall** | 8 | 4.0 | 1.09 | 1.13 |
| **Partial harvest recent** | 1 | 1.5 | 1.04 | 1.08 |
| **Partial harvest established** | 1 | 1.0 | 1.09 | 1.16 |
| **Mature** | 0 | 1.6 | - | - |
| **Road edge** | 0 | 1.8 | - | - |

[a] Expected values were calculated based on the percent of the habitat type within home ranges.
[b] Habitat types: Mid-successional short = 11-26 years old, 3.4-4.3 m tall regenerating clearcut, Mid-successional tall = 11-26 years old, 4.4-7.3 m regenerating clearcut, Partial harvest young = 1-10 years old, Partial harvest established = 11-21 years old, Mature = >40 year old second-growth stands, Road edge = 30 m on both side of roads.


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*CFRU Cooperators look at amphibian enclosures during the 30th Anniversary Fall Field Tour at the Penobscot Experimental Forest.*

# Biodiversity

Headwater Stream Study

Cutting Wood and Maintaining Late-Successional Forest Attributes

Biodiversity

# HEADWATER STREAM STUDY

**Ethel Wilkerson and John M. Hagan**

In 2001 we began this 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. This study was prompted by concerns about the impacts of timber harvesting on very small perennial headwater streams, where currently there are no shade or buffer requirements in state regulations. Our goal was to understand the effects on streams of leaving no buffer, or 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 elected to continue the study to monitor the timing of temperature recovery. We now have obtained two more years of temperature data from the experimental streams. This report provides water temperature results for all five field seasons (2001-2005) and data on recovery of riparian plant communities and canopy cover. We also report on macroinvertebrate community data that was collected in the first and second post-harvest years (2002-2003).

Table 8. Harvest treatments used in this study.

| Treatment | Harvest Prescription | Replicates |
|---|---|---|
| 0-m 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 |
| | | |

A manuscript summarizing the stream temperature results entitled, "The effectiveness of different buffer widths for protecting headwater stream temperature in Maine", has been accepted to the journal, Forest Science. A manuscript summarizing the water quality and macroinvertebrate and periphyton communities has also been submitted for publication.

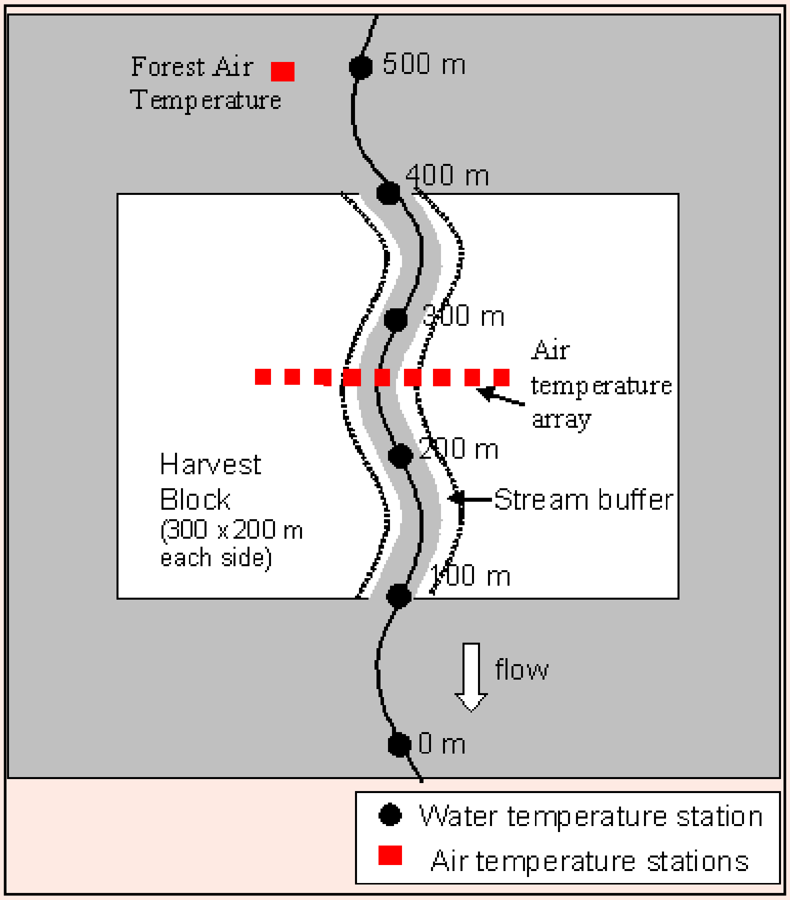
## STUDY DESIGN

In 2001 we assigned 15 headwater (1st order) streams in western Maine to one of five study treatments (Table 8). All streams were measured for water temperature and water chemistry parameters both before harvest (2001), and after harvest (2002-2005). In 2005, as in previous years, we deployed six automatic temperature recorders at 100-m intervals along a 500-m study reach in each of the 15 study streams (Figure 22).

## SUMMARY OF RESULTS

Mean weekly maximum water temperature at the lower boundary of the harvest zone (100 m station, Figure 22) increased 2.0-3.4°C in the 0-m (no buffer) treatment group and 0.1-2.3°C in the 11-m buffer treatment groups during the first three post-harvest years (2002-2004) (Figure 23). No temperature change was detected in 23-m buffer treatment streams or in partial-cut streams as a result of the harvest. In 2004, a cool summer (air temperatures 1.9-3.3°C below the pre-harvest year) resulted in smaller

Figure 22. Harvest layout.




Thus, four years after harvest there is still no evidence of stream temperature returning to pre-harvest levels in the 0-m or 11-m treatment groups. The average increase in stream temperature on the no-buffer streams in 2005 was only 0.2°C less than the highest temperature increase observed in the second post-harvest year (2003). For the 11-m treatment streams, temperature remains elevated above pre-harvest levels in 2005, but the temperature increases were smaller than those observed in the first two post-harvest years (the third post-harvest year [2004] showed no temperature increase due to abnormally cool air temperatures).

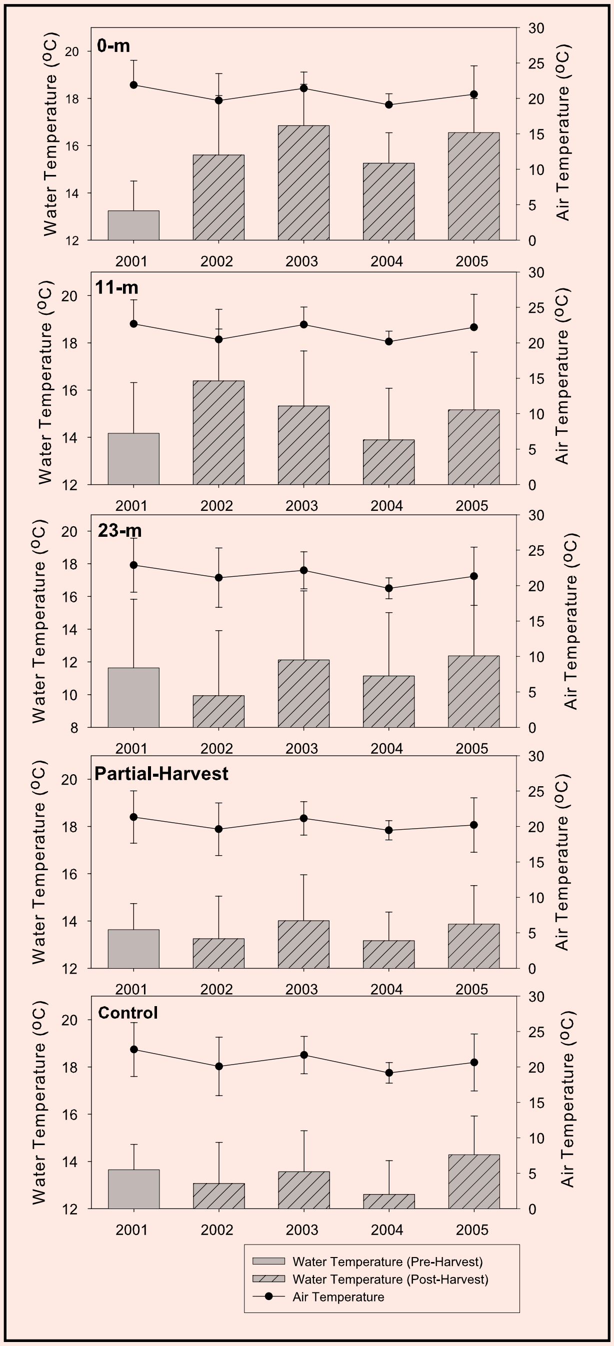
Temperature recovery is not likely to occur until inputs of solar radiation to the stream channel are reduced. Low vegetation (shrubs and saplings) and in-stream woody debris and slash can partially shade the stream from solar radiation and mitigate temperature changes associated with harvesting (Feller 1981). To better understand the relationship between understory vegetation and stream temperatures, we have monitored the height of the streamside understory vegetation and shade over the stream bed.

temperature effect in the 0-m and 11-m treatment streams, and cooler stream temperatures in the 23-m, partial harvest, and control treatment streams (Figure 23).

In 2005, the fourth post-harvest year, air temperature was within 0.5-1.8°C of pre-harvest levels (i.e., similar climatically). The average stream temperature in the 0-m treatment group was 3.2°C greater than the pre-harvest year, and similar to increases observed in the first post-harvest year. It appears that for the no-buffer streams, water temperature has not started to moderate, even four years after the harvest. Stream temperature in the 11-m buffer group was 1.1°C above pre-harvest levels four years following the harvest (Figure 23). Not surprisingly, in 2005 we continued to observe no changes in water temperature in the 23-m, partial harvest, and control treatment groups in any of the post-harvest years (Figure 23).

Within the harvest zone of the 0-m treatment group maples (red and sugar), hobblebush, ferns, flowering herbaceous plants, and raspberry dominate the understory vegetation (Table 9a). The height of the understory vegetation has rapidly increased following the timber harvest. The average height of all species of understory vegetation was 0.43 m in the second post-harvest year (2003), 0.69 m in the third post-harvest year (2004), and 0.76 m in the fourth post-harvest year (2005) (Table 9a). As the height of the understory vegetation has increased so have shade levels over the stream channel. Canopy closure has increased 10% in the four years following the harvest but remains 62% below pre-

Figure 23. The mean weekly maximum temperature from June 15- August 15 in the pre-harvest year (2001) and the four post-harvest years (2002-2005). 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.




harvest levels (Table 10). So far, the growth of understory vegetation and subsequent increase in shade levels in the 0-m treatment group has done little to mitigate the post-harvest increases in temperature. It is unclear how much shade is required to moderate temperature increases or the time period required for that level of shade to develop.

In the 11-m treatment group shade levels decreased only slightly after harvest (by 9%) due to removal of trees beyond the prescribed 11-m buffer (Table 10). Since the second post-harvest year, the height of the understory vegetation has increased only 0.13 m (Table 9b) and shade levels have increased 8% to within 1% of pre-harvest levels (Table 10). However, average stream temperatures remain 1.1°C above pre-harvest levels (Figure 23). The increased shade levels seem to have moderated increases in stream temperature; in 2005, temperature increases were 1.2°C below those observed in the first post-harvest year. We will continue to monitor stream temperatures, understory vegetation, and shade levels in 2006 and 2007 to track temperature moderation and recovery in the 0-m and 11-m treatment groups.

### Macroinvertebrate Communities

Macroinvertebrate samples were collected near the downstream boundary of the harvest zone (100 m station, Figure 22) in the first and second post-harvest years (2002-2003). Samples were collected in the spring in accordance to procedures developed by the Maine Department of Environmental Protection (Davies and Tsomides 2002). Taxonomic analysis of the macroinvertebrate samples showed that all treatment groups were dominated by the order Diptera, which represented between 48-64% of the sample in 2002 and 42-66% in 2003 (Table 11). Order Diptera contains midges (Chironomidae), black flies (Simulidae), mosquitoes (Culicidae), deer/horse flies (Tabanidae), no-see-ums (Ceratopogonidae), and other species of flies. Along with Diptera the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) made up over 90% of the species identified in the samples. There was little variability in community composition among the treatment groups in both years sampled (Table 11). This indicates that timber harvesting, regardless of buffer prescription and observed changes in stream temperature, did not alter the composition of the macroinvertebrate communities in our headwater streams.

The Maine Department of Environmental Protection (DEP) developed a classification system for macroinvertebrate communities based on statistical decision models (see Davies and Tsomides 2002). Comparing community structure data from our headwater streams sites to other streams across the state, the DEP model determined that the majority of our study sites met the criteria for Class A waterways. Class A waterways are defined as providing "natural habitat for aquatic life …aquatic life should be as naturally occurs" (Davies and Tsomides 2002). Out of the 15 streams in our study 11 sites in 2002 and 12 sites in 2003 were determined to

Table 9. Occurrence (% of total plots) and average height (m) of the dominant type of understory vegetation within the clearcut harvest zone of streams in the 0-m and 11-m treatment groups. Measurements were taken in $1m^2$ plots on both sides of the stream every 20 m along the stream segment in the second (2003), third (2004), and fourth (2005) post-harvest years (n=32 plots). Species can "appear" and "disappear" due to placement of $1m^2$ quadrant and determination of dominant vegetation. **nd** = not detectable.

| | 2nd Post-Harvest Year (2003) | | | 3rd Post-Harvest Year (2004) | | | 4th Post-Harvest Year (2005) | | |
|---|---|---|---|---|---|---|---|---|---|
| **Species** | **% of total** | **Ht. (m)** | **SE** | **% of total** | **Ht. (m)** | **SE** | **% of total** | **Ht. (m)** | **SE** |
| **A. 0-m (No Buffer) Treatment Group** | | | | | | | | | |
| Beaked Hazelnut | 4 | 0.76 | 0.12 | 5 | 1.42 | 0.33 | 4 | 1.20 | 0.24 |
| Fern | 24 | 0.33 | 0.03 | 18 | 0.42 | 0.06 | 17 | 0.54 | 0.07 |
| Flowering Herbs | 17 | 0.38 | 0.03 | 20 | 0.48 | 0.07 | 23 | 0.62 | 0.08 |
| Grass | 6 | 0.45 | 0.12 | 8 | 0.74 | 0.07 | 6 | 0.60 | 0.08 |
| Hobble | 14 | 0.50 | 0.04 | 12 | 0.68 | 0.08 | 13 | 0.73 | 0.09 |
| REMA | 11 | 0.39 | 0.04 | 4 | 0.56 | 0.03 | 11 | 0.96 | 0.07 |
| Sassparilla | 6 | 0.30 | 0.03 | 4 | 0.39 | 0.01 | 0 | nd | nd |
| Sedge | 8 | 0.37 | 0.04 | 9 | 0.68 | 0.06 | 1 | 0.60 | nd |
| STMA | 2 | 0.65 | 0.30 | 3 | 1.55 | 0.55 | 1 | 0.35 | nd |
| SUMA | 4 | 0.49 | 0.12 | 7 | 0.85 | 0.18 | 5 | 0.49 | 0.07 |
| Raspberry | 3 | 0.43 | 0.02 | 10 | 0.87 | 0.09 | 19 | 0.81 | 0.07 |
| All Species | 100 | 0.43 | 0.02 | 100 | 0.69 | 0.04 | 100 | 0.76 | 0.03 |
| **B. 11-m Buffer Treatment Group** | | | | | | | | | |
| Fern | 20 | 0.29 | 0.04 | 13 | 0.37 | 0.06 | 13 | 0.34 | 0.04 |
| Grass | 13 | 0.49 | 0.06 | 18 | 0.90 | 0.06 | 19 | 0.75 | 0.09 |
| Herb | 9 | 0.27 | 0.02 | 14 | 0.40 | 0.05 | 9 | 0.39 | 0.07 |
| Hobble | 16 | 0.55 | 0.04 | 23 | 0.56 | 0.05 | 24 | 0.62 | 0.06 |
| REMA | 7 | 0.33 | 0.07 | 6 | 0.56 | 0.13 | 9 | 0.54 | 0.05 |
| STMA | 9 | 0.44 | 0.03 | 7 | 0.71 | 0.12 | 6 | 0.61 | 0.10 |
| SUMA | 20 | 0.60 | 0.16 | 8 | 0.86 | 0.13 | 10 | 0.72 | 0.10 |
| Sassparilla | 4 | 0.29 | 0.03 | 5 | 0.30 | 0.03 | 8 | 0.28 | 0.04 |
| YEBI | 2 | 1.10 | 0.50 | 7 | 1.29 | 0.31 | 4 | 1.23 | 0.53 |
| All Species | 100 | 0.45 | 0.04 | 100 | 0.65 | 0.04 | 100 | 0.58 | 0.04 |

Table 10. Mean canopy closure taken 0.3 m above the stream channel in the pre-harvest year (2001), and first (2002) and fourth (2005) post-harvest years.

| | Pre-Harvest (2001) | | $1^{st}$ Year Post-Harvest (2002) | | $4^{th}$ Year Post-Harvest (2005) | |
|---|---|---|---|---|---|---|
| Treatment | Mean % | S.E. | Mean % | S.E. | Mean % | S.E. |
| 0m | 96 | 0 | 24 | 4 | 34 | 5 |
| 11m | 94 | 2 | 85 | 3 | 93 | 2 |
| 23m | 93 | 1 | 91 | 1 | 98 | 0 |
| Partial | 94 | 1 | 90 | 2 | 97 | 1 |
| Control | 96 | 0 | 94 | 0 | 98 | 0 |

be class A waterways (Table 12). The model was unable to determine a score for four sites in 2002 and two sites in 2003 because the overall number of macroinvertebrates collected from these sites was too small for the model to have acceptable predictive power. The streams that could not be assigned a score were spread out among the treatment groups and were streams that were most prone to drying in the summer months (Table 12). The A classification for the majority of our study sites further indicates that macroinvertebrate communities were not affected by timber harvesting.

## CONCLUSIONS

- Four years after harvest, stream temperatures remain elevated (3.2°C) above the pre-harvest year for the no-buffer streams despite rapid growth of understory vegetation and a 10% increase in shade levels over the stream channel. There was no substantial evidence of temperature moderation in 2005; average stream temperature was only 0.2°C lower than the peak warming post-harvest temperature we observed in the second post-harvest year (2003).
- For the 11-m treatment group in 2005, temperature also remained elevated (1.1°C) compared to the pre-harvest level but showed signs of temperature moderation. In 2005, average stream temperatures were 1.2°C below peak post-harvest temperatures observed in the first post-harvest year (2002).
- The composition of macroinvertebrate communities did not differ between harvested and unharvested sites regardless of the buffer prescription.

## PLANNED ACTIVITIES

This winter and spring we will be submitting several manuscripts for publication. In May, 2006, we will begin a fifth post-harvest field season, but we will only be measuring water temperature, water quality, understory vegetation communities, and over stream canopy closure.

Table 11. Percent composition of macroinvertebrate communities by treatment group for the first (2002) and second (2003) post-harvest years. Samples were taken near the downstream boundary of the harvest zone.

| | | % *Diptera* | | % *Ephemeroptera* | | % *Plecoptera* | | % *Trichoptera* | | % **Other** | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | n | 2002 | 2003 | 2002 | 2003 | 2002 | 2003 | 2002 | 2003 | 2002 | 2003 |
| 0m | 3 | 57 | 66 | 10 | 8 | 20 | 8 | 12 | 10 | 1 | 9 |
| 11m | 3 | 64 | 58 | 5 | 3 | 20 | 16 | 8 | 19 | 2 | 5 |
| 23m | 3 | 48 | 42 | 13 | 17 | 28 | 26 | 7 | 11 | 3 | 3 |
| Partial Harvest | 3 | 50 | 48 | 6 | 9 | 30 | 22 | 13 | 17 | 1 | 5 |
| Unharvested | 3[1] | 42 | 58 | 11 | 14 | 29 | 19 | 13 | 6 | 5 | 2 |

[1] n=3 in 2002, n=2 in 2003

Table 12. Maine Department of Environmental Protection (MEDP) classification score for macroinvertebrate communities of samples taken in the first (2002) and second (2003) post-harvest years. Class "A" waterways provide natural habitat for aquatic life. An "I" indicates the DEP model was unable to assign a classification score. The percent of wet days is calculated from the number of days flowing water was present at the downstream boundary of the harvest zone.

| | | 1st Post-Harvest Year (2002) | | 2nd Post-Harvest Year (2003) | |
|---|---|---|---|---|---|
| **Stream** | **Treatment** | **DEP Score** | **% wet** | **DEP Score** | **% wet** |
| Kibby | 0m | A | 100 | A | 100 |
| PiercePond1 | 0m | I | 64 | I | 90 |
| Skinner1 | 0m | A | 100 | A | 99 |
| Bald Mountain | 11m | I | 85 | A | 87 |
| Caratunk | 11m | A | 84 | A | 100 |
| Skinner2 | 11m | A | 100 | A | 100 |
| MassGore2 | 23m | A | 100 | A | 100 |
| Roxbury | 23m | A | 83 | A | 100 |
| Sanderson | 23m | A | 100 | A | 100 |
| MassGore1 | Partial | A | 84 | A | 63 |
| PiercePond2 | Partial | I | 61 | I | 80 |
| UpCup | Partial | A | 100 | A | 100 |
| Appleton | Control | A | 79 | A | 88 |
| Bryant | Control | I | 51 | NA[1] | 45 |
| Dud | Control | A | 100 | A | 100 |

[1] Sample was not collected due to stream drying

## ACKNOWLEDGEMENTS

Our work in 2005 was made possible by the great cooperation and support from Plum Creek Timber Co, Seven Islands Land Co., International Paper, and MeadWestvaco. We thank the CFRU, NCASI, and Manomet Center for funding this project.

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*An old snag provides both structure within a stand and accomodations for wildlife.*

Biodiversity

# Cutting wood and maintaining late-successional forest attributes

Andrew A. Whitman and John M. Hagan

In many temperate regions the loss of late-successional (LS) components in landscapes managed for wood has been one of the leading causes of the loss of forest biodiversity. Maine's forests still have a dwindling, but biologically significant component of LS forest—stands in which there is a cohort of trees 100-200+ years old. Scientific literature from temperate forests around the world suggests that these remnants likely play an important role in maintaining a region's forest biodiversity. The loss of this forest age class and its attributes from the vast working forest of northern Maine may pose a threat to maintaining well-distributed populations of native LS species in the region. One appropriate solution is to develop practical tools that land managers could use to better maintain for LS attributes in managed stands.

In 2002 the CFRU supported research to develop the LS Index, a rapid assessment procedure that can be used to quantify late-successional attributes of stands (Whitman and Hagan 2004). This procedure was developed because (1) forest managers have asked for simple, cost-effective metrics that can help quantify biodiversity, and (2) late-successional attributes tend to be the most vulnerable element of forest biodiversity in managed forests. Although developed with input from foresters, the LS Index had not been tested to determine if its use in the field improves retention of LS attributes. At the same time, it is widely recognized that riparian areas are typically lightly harvested to maintain shade and a filter strip and that riparian buffers might contain important levels of LS attributes and LS forest. Hence, the CFRU supported this study to determine (1) if using the LS Index increases the retention of LS attributes in harvested stands, above that found in standard harvest practices and (2) if riparian zones make important contributions to the retention of LS forest in managed landscapes.

*Late-successional forest structure helps maintain forest biodiversity.*

## STATUS

### LS Harvest Experiment

Before the experiment we conducted a workshop with foresters from eight landowners in April 2003. With their guidance, we developed the experimental design and identified the two treatments. At the request of the participat-

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ing foresters, we also provided a limited field training and review of a set of LS management guidelines for participating field staff:

**Goals of LS Management**

1) Maintain LS value
2) Make money cutting wood

**Guidelines**

Maintain large/old trees

1) Avoid reducing LS score more than two points (20%)
2) Avoid reducing large (>16" DBH) tree density ≥50%

Maintain ecological continuity

1) Avoid reducing LS score more than 2 points (20%)
2) Use uneven-age management
3) Leave trees with LS epiphytes
4) Avoid reducing canopy area or basal area by more than 40%
5) Leave areas un-entered
6) Grow/regenerate large (>16" DBH) /old trees
7) Avoid damaging large logs

Harvest blocks selected for the experiment were to be split into two, paired harvest units which were then assigned to one of the two harvest treatments: a control (CTRL) or LS treatment (LS). The CTRL treatment (Figure 24) was standard landowner harvest practices which were determined by the supervising forester. In the LS treatment (Figure 25), the supervising forester was to apply the LS Index to the stand, review the LS management guidelines, and retain as many of the pre-harvest LS attributes as possible while minimizing the amount of valuable timber left in the stand. The LS management guidelines had two goals: (1) to provide foresters with as much harvesting flexibility; and (2) to integrate the management of LS attributes with landowner silvicultural and economic objectives.

Participating landowners selected 12 pairs of harvest blocks for the experiment that were slated to be harvested using shelterwood or overstory removal harvesting in the late summer or fall of 2004. The stands in each pair were randomly assigned to each of the two treatments. We reviewed the LS Index and a set of LS management guidelines and discussed the integration of silvicultural, economic, and ecological objectives with each participating forester. Prior to harvesting, we scored each stand using the LS Index, counted host trees with *Lobaria pulmonaria*, *Collema* spp./*Leptogium* spp., and long (>6 in) *Usnea* spp., counted advanced regeneration, and measured and scored the economic value of trees. After harvesting we also assessed logging impacts: soil disturbance on skid roads, wounds

Figure 24. Post-harvest CTRL treatment northern hardwood stand in T11 R9 WELS (courtesy of Seven Islands Land Company).

on residual trees, condition of large logs, and canopy coverage. We used these data to assess the ecological benefits of using the LS Index and LS guidelines and the shortcomings in terms of lost revenue of unharvested timber, logging impacts, and silvicultural limitations. We present a partial analysis here.

**LS values in Riparian Areas**

We surveyed 23 PSL-2 riparian buffer sites in Kibby Township including six northern hardwood sites and 17 upland spruce-fir sites. Riparian buffer sites included buffers on 1st and small 2nd order streams.

**RESULTS**

**LS Harvest Experiment**

For northern hardwood stands, logging impacts were slightly lower in the LS treatment than the CTRL (Table 13). The LS treatment had slightly more canopy cover and slightly less skid road area with light impact and total skid road area. Stands in both treatments had about 5% of their area in severely impacted skid roads. LS treatment stands had about 1/3 less total basal area removed than CTRL stands. Percent removals of pulpwood tree basal area and sawlog and better tree basal area was statistically similar for both treatments. The LS treated stands had greater retention of large (>16" or 40 cm DBH) trees and retained a greater percentage of the original LS Index score than the CTRL stands.

For the upland spruce-fir stands, logging impacts, timber removals, and most LS attribute retention variables were statistically similar in LS treated stands and CTRL stands (Table 13). Retention of long (>6") *Usnea* spp. host trees was higher in LS treated stands and so LS treated stands better retained a greater percentage of the original LS Index score than the CTRL stands.

Overall, LS treatments were more effective in northern hardwood stands than upland spruce-fir stands. LS treatments in northern hardwood stands reduced logging impacts, maintained removals of sawlog and better trees, and well retained large trees and LS Index score. Upland spruce-fir stands in both treatments had similar logging impacts and timber removals. LS treated stands only retained a slightly greater percentage of the original LS Index score than the CTRL stands.

Figure 25. Post-harvest LS treatment northern hardwood stand in T11 R9 WELS (courtesy of Seven Islands Land Company).

Table 13. Mean (+ s.e.) logging impacts, timber removals, and retention of LS attributes for the two treatments of the LS Harvest Experiment. The two treatments were: (1) stands harvested using standard landowner practices (CTRL) and (2) stands harvested using the LS Index and applying the LS Management Guidelines (LS). Impact variables were only measured after harvest. Timber removal and LS attribute retention variables were measured pre- and post-harvest.

| | Northern Hardwoods Treatment | | | Upland Spruce-fir Treatment | | |
|---|---|---|---|---|---|---|
| Variable | CTRL | LS | t-test P-value[1] | CTRL | LS | t-test P-value[1] |
| Logging Impacts (percent cover) | | | | | | |
| Canopy cover | 44.1 (6.6) | 57.5 (9.7) | * | 41.5 (10.4) | 36.5 (13.8) | |
| Area with light skid road impact | 22.6 (3.8) | 18.0 (1.4) | * | 24.1 (2.9) | 26.1 (4.4) | |
| Area with severe skid road impact (e.g., rutting) | 5.1 (2.0) | 4.0 (1.0) | | 1.4 (0.2) | 2.4 (0.7) | |
| Total skid road area | 27.7 (3.9) | 22.0 (1.5) | * | 25.5 (3) | 28.5 (4.2) | |
| Timber removals (% basal area removal) | | | | | | |
| Pulpwood trees | 43.7 (8.6) | 29.3 (11.6) | | 52.1 (6.3) | 42.3 (5.7) | |
| Sawlog and better trees | 60.8 (9.3) | 57.3 (10.7) | | 63.2 (13.2) | 50.9 (14.2) | |
| Total Trees | 46.3 (4.3) | 29.3 (6.3) | ** | 50.1 (8.0) | 45.8 (7.5) | |
| LS Attribute Retention (% of pre-harvest levels) | | | | | | |
| *Collema*/*Leptogium* spp. (host tree density) | 51.1 (14.1) | 69.3 (15.8) | | 50.0 (50.0) | 80.0 (20.0) | |
| *Lobaria pulmonaria* (host tree density) | 73.1 (6.9) | 68.4 (7.5) | | 66.9 (14) | 79.9 (12.7) | |
| "Long" *Usnea* spp. (host tree density) | | | | 45.1 (16.6) | 69.7 (14.5) | ** |
| Large trees (≥ 40 cm DBH) | 41.2 (6.4) | 64.3 (4.6) | *** | 52.5 (17.6) | 48.7 (16.4) | |
| LS Index score | 56.4 (6.9) | 79.8 (6.7) | ** | 44.8 (16.5) | 59.5 (17.5) | ** |

[1] * P =0.2-0.1
** P>0.05
*** P>0.01



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The LS treatment approach applied in this experiment best achieved retention of LS attributes and LS Index score with little short-term sacrifice in northern hardwoods. Northern hardwood LS treated harvest units on average accomplished the goals set by the guidelines: (1) retained >50% of large trees, (2) retained LS epiphyte species, (3) retained >50% of original basal area, and (4) almost retained 20% of the original LS Index score. This LS treatment approach performed passably when applied to upland spruce-fir but not nearly as well as when applied to northern hardwoods. Upland spruce-fir treated units >50% of original basal area and LS epiphyte species but failed to (1) retain >50% of large trees, (2) retain >50% of original basal area, and (3) retain 20% of the original LS Index score. This difference in performance between the forest types was not entirely surprising. Foresters in northern Maine strongly dislike to leave trees with sound wood in partially cut spruce-fir stands as they expect to lose many retained trees to windthrow before being able to harvest the timber in the future. We will use the debriefing workshop in February to evaluate this explanation and better identify the appropriateness of this approach.

**LS values in Riparian Areas**

The average LS Index score for northern hardwood riparian buffer sites was 6.2 (s.d. = 2.1, n = 6). Four of the six northern hardwood sites scored >7 (scores typical of LS stands). The average LS Index score for upland spruce-fir riparian buffer sites was 3.7 (s.d. = 2.0, n = 17). Only one of the 17 upland spruce-fir sites scored >7 (score typical of LS stands). Hence, the ability of riparian buffers to capture LS forest stands was mediocre.

Plots in all but two (9%) of the surveyed riparian buffers contained at least one large (>16" or 40 cm DBH) tree and all but one of the riparian buffers contained at least one large (>14" or 35 cm DBH) log (4%). Riparian buffers averaged 2.4 (s.d.=4.9) large trees/acre (5.9/ha), 0.9 (s.d.=1.8) large logs/acre (2.2/ha), 1.1 (s.d.=3.9) *Lobaria pulmonaria* host tree/acre, (2.7/ha), 0.14 (s.d.=8.0) *Collema/Leptogium* spp. host trees/acre (0.35/ha), 1.1 (s.d.=5.0) long (>6") *Usnea* spp. host trees / acre (, 2.8/ha). Hence, riparian buffers retain many LS attributes but at densities lower than reported elsewhere for LS forest.

Overall, most riparian buffers contained LS attributes, many northern hardwood riparian buffers were LS stands, and few upland spruce-fir riparian buffers were LS stands. Riparian buffers may now be serving as sites for retaining low to moderate levels of LS attributes.

**OUTREACH**

This project included three outreach components: a groundwork workshop of participating landowner staff in April 2004, field training of landowner staff in summer of 2004, and debriefing workshop in February 2006. Research results were presented at two regional workshops: LSOG Dialogue, Portland, Maine, April 2005 (100 forest resource professionals from the northeastern US who reviewed LS forest conservation consideration for the northeastern US) and Ecological Forestry Workshop, western Maine, September 2005 (20 forest resource professionals from the eastern US who received training on ecological forestry techniques). A workshop for summer 2006 is being planned.

**TASKS**

1) Follow-up workshop/debriefing with landowner staff who participated in the experiment (goal: enhance participants learning experience and better assess the utility of the LS Index and LS management guidelines)(February 2006).
2) Manuscript: Can the LS index be used to improve the retention of LS to create and apply stand-level prescriptions for late-successional biodiversity: A field test .
3) CFRU Report: The contribution of riparian buffers to late-successional forest attributes
4) LS Management Workshop (July 2006)

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*On a CFRU Field Tour, Andy Whitman of Manomet Center for Conservation Sciences points out species that are indicative of late-successional forest structures.*

# Appendices

*Max McCormack stands at an old stump from some of his work at Weymouth Point.*

*Researchers from CFRU, University of New Brunswick and Mitchell Geographics interpret a new Depth-to-Water Table map.*

*CFRU and USFS scientists and staff lead a tour for Chief Dale Bosworth of the United States Forest Service at the Penobscot Experimental Forest in Bradley, Maine during September 2005.*

# 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 54 new articles, theses, reports, proceedings, and presentations to state, regional, national, and international audiences.

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## OTHER PRESENTATIONS

Wagner, R.G., Organizer and Moderator - Hardwood Markets and the Silviculture Needed To Get There New England, Special session at 85th Annual Meeting, New England Society of American Foresters, Portland, Maine. (March 2005)

Wagner, R.G., Herbicides: Mode of Action & Environmental Fate, Maine Christmas Tree Growers Association Annual Meeting, Augusta Civic Center. (January 2005)

## PUBLIC PRESENTATIONS

Harrison, D. J. Predators, prey, and forestry in northern and eastern Maine: a historical perspective. University of Maine at Machias Science Club and Downeast Salmon Federation, Machias, Maine. March 2, 2005.

Krohn, W. B. Maine's changing wildlife populations: a historical perspective. University of Maine at Machias Science Club and Downeast Salmon Federation, Machias, Maine. March 24, 2005.

Krohn, W. B. An overview of Maine's largest terrestrial predators. Senior College, University of Maine, Orono, Maine. April 1, 2005.

Wagner, R.G. Role of herbicides in forest management, St. Francis, Maine town meeting to vote on a resolution to prohibit aerial and ground application of herbicides for forestry purposes (April 2005)

*An old stump at the Weymouth Point site stands as a relic of CFRU research.*

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*CFRU members learn about research on uneven-aged management at the Penobscot Experimental Forest in Bradley, Maine.*

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*CFRU scientists at a research site assist a pilot after a crash landing.*

# Contact Information

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