Cooperative Forestry Research Unit

2004 Annual Report

MAFES MISCELLANEOUS REPORT 435

1865 THE UNIVERSITY OF MAINE

COOPERATIVE FORESTRY RESEARCH UNIT

ANNUAL REPORT 2004

CFRU

1865 THE UNIVERSITY OF MAINE

MAFES Miscellaneous Report 435

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

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Cover Photograph:

The flanks of Katahdin as seen through a two-aged spruce stand.
Spencer Meyer
2004

Contents

Introduction

The CFRU is one of the oldest industry/university forest research cooperatives in the United States. Funding to support the unit comes from private forest landowners and management organizations, wood processors, public agencies, and other contributors who want to solve specific forestry problems or generally want to advance forest management in the state of Maine through applied scientific research.

Over the last 30 years, the CFRU has influenced and been part of dynamic changes to forestry practices in the state of Maine. During that time, CFRU has served forest managers and landowners by conducting research that addressed their most pressing problems. Results from this research have been presented in over 400 publications. Several long-term research sites (e.g., Commercial Thinning Research Network, Weymouth Point, and Austin Pond) were also established and continue to be maintained.

As we enter the new century, our mission continues to be conducting applied scientific research that contributes to the sustainable management of Maine's forests. With support from 23 member organizations across the state of Maine, CFRU research is focused on the most pressing problems facing the state's forest managers and landowners. 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 notes, 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 continues to be a benefit of membership and have been a hallmark of our organization since its earliest days. This annual report documents progress made by the CFRU during fiscal year 2003-2004.

Highlights

ORGANIZATION

- Twenty-three members representing 5.3 million acres contributed $320,905 to support research activities this year (see page 14).
- Three new members (Frontier Forest, LLC, Katahdin Forest Management, and Sappi Fine Paper) joined the coop (see page 8).
- For every dollar contributed by our largest members, $11.79 of additional support was leveraged from other sources (see page 13).
- Significant progress was made in developing an alternative funding model for the long-term financial stability of CFRU (see page 18).

COMMUNICATIONS

- Two day-long workshops communicating the latest CFRU research results were held for over 100 foresters from member organizations (see page 19).
- CFRU scientists, staff, and graduate students delivered more than 13 publications and 66 presentations on their latest research results (see page 84).
- A new reference book on martens and fishers summarizing results from years of CFRU and other research was completed (see page 19).
- The CFRU logo was updated to provide a more modern look (see page 22).

RESEARCH

Silviculture

- Nitrogen fertilization can increase balsam fir volume growth by 1 cord/A/yr and yield 12% rates of return within 10 years if stands are fertilized after precommercial thinning and just before crown closure (see page 43).
- Substantial differences in wood volume recovery and financial returns were found among various methods of commercial thinning in spruce-fir stands (see page 25).
- Balsam fir seedlings were damaged more than red spruce seedlings by commercial thinning operations (see page 33).
- Increases in certain foliage chemicals may provide an early indication of tree stress after commercial thinning (see page 40).
- Two graduate student theses completed this year revealed how leaf area can be used to predict stand growth and understand density relationships (see pages 36 and 38).
- A new study on growing space reallocation after commercial thinning promises greater insight into the most effective methods of thinning (see page 30).
- A new version of SPOT (Stand Product Optimization Tool) was released (see page 47).
- A draft Northern Hardwood Growth and Yield model was sent to members for review (see page 52).
- An annotated bibliography about managing competing vegetation in young hardwood stands was completed (see page 54).

Wildlife Ecology

- Canada Lynx were found to prefer 11-22 yr old clearcuts in a mid-successional condition (trees 11-14 ft tall) (see page 56).
- Snowshoe hare populations, a crucial prey for Canada Lynx, appear to be relatively stable in Maine clearcuts that have been treated with herbicides, and appear to not follow cycles typically found in northern Canada and Alaska (see page 61).
- Managing forest landscapes for lynx and marten habitat needs appears to also provide suitable habitat for >85% of forest wildlife species (see page 64).

Biodiversity Conservation

- Significant progress was made toward developing a practical index of late-successional conditions for managed forest stands (see page 69).
- A new early-successional index is helping identify which managed forest conditions provide the best bird habitat (see page 79).
- Third-year measurements reveal how forested buffers of different widths affect stream water and air temperatures in harvested areas (see page 74).

Membership

Major Cooperators

Baskahegan Company
Clayton Lake Woodlands
FraserPapers, Ltd.
Frontier Forest, LLC
Hancock Timber Resource Group
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

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

The CFRU had a net loss of three members this year, going from 27 members in 2003 to 23 in 2004. As presented in the 2003 Annual Report, the recent sale of **MeadWestvaco** and **Maine Timberlands** significantly reduced member acres. The loss of **International Paper**, apparently as a precursor to the sale of all their Maine lands late this year, had the most dramatic effect on the CFRU dues base. The loss of four other members this year (**Pride Manufacturing**, **H. O. Bouchard**, **F. A. Madden**, and **Bethel Furniture Stock**) caused a reduction in member numbers, but only a very minor reduction in dues. The overall impact of these changes was a 24% reduction in member acres from 6.88 million in 2003 to 5.25 million in 2004.

To balance off these losses, CFRU was very fortunate to gain **Frontier Forest, LLC**, **Katahdin Forest Management**, and **Sappi Fine Paper** as new members of CFRU. **Frontier Forest** (represented by **Steve Coleman** of **Landvest**) and **Katahdin Forest Management** (represented by **Marcia McKeague**) return acres that were formerly in CFRU. The addition of **Sappi Fine Paper** (represented by **Carl Jordan**) as a new mill owning member reflects a new trend that we would like to build on with other mills in the state. We welcome these new members and their representatives to the Advisory Committee.

The impact of all CFRU membership changes was a 20% reduction in dues from $403,060 in FY02-03 to $320,905 in FY03-04. Had our three new members not joined, our dues base would have been reduced by 32% this year. Despite this reduction, CFRU has been able to maintain a high level of quality research activity, leverage a significant amount of funds from other organizations, and come in under budget.

CFRU was very fortunate to gain **Frontier Forest, LLC**, **Katahdin Forest Management**, and **Sappi Fine Paper** as new members.

A significant push will be made over the next year to reverse the loss of member support by pursuing membership from those institutional investors that have purchased so much of Maine's forestlands over the past five years. Contact is being made with **GMO Renewable Resources**, the company that recently purchased International Paper's lands, as well as the clients represented by **Prentiss & Carlisle**. We also will be making contact with other institutional investors and large owners of Maine's working forest. Concurrent with this effort to revitalize CFRU's membership base is an initiative to achieve long-term funding stability through a proposed Forest Research Commission similar to the Wild Blueberry Commission of Maine and the Maine Potato Board.

People

Staff

Robert G. Wagner
Director and Professor of Forest Ecosystem Science

Daniel J. McConville
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

Chair's Report

Another productive year has occurred for the Cooperative Forest Research Unit. This was my first year as Chair of the Advisory Committee. I have been involved with the CFRU since I began working in Maine in 1999, but being Chair of the Advisory Committee enables one to more than ever appreciate the effort and enthusiasm that the CFRU staff demonstrates on an ongoing basis. I would like to thank the immediate past Chair, **Doug Denico** for his dedication and leadership during the past two years of his term as Chair of the Advisory Committee.

Accomplishments and noteworthy events that have taken place over the past year include:

New Members
As of the Spring Meeting in 2004 there has been the addition of three new members to the Advisory Committee: **Frontier Forest, LLC**, **Katahdin Forest Management**, and **SAPPI Fine Paper**. SAPPI Fine Paper is the first "Mill Member." It is very encouraging to have these new members make this financial commitment and become full members of the Advisory Committee. I would like to welcome these new members and their individual perspectives to the discussions.

Staff Changes
In the Fall, **Dan McConville** decided to leave CFRU for a position in the private sector. Dan joined the CFRU Staff in May, 2000 and has been a great asset to the unit. Dan has been involved with many of the activities of the CFRU over the past four years including managing the Commercial Thinning Field Study, updating the website, organizing Fall Field Tours and information sessions with foresters, preparing Annual Reports, revising the CFRU brochure, and developing communication bulletins. Dan's dedication, enthusiasm and hard work will be missed by the Advisory Committee and the CFRU staff. I would like to wish Dan good luck in his new endeavors.

The CFRU has undertaken a national search to fill the Research and Communications Director position. In the interim, Spencer Meyer is temporarily filling this position.

I would like to welcome **Dana Smith**, as the Administrative Assistant. Dana has been very busy since she began in the Fall and has done an excellent job.

Forester's Workshops
In an effort to present new research information to foresters and land managers, a day-long workshop was held in Ashland in May. Over 70 people were in attendance for this information session, where the CFRU cooperating and project scientists presented the results to their research projects and how these results can be used to assist foresters and land managers in their land management decisions. This was an excellent method to communicate up-to-date research results to forestry professionals. CFRU staff and scientists did an excellent job to make the information understandable and demonstrate how the results can be applied to "on-the-ground" applications. Other workshops will be planned for the future.

Fall Field Tour and Meeting
A fall field tour was conducted over two days at the end of October in the Ashland area. The first day of the meeting was our Advisory Committee business meeting. The second day was a field tour in the Northern Maine Woods with various stops that centered around the theme of "Forest Management for Conservation Objectives." During the field tour the Advisory Committee members had the opportunity to discuss

lynx habitat requirements, management of late-successional hardwood stands, management of unique natural communities, and patch retention as a tool for conserving biodiversity. I would like to thank **Seven Islands Land Company** and **The Nature Conservancy** for hosting the tour and the cooperating scientists and **Inland Fisheries & Wildlife Biologists** for presenting information during the tour.

Research Priorities Survey

A survey of our research priorities was undertaken in the fall. This survey is carried out every five years to provide Advisory Committee members the opportunity to assess their research priorities. The results of the survey are used to provide direction for CFRU funding decisions and determine the areas where the cooperating scientists should direct their research.

Research

Over the past year many research projects have been completed and continued funding for the ongoing projects are described in this report. The CFRU is continuing to provide funding opportunities to research projects that provide information to land managers on the important issues affecting forest management in Maine. Research projects are ongoing in the areas of hardwood and softwood silviculture, wildlife ecology, and biodiversity conservation. I would like to thank the cooperating scientists, **Mike Greenwood**, **John Hagan**, **Dan Harrison**, and **Bob Seymour** and the project scientists, **Tim McGrath**, **Ralph Nyland**, and **Andrew Whitman** for their continuing efforts.

After looking back at all the accomplishments that have occurred during 2004, one would have to conclude that the CFRU had another successful year. I would like to thank all the members of the Advisory Committee, who all put forth a great effort and have expressed a sincere desire to improve the knowledge base of issues affecting the forest industry in Maine. On behalf of the Advisory Committee I would like to thank **Bruce Wiersma** and the University for continued support during times of increasing budget constraints. I would also like to thank **Bob Wagner** for providing stability and positive direction to the CFRU. The accomplishments of the unit would not have been possible without Bob's leadership and dedication.

In 2005 the Cooperative Forest Research Unit will be celebrating it's 30th Anniversary. The unit has provided the practical and vital answers to many of the issues affecting the forest land management in Maine. I am excited about celebrating this great accomplishment and looking forward to the next 30 years!

Hugh Crammond
Chair, CFRU Advisory Committee

Director's Report

In contrast to last year, where we saw a significant loss of CFRU members due to land sales, this year saw an increase of three new members. We welcome **Frontier Forest, LLC**, **Katahdin Forest Management**, and **Sappi Fine Paper** as new members of the CFRU. In addition, our research activity remains high and we were able to bring the CFRU in under budget once again. As a result, our financial picture for next year is brighter than last year at this time.

The quality of CFRU research comes from the dedication of our scientists. I extend special thanks 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. This year also saw several significant staff changes. **Julie Kahler** left as Administrative Assistant. Julie did a great job organizing the CFRU office. We were very fortunate to have **Dana Smith** take on responsibilities as the new CFRU Administrative Assistant. Dana has substantial experience at the University of Maine and I look forward to working with her in her new position. We also were very fortunate to have **Rob Keefe** join the Commercial Thinning project this year to lead the field crew and develop models on stand responses to commercial thinning. Two CFRU graduate students, **Justin DeRose** and **Spencer Meyer**, also completed excellent M.S. theses using the Commercial Thinning Network sites.

Our most significant staff change came from the departure of **Dan McConville** after five years to pursue an opportunity with one of our CFRU members. I want to personally thank Dan for his excellent work coordinating the research and communications activities for the unit. Dan and I worked closely together after the restructuring of the CFRU in 2000, and he can take credit for much of the way the unit looks today. During his tenure, Dan installed and maintained our Commercial Thinning Network sites, developed the SPOT program, organized many workshops and field tours, improved the web page, developed the electronic publication retrieval system, produced research reports and posters, developed new research projects, and improved the format for this annual report. We all wish Dan the best of luck in his new career. It will be difficult filling Dan's shoes in the coming year.

We also made significant progress during the year with developing alternative funding models for the CFRU. Thanks to the leadership of **Peter Triandafillou** (Huber Resources), **Steve Schley** (Pingree and Associates), **Jim Robbins** (Robbins Lumber), and **Alec Giffen** (Maine Forest Service) a proposal for a Forest Research Commission was more fully developed. I look forward to continued discussion and development of this proposal as we seek to provide a sustainable funding approach for the CFRU.

The success of the unit relies on the participation of it member organizations. The Advisory Committee is the focal point of this participation and it ultimately determines the success of the CFRU in meeting the needs of its member organizations. This year **Doug Denico** (Plum Creek) completed his term as Chair of the Advisory Committee. Special thanks go to Doug in providing substantial leadership during a turbulent period of membership. Doug's insight and determination guided us through a difficult period. I thank **Hugh Crammond** (Irving Woodlands) for his guidance and support as Chair during the past year. I also thank **Kenny Fergusson** (Huber Resources) and **Mike Dann** (Seven Islands) who agreed to serve as Co-Chair and Member-at-Large, respectively, this year.

Robert G. Wagner

Robert G. Wagner
CFRU Director

Financials

Twenty-three members representing 5.3 million acres contributed $320,905 to support CFRU activities this year (Table 1). This amount was $43,968 (16%) more than was invoiced due to the addition of three new members. We welcomed **Frontier Forest, LLC**, **Katahdin Forest Management**, and **Sappi Fine Paper** to the CFRU this year. Sound fiscal management by CFRU project scientists and staff resulted in spending $38,161 (8.6%) less than was approved by the Advisory Committee (Table 2). The savings came primarily from reduced administrative expenses from the departure of our administrative assistant and cost-sharing with other projects in measuring commercial thinning network plots. These savings were returned to the central account for future use on other CFRU projects.

CFRU spent 64% of its budget for research projects and 36% for administration, including staff/scientist salaries and other expenses (meetings, field tours, web maintenance, data bank, travel, safety, phones, printing). Research expenses were divided among five silviculture projects (35%), two wildlife ecology projects (19%), and four biodiversity conservation projects (46%) (Table 2). Using contributions from CFRU members, project scientists were able to leverage an additional $168,914 from other sources to support CFRU-sponsored research projects. When added to the $55,729 in-kind contributions from the University of Maine, the total value of CFRU research during this fiscal year was $545,548 or 70% above member contributions (Figure 1). The real power of leveraging, however, comes from CFRU members pooling their resources. For example, for every dollar contributed by our five largest members this year, they received $6.52 from other member contributions, $3.96 from external funding sources, and $1.31 from in-kind contributions from the University of Maine. Therefore, every dollar contributed by the largest CFRU members leveraged an additional $11.79 to support their highest priority research projects (Figure 2).

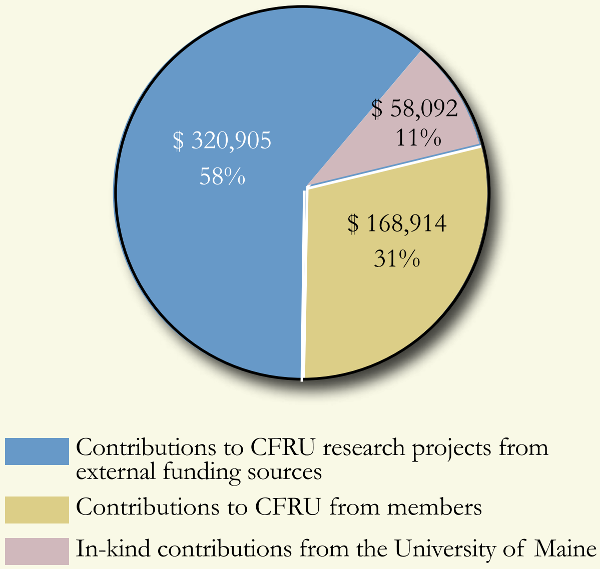


Figure 1. CFRU members contributed $320,905 this year. An additional $168,914 was leveraged from external funding sources, and the University of Maine contributed $58,092 of in-kind support.

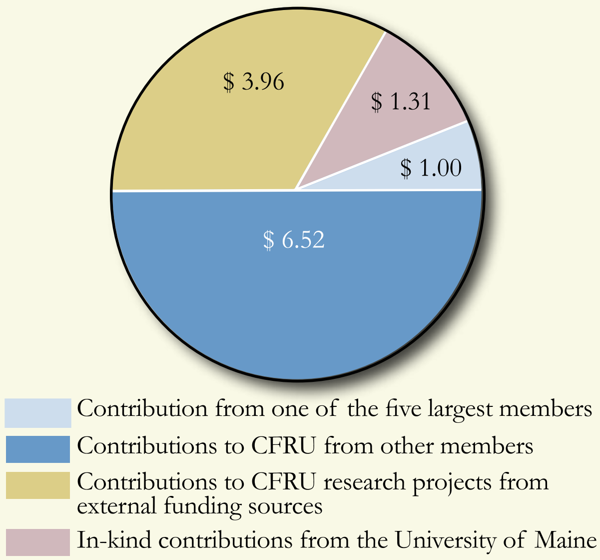


Figure 2. For every dollar contributed by one of our five largest members they received $6.52 from other members, $3.96 from external funding sources, and $1.31 from in-kind contributions by the University of Maine.

Table 1. CFRU cooperator contributions during FY 2003-04.

Cooperator	2004 Reported Acres	Amount Invoiced (Jan 2004)	Amount Received	Balance
Irving Woodlands, LLC	1,430,000	$76,500	$76,500	$0
Seven Islands Land Company	880,000	$48,700	$48,700	$0
Plum Creek Timberlands	863,000	$47,808	$47,808	$0
Maine Bureau of Parks and Lands	380,000	$21,850	$21,850	$0
Huber, J. M. Corporation	320,000	$18,400	$18,400	$0
Hancock Timber Resource Group	114,808	$6,601	$6,601	$0
Clayton Lake Woodlands	245,000	$14,088	$14,088	$0
Fraser Papers	236,614	$13,605	$13,605	$0
The Nature Conservancy	165,447	$9,513	$9,513	$0
Baskahegan Lands	101,629	$5,844	$5,844	$0
Prentiss and Carlisle	84,755	$4,873	$4,873	$0
Ste. Aurelie Timberlands	60,000	$3,450	$3,450	$0
Robbins Lumber Company	27,411	$1,576	$1,576	$0
Frontier Forest, LLC	53,338	$0	[1]$2,667	$0
Katahdin Forest Management	293,000	$0	[1]$16,848	$0
Sappi Fine Paper	0	$0	[1]$25,446	$0
Huber, J. M. Corporation, Wood Products	0	$1,500	$1,500	$0
Hancock Lumber Company, Inc.	0	$1,000	$1,000	$0
Landvest	0	$200	$200	$0
Field Timberlands	0	$100	$100	$0
Finestkind Tree Farms	0	$100	$100	$0
Western Maine Nurseries, Inc.	0	$100	$100	$0
Peavey Corporation	0	$137	$137	$0
TOTAL	5,255,002	$276,938	$320,905	$43,968

[1]New members who joined during FY03-04.

Table 2. CFRU project expenditures and balances for FY2003-04 (as of December 20, 2004).

Project (PI)	Approved amount	Amount spent	+ / -	%
Administration	$ 169,142	$ 145,033.73	$ 24,108.27	14.3%
Silviculture:				
Maine Commercial Thinning Research Network (Wagner/Seymour)	$ 66,974	$ 56,078.18	$ 10,895.82	16.3%
Factors affecting the regeneration and early growth of balsam fir and red spruce (Greenwood)	$ 4,000	$ 1,663.43	$ 2,336.57	58.4%
Remeasurement of CFRU fertilizer studies (Wagner/McConville)	$ 22,137	$ 22,116.71	$ 20.29	0.1%
Using the Stand Product Optimization Tool for analyzing harvest utilization problems (McConville)	$ 5,000	$ 4,200.00	$ 800.00	16.0%
Northern Hardwood growth and yield model (McGrath)	$ 6,300	$ 6,300.00	$ 0.00	0.0%
Wildlife Ecology:				
Snowshoe Hare-Canada Lynx responses to harvesting (Harrison)	$ 22,000	$ 22,000.00	$ 0.00	0.0%
Evaluating the umbrella species approach for biodiversity conservation on commercial forestlands in Maine (Harrison)	$ 28,500	$ 28,500.00	$ 0.00	0.0%
Biodiversity Conservation:				
Indicators for maintaining biodiversity in managed forests (Hagan)	$ 35,000	$ 35,000.00	$ 0.00	0.0%
Developing an index of biodiversity for early-successional biodiversity (Hagan)	$ 24,371	$ 24,371.00	$ 0.00	0.0%
Using the Late-Successional Index of biodiversity to document biodiversity contributions to sustainable forestry (Hagan)	$ 20,000	$ 20,000.00	$ 0.00	0.0%
Continued monitoring of the recovery of headwater stream water temperature following prescribed harvesting, and development of a riparian index of biodiversity (Hagan)	$ 40,000	$ 40,000.00	$ 0.00	0.0%
TOTAL	$ 443,424	$ 405,263	$ 38,161	8.6%

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

John Brissette	USFS Northeast Forest Experiment Station
Tom Charles	Maine Bureau of Parks and Lands
Steve Coleman	Frontier Forest, LLC
Brian Higgs	Baskahegan Corporation
Carl Jordan	Sappi Fine Paper
Marcia McKeague	Katahdin Forest Management
Bill Miller	Prentiss & Carlisle Co., Inc.
Jacques Morin	Ste. Aurelie Timberlands Company, 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

Advisory

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 21, April 21, and October 27-28, 2004. The October meeting included our annual field tour.

Field Tour

The theme of this year's annual field tour was "Forest Management for Conservation Objectives" and was generously hosted by **The Nature Conservancy**, **Seven Islands Land Company**, and **Huber Resources Corporation**. **Jennifer Vashon** from the **Maine Department of Inland Fisheries & Wildlife** (DIF&W) and **Dan Harrison**, **Bill Krohn**, and **Laura Robinson** from UMaine presented the latest results regarding lynx habitat requirements. CFRU members **Kyle Stockwell** (TNC), **Jim O'Malley** (Huber), and **Tim Scott** (Seven Islands) discussed the challenges and solutions of managing for late-successional hardwood stands. CFRU scientists **Andy Whitman** and **John Hagan** (**Manomet**) demonstrated how to maintain and quantify late-successional ecological value. More than 40 CFRU members participated in the tour (Figure 3). We thank the hosts, speakers, and CFRU staff for making the tour a great success.

Figure 3. CFRU members on fall 2004 CFRU field tour to The Nature Conservancy's St. John property.

Committee Member Changes

The addition of several new organizations to CFRU this year (see Membership on page 7) allowed us to welcome three new members to the Advisory Committee. We welcome **Marcia McKeague** (**Katahdin Forest Management**), **Steve Coleman** (**Frontier Forest, LLC**), and **Carl Jordan** (**SAPPI Fine Paper**) to the committee. We look forward to working with them in charting the future course of CFRU.

The sale of much of the **Hancock Timber Resource Group** lands in Maine this year meant that we lost **Henry Whittemore** from the Advisory Committee. Henry has been a great contributor to the committee over the years and we will miss his advice and counsel. We thank him for his excellent service to CFRU and wish him the very best in his new position.

Developing Stable Funding For Landowner-Sponsored Forest Research in Maine

Based on recommendations developed through a series of three executive summit meetings last year (see 2003 CFRU Annual Report), a task team continued work this year to develop viable options for providing a stable source of funding for landowner-sponsored forest research in the state of Maine. The task team, consisting of **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), developed a proposal to create a Forest Research Commission that had the desired attributes identified at last year's summit meetings.

The proposed Maine Forest Research Commission (MFRC) would blend three decades of success with the CFRU research model with the many decades of stability and success achieved by the Wild Blueberry Commission of Maine and the Maine Potato Board. The mission of the MFRC, like the CFRU, would be to advance research and education about sustainable forestry issues in Maine. Borrowing from the funding approach used by the Blueberry Commission and the Potato Board, the MFRC would be funded through a self-imposed tax by forest landowners. The state's Commercial Forestry Excise Tax would be amended to provide the funding. Under the excise tax, only landowners with more than 500 forested acres would contribute. The proposal describes the background, need, and vision for the commission, and was used to stimulate discussion and solicit constructive input about the mission, objectives, guiding principles, and organizational design of the new commission.

The task team identified four imperatives that needed to be met for the MFRC concept to be viable for landowning organizations. These requirements include: 1) an oversight board consisting only of forest landowners, 2) assessment rates for the excise tax supporting the commission set by the board, 3) funding decisions for the commission made only by the board, and 4) a mechanism for landowners to dissolve commission if it ceases to provide value. Based on conversations with representatives of the Wild Blueberry Commission of Maine and the Maine Potato Board, the task team was confident that these four imperatives could be achieved in the design of the commission.

Efforts by the task team focused on presenting the MFRC proposal to key forest landowning organizations around the state. Presentations were made to the Maine Forest Products Council in January, October, and November; to the Small Woodland Owners Association of Maine and the Maine Farm Bureau in March; and to the Governor's staff in June. As expected, there was significant concern about a proposed land tax, but each group also recommended continuing to develop the idea given the importance of having stable landowner-sponsored forest research. Strong support was received from the Maine Farm Bureau. Ongoing efforts are focused on continued communication with the Maine Forest Products Council, Small Woodland Owners Association of Maine, the Governor's office, and identifying potential legislative sponsors. The task team also is trying to organize a meeting with the Maine Landowners Alliance.

If sufficient support can be developed, a bill to develop the MFRC could be introduced to the Maine Legislature in December 2004. Otherwise, dialogue with key organizations about the idea will continue into next year.

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, including 3 journal articles, 3 research reports and notes, 4 books or book chapters, and 3 graduate theses. In all, CFRU staff and scientists produced more than 13 new publications this year. In addition, 66 conference presentations were given by CFRU staff and scientists at various meetings over the past year. See the Outreach section of this report (pg. 84) for a complete listing of all publications and presentations for this fiscal year.

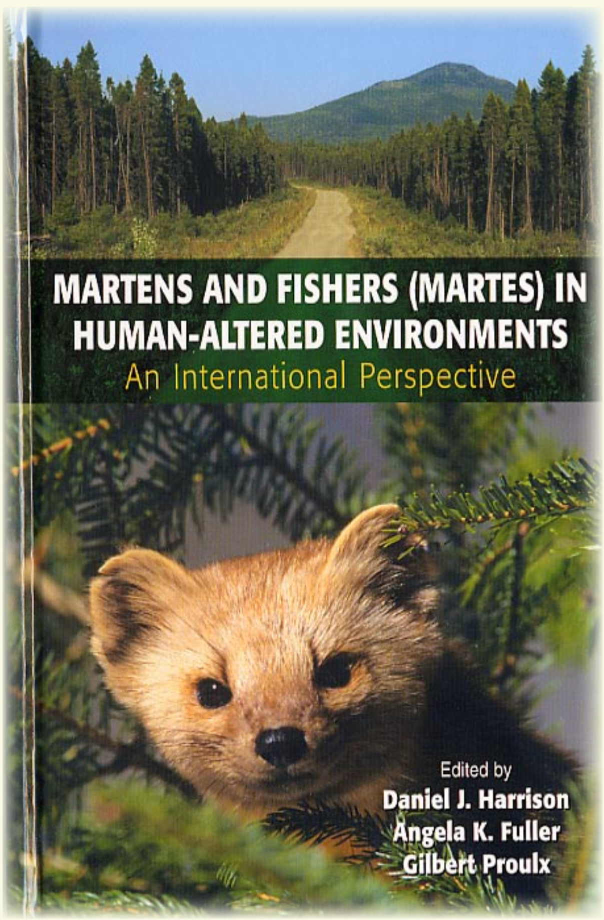


Figure 4. Cover of new book released in January, 2005, provides essential information about martens and fishers.

Much of the research on marten sponsored by CFRU over the past decade was included in a new book led by **Dan Harrision**. The book entitled, *Martens and Fishers (Martes) in Human-Altered Environments* (Figure 4) consists of 14 chapters with numerous figures and tables. Topics covered include "Status, Distribution, and Life History," "Habitat Relationships," and "Research and Management Approaches."

Workshops

CFRU members have consistently told us that they prefer field tours and workshops as the best vehicle for communicating the results of CFRU research. Toward that end, CFRU staff and scientists organized two day-long workshops this year. The first was held for the staff of **Plum Creek Timber Company** on December 16, 2003 in Fairfield, Maine. This workshop was attended by over 30 of Plum Creek's field staff and was such a success that we decided to offer the program (Table 3) to CFRU members on May 12, 2004 in Ashland, Maine. Nearly 80 staff from the **Baskahegan**, B**ureau of Public Lands**, **Fraser Papers**, **Huber Resources**, **Irving Woodlands**, **Katahdin Forest Management**, **Landvest**, **Seven Islands**, and **The Nature Conservancy** attended the Ashland workshop (Figure 5). The proceedings and PowerPoint presentations from these workshops are available on the CFRU web page.

Figure 5. CFRU members at the May 2004 workshop in Ashland, Maine.

After discussions with the CFRU Advisory Committee, it was decided that CFRU should hold one of these workshops about every 18 months as an effective means of ensuring that foresters and managers are kept up-to-date on the latest developments in forest research.

Website

The website continues to be an important tool for sharing our work among cooperators and showcasing it to the public. A proposal for significantly changing the content and style of the public side of the website was presented in April 2004. The goals are to redesign the public side of our website to more effectively com-

Table 3. Agenda from workshop entitled "Managing for Fiber Production, Wildlife Habitat, and Biodiversity: Latest Results from CFRU Research" organized for CFRU members in Ashland, Maine on May 12, 2004

Topic	Speaker
Introduction and overview of day	Hugh Crammond / Mike Dann
History and overview of CFRU	Bob Wagner
Silviculture & Production Forestry	
Maximizing net value from harvesting stands using SPOT	Dan McConville
Influence of stand history, harvest timing, site quality and removal rates on the response of spruce-fir stands to commercial thinning	Bob Seymour
Are herbicide spraying and PCT worth it in spruce-fir stands?	Bob Wagner
Maine's Commercial Thinning Research Network	Dan McConville
Thresholds for making vegetations management decisions and the long-term benefits of doing it right	Bob Wagner
How to access information on the CFRU web page	Dan McConville
Wildlife & Biodiversity Conservation	
Effectiveness of buffers for protecting stream temperature	John Hagan
Effect of clearcutting, precommercial thinning, and partial harvesting on forest dependent species: Part 1	Dan Harrison
Effect of clearcutting, precommercial thinning, and partial harvesting on forest dependent species: Part 2	Dan Harrison
Tools for identifying late-successional forest content	Andy Whitman
Managing for late-successional forest biodiversity	John Hagan
Wrap up	Hugh Crammond / Mike Dann

municate the value of the CFRU mission to the public. Research summaries will be provided in plain language and will be accessible through an attractive easy-to-navigate web design. The new site is expected to go live in 2005.

Field and Data

Our successful summer student internship program that began in 2003 was continued this year. We hired six students from several universities around the nation. 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. Accomplishments of the 2004 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 (see page 25);
(2) Annual re-measurements of regeneration plots on CTRN sites characterizing vegetation on over a thousand vegetation sample plots (see page 33); and
(3) Dissection and detailed measurements of 38 balsam fir trees, including 11,700 branches and 151 tree discs, for leaf areas and stem analysis of trees on a PCT fertilization study (see page 43).

In addition, field crews led by **Dan Harrison** and **John Hagan** collected data on a variety of wildlife habitats (see page 55) and biodiversity conservation projects (see page 68).

STAFF CHANGES

The CFRU experienced some significant staff changes this year. **Julie Kahler**, half-time Administrative Assistant, departed after only six months due to an out-of-state employment opportunity for her husband. However, Julie did a fine job getting the CFRU office into shape. After a brief search, we were very lucky to hire **Dana Smith** as our new Administrative Assistant. Dana brings 17 years of experience as an Administrative Assistant at the University of Maine working in Cooperative Extension, the College of Sciences, and the College of Arts & Sciences.

We also were fortunate to hire **Robert Keefe** this year to conduct a spatial analysis of growing space allocation in the Commercial Thinning Research Network, as well as lead the CFRU commercial thing field crew. Rob comes to the CFRU from the University of Idaho where he just completed an M.S. degree in forest biometrics. Rob's thesis research involved developing a regeneration model for the Pacific Northwest Coast variant of the Forest Vegetation Simulator. Rob also received a B.S. in Forestry from the University of New Hampshire in 1999. A successful USDA grant this year will allow Rob to work with the CFRU developing a new model of precommercial thinning growth responses over the next three years.

Two CFRU graduate students, **Justin DeRose** and **Spencer Meyer**, completed their M.S. thesis research on leaf area relationships on the Commercial Thinning Research Network sites with **Bob Seymour** in December 2004. Spencer and Justin's theses have been posted on the CFRU web page and articles from this work are in preparation. Justin has moved on to a Ph.D. program at Utah State University. Spencer is working in a temporary position for the CFRU and searching for a permanent job.

Our biggest staff change this year came from the departure of **Dan McConville** after five years to pursue an opportunity with **Prentiss & Carlisle**. As Research and Communications Coordinator for the unit, Dan accomplished a lot, including installing the Commercial Thinning Research Network and managing other long-term study sites, developing the SPOT computer program, organizing workshops and field tours, improving the web page, developing the electronic publication retrieval system, producing research reports and posters, developing research projects, and preparing the annual report. Dan's position has been advertised nationally and we hope to have the position filled by mid 2005. Our best wishes go to Dan and his growing family as he pursues new opportunities.

NEW LOGO

After nearly 30 years of use, we updated the CFRU logo this year. Our recent conversion to highly colored publications, presentations, and poster displays created the need to develop a bolder and more colorful version of the logo that would stand out in these applications. As CFRU has expanded its research mission in recent years, we also wanted the logo to more clearly reflect the full scope of forest research conducted by the unit.

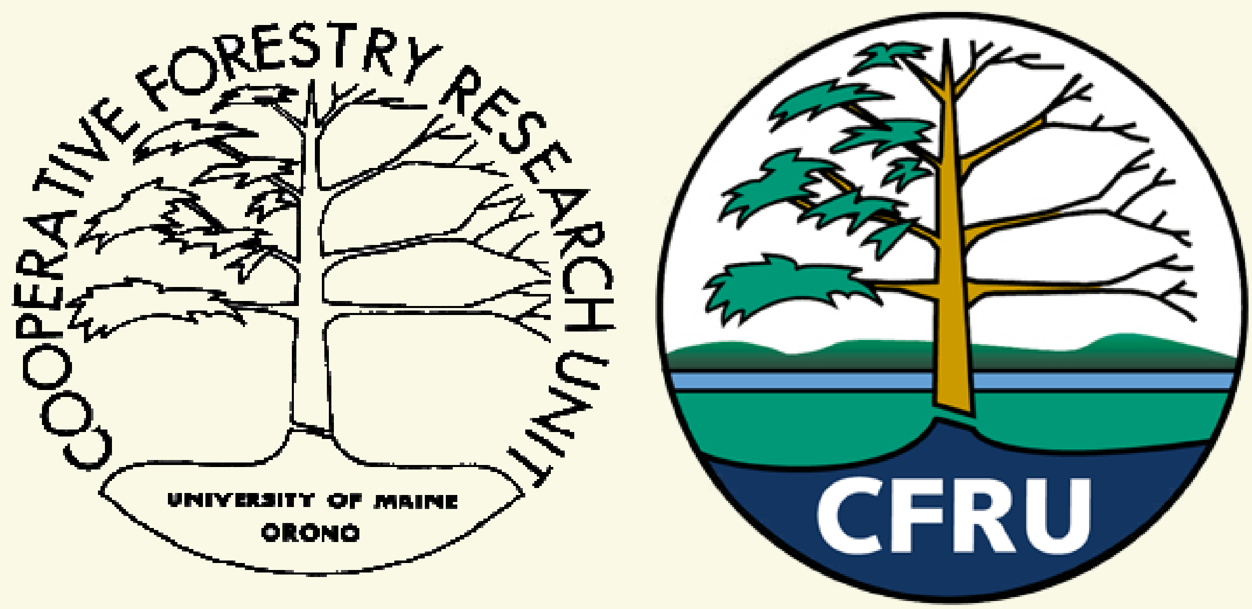
With the help of the UMaine Public Affairs & Marketing Department, we updated the CFRU logo (Figure 6). The original logo designed by **Maxwell McCormack** included a number of images related to the mission of the unit:

- Research on conifer and hardwood forests (left and right side of tree)
- Applied research for forest management (severed tree stem)
- Importance of soil resource (tree rooted in soil)

In creating a bolder and more colorful image, we maintained these original symbols and included several more symbols of the CFRU research mission:

- Landscape biodiversity and wildlife habitat (mountains in background)
- Water quality and riparian zone management (light blue line symbolizing lakes and streams)
- Understory vegetation and wildlife habitat (green on top of soil)
- Centered at the University of Maine (dark blue in soil and light blue in water are official UMaine colors)

Figure 6. Old CFRU logo (left) and updated CFRU logo (right).



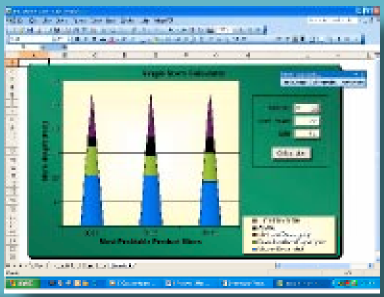
Silviculture

Improving forest productivity and the efficiency of forest management

The Commercial Thinning Research Network

Growth response and economic return from fertilization of pre-commercially thinned spruce-fir stands

The Stand Product Optimization Tool



Northern Hardwood Growth and Yield Model

A Review of Literature of Interfering Plants in Northeastern North American Hardwood Forests

Silviculture

The Commercial Thinning Research Network

Robert G. Wagner and Robert S. Seymour

Understanding growth and yield responses to commercial thinning in spruce-fir stands is the highest research priority for CFRU members. The Commercial Thinning Research Network (CTRN) was established in 2000 to address this need and is the largest ongoing silviculture research project of the CFRU. Eight-four research plots with over 12,000 tagged trees are being monitored annually on a dozen study sites across the state of Maine. Ongoing analysis is focused on improving current growth and yield models as well as our understanding about the effects of thinning spruce-fir stands.

In addition to the core study documenting growth and yield responses following commercial thinning, CTRN plots are also being used by a variety of researchers and graduate students to address other questions about commercial thinning (Table 4). For example, **Mike Greenwood** is documenting post-thinning patterns of cone production and regeneration by red spruce and balsam fir. Under the direction of **Bob Seymour**, graduate students **Justin DeRose** and **Spencer Meyer** completed their M.S. theses this year examining the relationships between leaf area, tree growth, and stand density. To better understand how effectively growing space was reallocated by commercial thinning treatments, **Rob Keefe** and **Bob Wagner** are investigating detailed spatial changes in stands before and after commercial thinning. **Rakesh Minocha** of the USFS Northeastern Research Station along with her collaborators continued assessing how commercial thinning affects physiological stress and metabolism in spruce and fir.

Progress on each of these CTRN component studies are presented in the following pages.

Table 4. Commercial Thinning Research Network Component Studies for FY 2003-04

Growth and Yield Studies

- Network maintenance, measurements, and analysis
- Factors affecting regeneration of red spruce and balsam fir
- Effectiveness of growing space allocation among commercial thinning treatments

Ecophsyiology Studies

- Relationship between leaf area index and relative density in commercially thinned red spruce and balsam fir stands
- Leaf area as a growth predictor in commercially thinned red spruce and balsam fir stands
- Effects of commercial thinning on physiological stress and metabolism in red spruce and balsam fir

Silviculture

Commercial Thinning Research Network: Maintenance, Measurements, and Analysis

Daniel J. McConville, Robert G. Wagner, and Robert S. Seymour

The CFRU Commercial Thinning Research Network completed its fourth season this year. The network currently consists of two controlled studies examining commercial thinning responses in Maine's spruce-fir stands. A dozen study sites were established on CFRU cooperator lands beginning in 2000 (Figure 7). 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) 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).

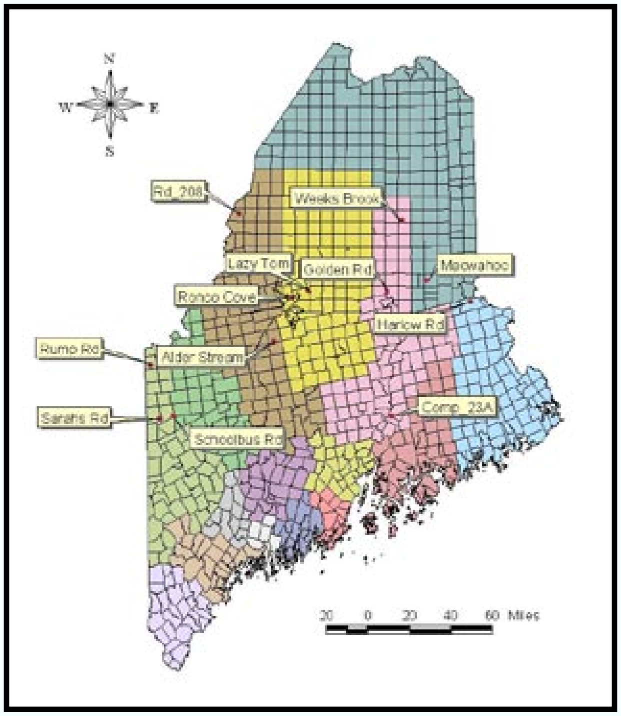


Figure 7. Location of twelve CFRU Commercial Thinning Network research sites.

Seven 0.20-acre measurement plots centered within one-acre treatment plots were established on each site. Before the commercial thinning treatments were applied, all trees within the measurement plot that met the minimum size requirement were measured for diameter at breast height (dbh) and location within the plot. A subset of these trees were measured for total height and height to live crown. After thinning, 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 12 sites. Each site is being measured according to a predetermined schedule (Table 5).

2003-04 Measurements

All scheduled measurements listed for 2003-04 in Table 5 were completed during summer 2004. These measurements included the third round of intensive post-treatment measurements (IM) at each of the PCT sites. The IM cycle includes measurement of DBH for all trees, measurement of total height and crown height for every other tree, as well as an in-growth and mortality assessment. At five of the six sites that have not received PCT (Schoolbus Rd., Sarah's Rd., 208 Rd., Golden Rd., and Rump Pond Rd.) we

Table 5. Approved plan for the establishment, treatment, maintenance, and measurement of current study sites in the CFRU Commercial Thinning Research Network Treatment for 2000-2010.

					Period of approved funding							
Landowner	**Site**	**FY99-00**	**FY00-01**	**FY01-02**	**FY02-03**	**FY03-04**	**FY04-05**	**FY05-06**	**FY06-07**	**FY07-08**	**FY08-09**	**FY09-10**
No PCT Sites:												
BPL	Schoolbus Rd.	Pre	IM1 / thin	DM	EM	DM	IM	DM	EM	DM	IM	DM
Seven Islands	Sarah's Rd.	Pre	IM1 / thin	DM	EM	DM	IM	DM	EM	DM	IM	DM
Ste. Aurelie	208 Rd.	Pre	IM1 / thin	DM	EM	DM	IM	DM	EM	DM	IM	DM
Huber	Golden Rd.	Pre	IM1 / thin	DM	EM	DM	IM	DM	EM	DM	IM	DM
Baskahegan	Harlow Rd.		Pre	IM1 /thin	DM	EM	DM	IM	DM	EM	DM	IM
MeadWestvaco	Rump Pond Rd.		Pre	na	IM1 / thin	DM	EM	DM	IM	DM	EM	DM
PCT Sites:												
Plum Creek	Ronco Cove	Pre	Thin1	IM1	IM	IM	IM	IM	IM / thin2	IM	IM	IM
IP	Macwahoc	Pre		IM1 / thin	IM	IM	IM	IM	IM / thin2	IM	IM	IM
IP	Alder Stream	Pre		IM1 / thin	IM	IM	IM	IM	IM / thin2	IM	IM	IM
Plum Creek	Lazy Tom		Pre / thin1	IM1	IM	IM	IM	IM	IM / thin2	IM	IM	IM
Irving	Weeks Brook Rd.		Pre	IM1 / thin	IM	IM	IM	IM	IM / thin2	IM	IM	IM
PEF	Comp. 23a		Pre	IM1 / thin	IM	IM	IM	IM	IM / thin2	IM	IM	IM

Pre = Plots installed and pre-treatment measurements (DBH, azimuth, and distance on every tree; total height and crown height on subset of trees across DBH class; in-growth plots installed on PCT sites; custom thinning prescriptions written for each plot based on pre-treatment data)

IM1 = Initial post-treatment tagging and intensive measurement (DBH, total height, crown height, azimuth, and distance on every tree)

IM = Intensive post-treatment measurement (DBH, total height, and crown height on every tagged tree; measure in-growth; and record

EM = Extensive post-treatment measurement (DBH on every tree, measure in-growth, and record downed and dead trees on every plot)

DM = Downed tree and mortality assessment (all downed and dead trees recorded on every plot)

Thin = All six thinning treatments applied to No-PCT sites

Thin1 = 0 year commercial thinning treatment applied to first two plots (PCT sites)

Thin2 = 5 year commercial thinning treatment applied to next two plots (PCT sites)

Thin3 = 10 year commercial thinning treatment applied to remaining two plots (PCT sites) completed the second round of downed tree and mortality assessments (DM), which is used to determine mortality patterns over time. The sixth non-PCT site (Harlow Rd.) received the first extensive measurement (EM), which includes measuring dbh on every tree, measuring in-growth, and documenting all downed and dead trees.

Initial Thinning Effects: Merchantable Volume and Net Revenue Removed

Now that all commercial thinning treatments and the pre- and post-treatment measurements have been completed, we are able to assess the amount of merchantable wood removed (Figure 8) and the net revenue received for each treatment (Figure 9). Using the latest version of the SPOT program (see page 47) developed by CFRU, the merchantable wood volume and financial value of the wood removed (based on differences between pre- and post-thinning stand conditions) were calculated. The cost of each thinning treatment was calculated using a modified version of the PPHarvest computer program developed by the U.S. Forest Service (Fight et al. 1999) and assumed the harvesting was done using a small single-grip processor. The estimated cost of thinning and transportation was subtracted from the financial value of the wood removed to determine the net revenue derived from each commercial thinning treatment.

Figure 8A indicates that on average about 53% more merchantable wood volume was removed with the 50% (768 ft^3/A) than the 33% (503 ft^3/A) relative density reduction treatments in the six 25-40 year old balsam fir stands that previously received PCT. There was a substantial difference in wood removed between these treatments on two of the six sites (Weeks Brook and Lazy Tom). The larger merchantable wood volume from the 50% thinning resulted in a 139% gain in net revenue over the 33% relative density reduction treatment ($281 /A vs. $117 /A) across the six sites (Figure 9A). All commercial thinning treatments produced positive net revenues except the 33% treatment on two of the study sites (Ronco Cove and Lazy Tom).

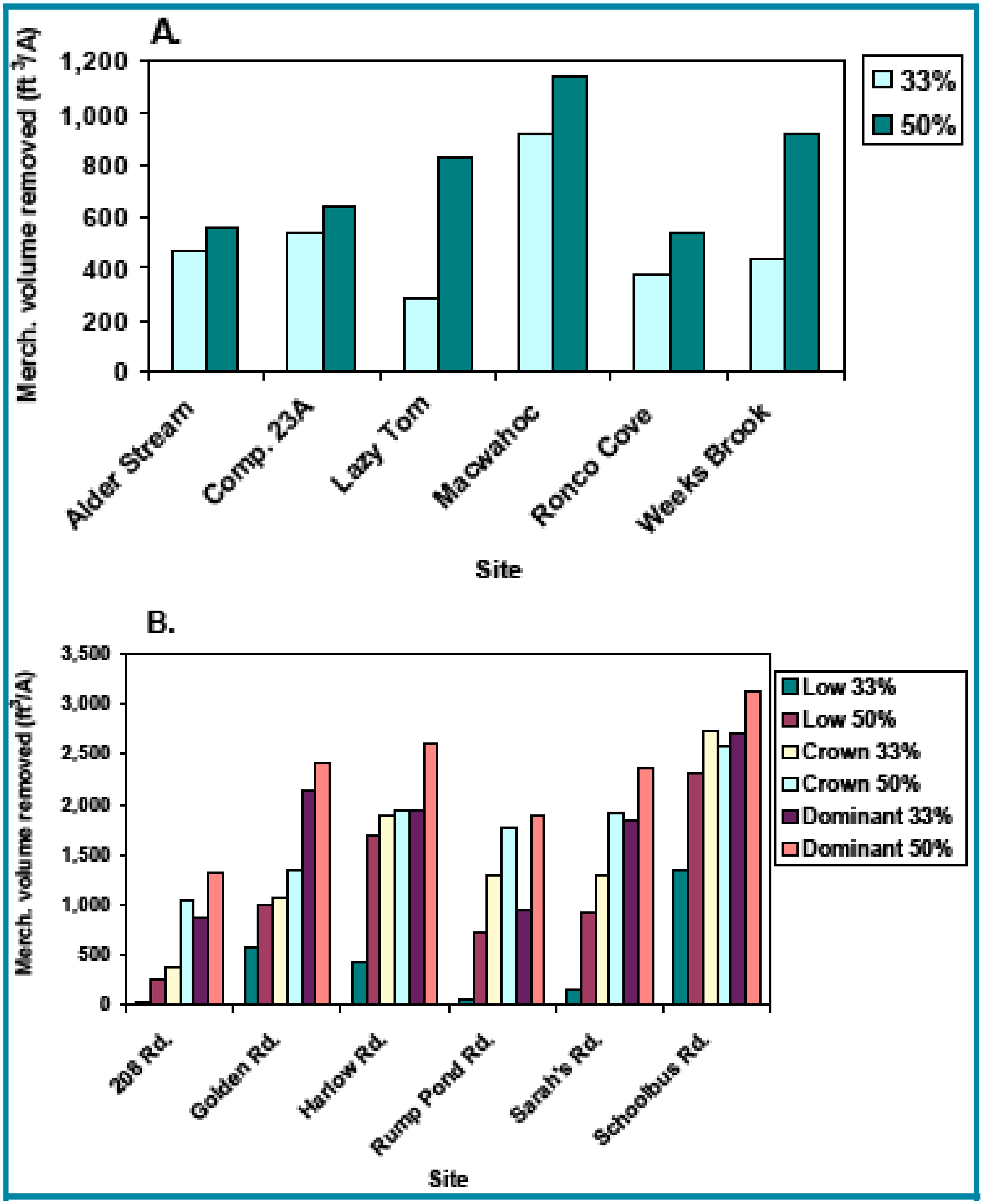
As expected, commercial thinning 40-70 year old spruce-fir stands that had not received previous PCT yielded substantially more merchantable wood volume than from younger balsam fir stands of the other study (Figure 8). In general, the dominant thinnings removed more volume than the crown thinnings, which yielded more than the low thinnings at both levels of relative density reduction (Figure 8B). These differences were strongly reflected in the net revenues received from each treatment, with the dominant thinnings producing about $1,645 /A, the crown thinnings producing about 62% ($1,011 /A) of the dominant thinnings, and the low thinnings producing only 8% ($134 /A) of the dominant thinnings (Figure 9B). Low thinnings had negative net revenues on more than half of the sites where it was applied. Larger differences generally resulted from the method of thinning (low, crown, dominant) rather than the amount of density reduction (33%, 50%).

Of course, removing more of the stand volume and value has a long-term influence on future stand growth and financial value (See 2002 and 2003 CFRU Annual Reports). Ongoing measurements are being used to evaluate the growth response of the residual stands following all treatments in both studies.

Establishment Report

Efforts during the coming year will focus not only on the next scheduled measurements, but in developing a web-based establishment report that includes all available information about the network sites, the experimental methods used, summary statistics of stand responses to thinning, raw data, results from other studies using the network plots, available publications, and

Figure 8. Merchantable volume removed (ft^3/A) for each commercial thinning treatment on six sites with previous PCT (A) and six sites without previous PCT (B).



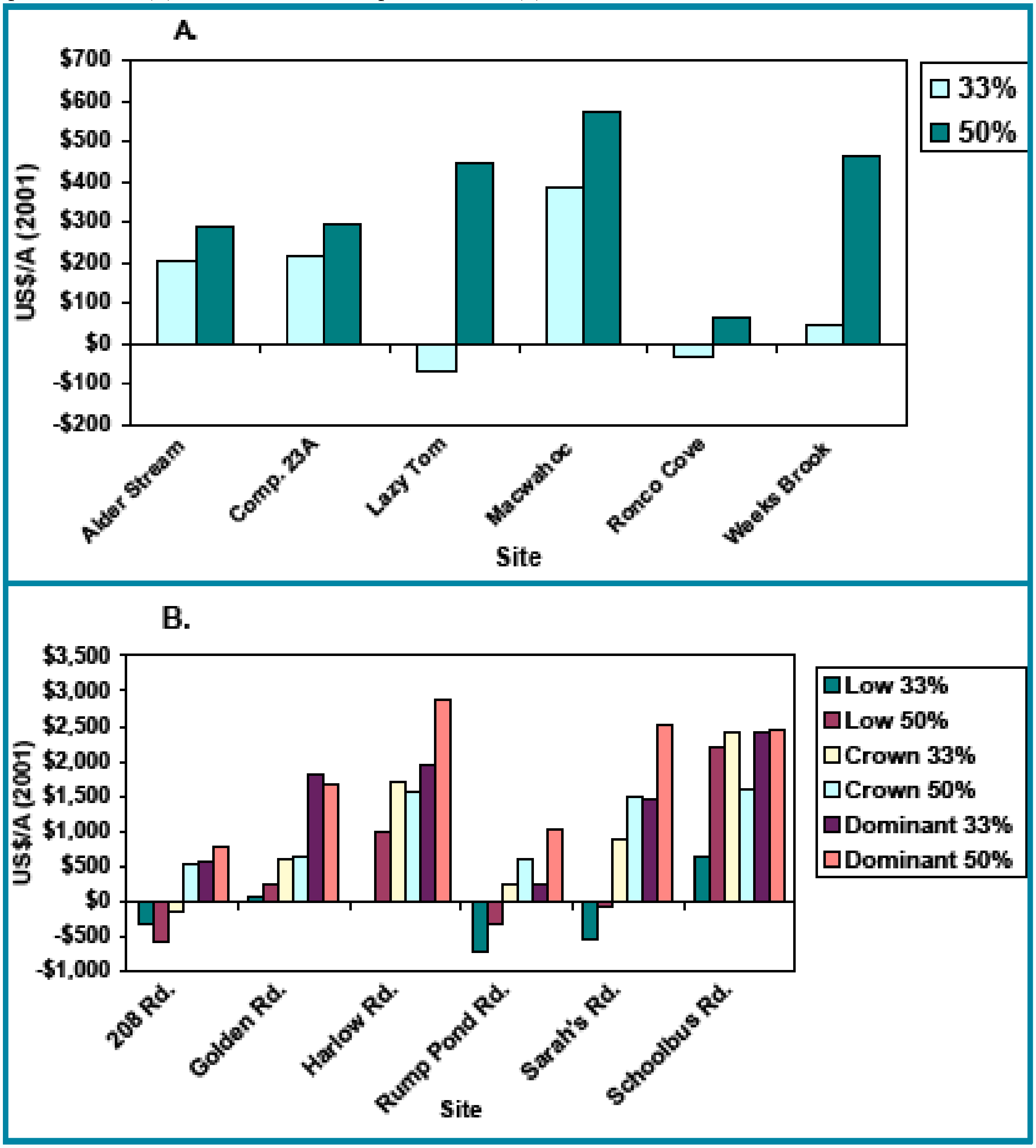
other information. Updates from ongoing studies using the network plots are provided in the following reports (pages 25 to 41).

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.

References

Fight, Roger D., Gicqueau, Alex, & Hartsough, Bruce R. 1999. Harvesting costs for management planning for ponderosa pine plantations. Gen. Tech. Rep. PNW-GTR-467. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 8 p.

Figure 9. Net revenue (2001 $/A) for each commercial thinning treatment (merchantable wood value removed minus estimated thinning and transportation costs using a small single grip harvester) on six sites with previous PCT (A) and six sites without previous PCT (B).



Silviculture

Effectiveness of Growing Space Allocation Among Commercial Thinning Treatments

Robert F. Keefe and Robert G. Wagner

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. A new project initiated in September 2004 is examining how effectively thinning treatments in the Commercial Thinning Research Network plots reallocated growing space to the residual stands. Results from this work will provide forest managers with a better understanding of 1) how commercial treatments reallocate growing space, 2) which treatments reallocate growing space most effectively, and 3) how the pattern of reallocation affects post thinning growth of individual trees and the overall stand.

Background

Commercial thinning prescriptions generally strive to achieve 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 the 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 effectiveness or uniformity of growing space reallocation from commercial thinning. Understanding these effects requires a spatial analysis of the stand before and after thinning.

Spatial analysis of forest stands generally uses two broad approaches. The first approach treats tree locations as either a set of points (Ripley 1981) or a mosaic of polygons (Matern 1979), and describes the characteristics of the distribution of these points or shapes in two- or three-dimensional space. The question of interest using this approach is usually concerned with whether the trees are clustered, randomly spaced, or uniformly spaced. This approach uses models that treat the points as having some observed and expected clustering or uniformity within a plot or stand. Dale (1999) described that these methods often reveal little about the nature of the spatial pattern. An alternative approach to quantifying competition has involved the calculation of competition indices as measures of the stress or growth potential for individual trees. Competition indices come in many forms and describe the vertical and horizontal characteristics of trees around a subject tree by summing the attributes of all trees in the surrounding neighborhood area (usually a circle). Competition indices are often included in growth and yield models as a means to quantify the effect of density-dependent processes. It is generally assumed that the competition index is an indirect measure of the environmental resource availability (e.g., light, water, nutrients) that drives tree growth.

Objective

The objective of this project is to address several key questions about the reallocation of growing space in commercially thinned spruce-fir stands:

- How do commercial thinning treatments affect horizontal and vertical distribution of growing space among individual trees in the residual stand?
- How do differences in relative density targets (33% vs. 50% reduction) following commercial thinning influence growing space allocation in previously precommercially thinned stands?
- How do differences in relative density targets (33% vs. 50% reduction) and thinning method (dominant vs. low vs. crown) following commercial thinning influence growing space allocation in unthinned stands?
- Is growing space allocation following commercial thinning correlated with the post-thinning growth of individual trees?
- Does variability in growing space allocation among commercial thinning treatment influence overall stand growth?

Approach

Data from the CFRU Commercial Thinning Research Network plots are being used to answer these questions. The locations of all trees were mapped in each plot using a compass and electronic distance meter (DME) before and after each thinning treatment. Stem maps are being generated using R software (R Development Core Team 2004), and pre- and post-treatment stems are matched using an algorithm based on diameter breast height (dbh), species and spatial location. The area in forwarder trails is being calculated using stem maps to identify individual trees adjacent to trails and connecting the tangents of outer crown drip-lines of their

predicted crown radii. It was assumed that a deviation from the tangent connecting outer crowns was due to an existing gap if it was greater than 45 degrees.

The two spatial analysis approaches (point or mosaic analysis and competition indices) are being used to quantify the spatial characteristics of the stands in each plot. A distance-dependent competition index (Hegyi's index) is being calculated for each tree before and after thinning. An example of the data being generated is shown in Figure 10. The variance of the competition index among trees in each treatment will be compared, as well as differences in the vertical and horizontal components of the competition index. Point analysis of the spatial distribution of the trees in each plot is being compared using Ripley's K-function (Ripley 1981) and other distributional statistics. Post-thinning growth of individual trees is being modeled using Honer's volume equations and will be correlated with the post-thinning competition index using regression analysis. Comparison of the various methods for analyzing spatial inventory data in an effort to quantify growing space and competition has raised questions about the fundamental objective of commercial thinning to apparently minimize variation in horizontal and vertical stand structure.

Products

A final report on the results of this work will be presented as a CFRU Research Report and as a presentation to the CFRU Advisory Committee. A draft report is expected in 2005. Questions about this project can be directed to **Rob Keefe** at 207-581-2894 or Robert_keefe@umit.maine.edu.

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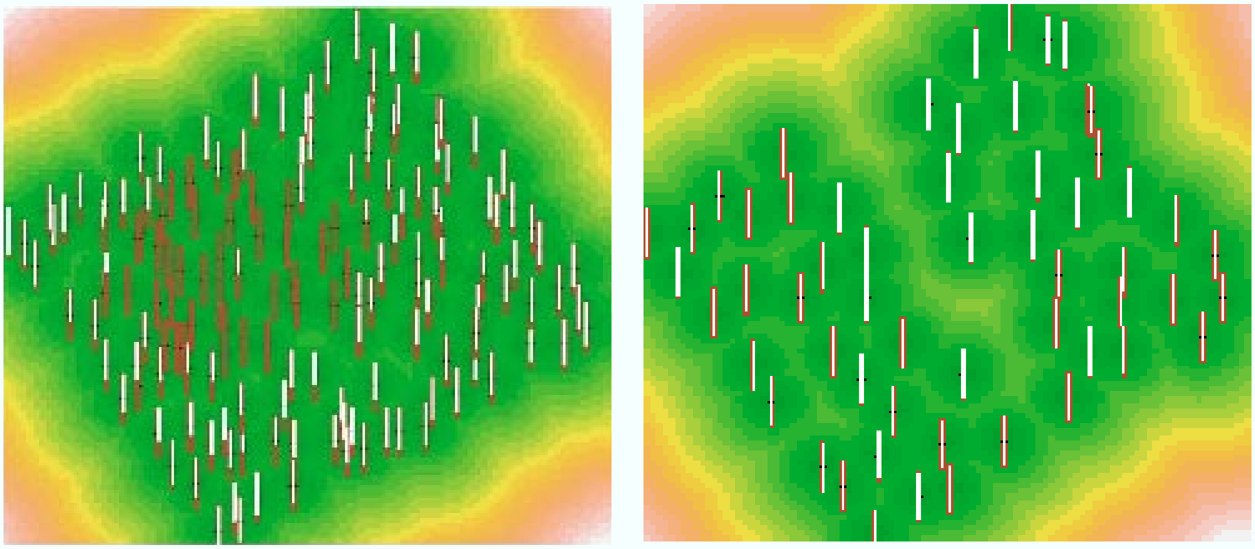
Figure 10. Graphical depiction of growing space allocation to individual trees on the 50% relative density reduction plot before (A) and after (B) commercial thinning at the Ronco Cove site. Each white bar depicts the location of an individual tree. The height of the brown bar indicates degree of competition each tree is experiencing from neighboring trees using the Hegyi index. The Hegyi index is calculated based on the number, relative dbh, and distance of neighboring trees. Reduction in the height of the brown bar after thinning depicts the increase in available growing space for each tree. The green background reflects the average distance among trees in the stand: dark green = shorter distances, yellow = longer distances.

A. Before Thinning B. After Thinning



Silviculture

Factors Affecting Regeneration of Red Spruce and Balsam Fir Following Commercial Thinning

Michael Greenwood and Daniel McConville

Growth and yield response from commercial thinning of spruce-fir stands is currently the highest research priority among industrial landowners. Although commercial thinning is not intended to initiate regeneration, heavy thinnings can initiate a new stand. Understanding these relationships is important to predict yields and future stand dynamics. The establishment of the Commercial Thinning Research Network (CTRN) has provided the opportunity to examine the effects of commercial thinning on spruce-fir seed production and seedling establishment. Towards that end, regeneration plots were established at a number of the thinning sites shortly after thinning began in 2001 (Figure 11). At the same time we have monitored the reproductive effort of red spruce and balsam fir at the same sites, in order to correlate reproductive effort with the appearance of seedlings in the regeneration plots. We now have three years of observations, and some interesting treatment effects have been observed on the relative abundance of red spruce regeneration.

Effect on germinants and seedlings

Data presented here are from sites that never received precommercial thinning and received later commercial thinning treatments in 2001. Data from 45 1-m^2 plots in each of the control, 33% and 50% crown-thinned treatment plots on four sites, sampled in three successive years, are summarized in Table 6. The crown thinning treatment consisted of removing co-dominant and dominant trees and leaving the best-formed

Figure 11. Summer students counting balsam fir and red spruce germinants and seedlings in 1 m^2 sample plot on commercial thinning network site.

Table 6. Number of germinants/A (< 0.3 ft. tall) and number of seedlings/A (0.3 ft. to 2 ft. tall) in untreated control and crown thinning treatments with 33% and 50% relative density reduction from 2002-2004.

	Relative density reduction (%)	2002	2003	2004	Mean
Germinants/A					
	33	10,475	10,250	11,127	10,617
	50	4,316	4,473	4,024	4,271
Red spruce	0	24,658	18,791	16,454	19,968
	33	28,164	23,309	24,209	25,227
	50	15,847	12,340	12,655	13,614
Seedlings/A					
Balsam fir	0	1,034	787	854	892
	33	2,225	2,023	2,990	2,412
	50	1,259	1,528	1,281	1,356
Red spruce	0	495	2,702	202	1,133
	33	2,360	1,056	967	1,461
	50	899	989	1,573	1,154

dominants to seed in future regeneration. For purposes of this study, we termed tree seedlings that emerged after the thinning treatments were applied as "germinants," and seedlings that regenerated before the thinning treatments were applied as "seedlings."

The number of balsam fir germinants was reduced dramatically by the thinning treatments, and the reduction was proportional to thinning intensity. The total number of germinants was highly variable among sites, reflecting a similar variation in basal area of residual balsam fir. The trends shown in Table 6 are evident across most of the sites, and are most pronounced on those sites with the highest number of balsam fir germinants. In contrast to balsam fir, the number of red spruce germinants increased in response to 33% crown thinning, and showed a slight decline in response to 50% removal. The total number of red spruce germinants per acre was similar across sites, reflecting roughly similar basal areas of residual red spruce. But the results were highly variable for red spruce among treatments and no clear trends were evident.

In contrast to germinants, thinning treatments did not exhibit any consistent effects on the number of seedlings per acre (which would have been present as advance regeneration before the thinning treatments were applied).

Reproductive effort in relation to germinant frequency

Estimates of reproductive effort for balsam fir and red spruce, based on an index calculated from the length of crown with cones times cone density across all trees, is shown for 2002-2004 in Table 7.

Table 7. Reproductive effort, defined as the length of crown with cones X cone density (estimated on a scale of 1-5) on all trees, is shown for 2003-2004.

	2002	2003	2004
Balsam fir	13.4	1.7	2.8
Red spruce	5.1	2.5	2.6

It was a good flowering year for both species in 2002, especially balsam fir, which produced and exceptionally heavy cone crop. The large increase in number of balsam fir germinants in 2003 reflects this large reproductive effort. Red spruce germinants did not increase in 2003, perhaps reflecting in part relatively less reproductive effort. Since germinants were defined as seedlings less than 0.3 feet tall, this category would probably include current year germinants as well as seedlings from the preceding one to two years.

Conclusions

Some important conclusions can be drawn from these data with regard to the impacts of commercial thinning on red spruce and balsam fir regeneration:

- Balsam fir germinants were dramatically reduced by thinning treatments; 33% removal resulted in a 3.5-fold reduction in germinant number, while 50% removal resulted in a 9-fold reduction. Red spruce germinants were unaffected. Thus the ratio of spruce to fir was increased from 0.5 to 3.2 with 50% thinning.
- Germinant loss due to direct damage from the thinning operation is unlikely because red spruce germinants were unaffected, and no reduction of larger seedlings was observed. The possibility that very young balsam fir seedlings are more sensitive to the increased light levels due to thinning must be considered.
- Balsam fir reproductive effort has been much more variable than for red spruce, and the large cone crop in 2002 accounts for the increase in germinants in 2003.

Recommendations

- In stands containing red spruce and balsam fir, the preferential establishment of red spruce advance generation may be increased by commercial thinning of trees that have reached reproductive age.
- Timing thinning entries to follow good cone crops should promote advance regeneration of both species.
- Further research is needed to validate the differential effects of thinning on germinant mortality reported here and to determine the cause for apparent sensitivity of balsam fir germinants to the effects of overstory removal.
- Continue regeneration surveys, but divide germinant category into current year, second year and third year.

Acknowledgements

Thanks to **Spencer Meyer** for assisting with the data collection and preliminary analysis of results presented here.

For more information, contact **Mike Greenwood** at Greenwd@apollo.umenfa.maine.edu or 207-581-2838.

Silviculture

Leaf Area as a Growth Predictor for Red Spruce and Balsam Fir in Managed Stands in Maine

Spencer R. Meyer and Robert S. Seymour

Managing stand density, both precommercially and commercially, reallocates growing space among residual trees. To adequately model forest growth and yield, we must understand the biological relationship between wood production and leaf area. Including leaf area may improve empirical growth models because it includes the direct influence of photosynthetic tissue. This study had two primary objectives: 1) to accurately predict individual-tree leaf area from easily obtained tree variables and 2) to use the amount of leaf area on a tree to predict five-year diameter growth.

Methods

During the summer of 2003, 46 red spruce and 43 balsam fir trees were destructively sampled to obtain leaf area and growth data for a random sample of trees across 12 sites of the Commercial Thinning Research Network (CTRN). Branch-level (Figure 12) and tree-level (Figure 13) models were then derived to predict leaf area from various tree variables (Figure 14). A comprehensive suite of model forms using both sapwood and allometric variables was screened to evaluate their predictive power and reliability across species, crown class, and geographic region of Maine.

Results

For both precommercially thinned balsam fir and unthinned red spruce, models based on area inside the bark and basal area (fir and spruce, respectively) performed best. However, the model performance varied according to the use of secondary tree variables, such as crown

Figure 12. Predicted maximum leaf area occurs higher in spruce crowns than in fir crowns for dominant (D) and codominant (C) crown classes than in intermediate (I) and overtopped (O) crown claases. Arrows show the point of maximum of leaf area per branch for spruce and fir.

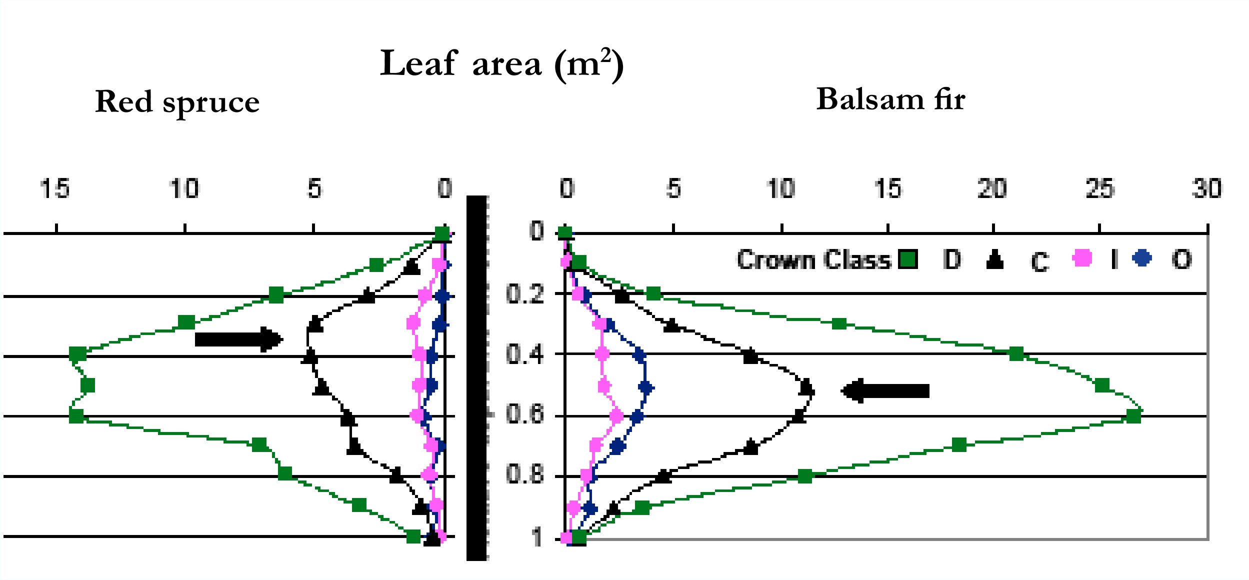
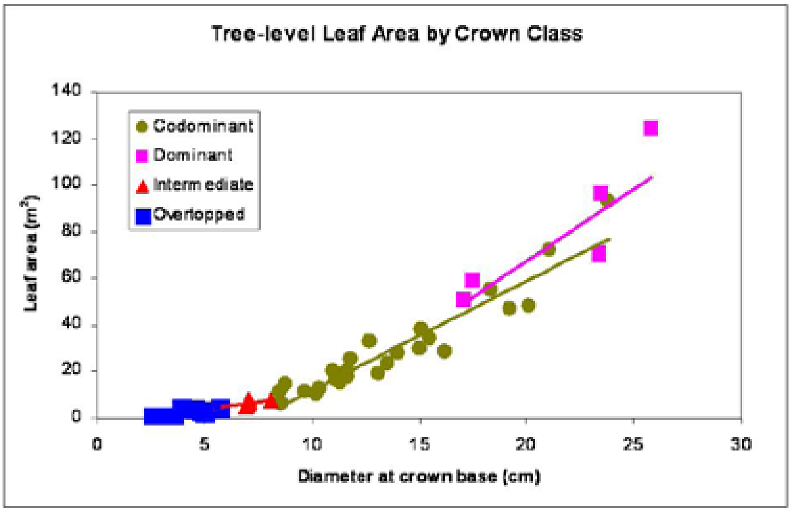


Figure 13. Leaf area per tree increases with diameter at the base of the live crown. Total leaf area per tree was higher for dominant and co-dominant trees than for intermediate and overtopped trees.



stands. We found that using two years of radial growth data best calibrated FVS for our stands. Despite this calibration, FVS still underestimated diameter growth. Our leaf area-based model outperformed the FVS models and had mean residuals equal to zero. The leaf area model must still be tested with independent datasets.

Application

This research contributes to the understanding of leaf area dynamics in Maine's managed stands. We demonstrated that leaf area models can be applied across a range of site conditions. We also found that tree-level leaf area can be reliably predicted from simple measurements that are commonly obtained in forest inventories. This study supports the potential of leaf area to improve growth and yield predictions when using models such as FVS.

Results from this work have been published in an M.S. thesis available on the CFRU web page. For more information regarding these leaf area models, please contact **Bob Seymour** at 207-581-2860 or Seymour@apollo.umenfa.maine.edu or **Spencer Meyer** at 207-581-2861 or Spencer_Meyer@umenfa.maine.edu.

Figure 14. CFRU field crew harvesting branches and leaves from tree on commercial thinning research site.

length and modified live crown ratio. Testing several forms of crown length and crown ratio as secondary predictors revealed little difference between definitions and we concluded that in conjunction with basal area, the best secondary predictor is modified live crown ratio. Sapwood models performed nearly as well as the best-fit models and accounted for some subtle departures from even-aged structure apparent within some stands. Sapwood models are operationally less preferable due to the intensive sampling required to measure the sapwood. Perhaps of most significance is the finding that neither geographic location nor site index was a significant factor affecting model performance for either basal area or sapwood area models.

Data from 10 of the CTRN sites, including 750 trees, were used to fit a leaf area-based model for predicting five-year diameter increments from projected leaf area and volume for both fir and spruce. Model performance was independent of crown class for fir and was consistent for dominant and codominant spruce trees, but did show moderate bias across geographic location. We corroborated previous findings and concluded that it is necessary to include site index in growth functions. Three radial increment calibrations and two geographic variants (Northeast and Lake States) of Forest Vegetation Simulator (FVS) were employed to predict five-year diameter increments for the PCT fir

Silviculture

Leaf Area Index, Relative Density and Growth Efficiency Relationships of Even-aged Balsam Fir and Red Spruce Stands

R. Justin DeRose and Robert S. Seymour

The trade-off between individual tree growth and stand growth has long been understood by foresters. One can balance these components of growth by controlling stand stocking, which regulates tree and stand leaf area index (LAI). Arguably the most ecologically sound method by which to measure stocking is relative density (RD), defined as the number of observed trees of average size per unit area divided by the biological maximum number possible for the site. RD is easily calculated using the density management diagram equations provided by Wilson et al. (1999). Relationships between LAI and RD are not well known for even-aged red spruce and balsam fir stands. Therefore, our objectives for this study was to: 1) test the relationship between LAI and RD (Figure 15), 2) determine whether RD could adequately predict stand LAI, and 3) assess the influence of species composition, tree age, and site quality on the relationship between LAI and RD.

Measurements were taken during the summer of 2003 on a stratified-random sample of the CFRU Commercial Thinning Research Network (CTRN) plots. Tree height, live crown ratio, diameter breast height (dbh), and crown class were determined, and two increment cores removed from each tree. The increment cores were used to calculate sapwood area of each tree, leaf area, and annual volume increment. Ninety trees were destructively sampled to determine the relationship between sapwood area and leaf area. Tree-level leaf areas were converted to all-sided leaf areas, thought to be more appropriate for comparisons between species, and summed for LAI.

Leaf area and relative density relationships

We found substantial differences between study sites based on whether they had been precommercially thinned (PCT) or not. The PCT sites were generally young (25 – 40 yrs) balsam fir stands of high productivity sites, while sites that had not been PCT (NOPCT) tended to be older (40 – 70 yrs) red spruce and balsam fir stands of lower site quality.

Our data indicated that these even-aged stands of balsam fir and red spruce followed trend A (Figure 15) when they were standardized by their site quality and measured as site index (SI). The results also suggested that there was a rapid increase in LAI with increasing RD for young stands until the onset of competition-related

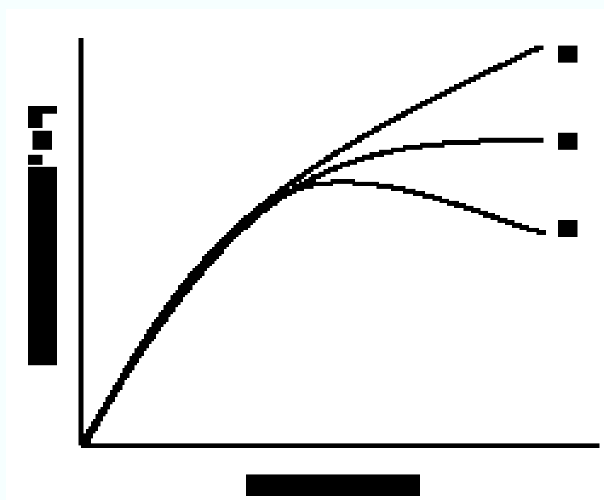


Figure 15. Hypothesized relationship between all-sided leaf area index (LAI) and relative density (RD). Results from this study suggest that curve "A" is the trend for stands in the CFRU commercial thinning study.

mortality (~ 50% RD) when the stands continued to increase in LAI with increasing RD, but at a slower rate.

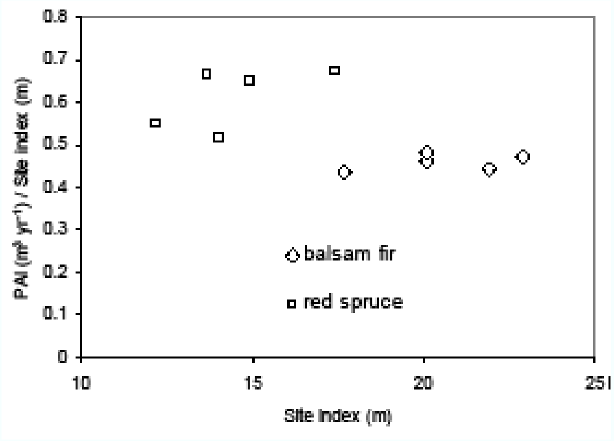
Perhaps the most interesting result of this work was the effect of SI on the observed LAI. For stands above ~50% RD, we found a significant correlation between SI and LAI, suggesting that maximum LAI was influenced by site quality. RD was a good predictor of LAI for PCT and NOPCT stands, but improved significantly when SI was included in the equation, providing further evidence of the effect of site quality on LAI.

All-sided leaf area was an appropriate metric for comparing the effect of red spruce and balsam fir composition on LAI. We found, in stands of mixed species composition, that red spruce contributed marginally more leaf area than balsam fir. In practice, the difference between the species is small enough that tree-level leaf area contribution to LAI for both species can be considered to be similar. These results led us to further investigate the effects of site quality on growth efficiency.

Growth efficiency

Growth efficiency (GE) is defined as stemwood volume increment per unit of leaf area and is widely used to assess the efficiency at which trees or stands are producing potentially merchantable volume. Previous work has shown GE to vary with different levels of fertilization and thinning. Little is known about how the natural range of site quality might affect GE, so we assessed whether GE was correlated with SI.

Figure 16. Gross periodic annual increment (PAI) divided by site index (SI) plotted over SI for balsam fir and red spruce stands.



Using the measurements described above, we predicted mean GE from dominant and codominant balsam fir and red spruce. Dominant and codominant trees were used to avoid problems with missing rings and potentially rapidly diminishing crowns of overtopped and intermediate trees. All-sided leaf areas were used in conjunction with species-specific volume equations built from the destructively sampled trees. Stand-level GE, periodic annual increment (PAI) and mean annual increment (MAI) were calculated.

The results suggested that SI was positively correlated with GE. That is to say, trees on sites with higher SI produced more wood per unit of leaf area. We also found that PAI was greater than MAI on the study plots, suggesting that CFRU Commercial Thinning Research Network sites are a number of years away from their biological rotation age, or culmination of mean annual increment. Stand-level GE was similar for each species, however, since the range of red spruce site indices was much lower, when productivity was calculated as PAI per unit of SI red spruce appeared superior (Figure 16).

Results from this work have been published in an M.S. thesis available on the CFRU web page and two papers have been submitted for publication. For more information regarding this study, contact **Bob Seymour** at 207-581-2860 or Seymour@apollo.umenfa.maine.edu.

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Silviculture

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. 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 collected during July 2003 from the Lake Macwahoc and Golden Road study sites were analyzed this year. Up to 25 spruce and fir trees were sampled per plot at Golden Road and 20 fir sampled per plot at Macwahoc (Figure 17). 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.

Figure 17. Field crew processing foliage samples on commercial thinning study site.

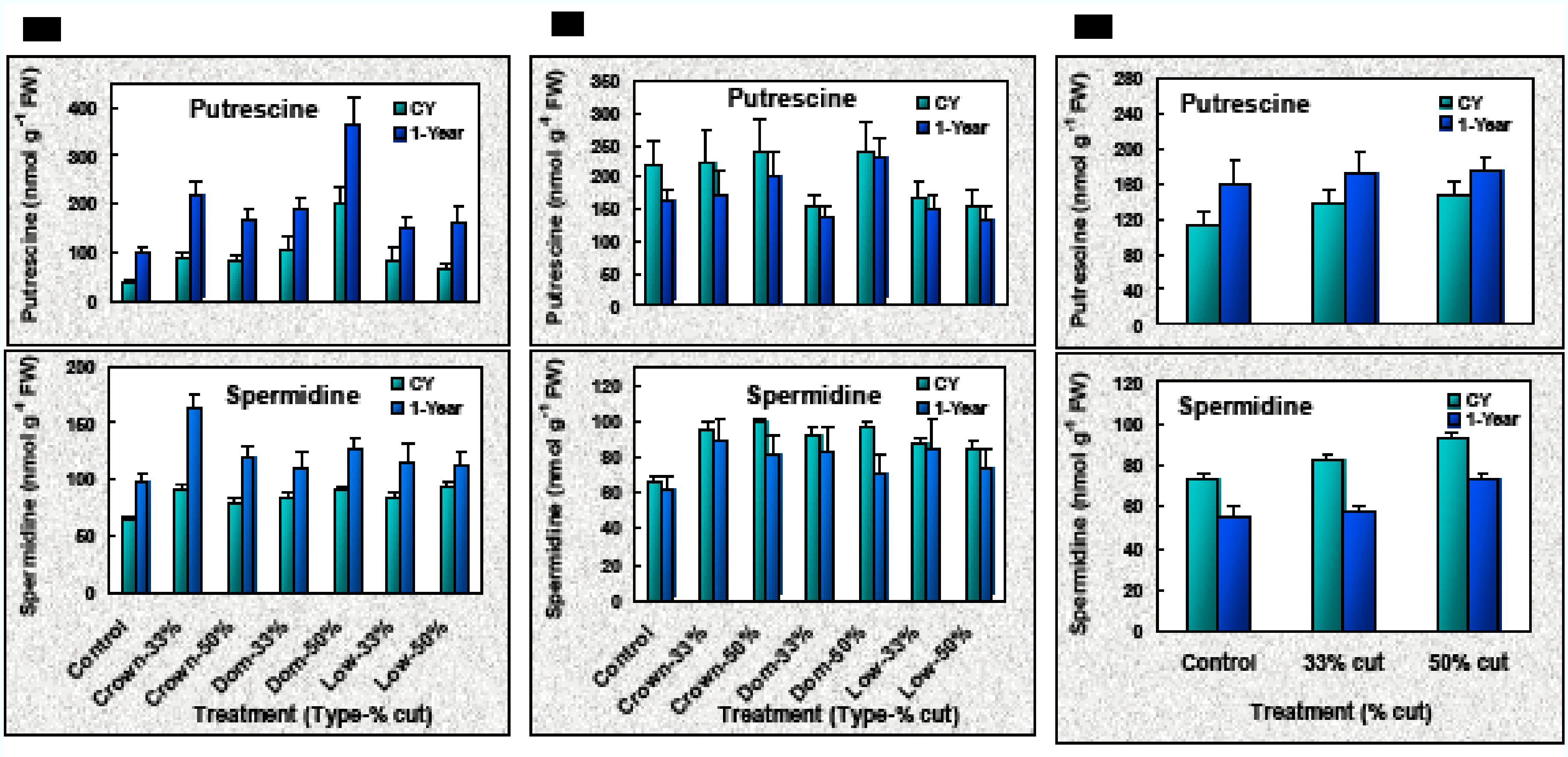

Figure 18. Levels of polyamines (putrescine and spermidine) in current year (CY) and 1-year-old needles of red spruce at Golden Road site (A), balsam fir at Golden Road site (B), and Balsam fir at Lake Macwahoc site (C) under various commercial thinning methods being tested.

Results from this analysis indicate that levels of putrescine and spermidine in the foliage of balsam fir and red spruce are influenced by thinning. Levels of both compounds increased relative to those found in unthinned stands for red spruce in most thinning treatments at Golden Road (Figure 18A). Both compounds also were higher in 1-year-old foliage than current foliage. Patterns for balsam fir at Golden Road were less clear, but spermidine levels appeared to increase with thinning treatment (Figure 18B). Putrescine and spermidine levels increased with the degree of commercial thinning in younger balsam fir stands, especially in current year foliage (Figure 18C). We are currently examining whether post-thinning growth response of the sample trees is correlated with levels of these polyamines or other compounds.

Based on the encouraging results from the 2003 samples, the study was expanded during the summer of 2004 to include two more CTRN study sites. Using the same procedures as the previous sites, foliage samples were collected from red spruce at the Harlow Road site and balsam fir from the Comp 23A study site. These samples are being analyzed and results will be reported next year.

More information about the study can be found by contacting **Rakesh Minocha** at 603-868-7622 or at rminocha@fs.fed.us.

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Growth Response from Nitrogen Fertilization of Precommercially Thinned Spruce-fir Stands

Robert G. Wagner, Daniel J. McConville, and Russell D. Briggs

The objective of this ongoing project is to evaluate whether nitrogen (N) fertilization following precommercial thinning (PCT) increases the productivity of spruce-fir stands. The background and justification for this project were described in the 2003 CFRU Annual Report (McConville and Wagner 2003). In late 2003, two CFRU fertilization studies (Weymouth Point and T30-31) established in the mid 1990s were remeasured. This pair of studies provides a unique opportunity to examine the effect of N fertilization just after PCT (two years) or about eight years after PCT when the stands are near crown closure.

Both study sites (Weymouth Point and T30-31) were clearcut harvested in 1981 and then naturally regenerated to balsam fir and red spruce. In the mid 1980s both sites were released from shrub and hardwood competition using aerially-applied herbicides. Around 1991, both sites were PCT to about 1,200 trees per acre. At the Weymouth Point site, 178 lbs/A (200 kg/ha) of N fertilizer (as ammonium nitrate) was applied two years after PCT (1993) to experimental plots that were replicated three times and blocked by soil drainage (moderately well-drained, somewhat poorly-drained, and poorly drained) (Briggs et al. 1999). At the T30-31 site, experimental plots (replicated five times) were aerially fertilized with 178 lbs/A (200 kg/ha) of N fertilizer (as ammonium nitrate) about eight years after PCT (1997) when the stands were near crown closure. Both studies have untreated control plots to allow for a direct comparison between fertilized and unfertilized treatments. In addition, the T30-31 study contains a nested sub-experiment to test controlled-release N fertilizer at 89, 178, and 357 lbs/A (100, 200, and 400 kg/ha).

In fall 2003, the diameter breast height (dbh), total height, height to live crown, and species were recorded for all tagged trees in each plot at the Weymouth Point and T30-31 study sites. These measurements provide the volume growth for all trees 12 years after PCT and 10 years after N fertilization at Weymouth Point, as well as about 12 years after PCT and six years after N fertilization at the T30-31 site.

Growth Response to Fertilization

Efforts during 2004 focused on the analysis of fertilizer responses in both studies. An Analysis of Variance was used to statistically determine whether significant increases in height, stem diameter, basal area, and stem volume growth occurred as a result of N fertilization. Our analysis indicates that fertilization increased wood volume growth in the T30-31 study but not in the Weymouth Point study.

Mean stand volume growth across soil types was only 0.2 cords/A/yr higher in the fertilized than unfertilized plots in the Weymouth Point study (Figure 19). Although there was 29% and 18% higher stand volume growth in fertilized than unfertilized plots on somewhat poorly drained and moderately well drained soils, respectively, in the Weymouth Point study, there was no significant fertilizer ($p = 0.73$) or fertilizer by soil drainage interaction ($p = 0.84$). In contrast, results from the T30-31 study (Figure 20) indicated that individual balsam fir had 82% higher volume growth in fertilized than unfertilized plots ($p = 0.0035$). Red spruce, however, showed no gain in individual tree volume growth ($p = 0.81$). When scaled up to the stand level, results from the T30-31 study suggested a mean increase in volume growth of 49% or about 1 cord/A/yr from fertilizing PCT stands near crown closure. The results also indicated no increase in volume growth from any of the controlled-release N fertilization treatments for balsam fir ($p > 0.378$) or red spruce ($p > 0.185$).

Although there are clearly differences in the experimental design and sites between the Weymouth Point and T30-31 studies, these results suggest that volume production gains from N fertilization may only occur when spruce-fir stands have received PCT and followed later by N fertilization just before crown closure (as in the T30-31 study). Fertilization shortly after PCT, as in the Weymouth Point study, does not appear to provide any substantial gain in wood volume growth regardless of soil drainage characteristics.

Figure 19. Periodic annual increment (PAI) (cords/A/yr) of balsam fir and red spruce stands 10 years after nitrogen fertilization (178 lbs/A) under three soil drainage conditions in the Weymouth Point study. Fertilization occurred two years after PCT. No statistical difference in volume growth from fertilization was found ($p = 0.73$).

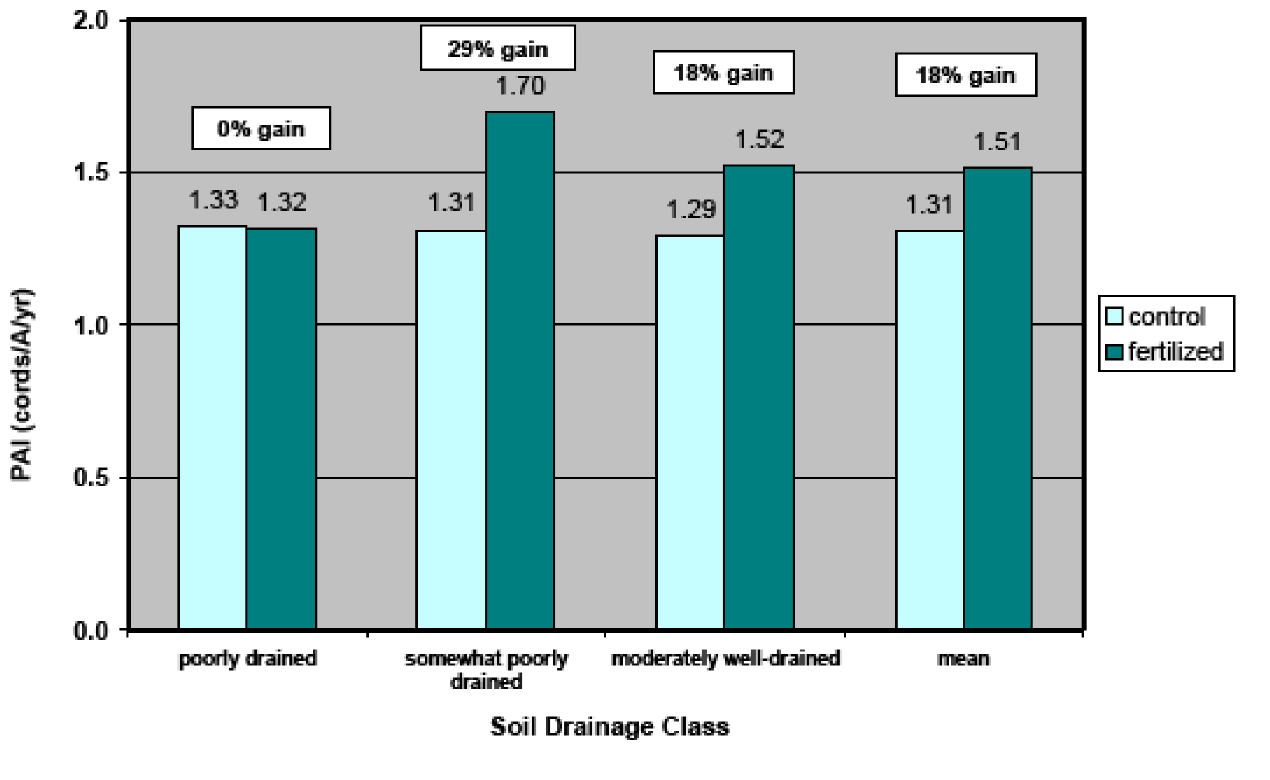
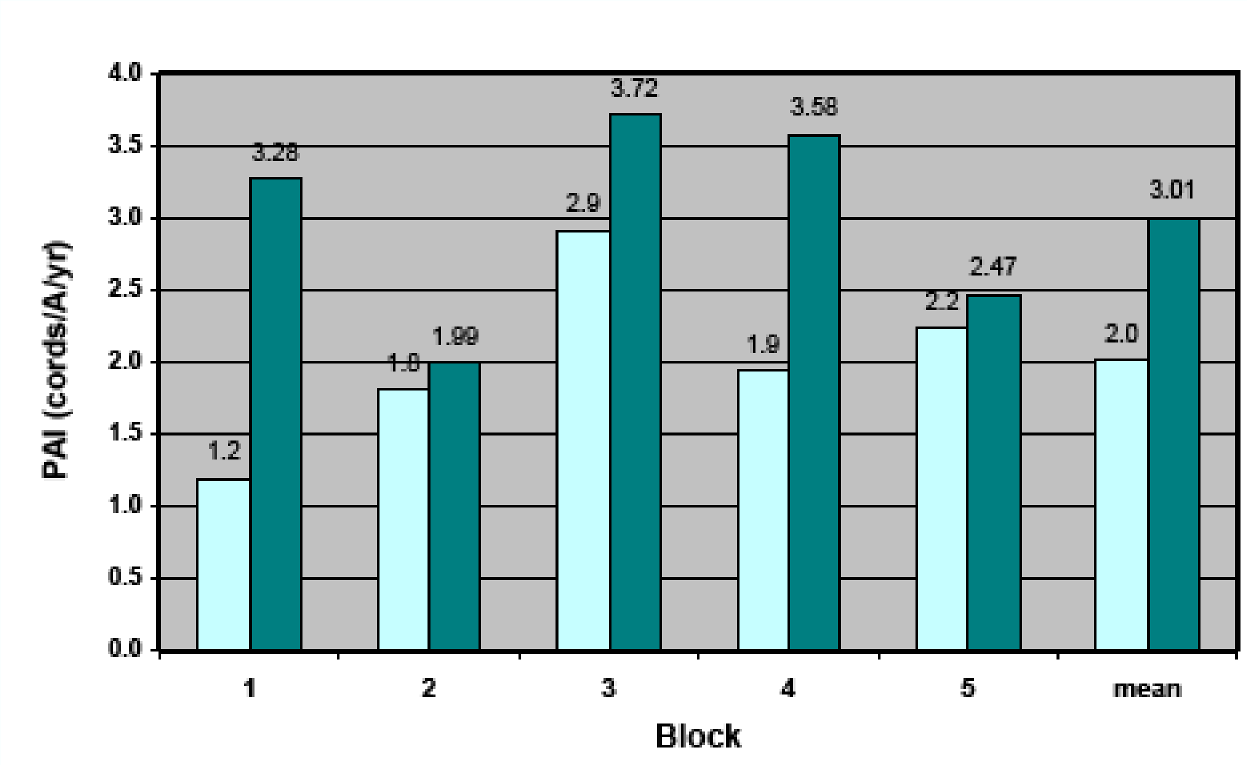


Figure 20. Periodic annual increment (PAI) (cords/A/yr) of balsam fir and red spruce stands 6 years after nitrogen fertilization (178 lbs/A) on five different blocks in the T30-31 study. Fertilization occurred about 8 years after PCT. Fertilization increased the stem volume growth of individual balsam fir ($p = 0.0035$), but not individual red spruce ($p = 0.81$).



Financial Analysis

We conducted a preliminary financial analysis based on the above results as well as the measured volume gains from fertilization in both studies to date (Table 8). Comparing a 0.2 cords/A/yr volume growth gain and 18 year investment period from fertilization to harvest in the Weymouth Point study to a 1.0 cords/A/yr volume growth gain and 10 year investment period from fertilization to harvest in the T30-31 study produced substantially different financial outcomes. The higher yield and delayed fertilization in the T30-31 study produced a net present value (NPV) of $60.13/A (7% discount rate) and an internal rate of return (IRR) of 12.2%. The lower volume gain and longer investment period in the Weymouth Point study produced NPV of $-62.72 /A (7% discount rate) and an IRR of 1.3%.

It should be noted that a conservative roadside wood value of only $15/ton (~$33/cord) for spruce and fir was used for this analysis. It was assumed that harvested wood was merchandized as a mixture of studwood and pulp, and that logging costs were for a single-grip harvester. Based on current wood prices, these results are probably quite conservative. Thus, results from these studies clearly indicates that N fertilization of PCT spruce-fir stands that are near canopy closure and on well-drained sites deserve a closer look.

Results from the T30-31 study suggested a mean increase in volume growth of 49% or about 1 cord/A/yr from fertilizing PCT stands near crown closure.

Table 8. Financial analysis of nitrogen fertilization in spruce-fir stands based on measured gains in volume growth from Weymouth Point and T30-31 studies.

Study	Wood volume growth gain from N fertilization (cords/A/yr)	Time from fertilization to harvest (Years)	Total volume gained (cords/A)	Total volume gained (tons/A)	Roadside value ($/ton)	Value of increased volume ($/A)	Fertilizer cost ($/A)	Discount rate (%)	Net present value ($/A)	Internal rate of return (%)
Weymouth Point	0.2	18	4	8.4	15	126	100	7.0	-62.72	1.3
T30-31	1.0	10	10	21.0	15	315	100	7.0	60.13	12.2

Biomass Analysis

In addition to the above analysis, we destructively sampled 38 trees during summer 2004 on the T30-31 study site where significant fertilizer growth gains had been observed. Nineteen pairs of trees among the five blocks were selected from the middle 50% of the diameter distribution based on initial tree measurements. Field crews felled each tree. All branches were cut from the tree near the stem and the diameters of all branches were measured. Several branches from various locations along the stem were removed for detailed foliage analysis. Foliage samples also were taken from predetermined branches in the crown for leaf area estimates. Four stem cross sections (discs) were taken from predetermined positions along the stem, sanded, and the ring widths marked and scanned using the Regent Image Analysis System and measured using WinDendro software. After the ring width analysis, the discs were dissected to determine specific gravity changes that may have resulted from fertilization. These biomass data are now being analyzed to provide a more detailed picture about the influence of fertilization on stem growth, leaf area, and the specific gravity of wood.

For additional information about this study, please contact **Bob Wagner** at 207-581-2903 or bob_wagner@umenfa.maine.edu.

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Silviculture

Using SPOT For Analyzing Harvest Utilization Problems

Daniel J. McConville

A new version of the SPOT (Stand Product Optimization Tool), a computer program that enables one to appraise the financial value of standing trees, was completed in 2004 (Figure 21). The program estimates merchantable stemwood volume, weight, and value for standing trees. Users input tree-level data including species, diameter breast height (dbh), and height; merchantability standards such as minimum top diameter, minimum length and length increment; and value and cost data including mill-delivered price by product, and trucking and harvest costs. SPOT virtually bucks and merchandizes the stand to maximize the financial value. The program output consists of a table that lists the expected products and values by mill and product class.

Several improvements were made in the latest version, which was released to CFRU members in the fall of 2004. These changes include a single-tree value and product calculator (Figure 22), the ability to enter pricing and cost data per unit ton rather than only cords and thousand pound units, a "kickdown factor" that allows users to

Figure 21. New SPOT introductory screen

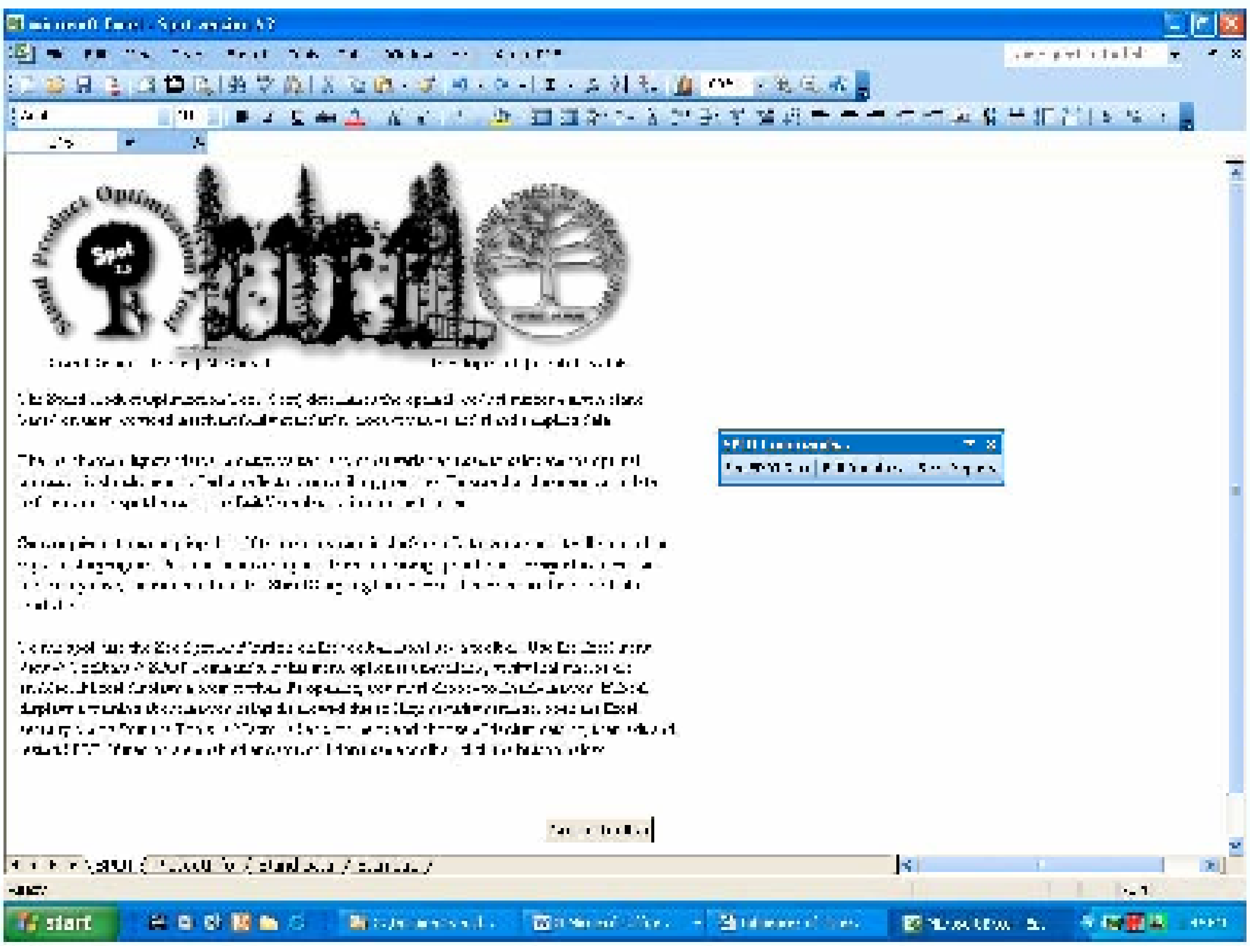
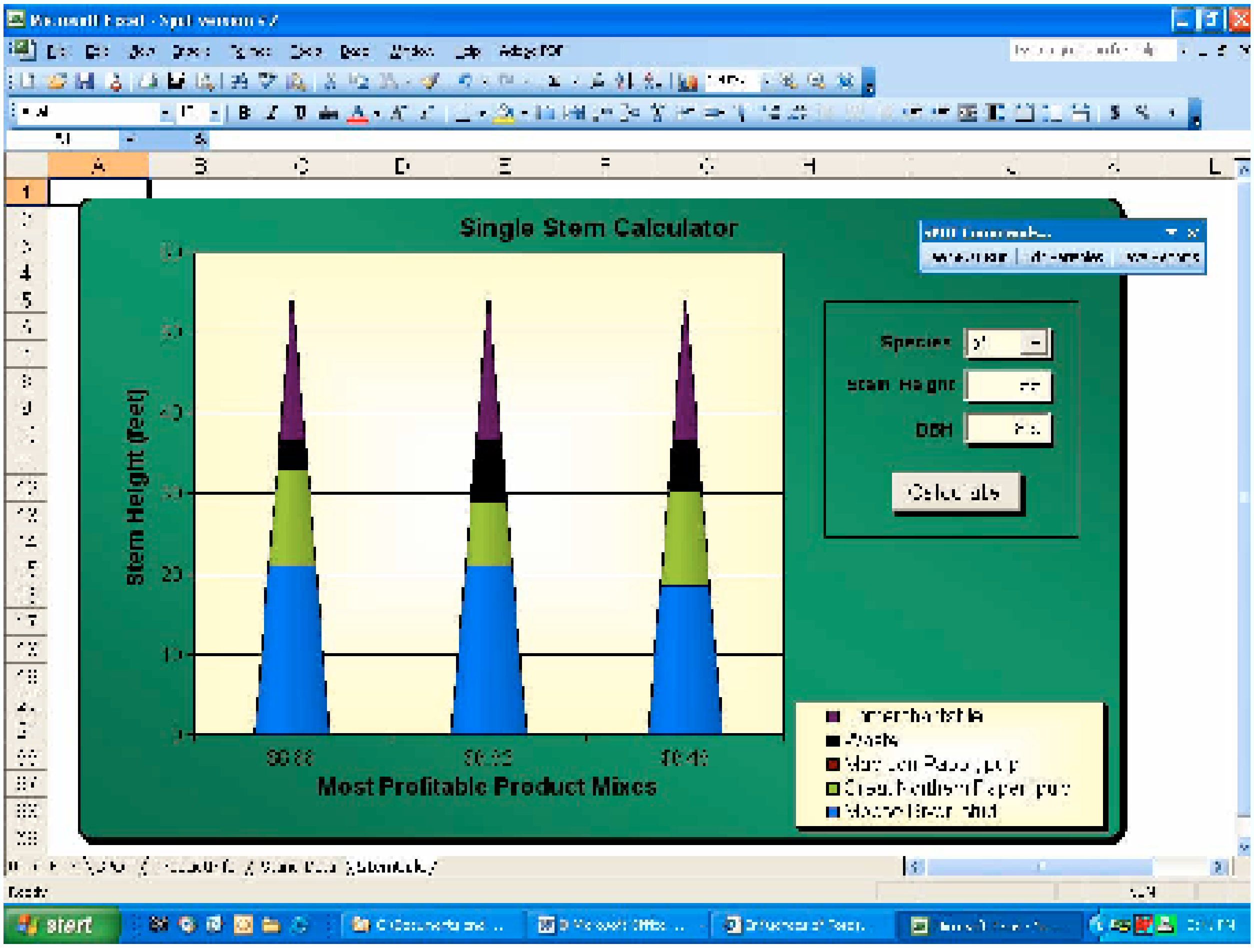


Figure 22. Screen showing new SPOT single-stem calculator feature.



specify a percentage of a product that meets the minimum size requirements but will not meet minimum quality constraints, detailed program documentation and additional user help.

Background

For a resource manager the capability to accurately appraise the financial value of standing trees now or in the future is critical to making an informed forest management decision such as whether or when to silviculturally treat or harvest a stand. The first version of SPOT, released to CFRU Cooperators and scientists in March 2003 (see 2003 annual report), was the first tool created that accurately quantified the financial value of standing trees in Maine.

SPOT calculates the most profitable way to utilize each tree stem in a stand based on user input cost, value, and merchantability specifications, and generates a report detailing values and quantities of products by product class. In addition to enabling one to financially appraise the value of standing trees, SPOT provides data necessary to optimally merchandize stems by determining the best bucking specifications and the mills to which products should be sent.

Prior to the creation of SPOT no tool existed for accurately determining the product mix and value of standing trees in Maine. The traditional method estimates the merchantable volume of sampled trees using diameter and total tree height data, uses a conventional minimum merchantable top diameter, and then calculates the volume to that minimum diameter. This method is imprecise and impractical for several reasons. First, it does not allow subdivision of a single stem into more than one product. For example, if the minimum merchantable top diameter for spruce saw logs is six inches the traditional method can accurately calculate the volume of a tree to a six-inch top; but if the tree can be divided and merchandized into more than one product (e.g., one 16-foot saw log plus a 12-foot piece of pulp), this method cannot be used to determine the combined value of the products. Second, mills require that products be cut to strict length specifications (e.g., 16 feet for saw logs with 0.5 feet of trim). The traditional method does not allow simultaneous calculation of the volume to a given top diameter and a specific merchantable length. Thus, the traditional method will almost always result in over-predicting volume. Last, merchantable size specifications are constantly changing and new products and markets are continuously becoming available. The traditional method of appraising value is inflexible and imprecise in an increasingly dynamic, complex, and competitive marketplace.

How SPOT works

Inputs

SPOT resides in a Microsoft Excel workbook containing six spreadsheets and several macros written in Visual Basic. Users input a tree list containing five variables for each row in the spreadsheet: plot number, number of stems, tree species (two-letter code), tree dbh (in.), and tree height (ft.). Users must enter site level information such as the number of plots and the plot size for fixed-area plots at the top of the spreadsheet, which is used to determine stand-level values in the report. For variable radius plots (prism plots) users must determine the number of stems per acre that each tree represents in the "number of stems" column and enter that value for each tree. In addition to the tree list, users must input merchantability specifications including the mill name and product name (i.e., pulp, sawlog, oriented strand board, etc.); mill-delivered value expressed either in cords, board-feet (International 1/4-inch log rule), or weight (lbs or tonnage); and merchantability standards including minimum top diameter (in.), minimum length (ft.), length increment (ft.), and maximum length (ft.). Users also input the stump height (ft.), the log trim for each product (ft), the trucking cost for each mill ($/cord), and the total cost to harvest, yard and load the products ($/acre).

Optimization

SPOT reads the data for a given tree in the tree list and reduces the possible products that the tree can be divided into based on the product specifications and the tree's species and size. With the possible combinations of products greatly reduced SPOT computationally bucks the tree into all the remaining possible combinations of products and selects the suite of products that result in the highest gross value (mill delivered value minus trucking costs). Summing the optimal gross value for each tree, subtracting the harvest, yarding and loading costs, and expressing the value on a per stand basis determines the optimal yield value for the stand.

Volume estimates

The procedure for this program is based on the volume equations published by Honer (1967). These equations allow calculations of the length of a given product to the specified minimum top diameter, account for merchantable length of the product, and recalculate the volume of the product. SPOT uses this procedure to determine all of the possible products that a tree can be divided into and then determines the suite of products with the highest net value. The program requires that users input inventory data including species, diameter and height data; market information including mill-delivered prices, minimum diameter, length and length increment data; and costs associated with harvesting and trucking products to regional mills. Based on this information, SPOT calculates the most profitable way to utilize each tree stem and generates a report tabulating maximum harvested volume for each product class, mill-delivered values, net profit (value minus costs), the merchantability standards and mills where each product should be sent.

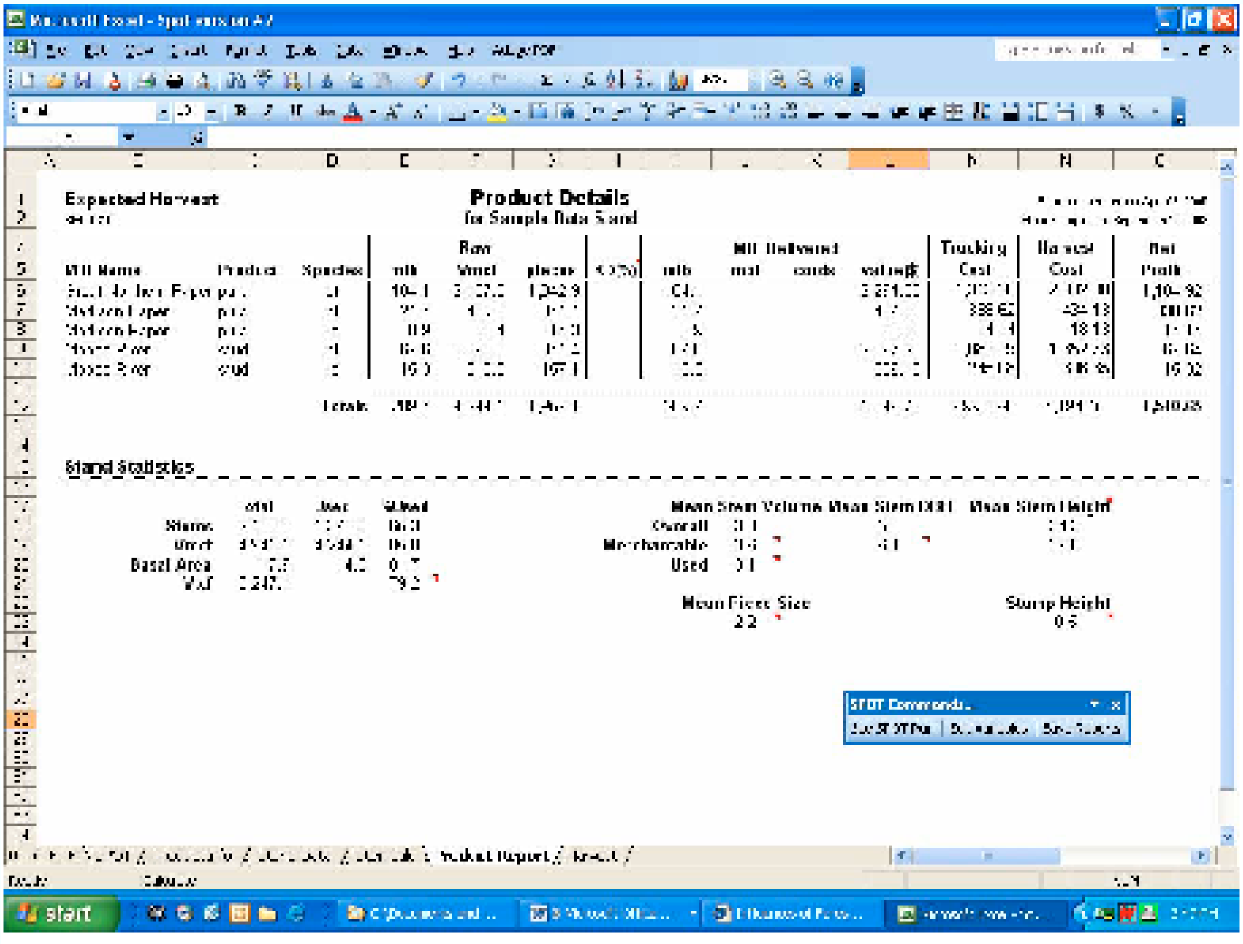
Weight estimates

Spot converts cubic feet values to cords using the conversion $1 ft^3 = 0.01176$ cords for all species. Spot uses species-specific Maine Forest Service conversion values to convert cords to weight (lbs).

Reports

After the optimization process is complete SPOT produces both a product and harvest report. The product report lists the mills to which the harvested material should be sent, estimates for the expected weight or volume, value of each product by product class, and the estimated trucking costs (Figure 23). It also contains stand statistics such as the volume, basal area, quadratic mean diameter and height, the number of merchantable and unmerchantable stems, and the total number of pieces cut. The harvest report, which is intended to be given to a logging contractor, contains the expected total volume or weight of harvested material by species, the mills to which the wood should be sent, and the merchantability specifications for each mill including the minimum top diameter, minimum length, length increment, and maximum length.

Figure 23. Screen showing SPOT output table.



Limitations

There are three important limitations to SPOT. First, SPOT assumes that trees are perfect in form. That is, any stem section that meets the minimum size requirements for a product can be merchandized as such unless the user specifies otherwise. Users may enter a "C" or the word "cull" in the stand data table next to the tree height to indicate that the tree is cull and should be merchandized as pulp. However, the cull designation can only be applied to the entire tree, and not a portion of a stem. Second, SPOT assumes perfect bucking. In order to reach the optimal value a logger must buck each log perfectly to achieve the tree's highest value. Third, SPOT assumes that the volume equations are perfect.

New Features

The new version of SPOT was completed in the fall of 2004 and replaces the 2003 version. The 2004 version features a single-tree calculator that allows determination of the economic value and products that can be derived from a single tree (Figure 23). Users input tree species, dbh, and height for a single tree, and the model predicts the most valuable method for merchandizing the stem and reports the product mix and value of the tree. This feature will allow users to assess the most profitable method for merchandizing trees without complete tree-level inventories.

An important limitation of SPOT is that it determines whether a piece of wood will meet a product class exclusively on size. However, quality can play an important role in value, especially for higher valued products such as veneer and sawlogs where defects such as sweep and rot exclude logs from these product classes. To compensate for this error, a "kickdown factor" was added that allows one to move a percentage of a product into another product class. For example, if it was assumed that only 30 percent of wood that meets the minimum size requirements for veneer can be merchandized as such because of quality limitations, the kickdown feature allows moving volume from the veneer class to another product class such as sawlog, pulp or both.

Significant changes were made to the Visual Basic code to virtually eliminate errors that cause the program to stop working properly. The user interface was redesigned to make the program more intuitive and efficient. In addition, users can specify the unit of mass, either thousand pounds (lb) or tons, that they wish to use for entering harvest costs, trucking costs, and mill-delivered prices. Other changes include new graphics and additional user help throughout the program.

For more information or help with SPOT, contact **Bob Wagner** at 207-581-2903 or bob_wagner@umenfa.maine.edu.

Silviculture

Northern Hardwood Growth and Yield Model

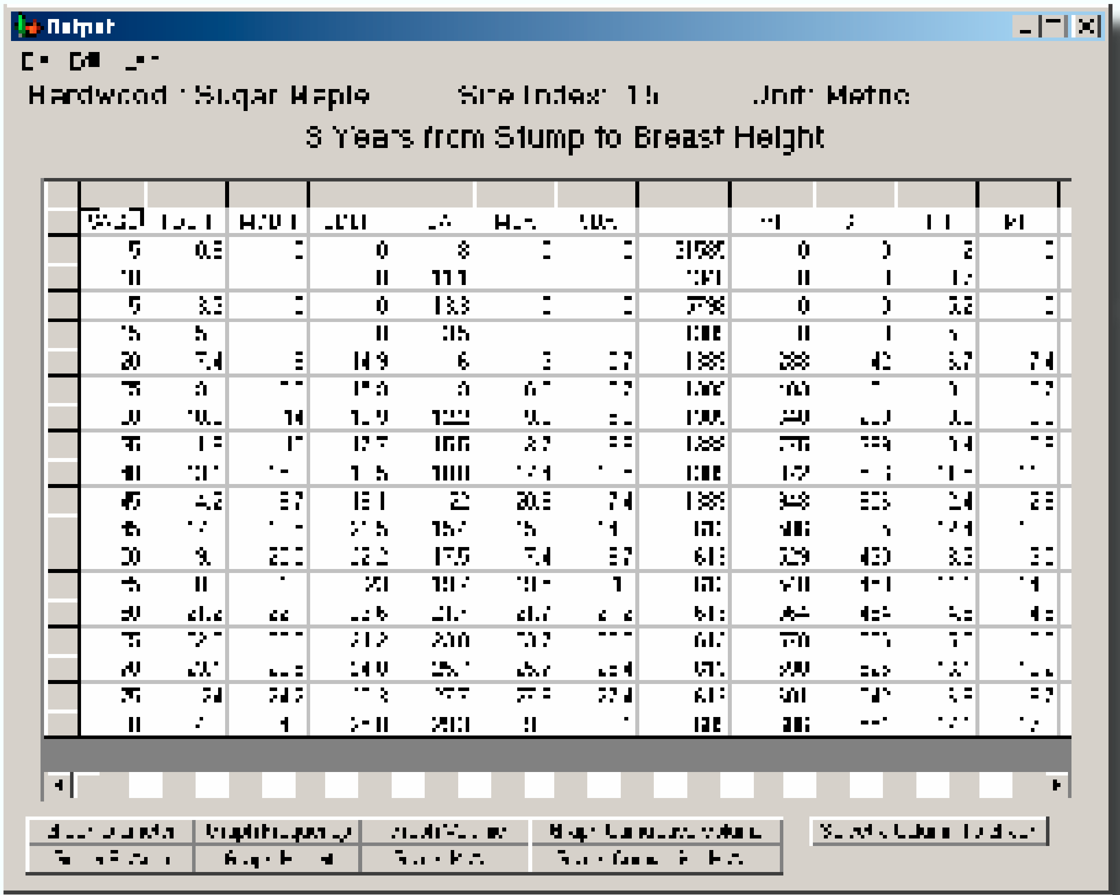
Tim McGrath

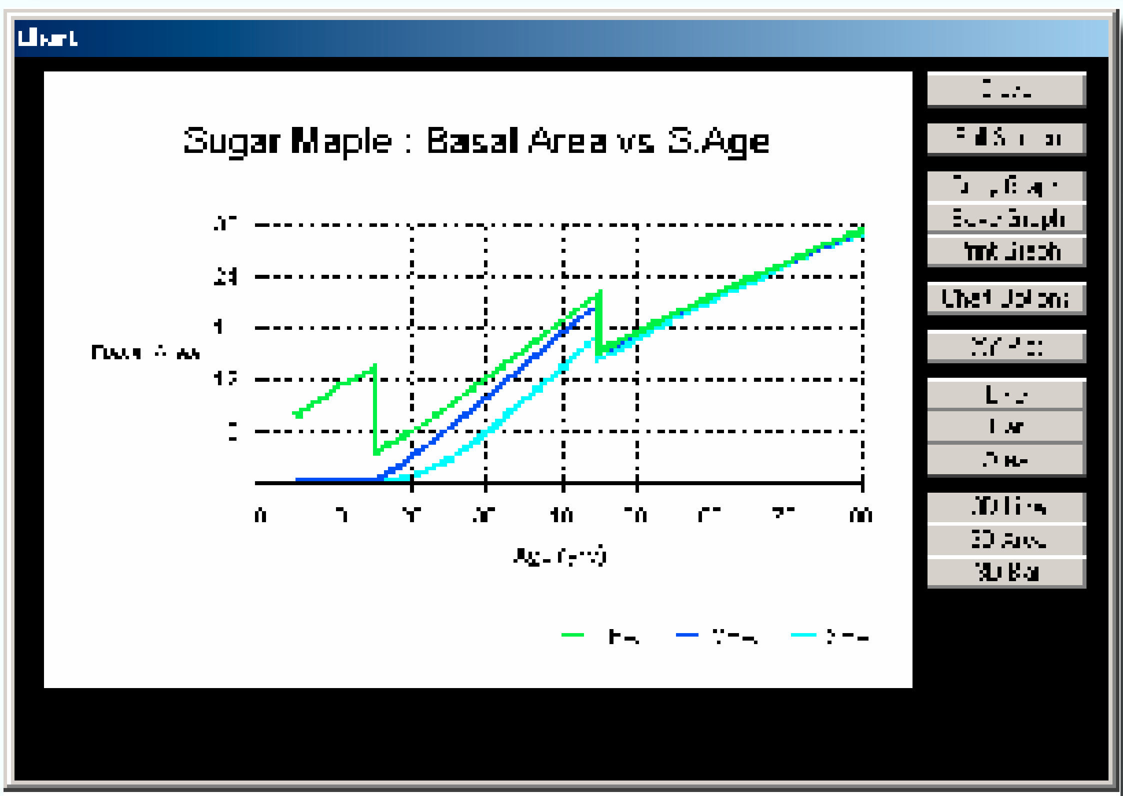
Efforts during the second and final year of this project focused on refining the Nova Scotia Hardwood Growth and Yield model (HWGNY). Data collected during 2003 from over 300 permanent sample plots on 50 study sites examining hardwood stand responses to precommercial and commercial thinning across Nova Scotia were compiled and edited. The study plots, which were established from 1978-97, include stands dominated by sugar maple, white birch, red oak, aspen, red maple and yellow birch. These data are now being used to recalibrate HWGNY and include enhancements concerning species-specific stand density and diameter growth relationships. The user interface of HWGNY was rewritten to increase stability and improve capabilities. For example, the user interface for the single use and batch mode, as well as graphing utilities, were improved. Samples of output screens are shown in Figure 24 (following page).

The HWGNY is a state dependent simulation model that uses site index, stocking, species, treatment type, intensity, and timing as driving variables. Precommercial thinning, commercial thinning, and unthinned stand conditions can be simulated. The beta version of HWGNY was completed in November 2004 and distributed to interested CFRU cooperators for testing and comment in December 2004. Feedback from CFRU members will be incorporated into the final version of the model.

Analysis and development of new growth relationships is nearing completion. Incorporation of these relationships into the model, testing of the model, and final documentation will be completed by winter 2005. For more information contact **Tim McGrath** at (903) 893-6102 or tpmcgrat@gov.ns.ca.

Figure 24. Example output table and graph from Nova Scotia Hardwood Growth and Yield model.





Silviculture

Review of Vegetation Management in Northeastern Hardwood Forests

Ralph D. Nyland

During the past year, we completed a bibliography and five review papers on various aspects of vegetation management for promotion of hardwood regeneration in the Northeast. The annotated bibliography, entitled *"The Role of Interfering Plants in Regenerating Hardwood Stands of Northeastern North America: An Annotated Bibliography for American Beech, Striped Maple, Hobblebush, Hayscented Fern, New York Fern, Bracken Fern, Raspberries, and Pin Cherry"* includes citations and summaries from 329 publications on all aspects of managing these competing species in hardwood stands. This bibliography is available on the CFRU web page and is being published by the Maine Agricultural and Forest Experiment Station (Figure 25).

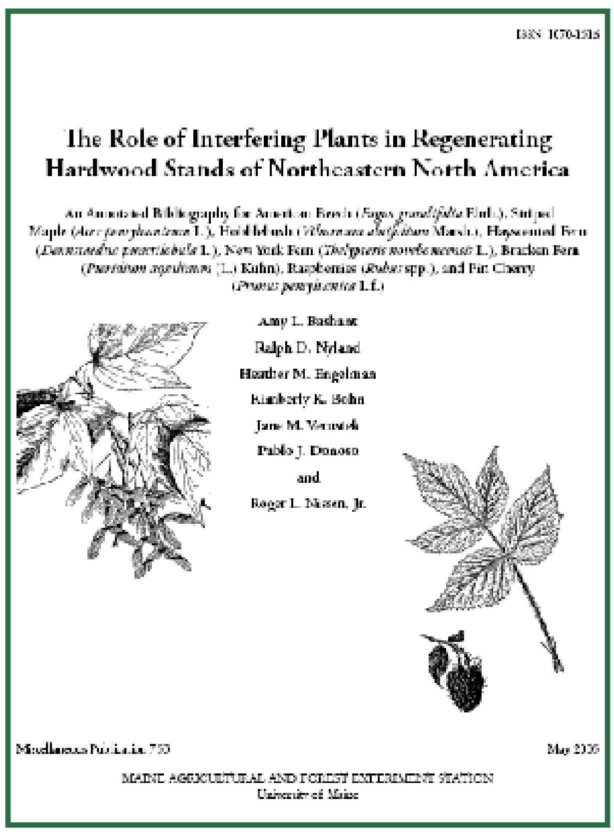
From this bibliography, four review papers have been completed summarizing the state-of-knowledge about managing American beech, striped maple, hobblebush, ferns, Rubus, and pin cherry in regenerating hardwood stands. The five reviews are entitled Interference to hardwood regeneration in northeastern North America:

- Assessing and countering fern interference
- Ecologic characteristics of American beech, striped maple, and hobblebush
- Controlling effects of American beech, striped maple, and hobblebush
- Pin cherry and its effects
- The effects of raspberries following clearcutting and shelterwood methods

These reviews have been posted on the CFRU web page and the manuscripts have been submitted to the Northern Journal of Applied Forestry for publication. Reviews from the journal have been favorable and plans call for these papers to be published as a series.

For more information about this project, contact **Ralph Nyland** at (315) 470-6535 or

Figure 25. Cover of CFRU annotated bibliography on the role of interfering plants in regenerating hardwood stands being published by the Maine and Agricultural Forest Experiment Station.


The Role of Interfering Plants in Regenerating Hardwood Stands of Northeastern North America

Amy L. Bashant
Ralph D. Nyland
Heather M. Engelman
Kimberly K. Bohn
Jane M. Verostek
Pablo J. Donoso
and
Roger L. Nissen, Jr.

MAINE AGRICULTURAL AND FOREST EXPERIMENT STATION
University of Maine

Wildlife Ecology

Improving our understanding about how forestry practices affect wildlife habitat

Influence of Forest Practices on Stand and Sub-Stand Scale Habitat Selection and Movements of Canada Lynx

Temporal Changes in Abundance of Snowshoe Hares in Maine: 1995-2002

Evaluating the Umbrella Species Approach for Biodiversity Conservation on Commercial Forestlands in Maine

Wildlife

Influence of Forest Practices on Stand and Sub-Stand Scale Habitat Selection and Movements of Canada Lynx

Angela K. Fuller and Daniel J. Harrison

Canada lynx (*Lynx canadensis*) occur across much of the northern United States and Canada, but Maine has the only verified population in the eastern United States. Lynx occur in harvested landscapes in Maine, but little is known about how they respond to sub-stand scale changes in forest structure associated with forest harvesting. We are evaluating the effects of forest practices on this federally threatened species to determine how lynx respond to the structural features of their habitat at fine spatial scales. Determining responses to structural features within forest stands will provide guidelines for maintaining important elements within harvested forests.

Lynx primary prey are snowshoe hares (*Lepus americanus*) (Saunders 1963, Brand and Keith 1979) and habitat use by lynx is closely associated with hare density (Koehler et al. 1979, O'Donoghue et al. 1998, Mowat et al. 2000). Within the Acadian forest, hares are closely associated with regenerating stands with an abundant coniferous understory (<1.5m in height) (Lachowski 1997, Fuller 1999). It is important to determine the direct and indirect effects of silvicultural practices on habitat choice by wide ranging species that depend on hares, such as lynx. Silvicultural practices that create early-successional stages may increase densities of snowshoe hares and associated foraging opportunities for lynx. However, habitat use by lynx may be associated with more than just access to snowshoe hares, but with overstory and understory features related to protection from predation.

Partial harvesting has the potential to reduce habitat quality for lynx because partially harvested mixed stands (52-59% basal area removal, 3-4 years post harvest) had the lowest density of snowshoe hares during winter among all overstory types (including regenerating clearcut, coniferous, deciduous, and mixedwood stands) sampled in northcentral Maine (Fuller and Harrison 2005). Partial harvesting is commonly practiced in Maine and eastern Canada and represented 96% of the forest acreage harvested in Maine in 2002 (Maine Forest Service 2003), but it is not known how lynx respond to the forest structure and reduced density of hares in these stands. It is important to determine the effects of alternative silvicultural practices on hares and lynx, including how varying densities of coniferous understories influence habitat choice.

Movement of lynx through different stand types and silvicultural treatments have implications for habitat selection, food search patterns, energy investments, and territorial and social behavior (Bascompte and Vilà 1997). Sub-stand scale movement patterns of lynx can be used to identify ways that lynx respond to the structure of the landscape, helping to identify which structural features are important. The characteristics of lynx paths may provide insights into the importance of the habitat type and structural features for foraging, providing cover, or protection from predation.

This study is funded by the Cooperative Forestry Research Unit, United States Fish and Wildlife Service, the Maine Forest and Agricultural Experiment Station, the Maine Department of Inland Fisheries and Wildlife, the Nature Conservancy, and the Department of Wildlife Ecology at the University of Maine.

Objectives

We are evaluating how lynx respond to structural features within forest stands at fine spatial scales. Determining the responses of lynx to structural features will identify important elements within forest stands that should be retained to promote use by lynx and help improve forest management guidelines.

The objectives of our study are to:

- Evaluate stand-scale habitat selection by lynx using snowtracking.
- Develop models to determine which structural, overstory, and prey abundance variables best predict sub-stand scale habitat selection by lynx across a range of forest types.
- Quantify sub-stand scale features of rest sites used by lynx and to evaluate lynx activities (e.g., foraging, resting, straight-line travel) in relation to habitat characteristics.
- Describe spatial-use and movement patterns via continuous line sampling of tracks in snow by radiocollared lynx within verified home ranges.

Approach

We located radiocollared lynx that were resting, intersected their tracks, and backtracked on snow to evaluate habitat selection. Habitat variables included in sub-stand scale (Figure 26) analysis provide a measure of the structure

Figure 26. A fresh snowshoe hare kill is encountered while backtracking lynx through a regenerating clearcut stand.

of the vegetation that is known, or suspected to influence the local abundance of snowshoe hares or lynx. Sample plots were conducted every 328 ft along the lynx trail and detailed vegetation data (e.g., canopy closure, tree height, basal area of deciduous and coniferous trees and snags, density of saplings, snow depth) were collected. Habitat variables will be compared between areas used by lynx and control sites on random straight-line transects sampled within the home range of the lynx. We verified the locations via GPS of all rest sites used by lynx and made vegetation and structural measurements to characterize those sites. Lynx activities on trails were recorded, including travel, urination, scat, chasing prey, and killing prey. We also recorded all prey that crossed or intersected the lynx trail.

Spatial-use and movement patterns include path shapes (tortuosity) of lynx in different overstory types (e.g., partial harvest vs. mature forest) and with different activities (e.g., hunting vs. traveling). We recorded all lynx trails with a GPS unit capable of continuous line sampling with real-time sub-meter accuracy. We will compare the path shape of lynx in different overstory types to evaluate the effects of forest type on movement decisions. To determine which variables best distinguish lynx and random transects, we will develop a priori models based on variables suspected to influence lynx use of landscapes at the sub-stand scale and use an information theoretic approach to rank model performance (Burnham and Anderson 2002). We will develop models using logistic regression to determine which sub-stand scale variables best predict the areas used by lynx by comparing them to characteristics of the vegetation on random transects within the home range.

Preliminary Results

We snowtracked six radiocollared lynx (3 females, 3 males) for 39.5 miles January - March, 2002 and 2003. We utilized continuous GPS sampling to track lynx and recorded overstory type along the lynx trails. We evaluated habitat selection at the scale of the forest stand by comparing the distance traveled by lynx in each overstory type (e.g., partial harvest, regenerating clearcuts, mature coniferous, mixedwood, and deciduous stands) to the percent of those overstory types within the 90% minimum convex polygon home range of each lynx. Habitat selection indices were calculated based on ratio of use (defined as the distance traveled by an individual lynx in a particular overstory type) and availability (defined as the total percent of that overstory type within the home range). We used the median of the natural log of the use/availability ratio (± 1 standard error) to evaluate habitat selection. A natural log transforms the selection index so it is centered on zero, which indicates use is in proportion to availability. Values greater than zero indicate selection for a habitat type, and values less than zero indicate selection against a habitat type.

Stand-scale habitat selection by lynx was strongest for short mid-successional regenerating clearcuts (11-14 ft tall, 11-22 yrs old) (Figure 27). Selection was probably strong for this silvicultural treatment due to high densities of snowshoe hares and a relatively open understory that created clear line-of-sight to hunt hares. Partially harvested stands (1-10 yrs old) were also selected for, but were ranked below short mid-successional regenerating clearcuts (Figure 27). Ground-truthing is still needed in partially harvested stands, so these results are preliminary. Lynx selected against tall mid-successional regenerating clearcuts (15-24 ft tall, 11-26 yrs old) and strongly selected against mature second-growth stands (>40 years old, mixedwood, deciduous, and coniferous) (Figure 27). Tall mid-successional clearcuts probably had greater understory canopy closure than short-mid successional clearcuts and made hunting hares more difficult and thus were selected against. Mature stands were strongly selected against; probably because of low densities of snowshoe hares. There was very low use of early regenerating clearcuts (<11 yrs old) (Figure 27) and these stands were avoided at the scale of the home range. This low usage was likely due to very low densities of snowshoe hares and no cover to

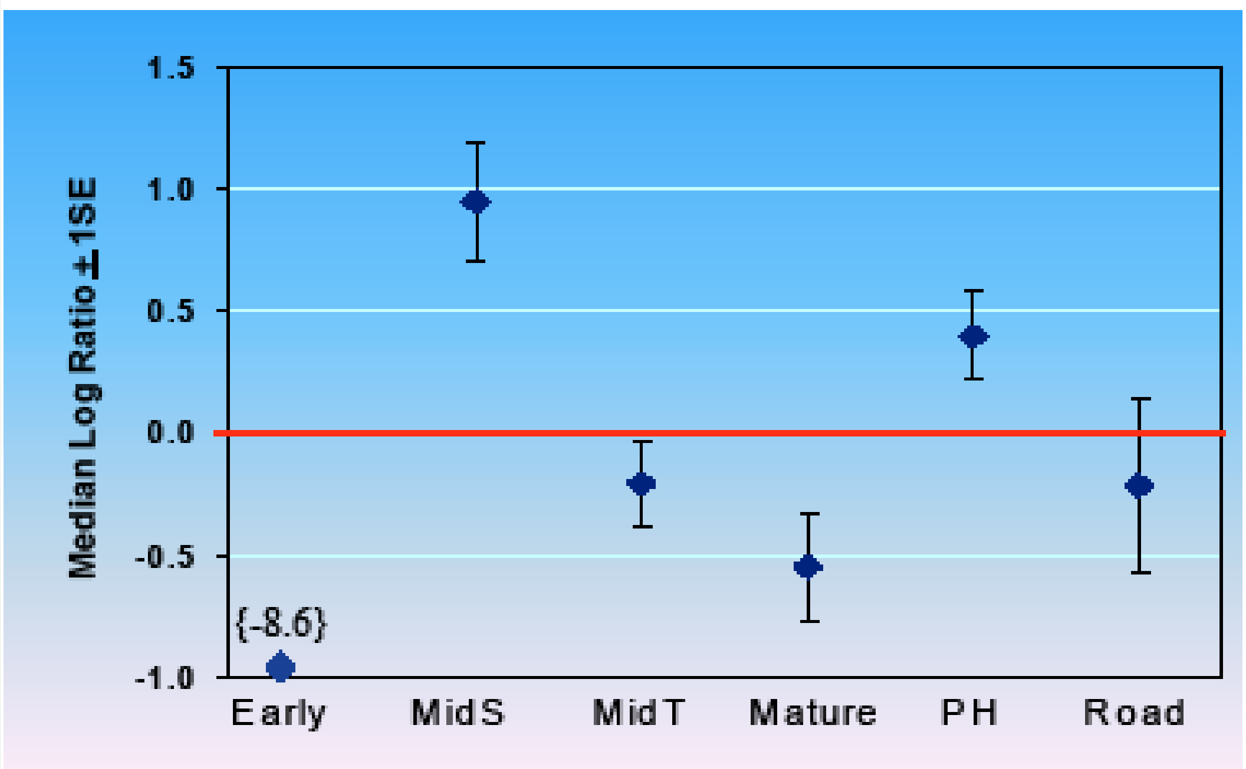


Figure 27. Selection indices [median log ratio ± 1 standard error (SE)] for 6 lynx (3 males, 3 females) snow-tracked in northwestern Maine during 2002-03. Selection indices greater than zero indicate selection for a particular habitat type grouping and indices less than zero indicate selection against. Selection indices that span zero indicate that use was in proportion to availability. Early = early successional clearcuts (cuts <11 yrs old, typically <11 ft tall); MidS = short mid-successional clearcut (trees 11-14 ft tall, 11-22 yrs old); MidT = tall mid-successional clearcut (trees 15-24 ft tall, 11-26 yrs old); PH = partially harvested (cuts 1-10 yrs old); Mature = second-growth mixedwood, deciduous, and coniferous (>40 yrs old, typically >40 ft tall); Road = road and road edge (98 ft buffer on either side of roads).

escape predation. Future analysis of the vegetation data will help our interpretation of habitat selection results at the stand-scale.

Outcomes

This project will provide scientific information needed to evaluate effects of alternative forest management activities, including partial harvesting, on lynx and their prey. We will provide guidelines for structural attributes that are important to retain in harvested stands. This information will be useful for forest managers to plan harvests that result in structures that are important for lynx and snowshoe hare. We will also determine the effect of sub-stand scale structure on movements of lynx.

Project Status and Timeline

In addition to the lynx snowtracking data described above, we also sampled straight-line transects within lynx home ranges and measured vegetation on all lynx tracks and random transects. In 2002, 34 miles of random straight-line transects were sampled within the home ranges of three lynx. Vegetation was sampled within 341 plots along the lynx trails and within 605 plots along random transects. In 2003, we sampled 28 miles of random straight-line transects within three lynx home ranges. Vegetation was sampled within 380 plots along the lynx trails and within 495 plots along random transects. Field work has been completed, but partially harvested stands will be ground-truthed in early spring 2005. Completion of the project is expected by May 2005. For more information contact **Dan Harrison** at 207-581-2867 or harrison@umenfa.maine.edu.

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Wildlife

Temporal Changes in Abundance of Snowshoe Hares in Maine: 1995-2002

Jessica Homyack, Daniel Harrison, and William Krohn

This one-year project is part of an 11-year study examining the effects of forest practices on snowshoe hares (*Lepus americanus*), which are an important prey species for many avian and mammalian predators in Maine and are the primary prey for the federally threatened Canada lynx (*Lynx canadensis*). Maine has the only verified population of lynx in the U.S. east of Minnesota. We are evaluating the weight of evidence to confirm whether lynx exhibit population cycles at the southeastern extent of their geographic range. This information is critical for evaluating whether human-induced habitat change or natural processes are responsible for population changes following forest harvesting.

Although 8 to 11 year population cycles of snowshoe hares are well-documented throughout northern Canada and Alaska, little is known about temporal changes in abundance of snowshoe hares at the southern portion of their range. Population dynamics of hares can be classified as cyclic, cyclic with reduced amplitude, fluctuating, or non-cyclic. The objectives of this study were to investigate whether an index of abundance for snowshoe hares collected across an eight-year period in north-central Maine displayed the distinguishing characteristics (i.e., synchrony, periodicity, 5-50 fold changes in magnitude) of hare population cycles in the more contiguous boreal forests of Canada and Alaska. Specifically, we investigated if the relative abundance of snowshoe hares increased synchronously and with extreme amplitude within regenerating conifer stands in north-central Maine during the period 1995-2002. On-going analyses are also evaluating snow-track surveys of hare abundance collected throughout Maine by the Department of Inland Fisheries and Wildlife to evaluate evidence for cycles and population synchrony at the regional and statewide scales.

Study Design

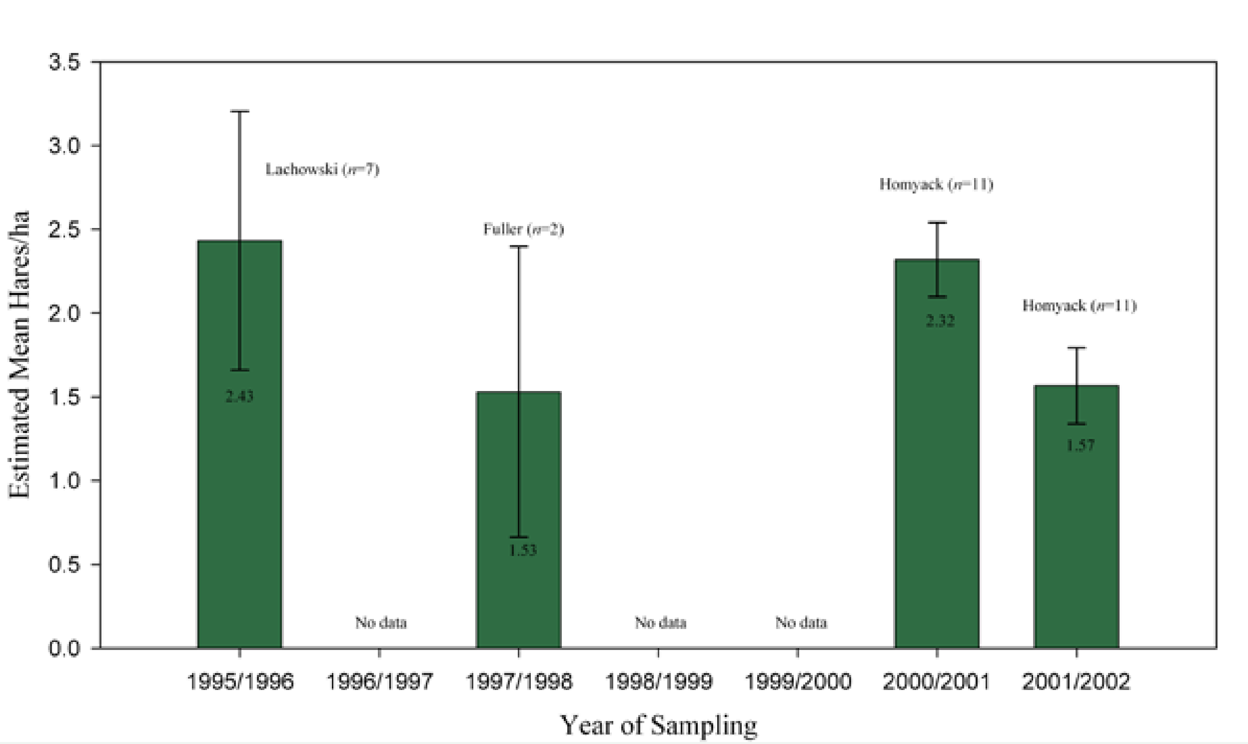
We sampled 31 regenerating conifer stands that were clearcut harvested (resulting in < 6.9 m^2/ha residual basal area of trees > 11.43 cm diameter breast height (dbh)) and aerially treated with herbicides (e.g., Glyphosate at ~ 1.7 kg/hectare (ha) acid equivalent). We established fecal pellet plots within regenerating conifer stands and converted densities of pellets to densities of snowshoe hare using the regression equation developed for Maine (Homyack 2003). During 1995-96 (Lachowski 1997) and 1997-98 (Fuller 1999) twelve 1.5 m^2 plots spaced at 10 meter intervals were established within the center of seven and two regenerating conifer stands, respectively. During 2000-02, Homyack (2003) sampled regenerating conifer stands (n = 11) with 84 pellet plots/stand placed at 20 meter intervals along 1.6 km of transect/stand. Pellets were counted and cleared from plots twice a year during all periods of study.

Results and Discussion

There was no detectable difference (t = 4.48, df = 3, P = 0.21) in snowshoe hare densities among regenerating forest stands of north-central Maine from 1995–2002 (Figure 28). Although a statistically significant difference was not detected, hare densities decreased by approximately 37% from the 1995–96 to 1997–98 leaf-off seasons, and 33% from 2000–01 to 2001–02 leaf-off seasons. Our stand-scale results suggested that at this spatial scale, the optimal habitat type retains relatively stable hare densities as compared to northern Canada and Alaska, where hare cycles are known to occur. Young, overstocked forest stands are often described as refuges for populations of hares because these areas retain high hare densities during population declines longer than more open forest (Wolff 1980). Regenerating conifer stands in Maine may be important source populations preventing extinctions in other small patches of dense forest at low densities, or for providing reproductive animals for population fluctuations (Wolff 1980, 1981). Our findings do not preclude the need for additional monitoring of hare populations in multiple habitat types for numerous years. Additional results from regional and statewide scales will be reported to the CFRU Advisory Committee next spring.

For more information contact **Dan Harrison** at 207-581-2867 or harrison@umenfa.maine.edu.

Figure 28. Estimated densities of snowshoe hares during leaf-off seasons (Oct-May) 1995-2002 within regenerating conifer stands in T 4 R 11 WELS and T 5 R 11 WELS, northern Maine. Lachowski (1997) and Fuller (1999) estimated densities of hares on 12, 1.5 m^2 plots/stand and Homyack (2003) estimated densities of hares on 84, 1.5 m^2 plots/stand. Densities of snowshoe hares were estimated from densities of fecal pellets using the relationship described by Homyack (2003).



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Wildlife

Evaluating the Umbrella Species Approach for Biodiversity Conservation on Commercial Forestlands in Maine

Daniel J. Harrison and Jeffrey Hepinstall

Forest landowners are expected to accommodate the habitat needs of all wildlife to avoid species loss and to maintain a viable distribution of organisms across commercially managed landscapes. Regulatory standards are already in place for deer wintering areas, bald eagle nesting areas, riparian zones, and for wetlands. Further, best management practices have been proposed for conserving vernal pools, to promote snags and legacy trees, and to promote the maintenance of coarse woody debris through time. Other species-specific conservation practices are also likely to be proposed for endangered threatened and special concern species in the future. Most of these conservation practices operate at the scale of the forest stand and do not address the critical spatial context of wildlife habitat needs across landscapes. Further, many stand-scale and species-specific conservation approaches have additive effects both economically and logistically for land managers.

Umbrella species have been proposed as a tool for simplifying biodiversity conservation by focusing on a few species with habitat needs that represent the minimal requirements for a diverse array of other species. Often, umbrella species are chosen because they have a representative habitat association (e.g., late successional, early successional) and are area-sensitive (i.e., require large areas that represent a range of spatial requirements of other less-area sensitive species). The umbrella species approach has been used to simplify biodiversity planning across federal lands in the U.S. and on Crown lands in Canada, but has been criticized because of the difficulty in quantifying benefits for biodiversity and because an unknown group of other species may still be at risk after applying an umbrella species approach. What has been lacking are sound models to accurately predict 1) the specific benefits to the target umbrella species and costs to managers of alternative conservation practices; and 2) the specific biodiversity benefits (i.e, which other species are helped and by how much) and costs of umbrella species conservation (i.e., which species receive no benefit or are harmed by efforts to conserve the umbrella species).

Maine is in a unique position for testing the umbrella species concept for conserving biological diversity. With CFRU and NCASI (National Council for Air and Stream Improvement) support, accurate, spatially explicit models have been developed for predicting habitat quantity, quality, and distribution for a mid-late successional species (marten; Harrison and Hepinstall), and for an early successional species (lynx;

Hoving, Harrison, and Krohn). Both species are area sensitive and are charismatic animals that the public can understand and relate to (i.e., they may also serve as conservation flagships). Further, both already receive national and international attention as indicator and umbrella species. Together, marten and lynx 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 U.S. east of Minnesota. Resulting from the recently completed Gap Analysis Project (Krohn et al. 1998), Maine also has an accurate, statewide, digital database of landcover (Hepinstall et al. 1999), coupled with spatially explicit models to predict habitat distribution and occurrence for 270 species of terrestrial vertebrates.

This project is complementary to the habitat planning process that has been developed by Maine Department of Inland Fisheries and Wildlife (IFW) for southern Maine and interfaces with ongoing efforts by IFW and conservation organizations (e.g., The Nature Conservancy) to plan for vertebrate biodiversity via habitat conservation in northern Maine.

Project Objectives

1. Evaluate how well broad-scale models that have been developed for marten and lynx accommodate the habitat needs of all of the other vertebrate species that occur on commercial forestlands in northern Maine.
2. Quantify the costs in vertebrate diversity of managing for either mid-late successional or early successional species and develop a model that optimizes overall vertebrate biodiversity at different intensities of land conservation planning.
3. Evaluate how well optimal models accommodate other important habitat features such as Deer Wintering Areas (DWA's).
4. Determine which vertebrate species require special conservation initiatives additional to managing for early and mid-late successional vertebrates.

Approach

We mapped the probability of occurrence of lynx and marten across northern Maine based on previously established models (Hepinstall and Harrison 2003, Hoving 1999). These models indicate that marten occurrence can be predicted with >80% reliability based on forest overstory characteristics, tree height, and fragmentation metrics from statewide satellite imagery. Similarly, the relative probability of lynx occurrence has been modeled based on snowfall, the extent of the landscape in late-regeneration (positive association), and the extent of deciduous forest in the landscape (negative association; Hoving et al. 2004).

Using spatial predictions for marten and lynx occurrences (> 80% probability of occurrence of either species), we then overlaid species predictions for early successional forest specialist and generalist species, and for mid-late successional forest specialist and generalist species based on models developed for the Maine Gap Analysis Project (MEGAP; Krohn et al. 1998). We tallied the number of species in each group that received a disproportionately greater benefit than the umbrella species, a similar (i.e., proportional) benefit, and those that realized a lower benefit than the target umbrella species. We used these results to identify those species that would benefit (disproportionately or proportionately) from the application of conservation planning based on habitat for marten, lynx, or both species. Species that are not adequately protected by habitat supply planning for marten or lynx were identified (i.e., these species may require additional management). We evaluated whether the more specific needs of these species would be addressed by other existing habitat conservation tools (i.e., shoreland zoning, riparian, or wetland protection), or whether additional conservation activities would be required. Next, we overlaid deer wintering areas mapped by MDIFW (Maine Department of Inland Fisheries & Wildlife) to evaluate to what extent umbrella species conservation complemented, or was additive to existing biodiversity conservation strategies.

Preliminary Results and Discussion

Our results indicated that using marten as a mid-late successional umbrella species would disproportionately benefit (i.e., benefit the other

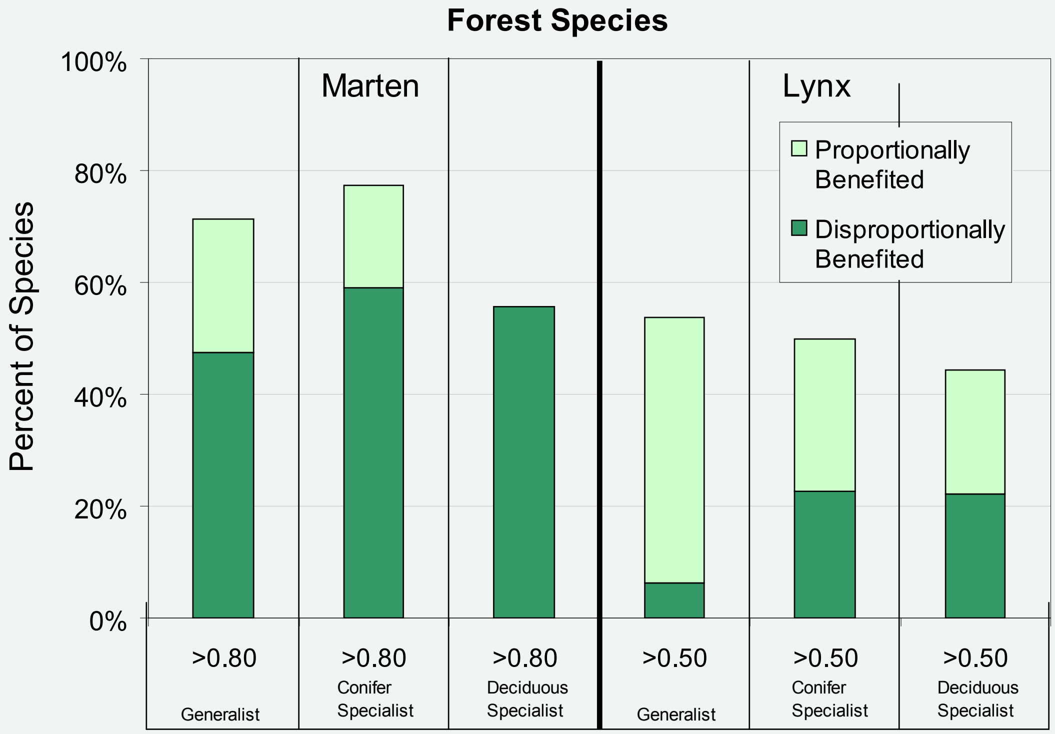

Figure 29. Percentage of species in each habitat guild disproportionately benefited or proportionately benefited by marten or lynx habitat conservation. Areas conserved for marten and lynx represent all of their habitat with predicted probability of occurrence of > 0.80 for marten and >0.50 for lynx, which represents 5.8% and 2.8% of northern Maine, respectively.

	% of Range	Forest Conifer	Forest Hardwood	Forest Generalist	Early-Successional
Marten Only		(n = 22)	(n = 9)	(n = 80)	(n = 20)
(>0.80 POC)	5.8	13 (59%)	5 (56%)	38 (48%)	0 (0%)
Lynx Only					
(>0.50 POC)	2.8	5 (23%)	2 (22%)	5 (6%)	8 (40%)
Both	8.4	18 (82%)	6 (67%)	43 (54%)	8 (40%)

Table 9. Number (and percentage) of species in each target habitat guild disproportionately benefited by martens, lynx, or both (POC = probability of occurrence).

species more than the marten) 70-85% of the forest generalist and specialist species occurring in northern Maine (Figure 29) and that lynx accomodated several other species. As predicted, lynx did a better job than marten at representing early successional species (Table 9).

We concluded that marten were an appropriate umbrella species on which to base landscape-scale biodiversity planning for mid- to late-successional species (76% of forest-associated species proportionally or disproportionally benefited). Adding lynx as an additional umbrella species would prevent 80% of early successional species from requiring special conservation efforts. Together, habitat conservation for marten and lynx would proportionally or disproportionally benefit >85% of forest species in Maine.

Early and mid-late successional habitats shift dynamically across landscapes. Therefore, a combination of early and late successional habitat planning may ensure that the full range of forest conditions needed to support economically viable forestry are complementary with the maintenance of vertebrate biodiversity through time. Our vision is that broad-scale biodiversity objectives for upland forest habitats could be achieved by focusing on the habitat requirements of as few as two umbrella species.

For additional information about this project, contact **Dan Harrison** at 207-581-2867 or harrison@umenfa.maine.edu.

Acknowledgments

We acknowledge David Payer, Angela Fuller, Don Katnik, and Dave Phillips for the use of their hard-earned field data. Funding for this project was provided by the Maine Cooperative Forestry Research Unit, the Maine Outdoor Heritage Fund, and the Department of Wildlife Ecology at the University of Maine.

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Biodiversity Conservation

Improving our understanding about the relation between forestry practices and biodiversity

Developing an index to quantify late-successional value at the stand and landscape level

Effectiveness of Different Buffer Widths for Protecting Riparian Values on Maine's Forested Headwater Streams

Developing an Early-Successional Bird Habitat Index for the Biodiversity Scorecard

Biodiversity

Developing an Index To Quantify Late-successional Value at the Stand and Landscape Level

Andrew A. Whitman and John M. Hagan

In 2002 the CFRU awarded a grant to develop an efficient assessment procedure that could be used to quantify late-successional (LS) attributes of stands and landscapes. This procedure was developed because (1) forest managers need simple, cost-effective metrics to help quantify biodiversity, and (2) late-successional attributes tend to be the most vulnerable characteristic in managed forests (Hagan and Whitman 2004). In 2003-04 we developed two rapid assessment LS indices (LSIs) to help forest managers and landowners easily identify high-value LS stands before harvest, track LS content across landscapes, and improve the conservation of LS attributes at the stand level. One LSI was developed for northern hardwood stands and the other for upland spruce-fir stands. Each LSI is comprised of two variables: large tree density and density of one or two LS macro-lichen species. The method for scoring the variables and LS macro-lichen species are different for each stand type.

During the summer of 2004 we conducted three field projects to validate the usefulness of the LSIs for forest managers (Figure 30). The first project is assessing the suitability of both LSIs to estimate and track the level of LS biodiversity at the landscape scale. This landscape level assessment will allow forest managers to quantify LS biodiversity levels in support of sustainable forest certification. In the second project, we are assessing whether the information gained from the LSIs can be used to improve the retention of LS content with little or no sacrifice of a stand's financial value. In the third project we are assessing whether riparian buffers have significant LS content. The data from all three projects are also being used to determine the sensitivity of the LSIs to harvest disturbance and to verify that LSIs can accurately identify LS stands.

The specific objectives for the overall project are to: 1) test the feasibility of the LS index to track LS content of managed forest landscapes, 2) test and improve the practicality of the LS index for making harvest decisions, and 3) assess the LS ecological contribution of riparian buffers for providing late-successional ecological value.

Figure 30. Field assistant Brian Milakovsky measures a large spruce tree while assessing the LS Index for an upland spruce-fir stand in Kibby Township, western Maine.

Project Status and Results

Objective 1 - Feasibility of the LS index to track LS content of managed forest landscapes

We applied the stand-level LSI to a random stratified sample of stands (n = 90-124 stands) for the LSI in three townships in western Maine: Kibby, Alder Stream, and Wyman Townships (Figure 31). We sampled more old stands than young stands because we expected old stands to have greater variation in LSI scores. Each township is owned by a different landowner and managed along a continuum of intensities based on the landowner's objectives; Kibby Township being the most intensively managed and Wyman Township the least intensively managed. All species types and age classes were sampled. A two-person team surveyed 6-10 stands per day typically evaluating each stand in 20 minutes. Travel time to between stands was the factor that most limited the number of stands sampled each day. After six weeks of experience, a team was able to sample a single township in three to four weeks. Data have been entered for most of Kibby Township and for parts of Alder Stream and Wyman Townships. We will use GIS data to estimate the mean LSI score of each landscape (weighted by stand type area).

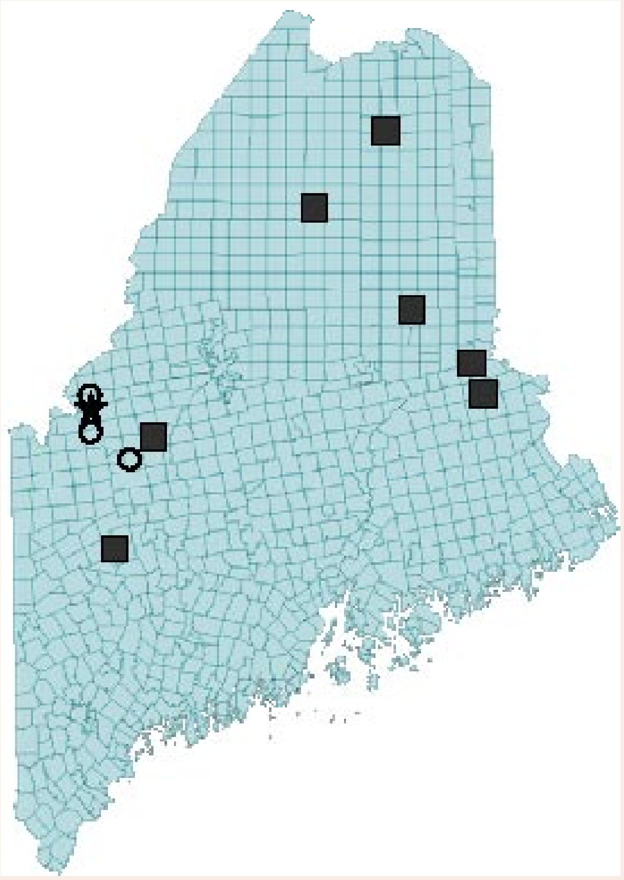

Figure 31. LS study sites across western, eastern, and northern Maine. Townships where stands were sampled for assessing the LS index at the landscape level are indicated by an open circle (Objective 1). Townships in which stands were sampled for the LS harvest experiment are marked by a black square (Objective 2). Riparian buffers were sampled for the LS index in the township marked with a filled star (Objective 3).

For Kibby Township, we estimated a mean LSI score of 2.41 (n = 124) (Figure 32). At the stand-level, the LSI scores can range from 0 to 10 (10 = LS value of an old growth forest). However, no landscape could average a "10" because of the presence of low scoring early successional wetlands and other low productivity sites, and also because not all old growth sites will score a "10" (Figure 33). Most acres scored < 2 (Figure 32). About 7.8% of the forest (11 stands) in Kibby Township had an LSI score > 7, scores typical of LS and old growth forests in Maine. Because of the rarity of LS stands, stands that score > 7 merit further study to determine if they have LS species rare to western Maine. They also warrant the consideration of harvest practices that best maintain LS content.

LSI scores varied considerably within each stand type (Figure 33). For example, most partial cut stands had LSI scores < 1, but a few had LSI scores > 5. These might include stands that had first entry shelterwood harvests where many large trees were left for removal in the next entry. Overall, hardwood stands had higher LSI scores than mixedwood and softwood stands in the same category. LSI scores for mature hardwood (northern hardwoods) and mixedwood (spruce-fir) stands averaged between four and six, with values up to nine. We found no statistical relationship (Pearson correlation, $p > 0.50$) between stand size and LSI score. However, the LSI score was more variable and averaged

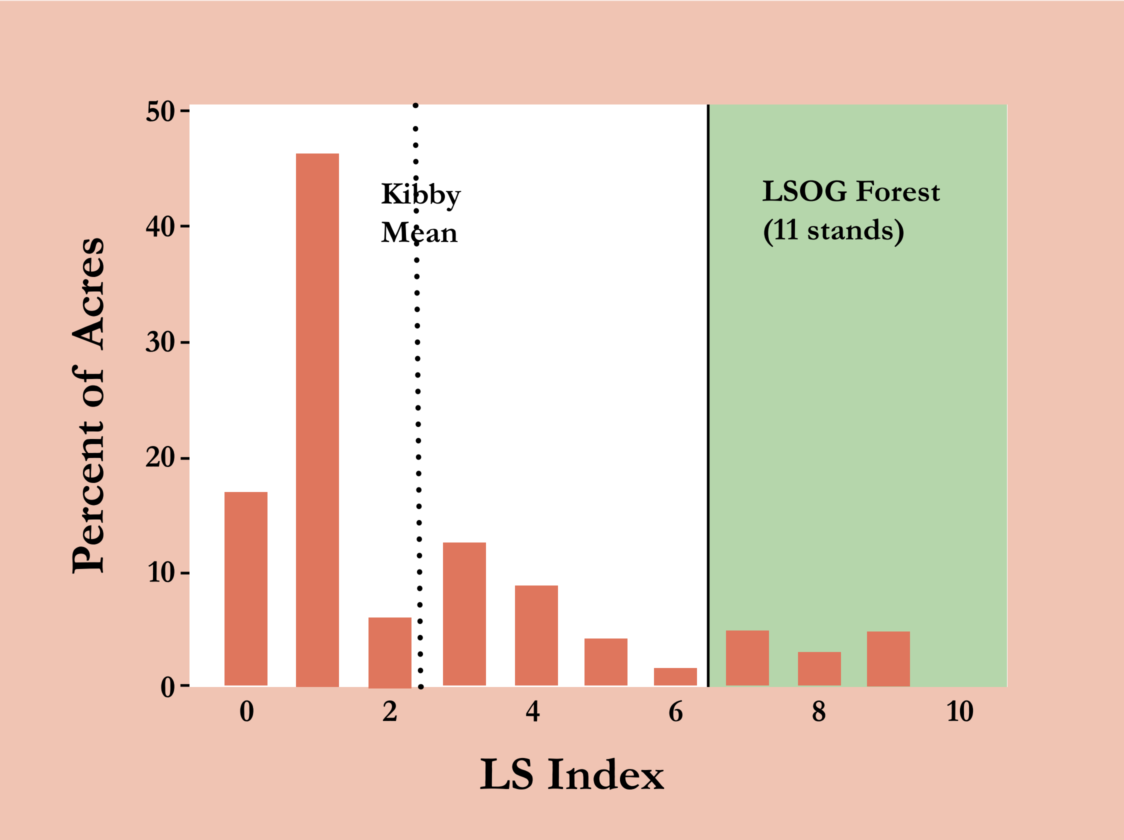

Figure 32. Percent of acres in Kibby Township with different LSI scores. Percent of acres with different LSI scores were calculated from the LSI score of 124 points that were randomly selected from each stand type. More, old stands were sampled than young stands because LSI scores have more variables in old stands (Figure 4). Percent of acres with a given LSI score was estimated by weighting for LSI score within each of the 16 stand types (see Fig. 4 for a list of stand types). Although most acres have an LSI score < 3, 7.8% of the acres (11 stands) scored > 7, which is well within the range of LSI scores for LS and old growth forests in western and northern Maine (see Figure 4).

lower in small stands (< 100 acres) than in larger stands (> 100 acres).

We are conducting a similar analysis of Alder Stream and Wyman Townships, and will use these data to identify efficient sampling strategies for estimating the LSI for landscapes. The LS variables for assessing LS biodiversity levels at the landscape scale could be readily incorporated into a forest biodiversity scorecard to help landowners track LS biodiversity over time.

Objective 2 – Can LSIs improve retention of LS content with little or no sacrifice of stand financial value?

With the cooperation of six landowners, 16 pairs of harvest blocks (n = 32) were selected for the LS harvest experiment. Eleven pairs were in northern hardwoods and five pairs were in spruce-fir forest. Pairs of harvest blocks were located in western, eastern, and northern Maine (Figure 31). We had planned to include more harvest blocks in the harvest experiment but landowner harvest schedules did not permit this. Prior to harvesting, we established permanent plots, scored each stand using the LSI, and conducted a limited timber cruise and regeneration survey. One harvest block in each pair was randomly assigned to one of two treatments: 1) harvesting carried out with a prescription for retaining LS attributes, and 2) harvesting without regard to retaining LS value (both treatments include the application of landowner's biodiversity guidelines). Before the former stands were harvested, we reviewed LS guidelines and the LSI method along with the silvicultural strategies of each landowner with the supervising forester.

All harvest blocks will be measured again after harvest in 2005 to assess the LSI and financial value of the residual stand. Across the pairs of harvest blocks within a forest type we will compare the pre- and post-harvest LSI scores to measure retention levels of LS content, identify any financial costs associated with the LS treatment, and assess possible tradeoffs between silvicultural/economic objectives and LS biodiversity objectives.

Objective 3 - LS ecological contribution of riparian buffers

In western Maine we applied the LSI protocols in 20 randomly selected riparian buffer strips along PSL-2 streams to evaluate their contribution to L-S attributes in the larger managed forest landscape. Although these data have not yet been analyzed, it is our impression that riparian areas have LSI scores similar to the same forest types on upland sites.

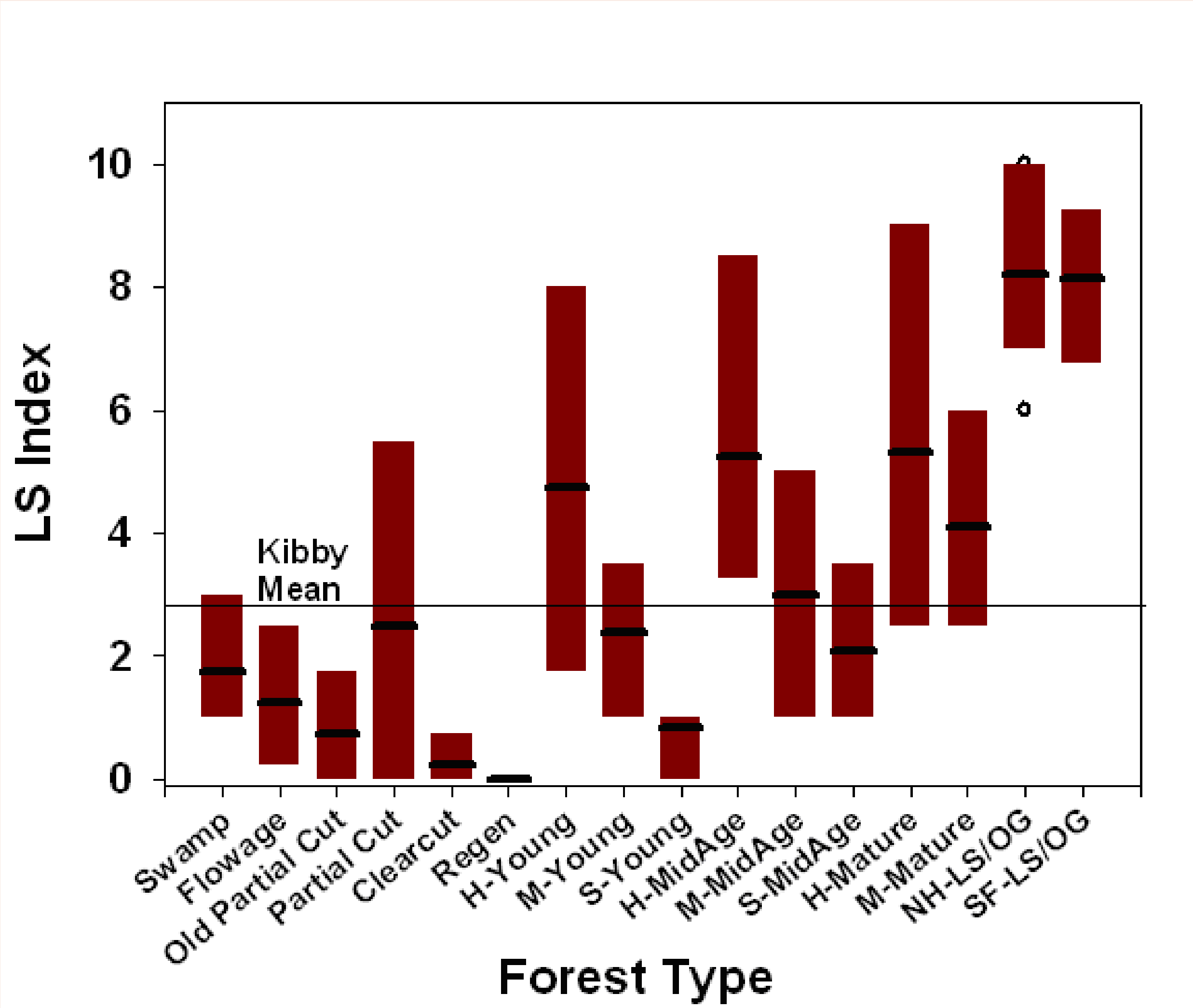

Figure 33. Box-whisker plots of LSI scores for different forest types in Kibby Township, western Maine. The heavy horizontal line within each box is the mean LSI score for a given forest type. The boxes indicate the 25th percentile, the median, and the 75th percentile LSI score for a given forest type. The bars above and below the boxes indicate the 5th percentile and the 95th percentile. Forest types beginning with the letter H are hardwood stands (mostly northern hardwoods) and those beginning with M or S are mixedwood or softwood stands (mostly upland spruce-fir forest). Mid-age stands have moderate volumes, are often harvested, and so can be considered low volume mature stands. NH-LS/OG data are from northern hardwood late-successional and old growth stands across northern Maine. SF-LS/OG data are from upland spruce-fir late-successional and old growth forests across northern Maine. LSOG data were added as reference points.

Additional Work

Beyond our three objectives, we also sampled additional northern pine sites in order to bolster sample sizes for the development of the northern pine LSI: six old-growth sites, five LS sites, and 15 sites that had varying levels of recent logging disturbance. We are also working with the Maine Forest Service to explore the use of LSI with FIA data to assess the distribution and abundance of LS forests in Maine.

Results from this work were also presented at seven meetings across North America. See Outreach section on pg. 85 of this report.

Summary

Results from this project to date suggest that:

- The LSI may be used to estimate average stand-level LS indices for landscapes. In the one township analyzed so far, the mean stand-level LSI score was low: 2.41 (maximum score of 10). About 7.8% of the township was in stands with LSI scores > 7.
- Riparian buffers appear to have LSI scores similar to the same forest types on upland sites.

Work Remaining

The following remains to be done to complete this project:

- Complete analysis on 2004 field data and report on the assessment of the LS content of landscapes and riparian buffers.
- Collect post-harvest data in 2005 on the LS harvest experiment blocks and report on results.

For more information about this project, contact **Andy Whitman** or **John Hagan** at (207) 721-9040 or by email awhitman@prexar.com or jmhagan@prexar.com.

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Anne Chouinard, Lisa Schauer, Brian Milakovsky, Chelsea Simmons, Jolan Sulinski, and Cheri Brunault assisted with fieldwork. This study was made possible through the assistance of major landowners and their staff: Irving Woodlands (Hugh Crammond), Plum Creek Timber Company (Frank Cuff, Doug Denico, and Kirk MacDonald), Huber Corporation (Kenny Fergusson, Joel Philbrook, and Jonathan Kelley), Baskhegan Company (Paul Cushman, Laurie McAllister, and Brian Higgs), Hancock Timber Co. (Peter McKinley and Shane Duigan), Penobscot Indian Nation (Russ Roy and the Land Management Committee), Maine Bureau of Parks & Lands (Steve Swatling), and Seven Islands Land Co. (Ken White, Greg Davis, and Pete Johnson). Funding was provided by the Cooperative Forestry Research Unit of the University of Maine, Merck Family Fund, and the Manomet Center for Conservation Sciences.

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Biodiversity

Effectiveness of Different Buffer Widths for Protecting Riparian Values on Maine's Forested Headwater Streams

John Hagan and Ethel Wilkerson

The objective of this study is to evaluate the effectiveness of different-width forested buffers for protecting headwater streams in western Maine. During 2004 we continued monitoring stream temperatures in the 0-m buffer (no buffer) and 11-m buffer treatments. This report summarizes water temperature results for all treatments (0m, 11m, 23m, and partial harvest buffer strips) during the four field seasons (2001-2004). We also report results of new measurements of the microclimate within the buffers and surrounding harvested areas. A more detailed analysis of stream temperature was reported this year in CFRU Research Report #04-01 entitled, "*The effectiveness of different buffer widths for protecting water temperature in headwater streams*."

Study Design

In 2001 we assigned 15 headwater (1st-order) streams in western Maine to one of 5 study treatments (Table 10). All streams were measured for water temperature before harvest (2001) and after harvest (2002-04). In 2004, as in previous years, we deployed 6 automatic temperature recorders at 100-m intervals along a 500-m study reach in each of the 15 study streams (Figure 34).

New Results

Stream temperature

Mean weekly maximum water temperature at the lower boundary of the harvest zone increased between 1.4-4.4°C in the 0-m and 1-1.4°C in the 11-m treatment group in the first two years

Table 10. Buffer strip treatments being compared.

Treatment	Harvest Prescription	Replicates
0m Buffer	Clearcut harvest zone, no buffers	3
11m Buffer	Clearcut harvest zone with partially harvested 11-m buffers, both sides	3
23m 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

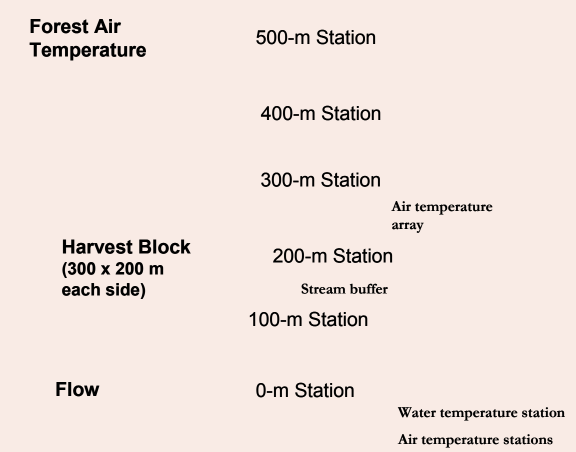


Figure 34. Experimental design of riparian buffer strip study showing water and air temperature sample locations.

after the timber harvest (2002 and 2003). We observed no significant changes in water temperature in the 23-m, partial harvest, and control treatment groups from pre-harvest values. In 2004, there was a noticeable decrease (0.9-3.2°C) in stream warming in the 0-m treatment group relative to the previous 2 post-harvest years (Figure 35). Temperatures in the 11-m treatment group in 2004 showed only slight deviations (-0.4 to +0.6°C) from the pre-treatment year (Figure 35).

The slight decrease in warming observed in 2004 in the 0-m and 11-m buffer streams might be interpreted as initial evidence of temperature recovery. However, these observations were more likely a result of cooler weather and increased rainfall in the summer of 2004. In 2004, the mean weekly maximum air temperature was between 1.8-2.1°C cooler than air temperature in the first 3 years of the study. Also, in contrast to all previous years, nearly all 15 streams contained some flow throughout the summer of 2004. Increased groundwater inflow as a result of increased rainfall probably also contributed to stream cooling during 2004. Further support that 2004 weather was driving the observations on the 0-m and 11-m buffer streams comes from the other streams, including the control streams, which also showed a decrease in stream temperature. Assuming that more normal weather conditions return in 2005, we should have a better understanding of whether streams are beginning to show temperature recovery.

Air Temperature

In addition to protecting stream temperature, forested buffers can also provide functional riparian habitat if the interior forest microclimate can be maintained within the buffer. To examine microclimate within the buffers and adjacent harvest zones, we deployed an array of air temperature probes through the buffers (Figure 34). We had enough temperature probes to sample two streams in each treatment; we did not sample the control streams. Monitoring stations extended from the harvest zone on one side of the stream, perpendicularly through the buffer, and into the harvest zone on the other side. Probe placement along each transect varied by treatment group in order to capture steeper temperature gradients near the buffer edge (Table 11). An interior forest reference probe was placed in closed canopy mature forest 100 m from the edge of the harvest zone. All temperature probes were programmed to simultaneously record temperature every hour. We calculated the deviation of each buffer array probe from the interior forest reference probe. We selected the warmest week of the summer for analysis to examine how well the various buffer treatments maintained microclimate under the most extreme seasonal conditions.

Table 11. Placement of air temperature probes in the riparian buffer and harvest zone. Locations in bold are in the harvest zone.

Treatment	Group	Distance from stream channel (m) on both sides of the					
0m Buffer	1	8	15	22	42	62	
11m Buffer	1	3.5	6	8.5	11	30	50
23m Buffer	1	8	15	22	42	62	
Partial Harvest	1	8	15	22	42	62	

Differences between air temperature within the clearcut harvest area and intact forest can be quite large. Within the clearcut, air temperature at some streams was up to 10°C warmer than the interior forest reference probe during the warmest time of day (Figure 36). As expected, warm air extended all the way to the stream in the 0-m treatment streams. Air temperature within the 11-m buffers was 3-5°C greater than temperatures in the intact forest. Temperatures near the edge of the 23-m buffers were up to 3°C warmer than intact forest temperature, but close to the stream air temperature remained within 1-2°C of interior forest air temperatures. The partial harvest treatments maintained interior forest temperatures near the stream, although there was an 8°C increase within the harvest zone of one partial cut treatment (Figure 36). The partial harvest areas have a residual basal area of 61-75 ft^2/acre.

Figure 35. Mean weekly maximum water and air temperatures from June 15- August 15 in the pre-harvest year (2001) and the three post-harvest years (2002-2004). Water temperature readings were taken at the lower end of the harvest zone (100-m station). Air temperature readings were taken within intact forest, 100 m from the nearest harvesting and 50 m from the stream channel.

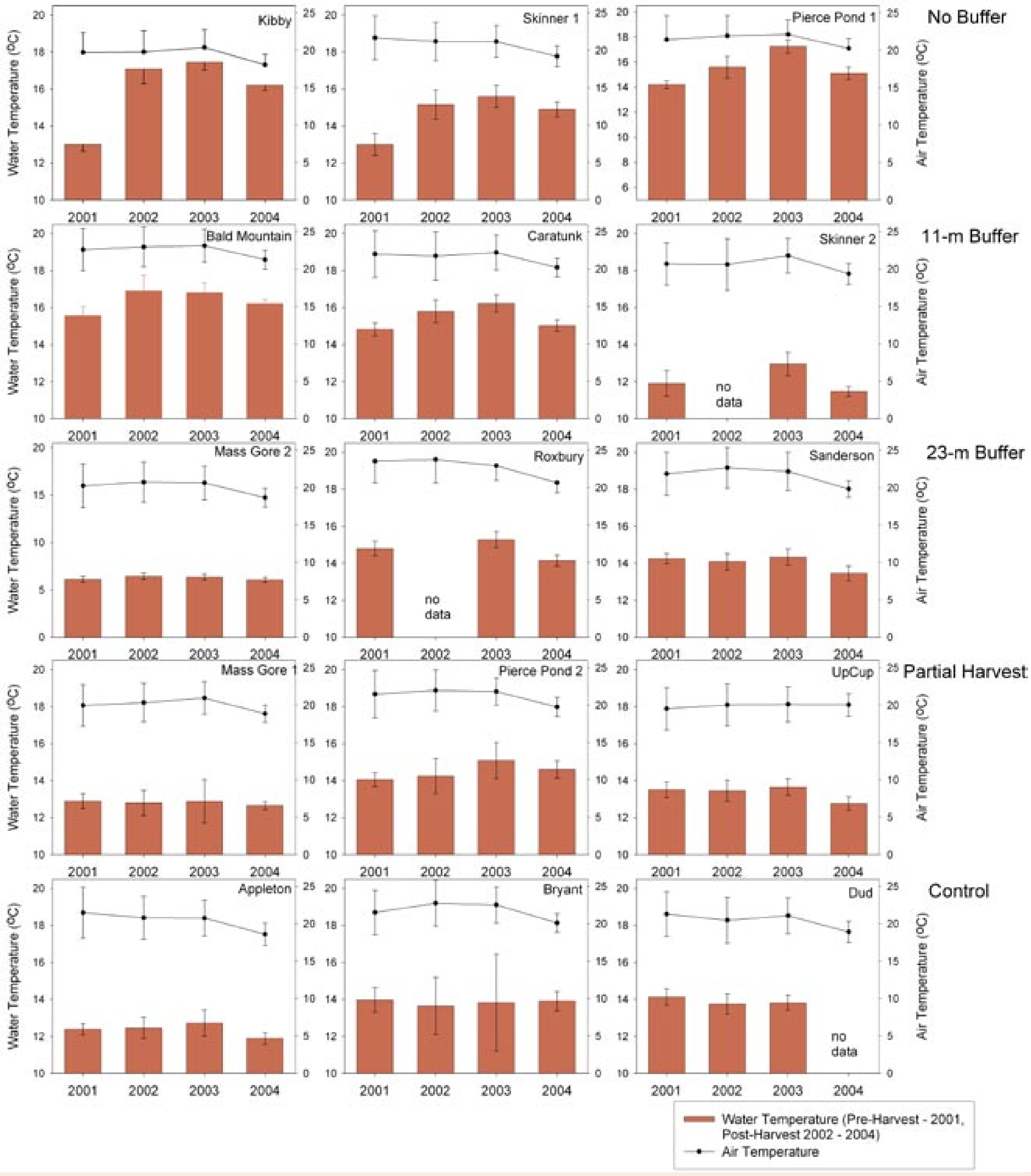
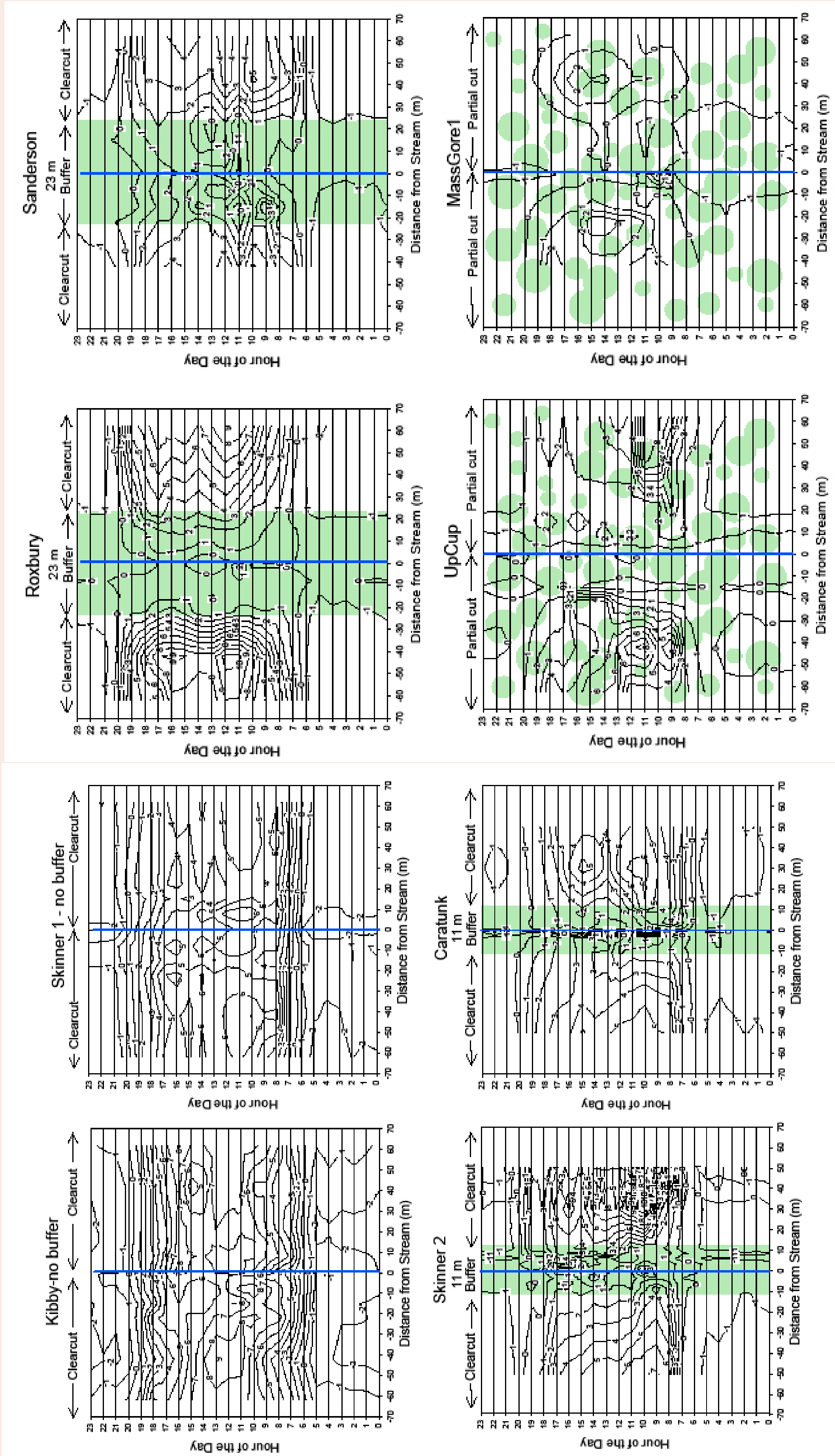


Figure 36. (Following page.) Differences in mean air temperature between each treatment (0m, 11m, 23m, and partial harvest buffer strips) and interior forest conditions throughout a 24 hr cycle during the warmest week in 2003 for two streams. Note that the y-axis is hour of the day. To interpret these graphs, imagine "walking" along the transect of temperature probes (see Figure 1) along the x-axis from left to right, at any given hour of the day, and then observing how air temperature would change relative to the interior forest as you moved from one probe to the next.


Sanderson
23 m Buffer
Clearcut
Roxbury
23 m Buffer
Clearcut
Skinner 1 - no buffer
Clearcut
Kibby-no buffer
Clearcut
MassGore1
Partial cut
UpCup
Partial cut
Caratunk
11 m Buffer
Clearcut
Skinner 2
11 m Buffer
Clearcut
Hour of the Day
Distance from Stream (m)

Our preliminary analysis indicated that the 23-m buffers or partial harvests were needed to maintain a narrow riparian zone characterized by a near-interior forest microclimate. Previous work indicated that the herbaceous plant community within 5 m of the stream is different from areas 5 to 45 m from the stream. We do not know if an interior forest microclimate is essential for maintaining these riparian plant communities.

Planned Activities

During winter and spring 2005 we will be submitting several manuscripts for publication. In May 2005, we will begin a fourth post-harvest field season, but we will only be measuring water temperature and riparian air temperature.

Comments or questions about this study can be directed to **John Hagan** at 207-721-9040 or by e-mail at jmhagan@ime.net.

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Biodiversity

Developing an Early-Successional Bird Habitat Index for the Biodiversity Scorecard

John M. Hagan and Andrew A. Whitman

Maintaining biodiversity is a fundamental goal of sustainable forestry programs. The biodiversity element of sustainable forestry, however, has been especially challenging for forestland managers. The challenge can seem overwhelming because biodiversity is defined as life in all its forms, from the level of the gene, to species, to whole ecosystems, including all the processes that maintain these various levels. A quandary arises: the number of species and all their potential interactions simply cannot be quantified, and yet something that is not being measured cannot be managed. The only practical approach to assessing "life in all its forms" is to measure a relatively few components that capture a range of important biodiversity values.

To meet this need we are developing a Biodiversity Scorecard that can be used to quantitatively assess biodiversity on forested landscapes. We envision a Scorecard comprised of 8 to 12 metrics that capture diverse components of biodiversity. We have already produced a late-successional forest index (see page 61 of this report). Here we report progress on development of an early-successional index based on birds.

One advantage of dividing biodiversity into components such as early-successional and late-successional habitats is that it allows managers to understand and manage for biodiversity components that can work in opposition to each other. Managers can set targets for each metric, recognizing that increasing one metric can reduce another. Such complexity can be managed once it is being measured in a framework such as a Biodiversity Scorecard.

We are developing an early-successional (ES) habitat index based on birds for two reasons: 1) we have an existing, rich data set on bird-habitat relationships that was collected in Maine in the early 1990s, and 2) many early-successional bird species are declining in the region (Table 12). For example, the White-throated sparrow is declining at about 5% per year in Maine, Vermont, and New Hampshire (combined) and about 8% per year in Massachusetts. In southern New England, the decline of agriculture and other land-use changes is resulting in dramatic losses of early-successional habitats, and hence species that depend on them (Askins 2001, Gobster 2001, Brooks 2003, Litvaitis 2003).

Since forest management activities in northern New England create early successional habitat types that are being lost in southern New England, forest management in the north may be helping to offset bird declines in southern New England. Consequently, it makes sense to include some measure of early-successional habitat for managed forests in the Biodiversity Scorecard.

Project Objectives

1. Develop an index that quantifies early-successional biodiversity value for birds in managed forest landscapes,
2. Calculate this index for example landscapes in northern Maine,
3. Contribute to the development of a suite of biodiversity metrics for sustainable forestry in Maine (others are late-successional, riparian/aquatic, and landscape values)

Results

Using our bird data set collected in the Moosehead Lake region of Maine in the early 1990s, we identified 14 species that were either tightly or loosely associated with early-successional habitats. We sampled 363 stands of all forest types and ages (from clearcuts to mature closed-canopy forest). We scored each of the 14 species as present or absent in each stand (based on two, 10-minute point counts). We also collected detailed habitat data at each bird point-count sampling station.

Our first task in generating an ES Index has been to determine which habitat variables best explain the presence or absence of each species. Ideally, we would like to identify one or two variables that account for the presence or absence of all 14 species. Moreover, we would like the important variables to be easily derived from timber inventory data; an ES Index will be of little or no use if new information must be gathered from the landbase. An alternative approach would be to identify the variables that can be derived from traditional timber inventory data, and then ask how well these variables explain ES bird presence/absence. However, we were interested in exploring whether some new,

Table 12. Annual percent change in 14 early-successional bird species populations according the Breeding Bird Survey (BBS 2005), for 2 time periods (1966-2003, 1980-2003) and for 2 geographic areas in New England. (* = P<0.10, ** = P<0.05)

Species	VT, NH, and ME % change				MA only % change			
	1966-2003		1980-2003		1966-2003		1980-2003	
Northern Flicker	-3.1	**	-2.9	**	-4.2	**	-4.2	**
Alder Flycatcher	+1.2		+0.8		+4.4		+4.4	
Black-and-white Warbler	+0.8		-2.4	**	-2.3	*	-2.3	*
Common Yellowthroat	-1.6	**	-2.0	**	-1.6	**	-1.6	**
Palm Warbler	+3.7	**	+4.2	**				
Canada Warbler	-2.7	*	-5.6	**	-4.4		-4.4	
Chestnut-sided Warbler	-2.4	**	-2.8	**	-1.4	**	-1.4	**
Magnolia Warbler	-1.5		-6.7	**	+0.1		+0.1	
Nashville Warbler	-3.1	**	-5.4	**	-1.6		-1.6	
Mourning Warbler	+1.1		-0.9		-7.5	*	-7.5	*
Lincoln's Sparrow	+2.1		-1.7					
Song Sparrow	-2.0	**	-1.2	**	-2.5	**	-2.5	**
Chipping Sparrow	+1.9	**	+1.5	**	+1.4		+1.4	
White-throated Sparrow	-4.2	**	-4.4	**	-8.3	**	-8.3	**

Table 13. Habitat variables used in species-habitat regression models for each of the 14 bird species.

Variable Name	Variable Description
TOT_BAS	Total basal area (>8 cm dbh) ft^2/ac
H_TREES	Number of hardwood trees (>8 cm dbh) per 0.05 ha
S_TREES	Number of softwood trees (>8 cm dbh) per 0.05 ha
N_DEAD	Number of dead trees (>8 cm dbh) per 0.05 ha
SHRUB_DIV	Shrub species diversity
SHRUBS_1	Shrub stem density (<1 m tall)
SHRUBS_1_2	Shrub stem density (1-2 m tall)
SHRUBS_2_4	Shrub stem density (2-4 m tall)
SHRUBS_4_6	Shrub stem density (4-6 m tall)
SHRUBS_6	Shrub stem density (6+ m tall)
SHRUBS_0_4	Shrub stem density (0-4 m tall)
SHRUBS_4_6P	Shrub stem density (>4 m tall)

simple-to-measure variables could be integrated into timber inventories that would improve the ES Index.

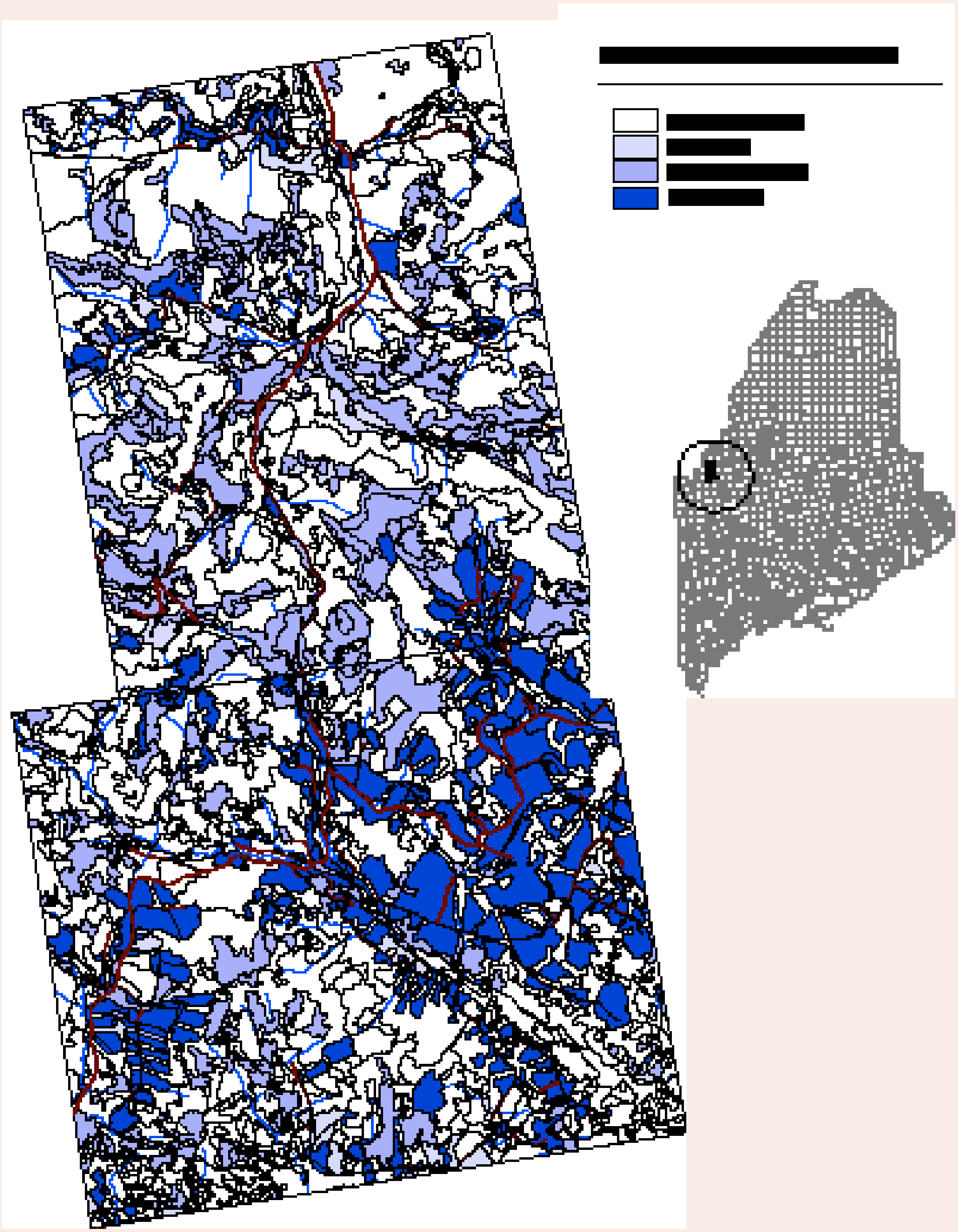
We used stepwise logistic regression for each bird species to evaluate which of 12 habitat variables (Table 13) might account for the presence of the species in a stand type. Each species had its own combination of variables that best described its occurrence (Table 14). However, one variable that consistently topped the list of explanatory variables was total basal area (trees >8 cm dbh), although various shrub density variables typically provided additional explanatory power, depending on the species. This was a welcome result because if total basal area can alone provide most of the explanatory power for most of the species, then a simple ES Index can be derived from timber inventory data and stand maps.

At present we need to rerun the analyses to examine how well total basal area performs as a single explanatory variable. Assuming that this single variable can serve as a reasonable surro-

Table 14. Variables that significantly explained the presence/absence of each species in a stand. Model R^2 indicates the proportion of variation in presence/absence of the species in a stand that can be explained by the statistically significant ($P<0.05$) variables listed. See Table 13 for variable codes.

Species	Significant Variables	Model R^2
Northern Flicker	TOT_BAS	0.13
Alder Flycatcher	TOT_BAS, SHRUB_DIV	0.57
Black-and-white Warbler	TOT_BAS, SHRUBS_2_4	0.17
Common Yellowthroat	TOT_BAS, SHRUB_DIV, SHRUB_1	0.71
Palm Warbler	TOT_BAS, H_TREES, SHRUBS_1,	0.79
Canada Warbler	SHRUBS_1_2, SHRUBS_2_4, N_DEAD	0.25
Chestnut-sided Warbler	TOT_BAS, SHRUBS_0_4	0.34
Magnolia Warbler	TOT_BAS, SHRUBS_0_4, SHRUBS_1, SHRUBS_2_4	0.18
Nashville Warbler	H_TREES, SHRUBS_2_4	0.32
Mourning Warbler	TOT_BAS, SHRUBS_1	0.35
Lincoln's Sparrow	TOT_BAS, SHRUBS_1_2, SHRUBS_4_6	0.57
Song Sparrow	TOT_BAS, SHRUBS_1_2	0.58
Chipping Sparrow	TOT_BAS, S_TREES	0.19
White-throated Sparrow	TOT_BAS, SHRUBS_4_6, H_TREES	0.71

Figure 37. Habitat suitability map for early-successional bird species. Kibby and Skinner townships in western Maine (~52,000 acres). Percents indicate the percent of the map area covered by habitat of the specified suitability.



gate of habitat suitability for these 14 species, we can easily generate a simple graphical and mathematical ES Index. Figure 37 shows Kibby and Skinner townships color coded according to ES bird species habitat suitability. We scored habitat (stand types) as 1) very low, 2) low, 3) moderate, and 4) high. Various approaches are possible for deriving a single ES Index for a landscape. One simple approach is to calculate the percent of the landscape that has 'high' habitat suitability and use that percent as the ES Index. In this case, Kibby and Skinner townships would score a 16 (out of 100%) (see Figure 37). Alternatively, we could combine 'high' and 'moderate' categories, in which case the score would be 39 (16% + 23%). A slightly more complicated alternative is to create two ES Indices, one that represents the percent of 'high' quality habitat (i.e., 16) and one that represents the percent of 'moderate' quality habitat (i.e., 23). Regardless of the Index chosen, it should be applied consistently across an ownership, and preferably among ownerships. All timber managers are able to estimate basal area of timber stand types, and should be able to easily calculate an ES Index once the basal area cut-off specifications are provided.

Remaining Work

We still need to generate threshold basal area values for each bird species. Thresholds represent an inflection point in basal area, above which (in the case of ES species) the species is significantly less likely to be present in the stand. We then need to match these basal area cutoff values with timber inventory data and existing stand classification systems (such as we did in Figure 37). The resulting index will have to integrate the different threshold values for the 14 different species and an objective process is needed to develop this index. However, the result will be a simple index such as presented in the previous section.

Comments or questions about this study can be directed to **John Hagan** at 207-721-9040 or by e-mail at jmhagan@ime.net.

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Appendices

APPENDIX A: Species List

Trees

Balsam fir	*Abies balsamea*
Fir	*Abies spp.*
American beech	*Fagus grandifolia Ehrh*
White spruce	*Picea glauca*
Red spruce	*Picea rubens Sarg.*
Spruce	*Picea spp.*
Red pine	*Pinus resinosa*
White pine	*Pinus strobus*
Eastern hemlock	*Tsuga canadensis*
Paper birch	*Betula papyrifera*

Animals

Canada lynx	*Lynx canadensis*
Snowshoe hare	*Lepus americanus*
Deer mouse	*Peromyscus maniculatus*
Red-backed vole	*Clethrionomys gapperi*
Woodland jumping mice	*Napeozapus insignis*
Southern bog lemming	*Synaptomys cooperi*
Meadow vole	*Microtus pennsylvanicus*
Short-tailed shrew	*Blarina brevicauda*
Masked shrews	*Sorex cinereus*
Smoky shrews	*Sorex fumeus*
Weasel	*Mustela spp.*
Eastern chipmunk	*Tamias striatus*
Red squirrel	*Tamiasciurus hudsonicus*

APPENDIX B.

List of Figures

APPENDIX C.

List of Tables

APPENDIX D.

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