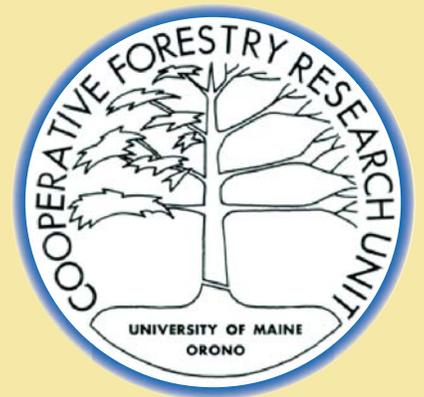


COOPERATIVE FORESTRY RESEARCH UNIT

2003 ANNUAL REPORT

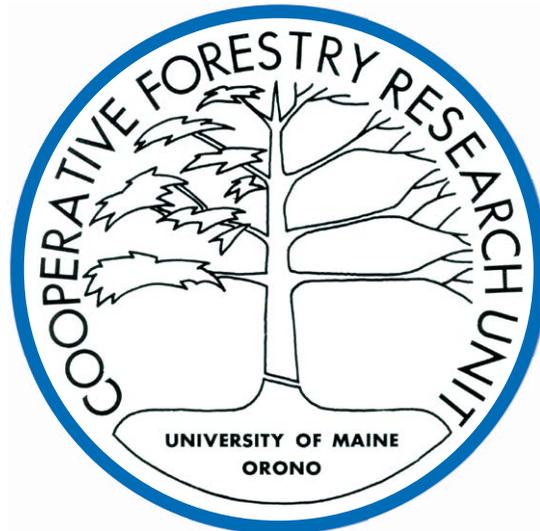


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REPORT 2684



COOPERATIVE FORESTRY RESEARCH UNIT

ANNUAL REPORT 2003



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

Cooperative Forestry Research Unit
5755 Nutting Hall
Orono, Maine 04469-5755
<http://www.umaine.edu/cfru>

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Introduction

The CFRU is one of the oldest industry/university forest research cooperatives in the United States. Funding for this organization comes from private industrial and non-industrial organizations, public agencies, and individual contributors who want to solve specific forestry problems or generally want to advance forest management in the state of Maine through scientific research.

Over the last 28 years, we have seen dynamic changes to forestry in the state of Maine. During this time, the CFRU served forest managers and landowners in the state by conducting research that addressed their most pressing problems. These projects resulted in the publication of over 400 CFRU sponsored documents. Several long-term research sites (e.g., Weymouth Point, Austin Pond, and the Commercial Thinning Research Network) were also established and continue to be maintained.

We have entered into a new century, and our mission continues to be conducting applied scientific research that contributes to the sustainable management of Maine's

forests. With current support from our 26 member organizations across the state of Maine, CFRU research is focused on a variety of problems facing the state's forest managers and landowners. Commercial thinning, riparian zone management, snowshoe hare and lynx habitat issues, the development of indicators for quantifying ecological value, and ways to improve hardwood management are currently being pursued by CFRU scientists.

Regular quarterly meetings, workshops, and conferences continue to be sponsored by the CFRU and are described in this report. 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. Our research results are rapidly communicated to our members through regular presentations, field tours, conferences, research reports, annual reports, web site, and articles in scientific journals. This annual report documents progress made by the CFRU during fiscal year 2002-2003.

Silviculture



Wildlife



Biodiversity



Highlights

ORGANIZATION

- CFRU was nominated for the 2003 Governor's Awards for Outstanding Accomplishments in Maine's Natural Resource-Based Industries.
- Twenty-seven members representing 6.9 million acres contributed \$403,060 to support research activities this year.
- Two new members (J.M. Huber Wood Products and Hancock Lumber Company) joined as millowning members.
- For every dollar contributed by our largest members, \$18.92 of additional support was leveraged from other sources.
- The sale of MeadWestvaco, Hancock Timber Resource Group, and Great Northern Paper lands substantially reduced contributing acres. In addition, long-time member International Paper left the coop for financial reasons. These losses reduced member acres by 29% this year.
- Three executive summits on the future of landowner-sponsored research were held to develop a plan for long-term financial stability of CFRU.

COMMUNICATIONS

- Scientists, staff, and graduate students delivered more than 28 publications and 57 presentations on CFRU research (see page 67).
- The entire collection of more than 300 CFRU publications from 1976 to 2000 were scanned and made available on the web page with a search engine (see page 20).
- CFRU co-sponsored the first Eastern CANUSA Forest Science Conference where more than 95 oral and poster papers were presented to more than 200 participants from across the region (see page 21).

RESEARCH

Silviculture

- A rotation-long analysis of the Austin Pond study demonstrated good financial returns from herbicide spraying and precommercial thinning (see page 36).
- An analysis of Maine's wood supply was published that identifies the highest priorities for silviculture research. (see page 20).
- Installation and treatment of all Commercial Thinning Research Network sites were completed (see page 24).

- Models of commercial thinning in previously precommercially thinned spruce-fir stands indicate that increased wood and financial yields are only likely if stands are not entered too soon and the density is not reduced by more than one third (see page 26).
- Two new graduate students began investigating the biological aspects of commercial thinning response (see page 28).
- The influence of commercial thinning on the regeneration of red spruce and balsam fir is being examined (see page 32).
- A new collaborative study with the U.S. Forest Service is examining whether the presence of specific biochemical compounds in foliage can be used as indicators of stress in spruce and fir (see page 35).
- A Stand Product Optimization Tool (SPOT) was developed to optimize the financial value of stands before they are harvested (see page 41).
- Steady progress was made developing a Hardwood Growth and Yield Model (see page 43).
- A new study is remeasuring plots on cooperator lands to assess whether fertilization of precommercially thinned spruce-fir stands is worthwhile. (see page 38).
- Literature reviews on the competitive effects and control of American beech, striped maple, hobblebush, ferns, Rubus, and pin cherry were developed (see page 45).

Wildlife Ecology

- A graduate thesis was completed that quantifies the effect of precommercial thinning on snowshoe hare and small mammals (see page 47).
- A radiocollar study of lynx is being used to examine their preferences for specific habitat conditions and the potential influence of forest management on lynx habitat (see page 53).

Biodiversity Conservation

- Third-year data were collected to evaluate the effectiveness of forested buffers of different widths for protecting headwater streams (see page 61).
- A new study to create an index of late-successional forest conditions for forest managers included a survey of 124 stands in 44 townships. Although late-successional stands are a small part of Maine's landscape, they can be found throughout western, eastern, and northern Maine (see page 58).

Members



Major Cooperators

Baskahegan Corporation
Clayton Lake Woodlands
Nexfor Fraser Paper, Ltd.
Hancock Timber Resource Group
Huber Resources Corporation
International Paper Company
Irving Woodlands, Ltd.
Maine Bureau of Parks and Lands
Maine Timberlands Company
MeadWestvaco Corporation
Plum Creek
Prentiss & Carlisle
St. Aurelie Timberlands Company
Seven Islands Land Company
The Nature Conservancy

Other Cooperators

Bethel Furniture Stock, Inc.
H.O. Bouchard, Inc.
Field Timberlands
Finestkind Tree Farms
Huber Engineered Woods
Landvest
F. A. Madden, Inc.
Peavey Manufacturing Company
Pride Manufacturing Company
Robbins Lumber Company
Western Maine Nurseries

People



Staff

Robert G. Wagner

Director and Professor of Forest Ecosystem Science

Daniel J. McConville

Research and Communications Coordinator

Julieann Kahler

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

Leadership

Although I hate to use clichés this one is worth repeating, “People are our number one asset.” It is easy to forget the importance of people when highlighting the accomplishments of an organization that is measured by the value of its data and information. But without the dedication of the CFRU staff, scientists and the advisory committee, and their ability to reach consensus, or nearly so as a unit, the data and information would be less useful.

This is particularly true for an organization that has gone through so much change over the past year and throughout its 29-year history. Challenges brought on by the ever-changing status of CFRU membership and its funding base has required careful, levelheaded involvement from advisory members to develop solutions to budgetary crises. This past year the Unit faced a particularly troubling crisis through the loss of three members; MeadWestvaco, International Paper, and Great Northern Paper. Not only did this represent a 29 percent decrease in the funding base but we also lost the participation of three devoted advisory members; **Tony Filauro**, **Si Balch**, and **Gary Donovan**. We will greatly miss the involvement and perspective that they brought to the CFRU.

The continuing funding crisis resulted in a series of summit meetings with forest industry leaders this past year.

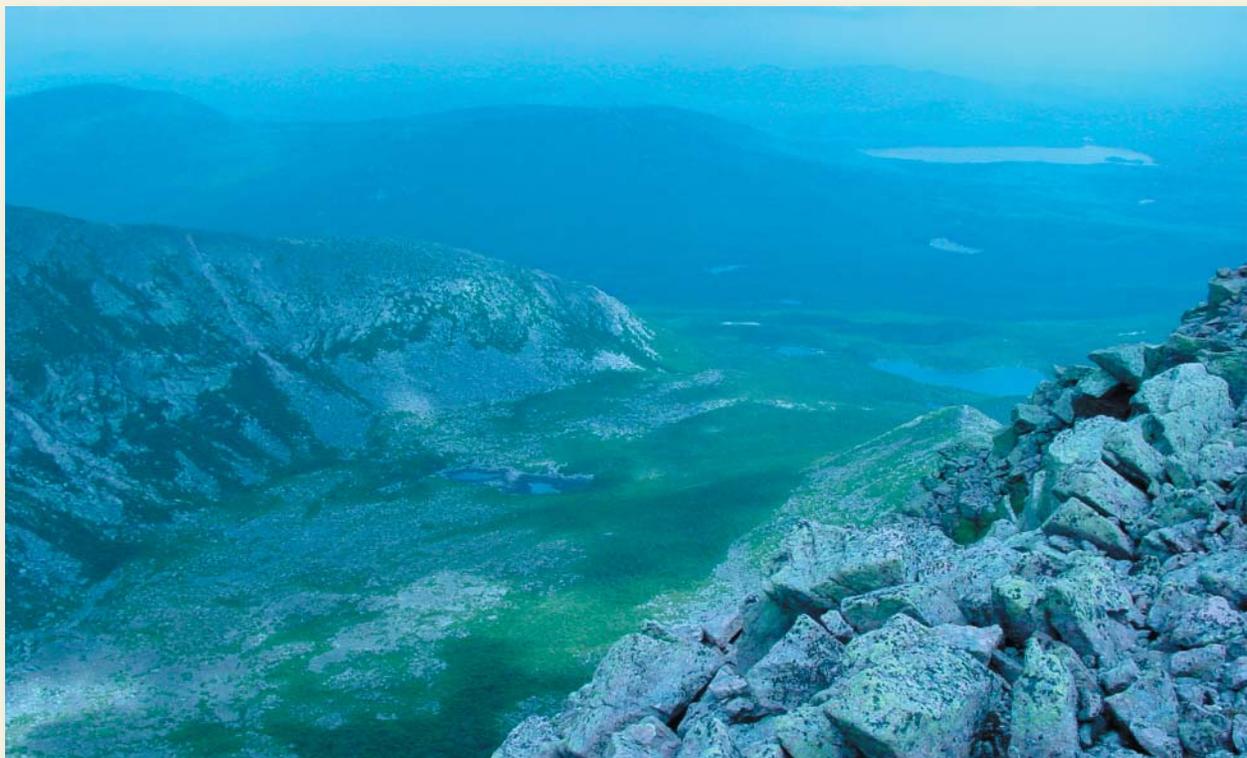
This summit process serves to demonstrate a continuing commitment by the industry to maintain a strong forest research effort at the University.

This past year, **Bob Wagner** and the CFRU Cooperating scientists continued to bring several pertinent research ideas to the table for consideration. Advisory members representing organizations with different objectives demonstrated tremendous success at determining the collective research needs of the group.

Two years have gone by and my term as Chair has expired but to stay in character I do have some advice to pass along. I would encourage anyone to actively pursue the Chair position. There is no better way to understand the Unit’s work and get to know the CFRU staff and scientists. The Chair position is an opportunity that overshadows any additional workload. I sincerely have enjoyed the privilege of working with all of you these past two years.

Doug Denico

Doug Denico
Chair, CFRU Advisory Committee



Leadership

Over the past three decades Cooperative Forestry Research Unit research has provided science-based information about the ecological effects of forestry practices that have improved Maine's forest policy and developed information and tools that have enhanced the efficiency and productivity of forest management for Maine's landowners.

In addition to its many research accomplishments, as pointed out by **Doug Denico, Hugh Crammond, and Peter Triandafillou** in their nomination of CFRU for the 2003 Governor's Awards for Outstanding Accomplishments in Maine's Natural Resource-Based Industries, CFRU-sponsored research has also "provided scores of undergraduate students, graduate students, and faculty in forestry and wildlife with the opportunity to learn about and help solve some of the most important problems facing forestland managers in the state. This investment has provided a wealth of expertise that has been drawn upon by forestry organizations, government agencies, and the public when information and advice was needed about key forestry issues."

The partnership between university and industry, through the CFRU, is working. We still face many challenges and I believe the CFRU is needed more than ever. The opportunities and responsibilities for executing forest research in Maine in the future are both exciting and daunting. Under the strong leadership of **Bob Wagner** and other CFRU leaders, I am confident that we will rise to meet these challenges. The CFRU has my complete support and, as always, I look forward to working with the faculty, staff, and cooperators in the coming year.



G. Bruce Wiersma
Dean, College NSFA



Leadership

This year presented CFRU cooperators and staff with a substantial set of contrasts. While our research activity remains high and we continue making progress on a number of high priority projects, we were all very disappointed by the loss of several large cooperators. After a substantial effort by all members to address dues issues raised by **International Paper Company** over the past two years, IP decided to leave the CFRU due to financial difficulties facing their Maine operations. Because IP was a founding member of CFRU and had maintained continuous membership for 28 years, the decision was especially difficult to accept. Adding to the difficulty was the sale of the **MeadWestvaco** and **Great Northern Paper** lands. The IP, Mead, and GNP losses reduced CFRU member acres by 29% over the past year.

The biggest impact in the short term, however, came from the loss of the people who represented these organizations. **Si Balch** (Mead), **Tony Filauro** (Great Northern Paper), and **Gary Donovan** (International Paper) have been pillars of support and expertise for the CFRU and Maine forestry community for many years. On behalf of all CFRU members and staff, I extend our deepest appreciation to Tony, Si, and Gary for their seemingly unlimited enthusiasm, interest, and contributions to the work of CFRU. Your contributions made us better and it is difficult to accept your absence at our Advisory Committee meetings.

As we seek new options for ensuring that The University of Maine forestry program includes landowner-sponsored research, I wish to thank **Steve Schley** (Pingree and Associates), **Peter Triandafillou** (Huber Resources), **Jim Robbins** (Robbins Lumber), **Alec Giffen** (Maine Forest Service), and **Roger Milliken** (Baskahegan Corp.)

for their leadership and outstanding efforts in the series of summits we held this year. I look forward to continued development of the ideas we generated this year.

One high spot during the year was the nomination of CFRU for a Governor's Award for Outstanding Accomplishments in Maine's Natural Resource-Based Industries. Although CFRU did not receive the award, we thank **Doug Denico** (Plum Creek Timber), **Hugh Crammond** (Irving Woodlands), and Peter Triandafillou for this nomination and the vote of confidence it represents.

Brian Higgs (Baskahegan Corp.) concluded his six years of service as an officer for CFRU this year. I want to personally thank Brian for his excellent advice and leadership during some challenging times over the past years. I also extend a special thanks to Doug Denico who had to quickly step up as Chair of the Advisory Committee over the past two years. Doug did an outstanding job leading us through some difficult meetings on the dues issue. I look forward to working with Hugh Crammond as the new Chair of the Advisory Committee.

This annual report includes the results of a number of exciting and innovative research projects. The projects describe herein reflect the value of having a strong landowner-sponsored research effort at The University of Maine.



Robert G. Wagner
CFRU Director

Financials

Twenty-seven members representing 6.9 million acres contributed \$403,060 to support CFRU activities this year (Table 1). This amount was \$20,480 more than was invoiced due to a \$17,980 payment for FY01-02 dues by **Maine Timberlands Company/GNP** and the addition of two new members. We welcome **J.M. Huber Wood Products** and **Hancock Lumber Company** as new mill-owning members.

Continued sound fiscal management by CFRU project scientists and staff resulted in spending \$28,887 (6.7%) less than was approved by the Advisory Committee (Table 2). The savings came primarily from salary reductions from the mid-year departure of our administrative assistant, departure of a CFRU graduate student, efficiencies gained by combining field crews and transportation needs under the commercial thinning and fertilizer projects, and from finding alternative sources of funding for the Eastern CANUSA conference. These savings were returned to the central account for future use on other CFRU projects.

CFRU allocated 59% of its budget for research and 41% for administration, including staff/scientist salaries and other expenses (meetings, field tours, web

maintenance, data bank, travel, safety, phones, printing). Research allocations were divided among five silviculture projects (49%), two wildlife ecology projects (20%), and two biodiversity conservation projects (30%) (Table 2).

The total contribution of CFRU members for this fiscal year was \$403,060 (Table 2). In addition to these member contributions, CFRU scientists leveraged \$640,832 from external funding sources to support CFRU-sponsored research projects. When added to the \$53,919 in-kind contributions from the University of Maine, the total value of CFRU research during this fiscal year was \$1,097,811 or 172% above direct 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 \$6.31 from other members, \$11.63 from external funding sources, and \$0.98 from in-kind contributions from the University of Maine. Therefore, every dollar contributed by the largest CFRU members leveraged \$18.92 to support their highest priority research projects (Figure 2).

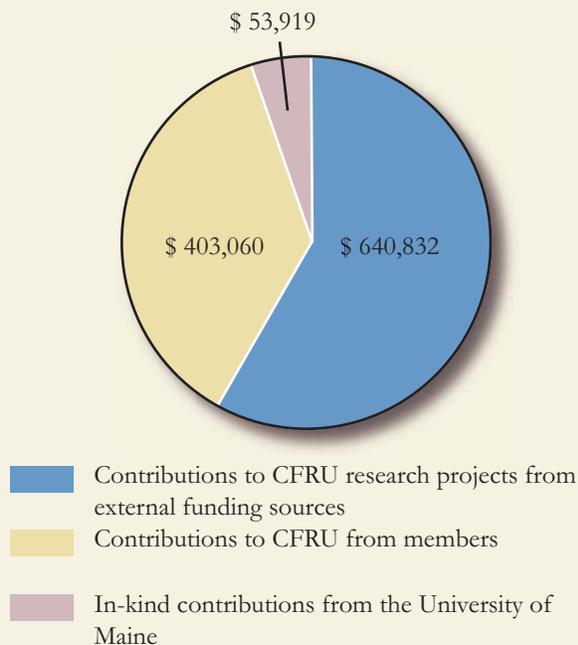


Figure 1. CFRU members contributed \$403,060 for the year, an additional \$640,832 was leveraged from external funding sources, and the University of Maine contributed \$53,919 in in-kind support.

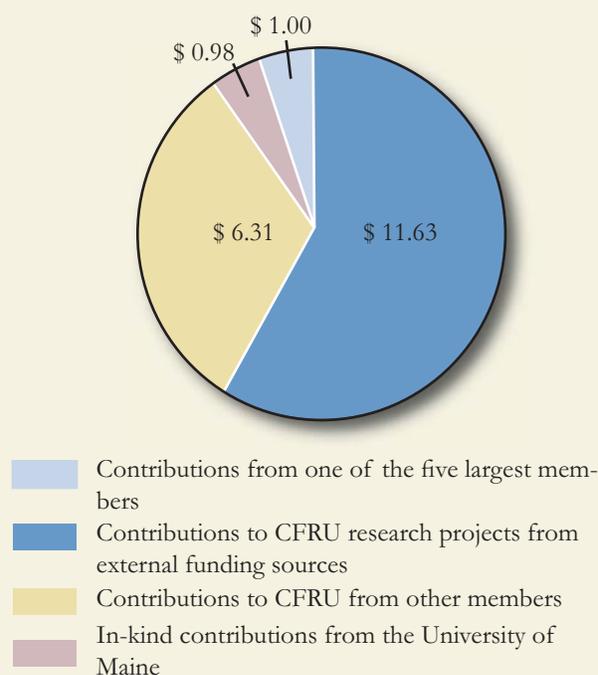


Figure 2. For every dollar contributed by one of our five largest members they received \$6.31 from other members, \$11.63 from external funding sources, and \$0.98 from in-kind contributions by the University of Maine.

Table 1. CFRU cooperator contributions during FY2002-03.

Cooperator	2003 Reported Acres	Amount invoiced (Jan 2003)	Amount Received	Balance
Irving, J. D. Ltd.	1,550,000	\$82,500	\$82,500	\$0
International Paper Company	1,226,545	\$66,327	\$66,327	\$0
Seven Islands Land Company	880,000	\$48,700	\$48,700	\$0
Plum Creek Timberlands	863,000	\$47,808	\$47,808	\$0
MeadWestvaco Corporation	527,510	\$30,194	\$30,194	\$0
Maine Bureau of Parks and Lands	349,414	\$20,091	\$20,091	\$0
Maine Timberlands Company/GNP		\$0	¹ \$17,980	
Huber Resources Corporation	320,000	\$18,400	\$18,400	\$0
Hancock Timber Resource Group	219,248	\$12,607	\$12,607	\$0
Clayton Lake Woodlands	245,000	\$14,088	\$14,088	\$0
Fraser Papers	238,880	\$13,736	\$13,736	\$0
The Nature Conservancy	187,136	\$10,760	\$10,760	\$0
Baskahegan Lands	101,629	\$5,844	\$5,844	\$0
Prentiss and Carlisle	84,676	\$4,869	\$4,869	\$0
Ste. Aurelie Timberlands	60,000	\$3,450	\$3,450	\$0
Robbins Lumber Company	30,000	\$1,576	\$1,576	\$0
Pride Manufacturing	0	\$468	\$468	\$0
Bouchard, H. O., Inc.	0	\$200	\$200	\$0
Landvest	0	\$200	\$200	\$0
Madden, F. A., Inc.	0	\$200	\$200	\$0
Bethel Furniture Stock	0	\$125	\$125	\$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
Huber Engineered Woods	0	\$0	² \$1,500	\$0
Hancock Lumber Company, Inc.	0	\$0	² \$1,000	\$0
TOTAL	6,883,038	\$382,580	\$403,060	\$0

¹ Payment received for unpaid dues in FY01-02.

² New members joined during FY02-03.

Table 2. CFRU project expenditures and balances for FY2002-03 (as of October 1, 2003).

Project (PI)	Approved amount	Amount spent	+ / -	%
Administration	\$ 178,004	\$ 164,153.74	\$13,850.28	7.8%
<u>SILVICULTURE:</u>				
Maine Commercial Thinning Research Network (Wagner/Seymour)	\$ 70,293	\$ 66,272.60	\$ 4,020.40	5.7%
Factors affecting the regeneration and early growth of balsam fir and red spruce (Greenwood)	\$ 4,000	\$ 2,137.49	\$ 1,862.51	46.6%
Northern hardwood growth and yield model (McGrath)	\$ 6,300	\$ 6,300.00	\$ 0	0.0%
Remeasurement of CFRU fertilizer studies (Wagner/McConville)	\$ 17,912	\$ 10,822.09	\$ 7,090.31	39.6%
Role of interfering plants in hardwood regeneration: literature review (Nyland)	\$ 25,000	\$ 25,000.00	\$ 0	0.0%
<u>WILDLIFE ECOLOGY:</u>				
Effect of precommercial thinning on selected wildlife species with special emphasis on snowshoe hare (Harrison)	\$ 23,076	\$ 22,807.35	\$ 268.65	1.2%
Influence of forest practices on both stand- and sub-stand scale habitat selection of lynx in northern Maine (Harrison)	\$ 28,502	\$ 28,501.43	\$ 0.57	0.0%
<u>BIODIVERSITY CONSERVATION:</u>				
Effect of buffer and filter strips on water quality and aquatic biodiversity (Hagan)	\$ 40,000	\$ 40,000.00	\$ 0	0.0%
Indicators for maintaining biodiversity in managed forests (Hagan)	\$ 35,000	\$ 35,000.00	\$ 0	0.0%
<u>OTHER:</u>				
Eastern CANUSA Forest Science Conference (Wagner)	\$ 2,000	\$ 206.00	\$ 1,794.00	89.7%
TOTAL	\$ 430,087	\$ 401,201	\$ 28,887	6.7%

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

The importance of our quarterly advisory meetings, which provide the means for direct interaction with our Cooperators, cannot be overstated. These meetings serve as a forum for scientists and landowners to discuss research ideas to ensure that the work is relevant, applicable, and of the highest quality. The Advisory Committee met four times during the year; January 29, 2003, April 17, 2003, July 1, 2003, and October 7, 2003 (business meeting and field tour).

The annual field tour, graciously hosted by **J.D. Irving**, was one of the year's highlights (Figure 3). The committee toured the Fundy Model Forest in southeastern New Brunswick visiting several research areas. We appreciate the efforts of Hugh Crammond, **Martin Fillion** and **Ian Taviss** of J.D. Irving, and **Nairn Hay** of the Fundy Model Forest for organizing this event.

Last, as a result of losing three Cooperators (International Paper, MeadWestvaco, and Great Northern Paper) we lost the participation of three enthusiastic and dedicated Advisory members in **Gary Donovan**, **Si Balch**, and **Tony Filauro**. We thank these three individuals for their service and wish them well as their careers take them elsewhere.



Figure 3. Martin Fillion of J.D. Irving (left) describing Irving's commercial thinning methods in mature spruce plantations, J.D. Irving seed orchard (right).

Doug Denico (Chair)	Plum Creek Timber Company
Hugh Crammond (Vice-Chair)	Irving Woodlands, LLC
Brian Higgs (Financial Officer)	Baskahegan Corporation
Kenny Fergusson (Member-at-Large)	Huber Resources Corporation
Si Balch	MeadWestvaco Corporation
John Brissette	USFS Northeast Forest Experiment Station
John Cashwell	Seven Islands Land Company
Tom Charles	Maine Bureau of Parks and Lands
Gary Donovan	International Paper Company
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	Nexfor Fraser Paper, Inc.
Paul Van Deusen	NCASI
Henry Whittemore	Hancock Timber Resource Group
G. Bruce Wiersma	The University of Maine College of Natural Sciences, Forestry and Agriculture

Advisory

MAINE FORESTLAND SALES, CFRU MEMBERSHIP, AND BUDGET IMPACTS

Sales of forestland by our cooperators and membership losses presented CFRU members with a significant challenge this year. Although this year was especially difficult with the sale of **MeadWestvaco** and **Hancock Timber Resource Group** lands, and the well-publicized bankruptcy of Great Northern Paper Company, the erosion of CFRU membership has been occurring since 1999 (Table 3). Institutional investors have been steadily purchasing lands held by traditional Maine forestland owners, including Georgia Pacific Corporation lands in 1999-2000 and a significant portion of Great Northern Paper Company lands in 1999. These new institutional investors have generally indicated that they only have short-term (5 to 10 years) investment plans for their forestlands, and in many cases wish to remain anonymous. As a result, those managing forestlands for these investors are not interested in supporting CFRU research. As a result, institutional investor purchases have reduced CFRU member acres by about two million acres (or 23%) since 1998.

To add to the difficulty, financial challenges facing **International Paper Company** (IP) in Maine this year forced them to terminate their CFRU membership. Because IP was a founding member of CFRU and had maintained continuous membership for 28 years, the decision was especially difficult for all concerned. A substantial effort by all members to address dues issues raised by IP over the past two years (see 2000 CFRU Annual Report) proved unsuccessful in the end.

The combined effect of land sales to institutional investors and the loss of IP reduced member acres from 8.6 million in 1998 to 5.3 million for 2004. This 3.3 million acre loss represents a 38.4% reduction in CFRU funding over the past five years. A reduction in funding base of this magnitude will clearly present a significant challenge for maintaining the breadth and depth of research projects that have been reported in CFRU annual reports over the past several years.

Bob Wagner (CFRU Director) presented CFRU members with details of the projected budget and research activity impacts from reduced funding at several meetings this year. As a result of the CFRU's re-organization in 1999, the small number of CFRU employees, project-based funding, and the payment of dues one year in advance of spending, the unit will be able to adapt to this year's funding reductions without the loss of any currently approved research projects or employees. The impact of this year's reductions, however, will be felt by the Advisory Committee over the next several years as there are fewer funds to allocate to new and current research projects. The net effect will be about a one-third reduction in available funds relative to this year if the current level of membership remains stable. Opportunities will continue to be sought to increase membership and pursue, where possible, membership by the new institutional investors in Maine's forestlands.

Table 3. Loss of CFRU member acres from 1999-2003.

<u>Year</u>	<u>Event</u>	<u>Number of acres lost from CFRU membership</u>
1999-2000	Sale of Georgia Pacific Corp. lands to institutional investor	447,000
1999	Sale of Great Northern Paper Co. lands to institutional investor	450,000
2002-03	Sale of Hancock Timber Resource Group lands	251,480
2003	Bankruptcy of Great Northern Paper Co.	326,915
2003	International Paper Co. leaves CFRU	1,380,267
2003	Sale of MeadWestvaco lands to institutional investor	529,158
TOTAL		3,384,820

SUMMITS ON THE FUTURE OF LANDOWNER-SPONSORED RESEARCH ON SUSTAINABLE FORESTRY ISSUES IN MAINE

Prompted by the loss of CFRU member acres and the importance of maintaining a viable landowner-sponsored research effort on sustainable forestry issues at the University of Maine, a series of three executive summits was held in May, August, and December of 2003. The summit participants (Table 4), representing about 7.3 million acres of Maine's forestland, developed a vision for cooperative forestry research in the state of Maine over the next decade and proposed potential mechanisms for achieving this vision.

Key attributes of the research program needed to meet the future challenges of sustainable forestry were identified:

- Conducts applied forestry research that improves the productivity and management of Maine's forest, as well as increases understanding about the complex relationship between forestry practices and key issues of sustainability
- Provides practical information that is useful to Maine forest landowners and managers, including the small woodland owners in the southern part of state
- Improves understanding about the relation between forest policy and the long-term sustainability of the state's forest industry and natural environment
- Conducts excellent, long-term research that represents balanced and diverse perspectives, and is flexible and adaptable to changing needs
- Provides timely and science-based information needed to meet evolving forest policies and the requirements of third-party forest certification
- Provides a publicly-recognized and highly-credible voice for responsible forest management
- Provides a strong communications, education, and outreach effort that ensures rapid transfer of research results to forest managers

Key attributes of the organizational structure needed to achieve this vision include:

- Benefits from input and participation from the full diversity of owners of Maine's forest land
- Supported by a stable, long-term, and broad base of funding where those landowners who benefit directly from the research contribute direct financial support
- Uses a stable funding base to leverage other research funds that can support core research efforts
- Centered at The University of Maine (Orono) to provide objectivity, credibility, and long-term organizational stability

As part of developing a vision for the future of research on sustainable forestry issues, summit participants examined various organizational models that might be used or adapted. Fortunately, other Maine natural resource industries such as the potato, wild blueberry, and lobster industries have faced similar challenges over the years and found long-term solutions. These industries

have used commissions or public instrumentalities to support research, extension, and other important industry functions. During two of the summit meetings, participants met with representatives of the Wild Blueberry Commission of Maine and Maine Potato Board to discuss their experiences.

A task team consisting of **Steve Schley** (Pingree and Associates), **Peter Triandafillou** (Huber Resources), **Jim Robbins** (Robbins Lumber), **Alec Giffen** (Maine Forest Service), **Roger Milliken** (Baskahegan Corp.), and **Bob Wagner** (CFRU) was developed from summit participants to further develop ideas from the summits into a discussion paper. This task team is currently working with various organizations to explore options for ensuring that Maine's forest landowners continue to maintain a strong research effort addressing sustainable forestry issues.

Table 4. Participants attending University of Maine summits during May, August, and December 2003 to address the future of landowner-sponsored research on sustainable forestry issues in Maine.

<u>Name</u>	<u>Organization</u>
Greg Adams	J.D. Irving
David Bell	Wild Blueberry Commission
Seth Bradstreet	Maine Potato Board
Blake Brunson	J.D. Irving
Tom Charles	Bureau of Parks and Lands
Tom Colgan	Wagner Forest Management Ltd.
Hugh Crammond	Irving Woodlands
Paul Davis	Plum Creek Timber Co.
Doug Denico	Plum Creek Timber Co.
Gordon Gamble	Wagner Forest Management Ltd.
Alec Giffen	Maine Forest Service
Mike Greenwood	Maine Forest Service
Lloyd Irland	Irland Group
Dave Lieser	International Paper Co.
Dan McConville	University of Maine, CFRU
Bruce McLaughlin	Robbins Lumber Inc.
Roger Milliken	Baskahegan Co.
Tom Qualey	Maine Potato Board
James L. Robbins	Robbins Lumber Inc.
Steve Schley	Pingree Associates Inc.
Nancy Sferra	The Nature Conservancy
Steve Sloan	International Paper Co.
Don Tardie	Nexfor Fraser Papers
Donovan Todd	Maine Potato Board
Peter Triandafillou	Huber Resources Corp.
Bob Wagner	University of Maine, CFRU
Bruce Wiersma	University of Maine

Activities

FIELD AND DATA

To increase the efficiency of collecting field data and to better attract summer applicants we initiated a new internship program this past summer. We hired nine students with science and liberal arts backgrounds from several universities around the country including Colby College, the University of Chicago, Harvard University, Iowa State University, SUNY College of Environmental Science and Forestry, Oberlin College, and the College of William and Mary. Students left with a better appreciation for the importance of sustainable forest management and research. We gained from their enthusiasm, hard work ethic, and attention to detail. In all the field crews completed the (1) annual re-measurements for the Commercial Thinning Research Network (see page 24) measuring more than 12,000 trees; (2) graduate student projects (see pages 28-31) destructively sampling and making detailed measurements on 94 trees, 20,400 branches, and 846 tree discs; and (3) the annual re-measurements for the red spruce regeneration project including characterizing the vegetation on 1,080 1-meter square vegetation grids and counting and identifying more than 45,000 germinants (Figure 4).

Long-term research sites

Long-term research sites are among the CFRU's most valuable assets. As such, the protection of these sites for ongoing or future research endeavors is essential. Today, our efforts are focused on protecting three important study sites, **Weymouth Point**, **Austin Pond** and the **Commercial Thinning Research Network**.

The Weymouth Point study is one of only three watershed studies in Maine that combines silvicultural and environmental research. Although inactive presently, it's maintenance is critical for future research. Over the past year we continued our efforts to ensure that important study site features are well marked and easy to locate on the ground. We have developed a Weymouth Point database that includes some of the most important data files from past research.

Begun in 1977, the Austin Pond study is the longest running controlled study in eastern North America documenting the long-term effects of herbicides and pre-commercial thinning. The most recent work at the Austin Pond study was completed by **Bob Wagner** and his graduate student **Howard Daggett** (see "Austin Pond Study" page 36). Although no future studies are planned



Figure 4. CFRU field crew taking one of the 20,400 branch diameter measurements on a balsam fir tree in a pre-commercially thinned stand.

we will continue to monitor and protect the site so that future research can be done. The GIS and important data have been archived for future work.

The Commercial Thinning Research Network represents the next generation of long-term CFRU research. The study began in 2000 and will be measured annually through the next decade. GIS and plot data are available on the CFRU website. The challenge for us is to ensure that the network, which includes 12 study sites spread throughout the state are protected.

COMMUNICATIONS

Publications

The goal of the CFRU communications program is to provide cooperators with timely and pertinent research results from CFRU projects in a form that cooperators find most useful. CFRU publications, made available on our website, have played a key role in delivering this information. Over the past year CFRU staff and scientists produced new publications including:

- Long-term effects of herbicide and PCT treatments on species composition, stand structure, and net present value in spruce-fir stands: The Austin Pond study (thesis)
- Assessing silviculture research priorities for Maine using wood supply analysis (Figure 5)
- Effects of PCT on snowshoe hares, small mammals, and forest structure in northern Maine
- 2002 annual report

In all, CFRU staff and scientists produced more than 80 new articles, reports and presentations over the past year (see page 67).

Website

The website continues to be an important tool for sharing our work among Cooperators and showcasing it to the public (Figure 6). As such we are continually working to make the site more attractive and functional. Two major web enhancements were added this year, a digital publications library and the Commercial Thinning Research Network database.

Over our 29-year history we have generated more the

300 internally published documents, including annual reports, research notes and reports and other related scientific and organizational publications. These have been made available free-of-charge to anyone requesting a copy. As our inventories dwindled and the costs of printing and shipping these publications grew we decided to implement a more efficient system—to make all of our publications searchable and available through our website. This year we scanned our entire collection of publications and created a search tool for locating and retrieving publications through

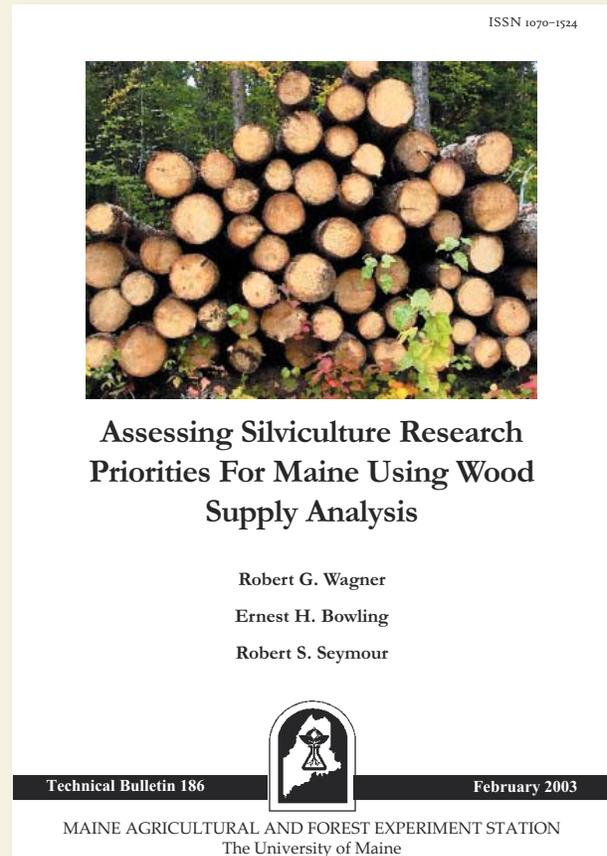


Figure 5. Released in February 2003, the Wood Supply report identified the highest priorities for silviculture research in Maine.



Figure 6. The CFRU website serves as an important tool for providing members and the public with important information regarding forest research and management in Maine.

our website. The search tool enables a variety of search methods including keyword, author, title and year to locate a particular document. Once the publication is located it can be downloaded directly from our website.

The Commercial Thinning Research Network study plot maps and data were added to the secure, password-protected side of the website. This allows member foresters the opportunity to use the data and have ready access to the location of the study sites. One of our goals next year is to add data and maps from other projects to the website.

Eastern CANUSA Forest Science Conference

The first Eastern Canada-USA (ECANUSA for short) Forest Science Conference was hosted by the University of Maine on October 19-20, 2002 (Figure 7). **Bob Wagner** (CFRU Director) initiated and led the conference along with **Dr. David MacLean** (Dean) of the University of New Brunswick's Faculty of Forestry and Environmental Sciences. CFRU was a co-sponsor of the conference along with **J.D. Irving, Ltd.** and the U. Maine Green Endowment Fund. In-kind support from the U.S. Forest Service, Northeastern Research Station also was provided.

The objectives of this biennial conference are to 1) educate forest managers, wildlife managers, policy makers, natural resource students, and interested members of the public about the latest results from scientific research on Maine's forest, 2) promote communications and collaborations on common forest resource issues between natural resource managers and researchers in Maine and the eastern Canadian provinces, 3) promote communications and collaborations among forest and wildlife scientists in Maine and eastern Canada about the latest research problems, methods, and results, and 4) provide a forum for graduate and undergraduate students working on forest-related problems in the eastern US and Canada to present their research findings, meet other forest scientists and students working on similar problems in the region, and

become educated about regional forest resource issues.

The conference will be hosted alternately by the University of Maine and University of New Brunswick, and held every two years. Five keynote presentations, over 50 oral presentations, and over 40 poster presentations were delivered to more than 200 participants during the one and half day meeting. The presentations covered four theme areas: 1) silviculture and forest production, 2) ecology and wildlife, 3) forest management, planning, and policy, and 4) wood products and forest operations/engineering.

The next conference is scheduled for October 15 – 16, 2004 in Fredericton, New Brunswick and will be hosted by the University of New Brunswick's Faculty of Forestry and Environmental Sciences. The program, proceedings, and attendee list from the 2002 conference, as well as information for the 2004 conference, can be found on the ECANUSA web page at www.umaine.edu/fes/ECANUSA.

STAFF CHANGES

Joanna Silva, our half-time Administrative Assistant moved to Virginia during the summer leaving the position open for a short period. We thank **Nora Ackley** (Dept. of Wildlife Ecology) for the excellent job she did filling in as the unit administrative assistant from August through September. We were very fortunate to hire **Julie Kahler** the new CFRU Administrative Assistant in October. Julie, who is a native of South Boston, graduated in 1991 from Johnson & Wales University with a BS in Hospitality Business Management. In addition, she also received an AS in Hotel & Restaurant Management in 1989 and an AS in Recreation & Leisure Management in 1990 from Johnson & Wales University.



Figure 7. The first Eastern Canada USA (ECANUSA) forest science conference, held in October 2002, was attended by more than 200 participants at the University of Maine in Orono

Silviculture

Improving forest productivity and the efficiency of forest management

The Commercial Thinning Research Network



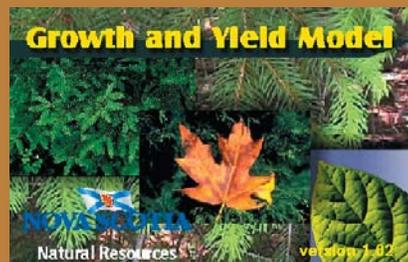
The Stand Product Optimization Tool

Stands	Area	Volume	Value	Yield	Yield	Yield	Yield	Yield	Yield
1	100	1000	10000	100	100	100	100	100	100
2	200	2000	20000	200	200	200	200	200	200
3	300	3000	30000	300	300	300	300	300	300

Austin Pond Revisited: Do Herbicides and PCT Pay?



Northern Hardwood Growth and Yield



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



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



Silviculture

The Commercial Thinning Research Network

INTRODUCTION

In a survey conducted in 1999, CFRU members identified a better understanding of commercial thinning in softwood stands as the top research priority. In response, the CFRU developed the **Commercial Thinning Research Network**. The first product from the network was a computer program called ThinMe. This tool is helping forest managers optimize financial and biological criteria for commercial thinning in Maine's spruce-fir stands.

To help in the longer term, a network of research plots comparing commercial thinning options was installed in 2000. Data now being collected from a dozen study sites across the state will help improve current growth models and our understanding about commercial thinning responses in spruce-fir stands. The plot network will be monitored and measured annually for several years to come.

While the fundamental purpose of the research network—to provide data for improving growth models—remains paramount, the installation has provided researchers with the opportunity to spinoff several studies (Table 5). **Dawn Opland** and **Bob Wagner** are completing an analysis that projects the long-term growth responses to thinning using growth

and yield models. Perhaps the most remarkable result from Opland and Wagner's analysis is that the most widely used growth and yield models in this region do a poor job of predicting responses to thinning, primarily because they are empirical rather than process models. In response to Opland and Wagner's findings, two new graduate students, **Justin DeRose** and **Spencer Meyer** with their major advisor **Bob Seymour** are investigating whether more biologically meaningful stand metrics, such as relative density and projected leaf area can improve our ability to predict growth responses following thinning.

In addition to the growth and yield work, two new projects are taking an ecological perspective on the effects of thinning. To describe how commercial thinning affects the recruitment of new trees, **Mike Greenwood** began work documenting how the thinning treatments influence regeneration success of red spruce and balsam fir. **Rakesh Minocha** of the USFS Northeastern Research Station along with her collaborators began work examining the effects of the various thinning treatments on physiological stress, carbon and nitrogen metabolism in trees, and their relationship to forest productivity. The details of all of these studies can be found in the next several pages.

Table 5. Commercial Thinning Research Network Studies for FY 2002-03

<i>Growth and Yield Studies</i>	<i>Ecophysiology Studies</i>
<ul style="list-style-type: none">• Study Site Establishment and Measurement• Projected Responses of Previously Precommercially Thinned Spruce-fir Stands to Commercial Thinning• Relationships Between Leaf Area, Structure and Relative Density in Even-aged Spruce-fir Stands in Maine• Leaf Area as a Growth Predictor for Red Spruce and Balsam Fir in Managed Stands in Maine	<ul style="list-style-type: none">• Factors Affecting the Regeneration of Red Spruce and Balsam Fir• Effects of Commercial Thinning on Physiological Stress, Carbon and Nitrogen Metabolism in Trees, and Their Relationship to Forest Productivity

Silviculture

Study Site Establishment and Measurement of the Commercial Thinning Research Network

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

One of the most significant accomplishments of the CFRU has been establishing the Commercial Thinning Research Network. The Thinning Network, which consists of two separate studies and was established in 2000 on CFRU cooperator lands throughout northern Maine. One study was established in intensively managed (precommercially thinned and herbicide treated) mature balsam fir stands to quantify the growth and yield response from timing of first commercial thinning entry (now, delay 5 yrs, and delay 10 yrs) and level of residual relative density (33% and 50% relative density reduction). The second study was installed in extensively managed (little if any previous management activity) mature spruce-fir stands to quantify the growth and yield response from thinning method (low, crown, and dominant) and level of residual relative density (33% and 50% relative density reduction).

Twelve study sites (6 in PCT, 6 in non-PCT) were chosen for these two studies (Figure 8). On each site, seven 1-acre treatment plots were established with a 0.20-acre measurement plot centered in each treatment plot. Trees within the measurement plot that met the minimum size requirement were identified at the species-level and measured for DBH, total height, crown height, and two-dimensional location prior to the commercial thinning treatments. Following the thinning treatments, trees were tagged so that they can be periodically re-measured and plots can be assessed for in-growth and mortality (Table #). To date, 12,365 trees have been tagged for long-term measurement across all 12 sites. We anticipate re-measuring plots for a minimum of 10 years and according to the schedule shown in table 6. For more information about the location, descriptions, and experimental design details for all sites please refer to the 2001 CFRU Annual Report.

This past summer we successfully completed all of the targets listed in table 6 for the 2002-03 fiscal year. These tasks included the initial post-treatment measurement for the Rump Pond Road site (MeadWestvaco), which completes the first post-treatment measurements for the entire study. In addition, the second round of intensive post-treatment measurements at each of the PCT sites was accomplished. The intensive measurement (IM) cycle includes a complete re-measurement of tree diameter, total height, and crown height, as well as an in-growth and mortality assessment.



Figure 8. Twelve study sites were installed beginning in 2000 to understand how trees respond to thinning. The sites were commercially thinned following the initial pre-treatment measurements and will continue to be monitored and measured through the next decade.

Six of the sites were installed in intensively managed (PCT plus vegetation management), and six in extensively managed sites (no PCT nor vegetation management; shown above).

At four of the sites that have not received PCT (Schoolbus Rd., Sarah's Rd., 208 Rd., and Golden Rd.) we completed the first round of extensive measurements (EM), which include measuring DBH and on every tree, measuring and recording in-growth if applicable, and recording downed and dead trees on every plot when necessary. In addition, we completed a mortality assessment (DM) at the Harlow Rd. site. We thank the CFRU members that have provided study sites and indirect financial contributions to establish the Commercial Thinning Research Network. Their substantial investment and long-term commitment to this project are much appreciated.

For more information about long-term measurements of Network sites, contact **Dan McConville** at (207) 581-2861 or dan_mcconville@umenfa.maine.edu.

Table 6. Approved plan for the establishment, treatment, maintenance, and measurement of current study sites in the CFRU Commercial Thinning Research Network for 2000-2010.

Landowner	Site	FY99-00	FY00-01	FY01-02	Period of approved funding							
					FY02-03	FY03-04	FY04-05	FY05-06	FY06-07	FY07-08	FY08-09	FY09-10
Non-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
Baskahagan	Harlow Rd.	-	Pre	IM1 / thin	DM	EM	DM	IM	DM	EM	DM	IM
MeadWestvaco	Rump Pond Rd.	-	Pre	-	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 downed and dead trees on every plot)											
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)											

Silviculture

Projected Responses of Previously Precommercially Thinned Spruce-fir Stands to Commercial Thinning

Robert G. Wagner

Last year's effort by CFRU graduate student Dawn Opland focused on projecting the long-term response to commercial thinning in spruce-fir stands that had never been precommercially thinned (See 2002 CFRU Annual Report). This year's effort focused on modeling potential growth responses of Commercial Thinning Research Network plots that had been previously precommercially thinned (PCT). The objective is to provide CFRU members with a preliminary estimate of how study plots are likely to respond to commercial thinning treatments (timing of the first commercial thinning entry and level of relative density reduction) that we have already applied or will be applied in the coming years. We also assessed the likely economic feasibility of commercial thinning under these conditions and examined the ability of current growth and yield models to simulate commercial thinning responses.

The analysis focused on three of the six PCT study sites (Ronco Cove, Macwahoc, and Alder Stream). Data collected from pre-treatment and first-year post-treatment measurements were used with the Forest Vegetation Simulator (NE TWIGS variant) to project future stand development for ten-year periods over the next 50 years. Tree species, DBH, total height, and number of stems were projected forward and used as the basis for total and merchantable wood volume calculations. Volume estimates were based on Honer's volume equations to calculate total volume, pulpwood volume, and sawlog volume. Stumpage prices from the Maine Forest Service, wood yields from the commercial thinning treatments, and projected development of the residual stands were used to calculate the net present value (NPV) for each plot over the 50-year simulation. A 4% discount rate was used for the NPV analysis. Wood yields and residual stand conditions for 5- and 10-year delayed thinnings were estimated based on actual results from the 2001 thinnings.

As would be expected, the untreated control plots (no commercial thinning) maintained the highest residual standing wood volumes throughout the simulation period. Residual volumes for the 33% removals were lower than the control and lowest for the 50% removals. FVS projections indicated that post-thinning volume growth was equal among treatments (i.e., growth curves remained



In response to projected shortages in Maine's wood supply landowners began pre-commercially thinning spruce-fir stands in the early 1980s. The first stands to receive PCT are now reaching merchantable size and are being commercially thinned.

We currently have little understanding of the effects of this commercial thinning on growth and yield responses. The purpose of this study is to provide a preliminary estimate of how precommercially thinned spruce-fir stands are likely to respond to commercial thinning.

parallel). FVS projections also seemed to provide reasonable growth predictions, unlike that found for some thinning treatments in non-PCT stands (See 2002 CFRU Annual Report).

Total wood production (including wood removed from commercial thinning) differed substantially among treatments. In general, 50% relative density reduction reduced overall wood production relative to the 33% treatments and the untreated controls. Delaying commercial thinning entry by 5 or 10 years and reducing density by only 33% were the only treatments that increased total wood production above that of

the untreated controls on the three sites. Early (0- and 5-year delay) and heavy (50%) commercial thinning reduced total volume production by 20% relative to the controls. Delayed (5 or 10 year) and lighter (33%) thinning increased total volume production by 7% relative to the control, and also increased the total sawlog production.

The mean NPV of these previously precommercially thinned spruce-fir stands was projected to increase for the next decade or more (Figure 9). The highest mean NPV among commercial thinning treatments was produced by the 33% removal with a 5- or 10-year delayed entry, and were the only treatments that had a higher NPV than the untreated controls. The 50% removal reduced NPV relative to the 33% removal at all three timings of entry; with the difference increasing the earlier the stands were commercially thinned. The peak NPV for the 10-year delay treatments was generally achieved 5 years later than for the 5-year delay treatment. The earliest entry (0 year) and the 50% removal with 5-year delay produced a

lower NPV than the untreated controls over most of the projection period.

In summary, projections of future stand conditions on previously precommercially thinned spruce-fir stands suggest that increased merchantable wood yields and higher NPVs may be obtained from commercial thinning, but only if the stands are not entered too soon and the relative density is not reduced more than 33%.

Continued measurement of CFRU Commercial Thinning Research Network plots during the coming years will test the accuracy of these model projections. Until then, this analysis provides CFRU members with a preliminary indication about the kind of growth and yield responses they can expect from commercial thinning Maine's spruce-fir stands in various ways. For more information about this portion of the study, contact **Bob Wagner** at (207) 581-2903 or bob_wagner@umenf.maine.edu.

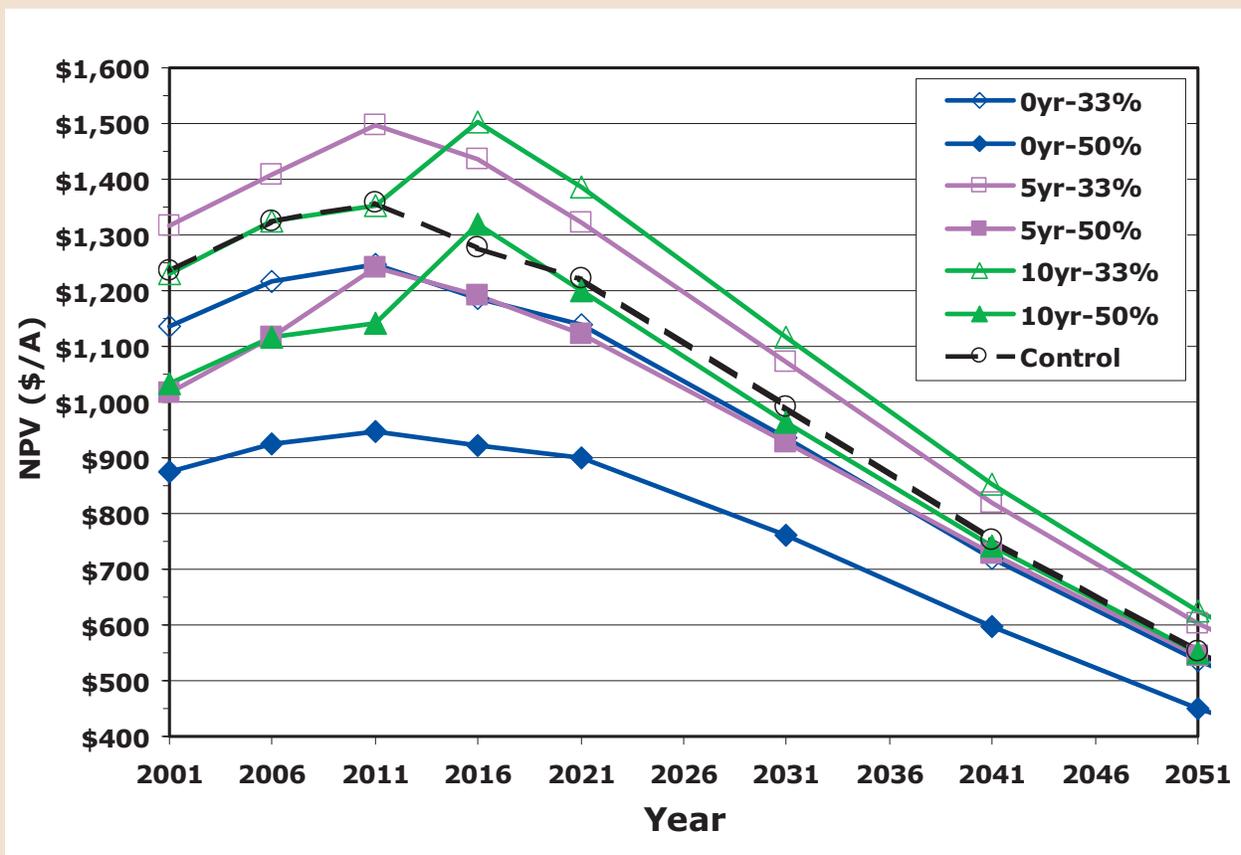


Figure 9. Net present value (NPV) for untreated controls and six commercial thinning treatments [three timings of entry (now, delay 5 yrs, delay 10 years) for first commercial thinning and two levels of relative density reduction (33% and 50%)] over a 50-year projection period in spruce-fir stands that had been previously precommercially thinned. Values are averaged among projections for the Ronco Cove, Macwahoc, and Alder Stream study sites. A 4% discount rate was used. NPV includes value of residual stand and value of wood removed from commercial thinning.

Silviculture

Relationships Between Leaf Area, Structure and Relative Density in Even-aged Spruce-fir Stands in Maine

R. Justin DeRose and Robert S. Seymour

INTRODUCTION

Softwood logging has been an integral part of the history of the northeast for nearly 100 years. With over a century of forestry experience in the area it is astonishing to note most forest land owners practicing antiquated forms of diameter limit cutting, which ignore the benefits of individual species silvical traits (Seymour et al. 1986). With Maine boasting such a large percentage of its land base in young vigorous forests, much as a result of the 1976-1984 spruce budworm outbreak, and potential for higher yield (Seymour 1993) the use of silvicultural practices has been increasing. Unfortunately relatively little is known about the outcomes of these treatments in the forests of Maine. The topic of a recent Maine Agricultural and Forest Experiment Station (MAFES) technical bulletin was prioritizing silvicultural research efforts using wood supply analysis (Wagner et al. 2003). The report emphasized the importance of research on silvicultural treatments specifically those with the most influence on increasing volume production. In 2001 the CFRU implemented a system of commercial thinning plots across the state to assess long-term changes to thinned stands with and without a history of precommercial thinning (2001 CFRU Annual Report). These long term plots will provide valuable information to further assess the benefits of two silvicultural activities, commercial and precommercial thinning, which are identified by the MAFES report as important for future wood supply.

Complicating the problem of silvicultural assessment is the inappropriate level of sophistication currently found in the regions growth and yield models. CFRU graduate student **Dawn Opland** found the USFS Forest Vegetation Simulator (NE-TWIGS variant) gives unexpected outcomes to even-aged intermediate thinning treatments (2002 CFRU Annual Report). Specifically even-aged, spruce-fir stands respond better to dominant thinnings, which leave more overtopped and intermediate trees, than low thinnings that remove these undesirable trees. This outcome is counterintuitive since we would expect the poorer quality trees left in a dominant thin to take much more time to respond than the dominant and co-dominant trees of the low thin. Other regions (lake states, inland empire) boast better predictive model variants

Conventional models used in Maine for predicting spruce-fir growth work well in the absence of forest management. Once a stand is thinned, however, the models behave poorly. The reason for this is that these conventional models are driven by the assumption that future wood growth is a function of current stem size. In reality a complex of factors drive the process by which trees grow.

Perhaps the most important of these factors for influencing growth responses following thinning is the relative amount of foliage compared with stemwood. Simply put, trees with a relatively large leaf surface grow more vigorously than trees with equal-sized stems but small crowns. The act of thinning can dramatically change the ratio of foliage to stemwood, and thereby affect the growth response of the residual stand. In contrast to these empirical models, many process-based models, which are widely used in other regions of the world, can accurately predict growth responses following thinning because they are driven by the relative amount of foliage.

Two graduate students, Justin DeRose and Spencer Meyer, in collaboration with their major advisor Bob Seymour are testing whether process-based growth models can improve the predictive capacity of existing empirical growth models. They are using data from the Commercial Thinning Research Network in their analyses. Please read the following pages to get a better understanding of where our growth modeling efforts are heading.

within the same FVS framework. Sparse quantitative data describing various silvicultural practices in Maine and the northeast limit improved model development.

One way to improve the predictive capability of growth and yield models is to use biologic explanatory variables for growth prediction instead of empirical “wood grows

wood” measurements such as diameter at breast height (DBH). Current empirical models such as the FVS NE-TWIGS variant also fail to include a sufficient amount of data from intensively managed stands. One way to overcome these drawbacks is to measure biologically meaningful variables from intensively managed plots. The biologic variable leaf area index (Figure 10) is a measurement of the ratio of projected needle area per ground area. It is of primary interest because of its role in the interception of light and subsequently photosynthesis. Leaf area has been used to guide management decisions in multi-cohort and single cohort stands (O’Hara 1996, 2001). The benefit of using leaf area to guide management decisions is its close relation to volume growth. Many authors have published accounts of a strong relationship between leaf area and volume growth (Long and Smith 1984, 1992, O’Hara 1999, Seymour and Kenefic 2002).

Since research priorities indicate a need for better growth and yield modeling we intend to relate leaf area to the more easily measured relative density across different stand structures. In this study, funded by CFRU and The Department of Forest Ecosystem Science at the University of Maine, we propose to measure leaf area using allometric relationships, structure and relative density of the CFRU commercial thinning research network plots. We hypothesize the relationship between leaf area and relative density at the plot or stand level will prove beneficial for more accurate growth and yield modeling in response to intensive silvicultural treatments.

OBJECTIVES

- Assess whether relative density can be used as a surrogate for leaf area in even-aged spruce-fir stands.
- Test this relationship between stands with and without PCT history.
- Test this relationship between dominant and low

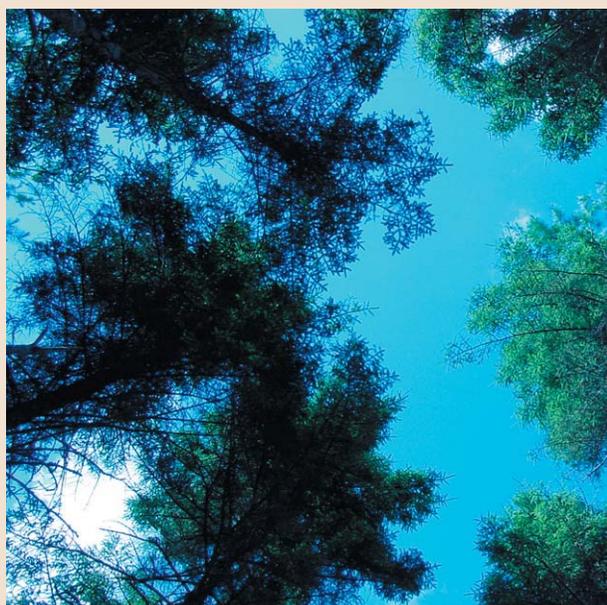


Figure 10. A view from plot center of foliage interceptsun light.

thinnings in stands without PCT history.

- Utilize the results to improve growth and yield modeling.
- Compare predictive ability of models with the Valentine (1994) mLCR sapwood area surrogate.

METHODS

During the summer of 2003 CFRU investigators Justin DeRose and Spencer Meyer along with a 9 person field crew completed measurements of the 12 Network sites. The 2002 census data was fielded by plot and divided into diameter class by live crown ratio class tables. The sample population was chosen from these tables. The plots measured differed by history of precommercial thinning (PCT). Plots measured on sites without PCT were dominant thins (2 intensities), low thins (2 intensities) and control (5 total). Plots measured on sites with PCT history included a dominant thin, a low thin, and two controls (4 total). Care was taken to randomly stratify the census data to accurately portray current stand conditions.

Measurements taken in each plot include DBH, bark thickness, height, height to lowest live branch, height to lowest live crown, and crown class. In addition, tree increment cores were extracted (Figure 11) and sapwood area, which is a surrogate for leaf area using the allometric relationship proposed by the pipe-model theory (Shinozaki et al. 1964) was measured. This relationship has been shown to be valid for both spruce and fir (Maguire et al. 1998, Gilmore et al. 1996). Ninety-six trees (8 near each plot) were felled, sectioned and sampled to validate the allometric relationship statewide. For a full description of whole tree sampling see page 31.

For more information about this study please contact **Justin DeRose** at (207) 581-2839 or densitymanager@yahoo.com.



Figure 11. Spencer Meyer extracting an increment core to estimate past diameter growth.

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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

INTRODUCTION

In order to predict the effects of commercial thinning, land managers in Maine must be able to accurately model forest growth. Forest stand structure is a function of many natural and human-caused processes. Currently, most growth models are empirically based on size attributes in stands. These model types are based on the assumption that wood growth is a function of itself. Using leaf area as a determinant of stand density and structure can apply physiological and ecological processes to stand growth. Models based on leaf area may reflect growth dynamics (i.e., differentiation) within the stand, while others assume all trees of similar sizes to have the same growth rate. The well-established leaf area-sapwood area (LA:SA) relationship may be used to estimate biologically-significant growth model parameters. The objectives of this study are to 1) validate the relationship between the leaf area and the sapwood area for spruce and fir in Maine, 2) quantify a growth modifier for individual trees and 3) better model the growth of managed stands based on crown dynamics.

With the help of nine summer field assistants, Spencer Meyer and Justin DeRose collected the data for this model building effort. During the month of August, 94 trees were destructively sampled, 282 fresh branches were collected, 846 discs were cut, and 20,400 branch diameters were measured. Sampled trees were representative of the trees in the study plots (Table 7) The subsequent months were spent processing the collected materials so that the leaf area data could be extracted. These data will be used to determine branch-level specific leaf area (SLA - unit green area/unit dry mass). The SLA will be applied to all branches to estimate total tree leaf area (LA). The LA will then be regressed with sapwood area (SA) to calculate the LA:SA relationship. This LA construction method will be compared to that of Gilmore et al. (1996) and to the Valentine model (Valentine et al. 1994) to evaluate its effectiveness for estimating leaf area. Analysis of Variance will be used to evaluate the model's performance across several variables, including site, age, and crown position. Inter-model comparisons will be evaluated with Furnival's index of fit (1961) following the procedures of Kenefic and Seymour (1999) and Gilmore et al. (1996).

By using growth increment cores taken (see page 28 for description of increment core sampling matrix) at all sites during the 2003 field season, this study will attempt

to reconstruct past leaf area based on constructed LA:SA equations. Stand growth will be projected 5 years in the future using the reconstructed growth data with Forest Vegetation Simulator (NE-Twigs). NE-Twigs results will be compared to the actual growth change observed from the radial increment record. Volume increment to PLA relationships will be compared across sites with ANOVA. Ratios of past to current volume increment will be compared to investigate its use as a growth potential modifier. Several parameters will be examined to construct a growth potential modifier that most improves NE-Twigs' performance.

For more information contact **Spencer Meyer** at (207) 581-2878 or spencer.meyer@umit.maine.edu.

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Table 7. Ranges in pre-treatment (pre) and sampled tree characteristics**

	PCT		Natural	
	Pre	Sample	Pre	Sample
Mean Age	37	37	57	57
Dom. species	BF*	BF	RS*	RS
Min. DBH (in.)	1.0	2.1	1.0	1.9
Max. DBH (in.)	14.2	12.6	21.3	13.4
Mean DBH (in.)	5.5	6.3	4.3	6.7
Min. Ht. (ft.)	12.5	19.4	7.2	18.7
Max Ht. (ft.)	57.1	56.1	80.1	67.6

*BF = balsam fir and RS = red spruce

**Range limits were not always obtainable due to rot in larger trees and the minimum, reasonable size required for stem analysis.

Silviculture

Factors Affecting the Regeneration of Red Spruce and Balsam Fir

Michael Greenwood, Cristin O'Brien and Dan McConville

SUMMARY

The objective of this project is to identify factors affecting the regeneration of balsam fir and red spruce, with particular emphasis on encouraging red spruce regeneration. Cristin O'Brien, a graduate student in our Horticulture program has also been working with us to make further observations on the effects of moisture level and light intensity on germination and seedling growth. The following findings will be discussed in terms of recommendations to increase the regeneration success of red spruce: 1) 2002 was a relatively good cone year for balsam fir but 2003 was not, 2) balsam fir seedlings allocate much more biomass to roots than red spruce under all light conditions but red spruce shoots are capable of indeterminate growth in high light, 3) balsam fir seedlings may tolerate drought better than red spruce and 4) balsam fir first year seedlings comprise 95% of all conifer seedlings in regeneration plots in 2003.

Cone Production and regeneration assessment

Conifer regeneration data were collected last summer in the plots established in 2002, and in fall cone production estimated again as in 2002. In 2003, 45,500 conifer germinants were observed across all the plots, 43,000 of which were balsam fir! Almost twice as many balsam fir trees produced seed than red spruce in 2002, and the flowering index (cone density x length of live crown with cones) was almost 3-fold greater than balsam fir (Table 8). In 2003, cone production decreased more than 4-fold for balsam fir over 2002, but in red spruce the decline was about 2-fold. While a good cone year partially accounts for the dominance of balsam fir seedlings in 2003, it does not explain why virtually no red spruce seedlings were observed.

Table 8. Estimates of cone production by balsam fir and red spruce at 5 thinning sites for 2002 and 2003. Flowering index is the product of the length of crown bearing cones times and estimate of cone density.

	2002		2003	
	BF	RS	BF	RS
Number of trees sampled	113	148	77	142
Percent of trees with cones	85	43	14	22
Flowering index	17	6	1	4

Virtually all of the softwood extracted in Maine is harvested through partial cutting methods but little is known how such harvest practices affect regeneration success. The purpose of this study is to describe how thinning affects the regeneration success of two ecologically and economically valuable species, balsam fir and red spruce.

Two years of understory regeneration measurements reveal that balsam fir is more successful than red spruce in repopulating recently thinned stands. The relative success of this species may be due to its strategy of allocating energy to root production rather than to leaves and stems.



In a study conducted at the PEF, Abbott and Hart (1960) reported that mice and voles have a very strong preference for spruce seed over that of balsam fir. They removed 25 times as much spruce seed (on a weight basis) from a feeding station in the fall and early winter. Predation may therefore also favor survival of balsam fir. However, a feeding station where seed is concentrated does not mimic foraging for seed scattered on the forest floor. Another foraging study is being undertaken by Keith Kanoti, a graduate student, which may provide more realistic foraging conditions.

Effects of moisture on seed germination and early seedling development

The effects of 6 different moisture regimes on seed germination are shown in figure 12. The regimes were maintained gravimetrically by watering the germination medium (sieved organic matter from a spruce-fir stand) when moisture level declined 10 to 70% on a weight basis. There was no effect on total germination by increased moisture stress with the exception of the highest stress level for red spruce, where a significant decline was observed. While germination was slower with reduced watering frequency, seeds of both species can tolerate a wide range of periodic drying treatments, but balsam fir may be more resistant to the highest level of stress.

Two replicates of this study were carried out in growth chambers with different light intensities (Table 9). The seedlings were allowed to grow for about 16 weeks in these environments after which the seedlings were measured and dry weights taken. The results show that in all replications at the lowest light intensity (block 1) there was no difference in weight between balsam fir and red spruce (Table 9). In contrast, with twice as much light, balsam fir seedlings put on significantly more dry weight than red spruce. Balsam fir seems to be able to exploit the increase in low levels of light intensity more efficiently than red spruce. In these light-limited environments, the growth of both species was little affected by available moisture. However, when a comparable group of seedlings were grown under full sun in the greenhouse for about 20 weeks, red spruce produced much more dry mass than balsam fir (see 2002 CFRU Annual Report). The reason for this reversal is that red spruce undergoes continuous indeterminate shoot growth during the growing season when moisture and light are not limiting, whereas balsam fir only produces one flush of growth. Balsam fir allocates significantly more biomass to roots in all three environments.

Thus although both balsam fir and red spruce are considered shade tolerant conifers and compete with one another, their seedlings appear to have very

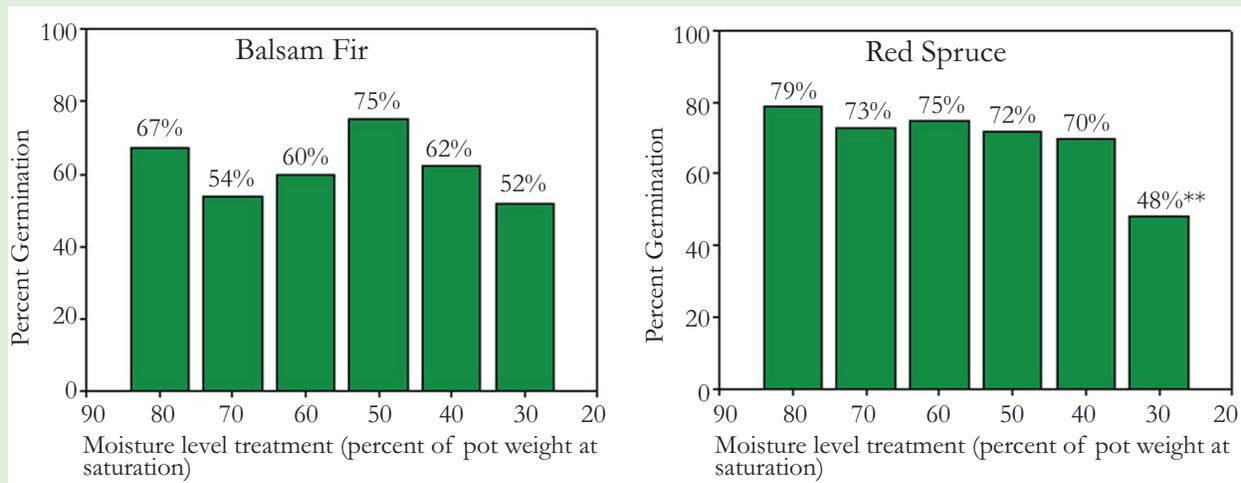


Figure 12. Percent of germination for balsam fir and red spruce at different moisture levels.

Table 9. Total seedling dry weight and root/shoot ratios, (R/S) (± SE) 105 days after germination (growth chamber) and 150 days after germination (full sun, greenhouse).

Light intensity	Balsam fir		Red spruce	
	Dry wt.,mg	R/S	Dry wt.,mg	R/S
65 μmoles/m ² /sec (growth chamber)	48 ± 1.2	0.58 ± .05	38 ± 0.8	0.25 ± .02
130 μmoles/m ² /sec (growth chamber)	72 ± 1.6	0.53 ± .02	34 ± 1.6	0.36 ± .02
1000-1500 μmoles/m ² /sec (full sun)	854 ± 68	0.29 ± .13	230 ± 16	0.70 ± .06

different morphological and physiological strategies for successful regeneration. Several of these differences could account for the relatively greater success of balsam fir regeneration, and may as well suggest strategies to encourage red spruce. Balsam fir germination can tolerate more moisture stress than red spruce, and balsam fir seedlings may tolerate greater moisture stress because of their greater allocation of biomass to roots. We repeated the moisture stress studies (see 2002 CFRU Annual Report) with exactly the same results: when grown in separate containers, balsam fir seedlings can withstand drought that kills almost all red spruce seedlings of the same age which have much larger shoots.

RECOMMENDATIONS

The regeneration of red spruce and balsam fir are probably about equally limited by the capacity to produce viable seed, or the capacity seed (that survives predation) to germinate over a wide range of conditions. The fact that red spruce seedlings can undergo indeterminate shoot growth can be potentially be exploited on sites where ample light and moisture are available. Under these conditions young red spruce seedlings can potentially

put on much more shoot growth than balsam fir, but such conditions would also benefit other competitors like grasses and other plants. This competition would have to be controlled, probably with herbicides, for red spruce to realize its growth potential. Available light can be manipulated by harvest practices, which could be timed to follow good cone years, and seed predation can potentially be controlled. Provision of adequate moisture is clearly more problematic.

FUTURE WORK

During the summer of 2004 we will collect another season of seedling and vegetation data (Figure 13) and summarize differences in species composition during the fall of 2004.

For more information please contact **Mike Greenwood** at 581-2838 or greenwd@umenfa.maine.edu.

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Figure 13. Field technicians counting conifer seedlings in Commercial Thinning Research Network plots during Summer 2003.

Silviculture

Effects of Commercial Thinning on Physiological Stress, Carbon and Nitrogen Metabolism in Trees, and Their Relationship to Forest Productivity

Rakesh Minocha, John Aber, Subhash Minocha, and Robert G. Wagner

A new collaborative project was initiated this year using the **CFRU Commercial Thinning Network** study sites. A research proposal by **Rakesh Minocha** (USFS, Northeast Research Station), **John Aber** (University of New Hampshire), **Subhash Minocha** (University of New Hampshire), and **Bob Wagner** (CFRU) was funded this by the U.S. Forest Service's Agenda 2020 program. In-kind contributions are being provided by CFRU.

The objective of the project is to examine 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. Previous work by Rakesh Minocha and her colleagues have shown that putrescine (a common polyamine) and arginine can be used as early indicators of physiological stress caused by chronic nitrogen fertilization or acid deposition, and may be a precursor to reductions in growth, crown deterioration, or tree death. Significant changes in a few specific amino acids and spermidine (also a common polyamine) along with changes in putrescine also may indicate increases in growth. Recent commercial thinning treatments on network study plots provide a good

opportunity to examine spruce and fir trees of different ages that have been thinned to various degrees, and therefore possibly stressed to various degrees. This work is testing whether biochemical changes evident shortly after commercial thinning are correlated with longer-term changes in tree growth (Figure 14).

During July 2003, Minocha and her field crew collected foliage samples from trees on the Lake Macwahoc (IP) and Golden Road (Huber Resources) study sites. Up to 25 spruce and fir trees were sampled per plot at Golden Road and 20 fir sampled per plot at Macwahoc. 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. Data analysis is ongoing and interim results will be reported in next year's annual report. Additional samples will be collected next year to examine year-to-year changes in foliage compounds. More information about the study can be found by contacting **Rakesh Minocha** at 603-868-7622 or at rminocho@fs.fed.us.

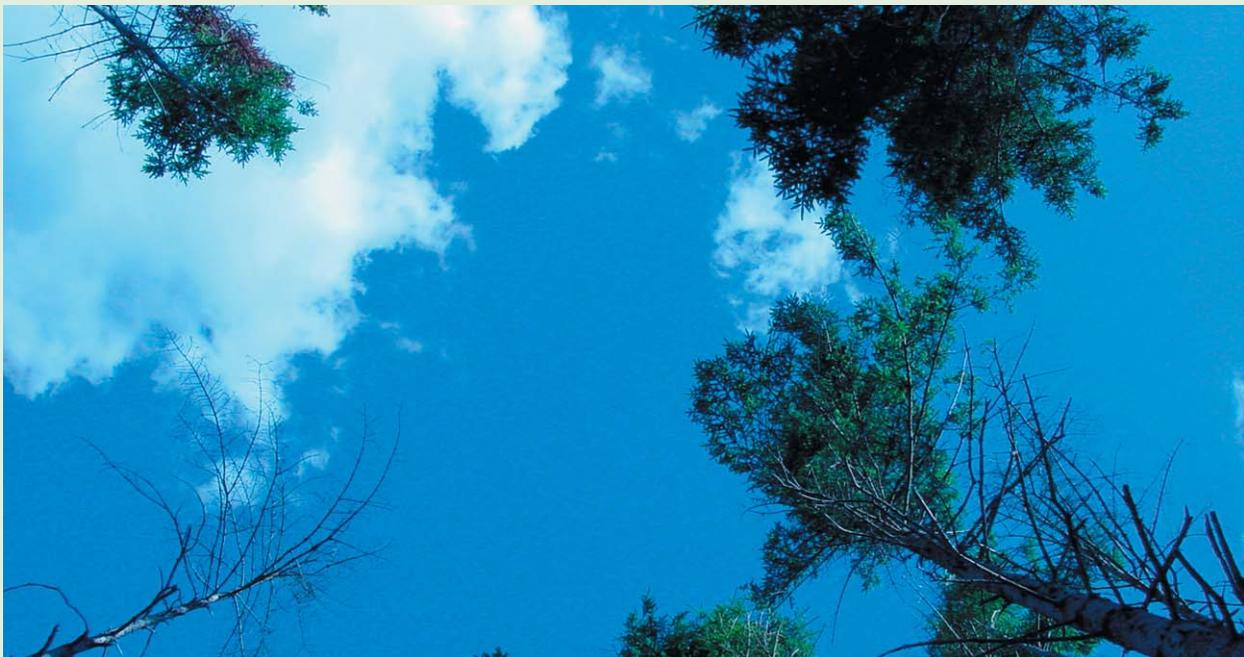


Figure 14. Poor residual crown conditions resulting from a dominant thinning at the Huber Resources Golden Road research site. Dominant thinning treatments may have triggered a decline in vigor, and in some cases mortality.

Silviculture

Austin Pond Revisited: Do Herbicides and PCT Pay?

Robert G. Wagner

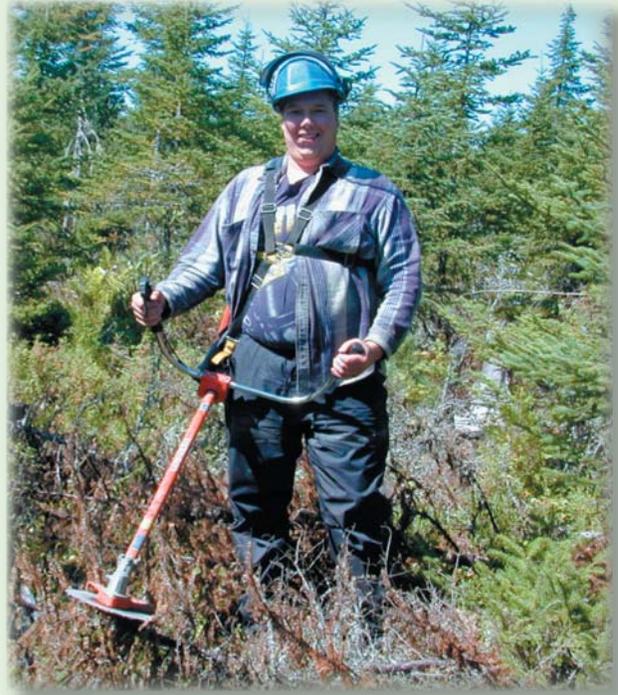
INTRODUCTION

This year concluded the analysis and reporting from the 1999 remeasurement of the Austin Pond study plots. **Howard Daggett** completed his M.S. thesis in the summer of 2003. The final results also were presented to the Advisory Committee and at several conferences and workshops during the year. The completed thesis (Daggett 2003) is available on the CFRU web page and papers are being prepared for journal publication. An analysis of understory vegetation diversity on the Austin Pond plots also was completed this year.

Based on the stand conditions we measured at year 29 and computer projections of future stand development, we concluded the following about aerial herbicide application and precommercial thinning (PCT) in Maine's spruce-fir stands:

Herbicide and PCT effects

- Herbicide treatments substantially increased dominance of spruce-fir. Spruce-fir wood volume was 74% of the total in herbicide-only plots compared to 23% in untreated plots. Based on stand projections, spruce-fir dominance will persist through the rotation.
- Herbicide treatments alone did not increase total stand volume, merchantable volume, or financial value by year 29. Stand projections, however, suggest that the merchantable volume of herbicide-only plots will surpass untreated and thinned plots within 20 years.
- There was little difference in long-term stand composition and wood volume among types of herbicides or rates of applications. Glyphosate, triclopyr, and various combinations of phenoxy herbicides produced similar stands over time.
- PCT provided follow-up control of hardwoods not controlled by herbicide treatments. When applied alone, PCT produced a stand dominated (88% of volume) by spruce-fir.
- The long-term effectiveness of herbicide and PCT treatments was dependent upon whether the treatments were applied in combination. Herbicide release increased the number of trees in larger diameter classes, thereby allowing released spruce and fir to take better advantage of later PCT. When herbicide and PCT treatments were applied in combination, 92% of the 29-year stand volume was spruce-fir.
- When preceded by an herbicide treatment, PCT



reduced total standing volume by 29%, increased merchantable volume by 88% (158% for spruce-fir), and increased financial value by 177% (200% for spruce-fir).

Financial returns

- Based on current stand conditions and projections by the Forest Vegetation Simulator (NE-TWIGS), the maximum net present value (or financial rotation) for Austin Pond stands will occur at 50 years (Figure 15). The financial rotation was similar for all treatments.
- Without herbicide or PCT treatments (untreated control plots), an intolerant hardwood stand (primarily aspen and red maple) with merchantable volumes and financial values comparable to herbicide and PCT treated plots developed.
- The net present value (NPV) of herbicide-only treatments was about \$200 / A (or 55%) higher at 50 years than the NPV for untreated plots or those that received PCT (Figure 1). The dominance of low value hardwoods in untreated plots reduced the NPV relative to that of herbicide-treated plots. Although PCT-treated plots had high merchantable volumes and financial values, the high cost of PCT (\$200

/A) relative to that of herbicide application (\$50 /A) reduced the NPV for any treatment receiving PCT. As a result, the NPV of untreated plots and those that received PCT was similar at financial rotation.

- Herbicide and PCT treatments produced good internal rates of return: herbicide only = 8.0%, PCT only = 6.1%, Herbicide + PCT = 5.8%.

Species diversity

- Despite the substantial increase in dominance of spruce and fir following herbicide and PCT treatments, the species richness of the overstory trees at 29 years was equal to that of the untreated control plots. Herbicide treatments alone produced mixedwood stands.
- No difference was found in the cover, richness, diversity, or evenness of understory plant species between herbicide treated and untreated plots 23 yrs after treatment.
- The abundance (% cover) of understory plants in PCT-treated plots was double (30% vs. 15%) that of unthinned plots 14 years after treatment. In addition, PCT increased the richness and Shannon diversity index of understory plant species by 29% and 15%, respectively.

In summary, herbicide and PCT treatments were necessary to increase the long-term dominance of spruce and fir at Austin Pond. Investments in these treatments are projected to provide good rates of financial return. The long-term species diversity of overstory trees and

understory vegetation was not reduced by herbicide or PCT treatments, and there appears to be a longer-term gain in understory abundance and diversity in PCT-treated stands.

FUTURE DIRECTIONS

One of the original objectives of this Austin Pond remeasurement was to evaluate the possibility of adding new silvicultural treatments to the existing study plots. Just as dividing the original herbicide plots in the mid 1980s to apply PCT treatments substantially increased the long-term value of the study, adding additional treatments such as commercial thinning and fertilization may further increase the long-term value of Austin Pond. The latest results from the CFRU Commercial Thinning Network indicate that it is probably too early to begin commercially thinning at Austin Pond. During the next few years we intend to evaluate various options for including new treatments that can enhance our understanding about how spruce-fir stands respond to different silvicultural systems.

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

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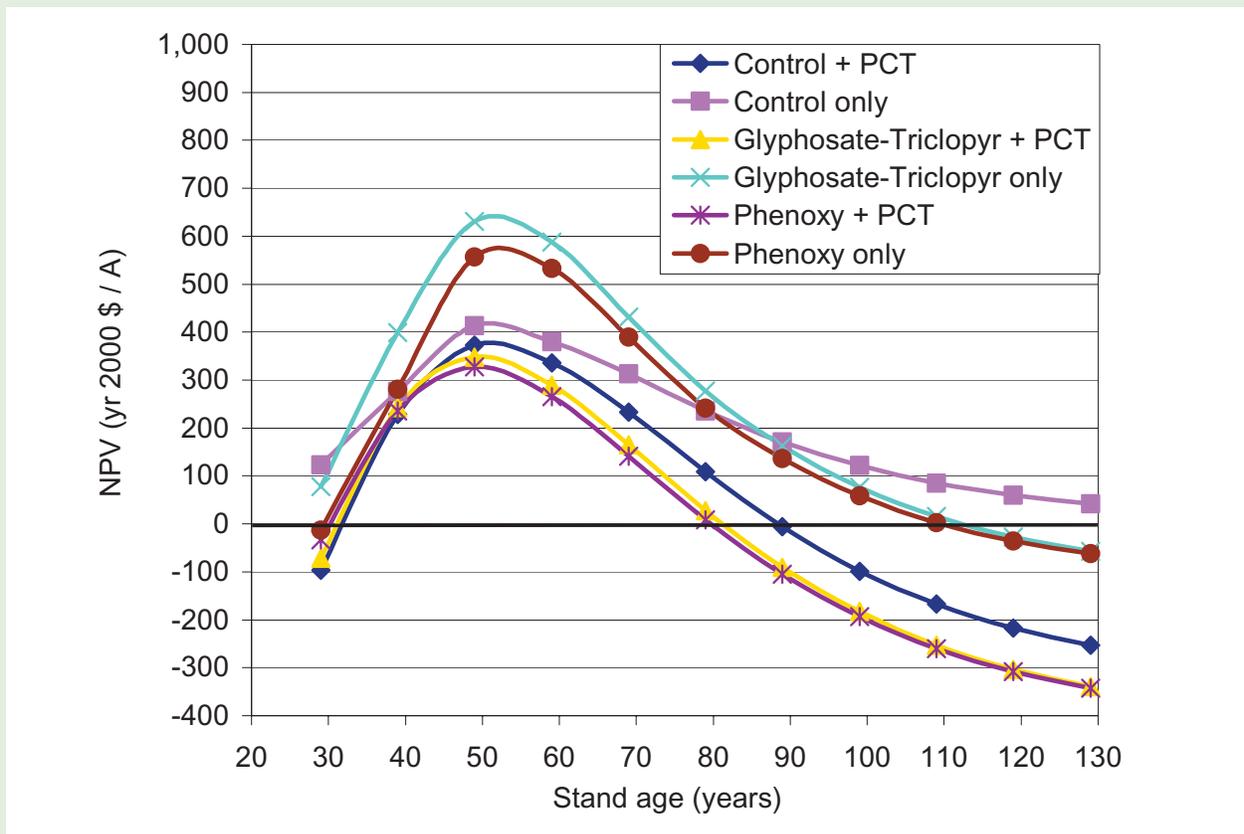


Figure 15. Projected net present value (NPV) for six combinations of herbicide and PCT treatments for 100-years on the Austin Pond Study. NPV is in year 2000 dollars and was calculated using a 4% discount rate.

Silviculture

Growth Response and Economic Return from Fertilization of Precommercially Thinned Spruce-fir Stands: Remeasurement of CFRU, IP and Irving Woodlands Study Sites

Daniel J. McConville and Robert G. Wagner

INTRODUCTION

Use of fertilizers to enhance the nutrient availability and growth of forest stands is a standard practice in many managed forests throughout the world. Fertilization regimes have been used in the Pacific Northwest and the Southeast US to increase stand productivity and to shorten rotation periods. More than 370,000 acres of loblolly pine are fertilized annually in the Southeast (Zhang and Allen 1996). The use of fertilizers in Maine's spruce-fir forests, however, is rare, primarily because there is insufficient information to support the practice (Seymour 2004).

Relatively little forest fertilization research has been done in Maine. The work that has been done, primarily monitoring the tree-level responses of spruce to fertilization has yielded mixed results. Shepard (1981) reported that nitrogen (N) additions did not increase diameter growth in a thinned 50-year old white spruce plantation for three years (including application year) following the fertilizer treatment. A few studies reported dramatic increases in proportional growth for mature red spruce trees (70-110 year old), but only small absolute growth increases (Shepard 1985, Shepard and Reams 1987, Shepard 1989). For example, fertilization increased five-year diameter growth by 53 percent, which only corresponded to an absolute increase of 0.10 in. for the five-year period, or 0.02 in. per year compared with the untreated plots (Shepard 1989).

In a CFRU study established in the early 1990s Briggs et al. (1999) applied N in a young spruce-fir stand (age 10) with and without PCT to determine its effect on crop tree growth. No differences in crop tree height and diameter



Although the CFRU undertook several fertilizer projects during the 1980s, the effects of fertilization on tree and stand growth in the Northeast US are not clear. Past CFRU studies applied fertilizers to over-mature, natural spruce stands growing on poor sites. However, results from more recent research around the world have shown that several factors affect whether or not trees respond to fertilizers, such as the timing of the application within the life of the stand and the soil type. These studies suggest that rapidly growing stands on good sites respond more favorably to fertilization.

The intent of this study is to quantify fertilization impacts in intensively managed, young, rapidly growing spruce-fir stands, and to test whether fertilization of these stands is economically worthwhile. We are re-measuring several research trials initiated in the 1990s and will be reporting tree and stand-level growth effects of fertilization treatments and the economic benefits, if any, of fertilization.

growth were apparent three years following the treatment. However, foliage from fertilized crop trees had higher N concentrations and greater needle mass suggesting that increases in stem volume may be delayed beyond the measurement period.

In 1997 Briggs established a study to test the effects of mid-rotation nitrogen fertilization on growth responses

of balsam fir trees (Briggs 2002). Briggs hypothesized that a combination of spacing, competition control, adequate drainage, and timing of fertilization at or near canopy closure may be the key factors determining the success of nitrogen applications. Moreover, evidence suggests that balsam fir is more responsive to fertilization than red spruce (Meng and Seymour 1992). To test this hypothesis Briggs established N treated and untreated study plots in moderately drained to well-drained soils dominated by balsam fir that had received PCT and were near the time of crown closure. Three-year results demonstrate a 71% increase in height growth (Briggs et al. 2001). Basal area or volume increment comparisons have not been analyzed.

Irving Woodlands, LLC and International Paper, Co. (IP) established two other fertilizer studies in the late 1990s. The Irving trial was established to examine the effects of Photomag® (magnesium monohydrogencarbonate) on growth responses in a black spruce plantation. Photomag® was developed in Europe and is intended to enhance chlorophyll synthesis by allowing Mg to directly penetrate the leaf where this enhancement has been documented to occur. The IP fertilization trial was installed to examine N and P effects on a mid-rotation pre-commercially thinned balsam fir stand.

The objectives of this new project are to:

- Remeasure all study plots in two CFRU fertilization trials (Briggs/IP study and Weymouth Point) and two industry trials (Irving and IP studies)
- Compare volume growth of fertilized and unfertilized plots that have been pre-commercially thinned
- Model future stand growth and perform an economic

analysis based on response to fertilizer treatment

- Compare biomass (foliage, stem and branch wood) development for fertilized and unfertilized pre-commercially thinned plots
- Compare foliar nutrient content of fertilized and unfertilized plots
- Based on results, identify future research needs related to fertilizing Maine's softwood stands

METHODS

- Remeasure tree height and the tree diameter at breast height (DBH) of all tagged trees on two CFRU studies and on two IP fertilizer sites
- Randomly select and destructively sample 20 treated and 20 control trees at the Briggs/IP site for measurement of stem, foliage, and branch biomass, as well as complete stem analysis (Figure 16)
- Determine nutrient content (N, Ca, P, K, Mg along with the micronutrients S, Fe, B, Zn, Mo, and Mn) of foliage samples collected from randomly selected sample trees in treated and control plots (Briggs/IP site)
- Compare height, DBH, and volume growth response of fertilized and control trees on all sites
- Use a growth model to estimate long-term gains from fertilization and determine net present value of fertilization in spruce-fir stands

ANALYTICAL APPROACH

For the replicated study designs (Briggs/IP study and Weymouth Point), we will analyze the response variables (height, DBH, volume growth, biomass components, and foliar nutrients) using ANOVA and regression where



Figure 16. Trees will be destructively sampled to determine how nutrient inputs influence the relative amount of stemwood, branchwood, and foliage.

appropriate. For the unreplicated studies (Irving and IP studies), we will treat these data as case studies indicating the amount and percentage of difference between treated and untreated plots, but will be unable to conduct any valid statistical analysis due to the lack of replication.

PROJECT STATUS

In the fall of 2003 all previously tagged trees at each of the four research study sites (Weymouth Point, Briggs/IP, Irving, and IP) were remeasured. More than 2,600 trees were measured and the DBH, total height, height to live crown and species were recorded for each.

During the summer of 2004 we will begin the destructive biomass sampling to determine component biomass and volume increment for treated and untreated plots.

For more information contact Dan McConville at (207) 581-2861 or dan_mcconville@umenfa.maine.edu.

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Silviculture

The Stand Product Optimization Tool

Daniel J. McConville

INTRODUCTION

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 Stand Product Optimization Tool (SPOT), released to CFRU Cooperators and scientists in March 2003, was the first tool created that accurately quantifies 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 classes. 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 is to estimate the merchantable volume of sampled trees using diameter and total tree height data, use a conventional minimum merchantable top diameter and then calculate the volume to that minimum diameter. This method is imprecise and impractical for several reasons. First, it does not allow one to subdivide a single stem into more than one product. For example, if the minimum merchantable top diameter for spruce saw logs is 6 inches one can use the traditional method to accurately calculate the volume of a tree to a 6-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) one cannot use this method to determine the combined value of the products. Second, mills require that products be cut to strict length specifications (e.g., 16-feet for sawlogs with 0.5 feet of trim). The traditional method does not allow one to simultaneously calculate 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.

The Stand Product Optimization Tool (SPOT), released to CFRU Cooperators and scientists in March 2003, is the first tool to accurately quantify the financial value of standing trees in Maine's forests. SPOT was born out of the necessity to quantify how intensive silviculture practices that change the size and shape of tree stems ultimately affect the economic value of a stand.

SPOT "virtually bucks" each tree (from inventory data) and determines all possible combinations of forest products that can be harvested and utilized in a forest stand. SPOT selects the highest valued suite of products and produces a report detailing the net value and quantity of each product in a stand.

An updated version is scheduled to be released in 2004.

HOW SPOT WORKS

Input

SPOT resides in a Microsoft™ Excel™ workbook containing six spreadsheets and several macros written in Microsoft™ Visual Basic™. Users input a tree list containing five variables for each row in the spreadsheet: plot number, the number of stems, the tree species (two-letter code), the tree DBH (in.), and tree height (ft.). Users must enter site level information—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, product name (i.e., pulp, sawlog, OSB, etc.); mill-delivered value expressed either in cords, boardfeet (International 1/4-inch log rule), or weight (mlb); 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 virtually bucks the tree into all the remaining possible combination 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 one to calculate 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. Based on user-input data 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), and the merchantability standards and mills where each product should be sent.

Weight estimates

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

Output

After the optimization process is complete SPOT produces 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 and value of each product by product class, and

the estimated trucking costs (Figure 17). 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.

LIMITATIONS

There are a couple of 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.

NEXT STEPS

A new version of SPOT will be completed during 2004 and released to CFRU Cooperators shortly after completion. The new version will feature a new input for logging costs that users can enter values on a per unit rather than per acre basis. Another goal will be to create a single-tree calculator that will calculate the value as well as the bucking specifications for a single tree.

For more information contact Dan McConville at (207) 581-2861 or dan_mcconville@umenfa.maine.edu.

Expected Harvest (peracre)			Product Details							
SPOT 0.9			for Harlow 4 Stand							
Mill Name	Product	Species	Harvest			Mill Delivered Value (\$)			Trucking Costs	Gross Profit
			cords	mlb	mbf	cords	mlb	mbf		
Pulp Mill	pulp	rs		48.8			1,074.65		162.80	911.85
Pulp Mill	pulp	wp		6.7			67.45		21.95	45.50
Saw Mill	sawlog	rs						445.05	37.15	407.90
Saw Mill	sawlog	wp						428.45	36.40	392.05
Stud Mill	stud	rs		132.9			3,720.80		442.95	3,277.85
Totals				188.5	2.8		4,862.90	873.50	701.25	5,035.15
							5,736.40	Harvest Costs	\$	-
								Net Profit	\$	5,035.15
Stand Statistics										
	Total	Used	%Used	Mean Stem Volume		Mean Stem DBH		Mean Stem Height		
Stems	745.0	640.0	85.9	Overall	6.3	6.1				48.5
Vmcf	4,284.3	4,257.7	99.4	Merchantable	6.7	6.8				53.3
Basal Area	178.2	175.5	98.5	Used	6.7					
Vtcf	4,726.6		90.6							

Figure 17. An example of SPOT product report showing estimated harvested material and value by product class.

Silviculture

The Northern Hardwood Growth and Yield Model

Tim McGrath

BACKGROUND

In 1978, the province of Nova Scotia initiated a program to establish even-aged thinning studies to determine what silviculture tools would be effective in enhancing the productivity and quality of hardwood stands. There were 50 study sites established throughout Nova Scotia during the period from 1978 to 1997. Two-thirds of the study sites test commercial thinning treatments, while one-third examine precommercial thinning treatments. Roughly half of the plots are dominated by sugar maple with white birch, red oak, aspen, red maple and yellow birch dominating the other sites. Most study sites include two replications of four treatment intensities (including controls). In the case of the commercial thinnings, 20, 40 and 60 percent of the basal area was removed, while the PCT's typically included

spacings of 6x6, 8x8 & 10x10 feet. Permanent sample plots were established in each replication after treatment and data were collected at the tree level, including height, age, and DBH.

Information from these studies has been utilized to produce preliminary hardwood management guidelines as shown in Nova Scotia's Forestry Field Handbook (NSDNR, 1993) and a Beta version of the Hardwood Growth and Yield Model (NSDNR, 1997a). These tools have been distributed and are used in Maine, New Brunswick and Nova Scotia to assist in managing hardwood forests (Figure 18.). Further refinements of the Hardwood Growth and Yield Model would be possible by re-measuring the existing trials. In 2002, a project was initiated with funding from the CFRU to help complete this work.



Figure 18. The Hardwood Growth and Yield is currently available to CFRU cooperators in a beta format. An updated version is expected sometime in 2004.

STATUS

As of December 2003, over 300 permanent sample plots located in hardwood management trials have been remeasured and maintained. Project funding was utilized to hire a field assistant and to provide travel funds to help carry out this work. Plot boundaries were re-established and trees repainted and tagged to insure the integrity of these trials. Tree-level information, including diameter height and condition were re-measured and entered into data base systems. The data are now ready for editing and analysis. The results will then be utilized to derive refined relationships for use in the Hardwood Growth and Yield model (HWGNY) scheduled for completion in November 2004. The HWGNY is a state dependent simulation model with site index, stocking, species, and treatment type, intensity and timing as driving variables. Precommercial thinning, commercial thinning and un-thinned stands can be simulated.

Concurrently, progress has been made in developing a user-friendly interface for using the model (Figure 19).

For more information contact Tim McGrath at (903) 893-6102 or tpmcgrat@gov.ns.ca.

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Growth and Yield 1.02

File Edit Run

Growth and Yield Models: Hardwood

Steps

- 1 Choose Model:** **Hardwood**
Unit Type: **Metric**
- 2 Natural Regen:** No
Plantation: No
X: 0.0 Y: 0.0
Tree Frequency: **1800**
- 3 Dominant Species:**
Sugar Maple
- 4 Site Index (@50):** **15**
Land Capability: 0
- 5 Expected Stocking:** **80 %**
- 6 Simulation Duration:**
Age: **80**
DBH: 0.0
- 7 Management Options:**
Treatment: 1 2
Age: 15 45
DBH: 0.0 0.0
% B.A.: 0.0 **30**
Spacing: 2.4

Step 7:

Choose One of the options below

Treatment 1

Age: 15
DBH: 0.0
B.A. Reduction (%): 0.0
Spacing: 2.4

Treatment 2

Age: 45
DBH: 0.0
B.A. Reduction (%): 30

Enter the age or diameter at which a precommercial or commercial thinning is to be simulated. Specify precommercial thinning (performed before stand is 9 m tall) in spacing. Specified spacing must be between 1.5 and 3.0 metres. Specify commercial thinning (performed after stand averages 14 cm in diameter) as a percentage basal area reduction. Basal area reductions must be between 10 and 60 percent. Treatment 2 can only be a commercial thinning.

Run

Figure 19. The Hardwood Growth and Yield interface (shown above) simplifies the procedure for generating growth and yield simulations compared with the original DOS format Growth and Yield.

Silviculture

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

Ralph D. Nyland

BACKGROUND

In 2002, the CFRU Hardwood Silviculture Research Sub-Committee approved the development of several literature reviews about vegetation management in hardwood stands. Seven individuals associated SUNY College of Environmental Science and Forestry have contributed to this project. They include Jane M. Verostek, Senior Assistant Librarian; Roger L. Nisen, Jr., Senior Instructional Support Specialist; Amy L. Bashant, Research Scientist; Kimberly K. Bohn, Phd. candidate; Heather M. Engelman, Visiting Instructor and PhD. candidate; Pablo Donoso, Assistant Professor of Silviculture, Universidad Austral de Chile; and Ralph D. Nyland, Distinguished Service Professor (Figure 20).

Since starting the work we completed literature searches for effects of the target species: American beech, striped maple, hobblebush, ferns, Rubus, and pin cherry. Draft versions of the literature reviews have been completed for all except pin cherry. In addition, we finished drafts of the annotated bibliography of pertinent references for American beech, striped maple, hobblebush, and ferns.

During September 2003 we sent to CFRU the first drafts of the materials related to American beech, striped maple, hobblebush, and ferns. Those served an example of the approach taken in the work, and the format of output from the project. Currently, we are editing and revising the manuscripts as noted above, and expect to complete those revisions by the end of January 2004. At the same time we are abstracting the papers dealing with pin cherry, with a goal of finishing that work early in 2004. Preparation of the pin cherry literature review will follow shortly thereafter. We must also develop the annotated bibliography for Rubus.

We expect that this work will provide four papers suited for publication in a source like Northern Journal of Applied Forestry, as follows:

- Interference to hardwood regeneration in northeastern North America: Ecologic characteristics of American beech, striped maple, and hobblebush
- Interference to hardwood regeneration in northeastern North America: Controlling effects of American beech, striped maple, and hobblebush

- Interference to hardwood regeneration in northeastern North America: Assessing and countering fern interference
- Interference to hardwood regeneration in northeastern North America: Raspberries and their effect on regeneration success
- Interference to hardwood regeneration in northeastern North America: Interference from pin cherry following even-aged reproduction method cuttings

Based upon accomplishments to date, we anticipate sending the first manuscript for review by CFRU during December 2003, and submitting it for publication early in 2004.

The annotated bibliography will have sections comparable to the titles listed above. We will use a format suitable for keeping the parts together in a 3-ring binder, allowing users to add new sections and additional citations as they become available. We will send the first component to CFRU by the early part of 2004 and expect to complete all work before Summer 2004.

For more information about this project, contact **Ralph Nyland** at (315) 470-6535 or rnyland@mailbox.syr.



Figure 20. Ralph Nyland (left) wishes to express his gratitude to those who assisted with this project including Jane Verostek (left sitting), Kimberly Bohn (standing), and

Wildlife Ecology

*Improving our understanding
about how forestry practices
affect wildlife habitat*

**Effects of Precommercial Thinning
on Select Wildlife Species in Northern
Maine, with Special Emphasis on
Snowshoe Hare**

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



Wildlife

Effects of Precommercial Thinning on Select Wildlife Species in Northern Maine, with Special Emphasis on Snowshoe Hare

Jessica A. Homyack, Daniel J. Harrison, and William B. Krohn

INTRODUCTION

Snowshoe hares (*Lepus americanus*) are an important prey species and dominant herbivore across much of their wide geographic range, and forestry practices that degrade habitat may have serious ecological effects. Further, the influence of precommercial thinning (PCT) on hares has been questioned in relation to indirect effects on recovery of the federally threatened Canada lynx (*Lynx canadensis*). Although Maine has the only verified population of resident lynx in the northeastern U.S.A., the relationships between lynx, habitat, and forestry practices are not thoroughly understood. Lynx are specialized predators of snowshoe hare and occurrences of lynx are positively associated with landscapes dominated by regenerating conifer stands (Hoving 2001). Regenerating stands with a history (approximately 12-28 years prior) of complete overstory removal also support the highest snowshoe hare densities in Maine (Fuller 1999, Hoving 2001). However, little is known about the temporal effects of stand succession on densities of snowshoe hare at the southern periphery of its range, particularly after intensive management of vegetation.

PCT is a silvicultural technique that decreases stem density and may reduce densities of hares relative to unthinned, regenerating stands (Sullivan and Sullivan 1988, Sullivan et al. 2002). Further, the biological assessment of the effects of U.S. National Forest land and resource management plans on Canada lynx suggested that forest thinning might reduce foraging habitat of lynx in the northeastern U.S.A. (Hickenbottom et al. 1999). The total area of land precommercially thinned from 1990 to 2000 increased 2.3-fold in Maine (from 4,352 to 9,950 ha), 2.5-fold in Nova Scotia (from 3,228 to 8,113 ha), 2.7-fold in New Brunswick (from 15,012 to 40,401 ha), and 4.3-fold in Quebec (from 22,833 to 98,228 ha) (Canadian Council of Forest Ministers 2002, Maine Forest Service 1994-2002). Thus, PCT has occurred on an increasing area of forested land in the Acadian forest and managers will be asked to justify this practice based on maintaining wildlife habitat and biodiversity.

Currently, there is insufficient information concerning the influence of PCT on habitat of snowshoe hares, small mammals, and other potential prey species for lynx and other forest-dwelling carnivores. Little research has been



conducted on the effects of PCT on snowshoe hare for longer than 4 years post-treatment (Sullivan and Sullivan 1988, de Bellefeuille et al. 2001), and most studies on the effects on small mammals lasted only 2 to 3 years after treatment (Lautenschlager et al. 1998, Sullivan et al. 1998, but see Sullivan et al. 2002). Further, most studies investigating effects of thinning on wildlife species have been conducted on stands that were precommercially thinned, but not previously treated with herbicide. Herbicide treatment of forest stands several years prior to PCT is commonly applied to stands throughout much of the Acadian forest, and has strong effects on overstory structure and understory responses to subsequent PCT (see page 36). Therefore, we investigated the effects of PCT, from 1-16 years since thinning, on snowshoe hares, small mammals, and forest structure within herbicide-treated clearcuts in the commercial forests of northern Maine.

This project received financial support from the Maine Cooperative Forestry Research Unit, National Council

for Air and Stream Improvement, the Maine Cooperative Fish and Wildlife Research Unit (U.S. Geological Survey, University of Maine, Maine Department of Inland Fisheries and Wildlife, and Wildlife Management Institute, cooperating), the U. S. Fish and Wildlife Service, and the Department of Wildlife Ecology, University of Maine. Great Northern Paper Company, Plum Creek Timber Company, and International Paper Company provided access to their lands and generated maps of stand type.

OBJECTIVES

We examined the effects of PCT on selected wildlife species and forest structure, from 1-16 years post-PCT treatment. We placed emphasis on snowshoe hares because of their affinity for habitats with complex forest structure and high stem densities of conifer saplings, and because of its importance as a prey species for Canada lynx and other predators. The specific objectives of this study were to:

1. Quantify and compare overstory, understory, coarse woody debris (CWD), and vertical and horizontal structure on herbicide treated clearcuts, with and without PCT, at different intervals since thinning;
2. document the stand-level effects of PCT, at different intervals since thinning, on associated vegetation changes, and relate them to densities of snowshoe hare and small mammals and;
3. develop a predictive model of the relationship of hare density to overstory, understory, coarse woody debris, and structural variables.

APPROACH

We selected 7 townships (Hersey, T 4 R 11 WELS, T 5 R 11 WELS, T 4 R 12 WELS, T 1 R 13 WELS, Spencer Bay, and Days Academy Grant) in the commercial forests of northern Maine that fall within the historical lynx distribution to compose the study area (Figure 21) (Hoving et al. *In press*). Hersey Township is located in Aroostook County whereas the other 6 townships are located in Piscataquis County,

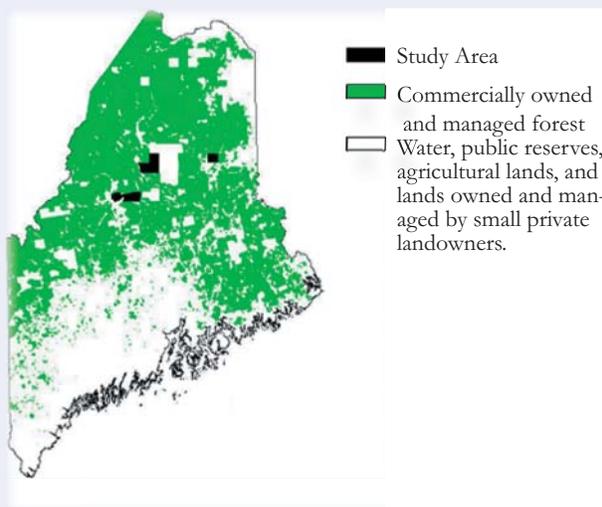


Figure 21. Location of study sites within 7 townships in the commercially owned and managed forests of northern

Maine. Great Northern Paper Company, Millinocket, Maine; Plum Creek Timber Company, Fairfield, Maine; and International Paper Company, Costigan, Maine managed the study area for pulp and sawtimber production. We examined site quality, tree density, diameter breast height (DBH) of dominant trees, and size and spatial independence before selecting forest stands as study sites. Site quality of stands was estimated with 4 to 6 soil cores taken throughout the stand. Stands were assigned a site quality index value from 1 (highly productive) to 5 (unproductive) according to Briggs' (1994) scale of forest tree productivity.

Treatment stands were clearcut (timber harvesting resulting in residual basal area of acceptable growing stock trees > 11.4 cm dbh of < 20.7 m²/ ha) 1967-1987, aerially herbicided (e.g., Glyphosate at ~ 1.7 kg/ha acid equivalent) 1977-1988, and precommercially thinned with motor-manual brush-saws from 1989-1999. Unthinned stands were clearcut 1974-1983 and herbicided (e.g., glyphosate at ~ 1.7 kg/ha acid equivalent) 1982-1988. Stands were divided into blocks (i.e., development classes) based on date of precommercial thinning. We paired treatment stands with an unthinned stand with similar site quality, year of clearcut and year of herbicide. Stands were paired to avoid any gross biases arising from the variation in years of treatments, however stands were not paired in the statistical sense and were not treated as such in analyses. Due to a lack of perfectly paired sites, we allowed some latitude (1-2 years) in pairing stands based on the date of silvicultural treatments. The study design included 25 precommercially thinned stands at approximate 5-year intervals since thinning (1 year post-thinning, n = 6; 6 years, n = 6; 11 years, n = 7, 16 years, n = 6) and 13 paired unthinned stands (1 year, n = 5; 6 years, n = 5; 11 years, n = 3). The ratio of PCT-treated to unthinned stands in the 11-year development class was unbalanced, and unthinned stands were lacking in the 16-year development class, because we were unable to locate unthinned stands that met the criteria of similar site quality, year of clearcut, and year of herbicide-treatment.



Figure 22. During spring 2001 and 2002 we captured 242 snowshoe hares 772 times across 8 stands (4 treated with PCT, 4 unthinned) in northern Maine.

METHODS

Snowshoe hares

We established 46.7 km of pellet transects in 30 stands including 17 treatment stands (1 year since PCT, $n = 5$; 5-6 years since PCT, $n = 5$; 9-11 years since PCT, $n = 7$) and 13 paired, unthinned stands. We established 1.6 km of transect in 28 stands and the remaining 2 stands had 1.18 km and 1.34 km resulting from their size and irregular shape. Transects were placed >35 m from edges to minimize edge-effects. When possible, we established 4 parallel, 400 m transects in a stand and separated transects by 65 m. We marked 5 m by 30 cm pellet plots at 20-m intervals along transects for a total of 84 plots per stand, or 2,480 plots across the entire study. Hare pellets were cleared from plots during October 18-25, 2000 so that only pellets deposited after leaf-off were counted spring 2001. Subsequently, we counted and cleared pellets 4 times during the length of the study: 17 May – 14 June, 2001, 13 September – 29 September, 2001, 10 May – 17 June, 2002, and 13 September – 13 October, 2002. Thus, spring pellet counts (sampled May-June) were used to estimate hare abundance during the previous winter, or leaf-off season, and fall pellet counts (sampled September-October) were used to estimate abundance during the previous summer, or leaf-on season.

To evaluate the relationship between pellet densities and

estimated densities of snowshoe hares, we live-trapped hares within the core portions of 2 thinned stands and 2 untreated stands during May-June, 2001 and in 2 different thinned and 2 different untreated stands during May-June 2002. Single-door collapsible Tomahawk traps (Model 205) (Tomahawk, Wisconsin, U.S.A.) were set on 10.1 ha grids. Trap stations were spaced 65 m apart, and traps were set < 2 m from the station and baited with alfalfa cubes. We marked hare with unique, individually numbered ear or foot tags and released them on the trap-site (Figure 22). We recorded sex, reproductive condition, and length of the right hind foot of each captured individual. During live-trapping, we captured 128 hare (69 M, 59 F) 308 times in 2001 and 114 hare (64 M, 49 F, 1 unknown) 464 times in 2002.

Small mammals

We established 24 grids for trapping small mammals on stands treated with PCT from 4 development classes: 1 year since PCT ($n = 6$), 5-6 years since PCT ($n = 6$), 9-11 years since PCT ($n = 6$), and 14-16 years since PCT ($n = 6$). We established 13 grids for small mammal trapping on stands with similar site histories, but without subsequent PCT. We trapped mice, voles, and shrews within stands during June-August 2000 and 2001 (Figure 23). Trapping periods occurred on 6 consecutive nights and we captured small mammals in

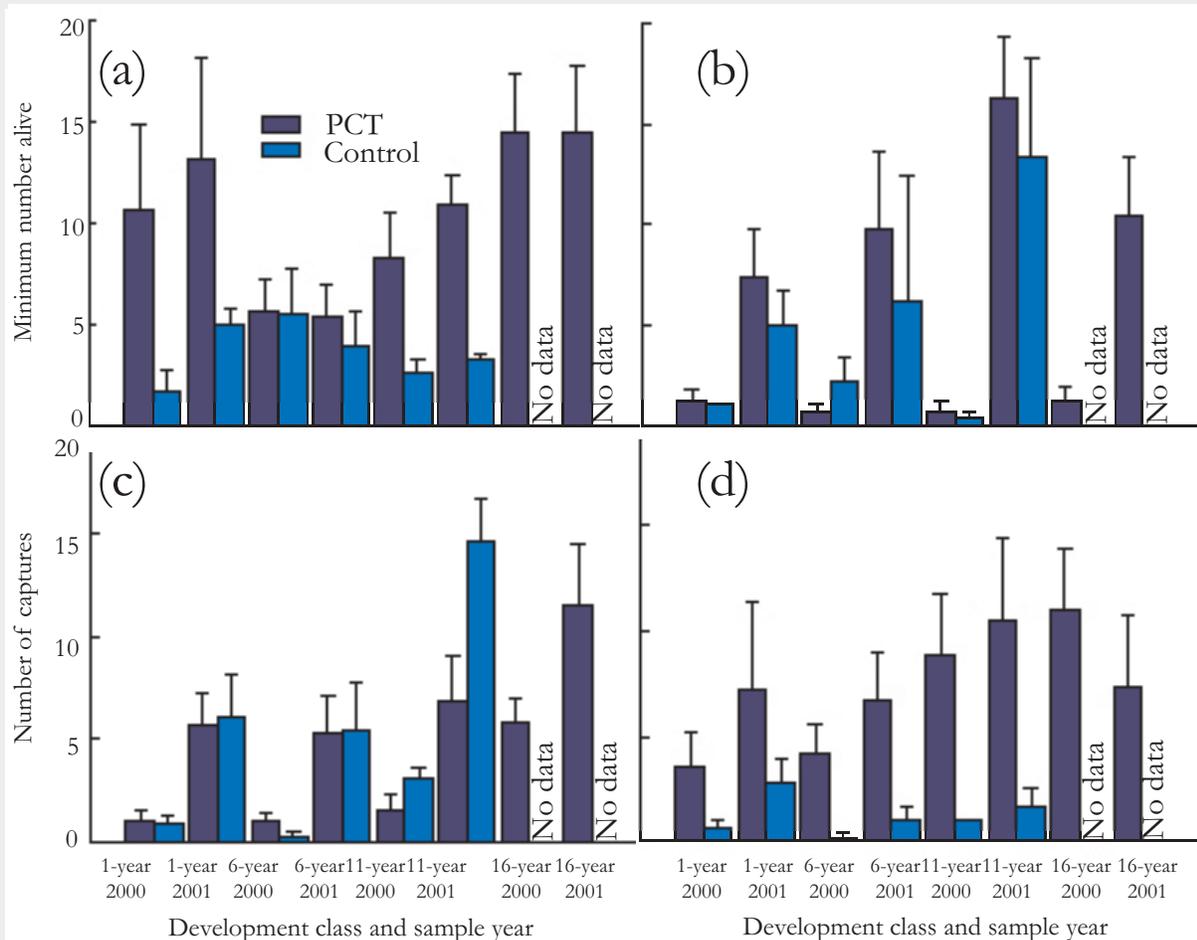


Figure 23. Mean minimum number alive (SE) red-backed voles (a) and short-tailed shrews (b), and number of captures of deer mice (c) and masked shrew in 24 stands treated with PCT and 13 similar control stands from 1 to 16 years post-treatment during summer 2000 and 2001 in northern Maine.

64 Bolton live-traps (B. N. Bolton, Inc. Vernon, B. C.)/ grid baited with rolled oats and peanut butter. We ear-tagged mice and voles with a uniquely numbered ear tag (Monel no. 1005-1) and recorded species, age-class, sex, reproductive condition, and presence of external macro-parasites for individuals. We captured 600 red-backed voles (*Clethrionomys gapperi*), 347 deer mice (*Peromyscus maniculatus*), 10 woodland jumping mice (*Napeozapus insignis*), 2 Southern bog lemmings (*Synaptomys cooperi*), and 1 meadow vole (*Microtus pennsylvanicus*) during 2000 and 2001. Further, we had 399 captures of short-tailed shrews (*Blarina brevicauda*), 386 captures of masked shrews (*Sorex cinereus*), 5 captures of smoky shrews (*Sorex fumens*), 15 captures of weasels (*Mustela spp.*), 51 captures of eastern chipmunks (*Tamias striatus*), and 11 captures of red squirrels (*Tamiasciurus hudsonicus*). Species other than red-backed voles, deer mice, short-tailed shrews, and masked shrews were excluded from analysis because capture success was too low for a meaningful or statistically powerful analysis.

Forest structure

We completed extensive, stand-scale habitat measurements on all 30 stands. Five plots per 400 m of transect were established at random locations on the pellet transects for a total of 20 plots per stand. We measured 27 variables that described the characteristics and structure of the understory, overstory, woody debris, or ground cover within 25 m² plots in thinned stands and 10 m² plots in unthinned stands. Larger plots were established on thinned stands to effectively sample stands of varying densities, and to sample a similar number of crop trees per stand.

RESULTS AND DISCUSSION

Densities of snowshoe hare were linearly related to densities of fecal pellets during leaf-off seasons and this functional relationship could reasonably predict

abundances of hares at a stand-scale in northern Maine. Densities of snowshoe hare were consistently lower ($P < 0.001$) in stands treated with PCT during both leaf-off and leaf-on seasons across 2 years of study (Figure 24). Regenerating conifer stands without PCT supported approximately twice as many hares as similar stands treated with PCT. In this investigation, the greatest density of hares occurred in the unthinned stands in the 1-year development class (17-24 years after clearcutting), whereas the lowest density of hares occurred in thinned stands (25-32 years after clearcutting, 9-11 years post-PCT). Although thinning appeared to reduce the density of snowshoe hare at a stand-scale, it may have a weaker, negative effect on hare numbers than silvicultural practices that favor retention of overstory trees throughout the rotation, such as some forms of partial harvesting (Fuller 1999).

Small mammals had species-specific responses to PCT, but overall tended to reach their greatest densities in stands in the 11-year and 16-year age class. PCT positively affected, or produced no detectable effect on the abundances of the 4 most common species of voles, mice, and shrews within our study areas in northern Maine. Abundance of red-backed voles and number of captures of masked shrews were greater in stands treated with PCT than reference stands, but deer mice and short-tailed shrews responded positively to stand age rather than treatment. Deer mice, short-tailed shrews, and masked shrews exhibited large inter-annual fluctuations, with greater numbers captured during the 2nd year of sampling.

We documented differences in forest structure occurring with both PCT and stand development that indicated that vegetation structure changes dramatically with thinning and with stand succession. Near-ground cover, overstory cover, and the structure of the understory accounted for >80% of the variation in thinned (from 1-11 years post-treatment) and unthinned forest. Further,

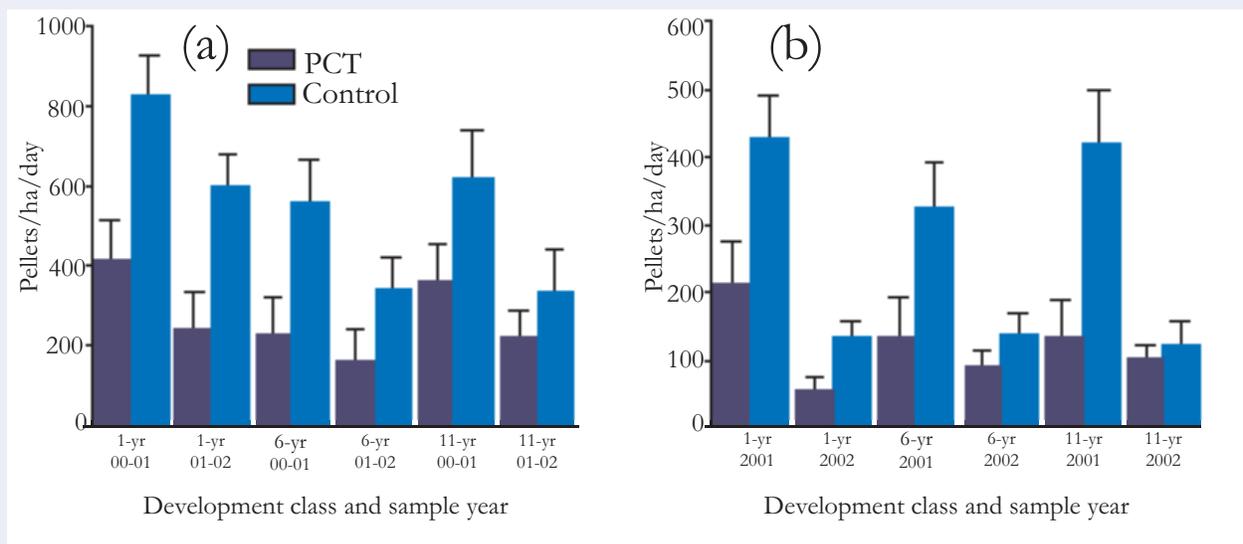


Figure 24. Mean (SE) number of snowshoe hare pellets/ha/day in PCT stands and similar unthinned stands in northern Maine during a) leaf-off seasons, 2000-2002, and b) leaf-on seasons, 2001-2002.

horizontal cover, an overstory to understory contrast, and an herbaceous vegetation gradient described >75% of the variation in vegetation structure among stands of 3 development classes. PCT appeared to accelerate the simplification of understory structure associated with normal stand development in herbicide-treated clearcuts.

MANAGEMENT IMPLICATIONS

A minimum of 40-60% understory horizontal cover has been suggested to maintain densities of snowshoe hare in forest stands (Wolfe et al. 1982, Litvaitis et al. 1985). During our study stands treated with PCT likely were below the structural threshold associated with the higher densities of hares observed within unthinned stands. Therefore, maintaining understory complexity within stands treated with PCT may help to mitigate the negative effects of thinning on densities of hare. Forest managers could attempt to maintain greater number of understory stems/ha (i.e., greater horizontal cover) in thinned stands by reducing spacing distances between crop trees to maximize post-treatment densities of snowshoe hare; however, we recognize that silvicultural objectives could be compromised (Seymour 1993).

Although PCT may have negative effects on wildlife species that are strongly associated to regenerating forest, this practice may positively influence species that use stands with more open understories, such as red-backed voles. Thinning increased or maintained abundances of forest-dwelling small mammals across a range of years since treatments; these results suggest that PCT may produce positive and long-term responses within the small mammal community.

All forest stands examined in this study were treated with an aerial application of herbicide prior to PCT, which apparently causes long-term effects on vegetation structure and composition. The results from this study will likely differ from stands without herbicide release, from other thinning regimes, and from other geographical areas outside of the Acadian forest where development of understory structure varies. Relative to precommercial thinning, other silvicultural trends in the Acadian forest (e.g., increasing extent of partial harvests) may exert a stronger influence on stand-scale and landscape-scale densities of snowshoe hares and small mammals, and could be associated with greater indirect effects on forest carnivores. Landscape-scale effects of alternative silvicultural practices on hares, lynx, and other forest carnivores are the focus of a new collaborative study among forest industry sponsors, The University of Maine, Maine Cooperative Fish and Wildlife Research Unit, U.S. Fish and Wildlife Service, and Maine Department of Inland Fisheries and Wildlife. CFRU has committed partial funding support for that project during FY's 2005 and 2006.

STATUS

The precommercial thinning project was completed during FY 2003 and the final report was presented to the

CFRU advisory committee on April 17, 2003. Jessica Homyack successfully defended her thesis in February 2003 and received her M.S. in Wildlife Ecology from the University of Maine in May 2003.

A 1-year companion study was funded during FY 2004 to develop stand-scale tools for predicting effects of alternative forest practices, (e.g., shelterwood systems, different spacing in thinned stands, partial harvests) on densities of snowshoe hare across a range of stand conditions. These tools should be available to forest managers by late 2004 and will provide an alternative to costly and time intensive sampling of hare densities when attempting to evaluate effects of different silvicultural alternatives on this keystone wildlife species.

For more information about this project please contact Dan Harrison at (207) 581-2867 or harrison@umenfa.maine.edu.

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Wildlife

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

Angela K. Fuller and Daniel J. Harrison

INTRODUCTION

Maine has the only verified population of Canada lynx (*Lynx canadensis*) in the eastern United States. Lynx occur in harvested landscapes in Maine, but little is known about their specific responses to heterogeneity over a range of small spatial scales, or how they respond to sub-stand scale changes in forest structure associated with forest harvesting. The implication that silvicultural practices threaten lynx populations is largely untested and based on a frequently cited assumption that lynx require mature and overmature conifer forests. Lynx are food specialists that are predicted to respond to the fine-scale habitat choices associated with their primary prey, snowshoe hares (*Lepus americanus*) (Koehler et al. 1979, O'Donoghue et al. 1998, Mowat et al. 2000). 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 sub-stand scale habitat selection by lynx will be useful for evaluating the effects of alternative silvicultural practices on lynx and their prey. Additionally, determining responses to structural features within forest stands will provide guidelines for maintaining important elements within harvested forest stands.

Silvicultural practices that promote dense conifer understories and lateral cover may be beneficial to snowshoe hare and lynx. Because precommercial thinning (PCT) is practiced in Maine (17,323 acres PCT 2002) (Maine Forest Service 2003), it is important to determine the direct and indirect effects of silvicultural practices such as PCT on habitat choice by wide ranging species which depend on hares, such as lynx. Additionally, precommercial thinning that results in thinning or removal of understory structure may reduce habitat quality for lynx (Mowat et al. 2000) because hare densities have been documented to decline immediately after manual spacing in conifer stands in the Pacific Northwest (Sullivan and Sullivan 1988) and for at least 11 years after thinning in Maine (Homyack et al. 2003). Snowshoe hare in Maine are closely associated with regenerating stands with abundant coniferous saplings (< 1.5 m height) (Fuller 1999), which are likely reduced after thinning to promote growth of crop trees; this practice may affect lynx if densities of hare are reduced. In addition to precommercial thinning, partial harvesting is a common silvicultural practice



and represented 96% of the forest acreage harvested in Maine in 2002 (Maine Forest Service 2003). Fuller (1999) documented reduced densities of hares in partially harvested mixed stands (52-59% basal area removal, 3-4 years post harvest), but it is unknown how lynx respond to this form of harvesting when foraging. It is important to determine the effects of alternative silvicultural practices on hare 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). The most traditional approach for understanding movements and habitat use by wildlife involves the quantification of relative time spent in different habitat types using radiotelemetry. The analysis of specific movement patterns of animals is usually not conducted because of the difficulty in obtaining and analyzing the data. However, sub stand-scale movement patterns can be used to identify the ways that lynx respond to the sub-stand scale structure of the landscape, thus providing insights into which structural features are important.

As individuals move through landscapes, they encounter variations in habitat type and structural features, and respond to those changes with changes in movement behavior (Crist et al. 1992). The foraging behavior of lynx and their movement patterns are largely influenced by their strategies used to hunt snowshoe hares (Mowat et al. 2000). In the southwest Yukon, lynx and hare habitat

use were studied over the course of a cyclic fluctuation, and the stand-scale pattern of habitat selection by lynx closely matched that of snowshoe hares (O'Donoghue et al. 1998). Thus, lynx may perceive habitat and structural attributes at a coarse grain because they likely respond to areas with high densities of coniferous saplings, which are associated with snowshoe hares in Maine (Fuller 1999), and may be less sensitive to specific structural features of forest stands that occur at even smaller scales (e.g., coarse woody debris). Straight line travel by lynx may indicate traveling, while more tortuous paths may indicate hunting or foraging behavior (Arditi and Dacorogna 1988). The scale of patch use by species can change in response to changing distribution of prey (Haskell 1997), and predators may use area-restricted search behaviors (Kareiva and Odell 1987, Haskell 1997), depending on the distribution of prey. 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. We are using the characteristics of the path as a measure of how sub-stand scale structure affects movement of individual lynx. Sub-stand scale habitat selection and movement patterns of lynx can only be evaluated by measuring the structure of the habitat in the immediate vicinity of the individual. Snowtracking is the only method in which to measure sub-stand scale habitat in areas where lynx are known to be present.

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

Although previous studies have documented stand-scale responses of lynx to specific habitat types, no studies have specifically evaluated habitat selection for lynx at smaller spatial scales. We are evaluating how lynx respond to structural features at fine spatial scales. Determining the responses of lynx to structural features of forest stands will provide sub-stand scale guidelines and will identify important elements within forest stands which should be retained to promote use by lynx.

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 substand-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 (Figure 25). Habitat selection will be evaluated at the scale of the forest stand by comparing the distance traveled by lynx in each overstory type (e.g., PCT, partial harvest, regenerating clearcut, coniferous, mixedwood, deciduous stands) to the percent of those overstory types on random straight-line 1-km transects within the home range of each individual. We will analyze the data using a stand-scale habitat selection analysis that compares use of habitat types on lynx transects to the availability of habitat types on random straight-line transects within the home range of each lynx.

Habitat variables included in sub-stand scale analysis provide a measure of the structure of the vegetation that is known, or suspected to influence the local abundance of snowshoe hares or lynx. Each variable describes the habitat in the immediate vicinity of the focal lynx. Sample plots were conducted every 100m 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



Figure 25. We located lynx using radiotelemetry, intersected their tracks, and then backtracked on snow to evaluate habitat selection.

control sites on random straight-line transects sampled within the home range of the lynx. We verified the locations of all rest sites used by lynx via GPS and took vegetation and structural measurements to characterize those sites (Figure 26). 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. Scats found along the trail were collected and will be used for diet analysis (Figure 27).

Spatial-use and movement patterns include path shapes (tortuosity) of lynx in different overstory types (e.g., PCT vs. partial harvest vs. mature forest) and with different activities (e.g., hunting vs. traveling). We archived 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 the 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.



Figure 26. Evidence left in the snow indicate lynx rest sites (left) and recent use by a female and three kittens in a partially harvested stand (right). These sites were measured, mapped and characterized to determine lynx use.



Figure 27. A female lynx recovers from anesthesia after the radiocollar was replaced.

OUTCOMES

This project will provide scientific information needed to evaluate effects of alternative forest management activities, including PCT, 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 will result in structure that is important for lynx and snowshoe hare. We will also determine the effect of sub-stand scale structure on movements of lynx. Identifying at what spatial scales lynx respond to heterogeneity on the landscape will provide a better understanding of the effects of forest harvesting on lynx.

Project Status and Timeline

Three lynx (2F, 1M) were snowtracked for 31.8 km between 4 January and 28 March, 2002 and 55 km of random straight-line transects were sampled within the home ranges of the 3 lynx. Vegetation was sampled within 341 plots along the lynx trails and within 605 plots along random transects. Three additional lynx (1F, 2M) were snowtracked for 32.8 km between 4 January and 1 April, 2003 and 45 km of random straight-line transects were sampled within their home ranges. Vegetation was sampled within 380 plots along the lynx trails and within 495 plots along random transects.

For more information about this project contact Angela Fuller at (207) 581-2869 or afuller@umenfa.maine.edu.

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Biodiversity Conservation

*Improving our understanding about
the relation between forestry practices
and biodiversity*

Indicators for Maintaining Biodiversity in
Managed Forests



The Effectiveness of Different Buffer
Widths for Protecting Riparian Values on
Headwater Streams



Biodiversity

Indicators for Maintaining Biodiversity in Managed Forests

Andrew Whitman and John Hagan

INTRODUCTION

One of sustainable forestry's next steps will be to quantify biodiversity so that we can improve our ability to manage for forest biodiversity. Coarse filter approaches such as reserves, conservation easements, umbrella species, forest certification, and BMPs have greatly improved our ability to maintain habitats, ecological processes, and landscapes for common forest species. Fine filter approaches are used to protect the most vulnerable and rare forest species and their habitats and have kept many forest species from becoming extinct. For most biodiversity components we lack the tools and resources to know where we are going and what we are conserving. Hence practitioners and the public alike are skeptical and confused about sustainable forestry. This project is building indicator-based scoring tools to help forest managers better understand and manage for biodiversity.

One challenge for managers is that forest biodiversity is so big that it defies our ability to measure it. The reality is that managers, policy makers and stakeholders tackle this "big" value by focusing their efforts on sub-values such as water quality, species diversity, endangered species, pre-settlement conditions, or old growth forest. This year's effort focuses on late-successional forest biodiversity values (LS values) and the subsequent years' research will focus on developing indicator tools for early successional, aquatic-riparian, and landscape values as well.

This project began working on an LS index because LS values are the forest biodiversity values that are the most vulnerable to the impacts of forest management. In other regions the loss of LS components in landscapes managed for wood has been one of the leading causes of the loss of forest biodiversity. In Finland, an estimated 5% of forest species are predicted to go extinct in the next 50 years as a result of efficient modern forest practices (Hanski 2000); most of these species depend on structural characteristics of old forest, such as large old living trees, standing snags, or fallen dead wood. It is not widely appreciated that Maine's forests still have a dwindling, but biologically significant component of late-successional forest-stands in which there is a cohort of trees 100-200+ years old. These old stands have been virtually "invisible" because ecologists have not systematically studied or surveyed the working forest for this older forest age class. A rapidly growing body of scientific literature from temperate forests around



the world suggests that these remnants likely play an important role in maintaining a region's forest biodiversity. The loss of this forest age class and its components from vast working forest of northern Maine may pose a threat to maintaining well-distributed populations of native LS species in the region. Practical LS tools can help land managers better understand LS forests and learn how to maintain for LS components in managed forests.

GOALS

1. Create an efficient LS index to help foresters better understand and manage for LS values at the stand level;
2. Create a LS index to be used with timber inventory data to track LS values at the land ownership level;
3. Improve the ability of landowners to understand and manage for LS values in managed forest.

STATUS

We focused on a limited suite of indicators of LS values (Table 10) that score high in our review for relevance (sensitivity primarily to forest management), scientific merit (level of support by scientific literature), ecological breadth (number of ecosystem elements indicated by indicator), practicality (ease of measurement), and utility (ease at which foresters and land managers could use an indicator for making decisions). Our evaluation process focused our research on a limited number of plant species, trees, snags, logs, and stand history. These indicators serve as direct and indirect indicators of many different ecosystem components.

We surveyed 124 forest stands in 44 townships throughout western, eastern, and northern Maine (Figure 28). Within each major forest type (northern hardwoods, conifer-northern hardwoods, northern pines, and spruce-fir flat), we sampled 4-8 stands in each of four age classes (regeneration [< 20 years old], young [20-45 years old], mid-age [45-70 years old], and mature [> 70 years old]). Young stands included overstory removals and mid-age stands will include partial cuts. Clearcuts (Figure 29a) and old growth (Figure 29b) were sampled as reference stands.

Table 10. Measured variables and ecosystem components directly (D) and indirectly (I) indicated by each variable. LS indicators will be calculated based on these variables.

Variables	Ecosystem Element		
	Species Composition	Forest Structure	Ecosystem Function
Woodpecker use	D	I	I
Selected hervaeous plant species	D	I	I
Selected epiphytic lichen, moss, and liverwort species	D	I	I
Selected fungi species	D	I	I
Selected epixylic lichen and moss species	D	-	I
Vertical structure	I	D	-
Shrub density	I	D	-
Logs	I	D	I
Large trees and snags	I	D	I
Trees and snags	I	D	I
Canopy closure	I	D	I
Soil organic layer depth	-	D	I
Large logs	-	D	I
Disturbance history (logging and fire)	I	I	D
Sawn stump age and density	-	I	D

Within each landscape (one to 10 townships in size) we randomly selected stands from each age class - forest type category. In order to establish late-successional reference conditions, we sampled 5-10 accessible old growth stands in each of the four major forest types. Old-growth sites had been identified as old growth by the Maine Natural Areas Program through field surveys and use of tree cores. The forest type of each stand was verified in the field. We sampled the variables list in Table 1 in 200 m belt transects which varied in width depending on the variable being measured. Data from 2003 have been entered and are being proofed for errors.

RESULTS

Although we will not have an index until the field data are completely analyzed, we can make three points based on field observation. First LS stands are not common in any landscape and probably account for less than 4% of the area of most townships.

Second most managed forest landscapes in Maine contain stands with densities of late-successional features that are distinctively higher than other stands in the surrounding landscape. Third for sampling it was easiest to find LS northern hardwood stands, then LS

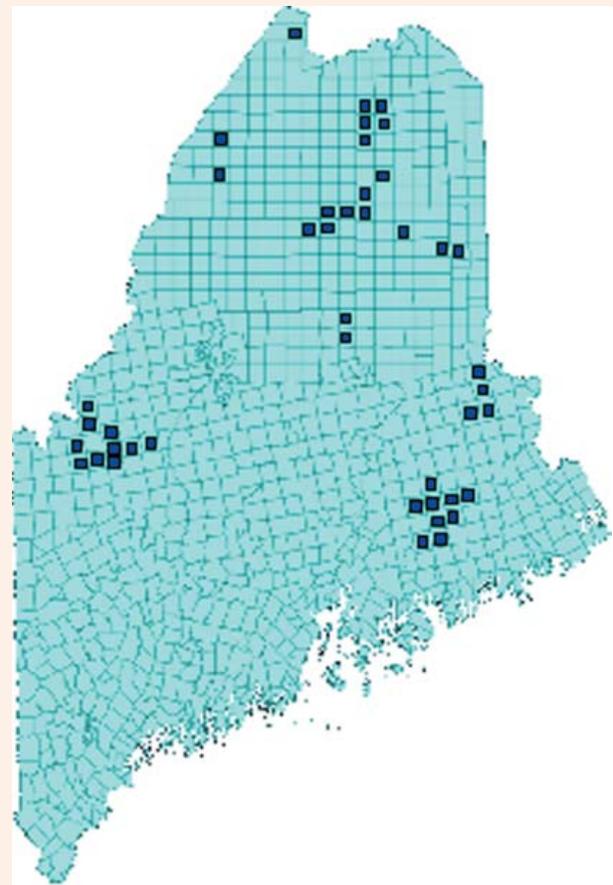


Figure 28. Study sites across western, eastern, and northern Maine. Townships where stands were sampled for developing the LS index are indicated by a square.

conifer-northern hardwoods, then LS spruce-fir flat, and then LS northern pines. Although this was influenced by abundance of stands in different forest types and accessibility, it also reflects the abundance of LS stands. LS northern hardwood stands were the most easily found and LS northern pine stands were most difficult and this probably reflects the relative vulnerability of each type. Fourth regional effects exist where landscapes with longer and more intense management histories have fewer stands with high LS values. Frequently this pattern could be explained by proximity to the transportation network (early on, streams and rivers and now, roads) and mills. Location has led to some landscapes having greater cumulative impacts due to more frequent and heavier harvest entries.

MAJOR FINDING

LS stands are a small part of Maine's landscape but can be found throughout western, eastern, and northern Maine. Regional differences in abundance exist probably due historical effects such as proximity to mills.

OUTREACH

The project has made three important presentations on the LS index. At the national meeting of the SAF membership, Buffalo, New York (October 26-28) we gave a talk about the LS index to an audience of about 70 people titled: "A tool for quantifying forest certification and forest conservation easements". At the Forest Ecosystem Information Exchange meeting of 150 forest resources professionals, Orono, Maine (October 4), we gave a talk titled "Assessing biodiversity at the stand scale: An index of late-successional biodiversity". Finally we gave talk about the LS index and patch retention to a small discussion group comprised of 18 policy makers

and stakeholders from industry and the environmental community (November 16) titled "Late successional management tools".

TASKS

Complete analysis on 2003 field data and report on the LS index and LS indicators for timber inventory analysis.

For more information on this study contact **Andy Whitman** and **John Hagan**, Manomet Center for Conservation Sciences, 14 Maine Street, suite 404, Brunswick, ME 04011 (207) 721-9040 or email awhitman@prexar.com or jmhagan@prexar.com.

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Figure 29. (a) 1-year old clearcut northern hardwood forest in T14 R7 WELS after site preparation. (b) old-growth northern hardwood forest in Big Reed Nature Preserve T8 R10 WELS.

Biodiversity

The Effectiveness of Different Buffer Widths for Protecting Riparian Values on Headwater Streams

John Hagan and Ethel Wilkerson

INTRODUCTION

In 2003 we completed the second post-harvest field season (May-September) on this 3-yr experiment to evaluate the effectiveness of different-width forested buffers for protecting headwater streams. Although 2003 was originally intended to be the final year of this study, we will be continuing scaled-back monitoring in 2004 and 2005. Our primary purpose for continuation is to monitor recovery of water temperature on the 0-m buffer (no buffer) streams as the shrub layer redevelops. A comprehensive project report of all aspects of this study will be available in May, 2004. This report provides a few of the results to date, however water temperature data from 2003 are still being proofed at the time of this report.

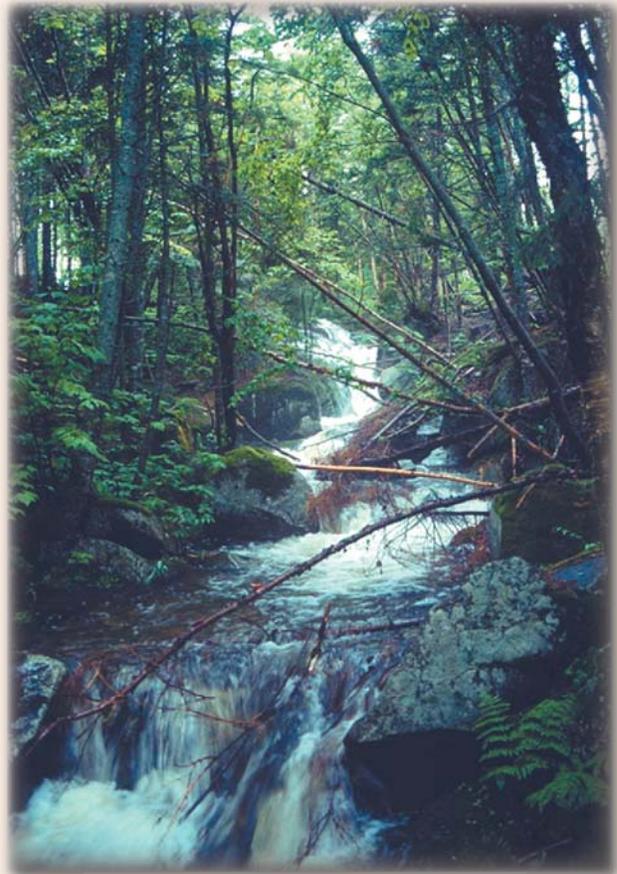
STUDY DESIGN

As a review, we assigned 15 headwater (1st-order) streams in western Maine to one of 5 study treatments (Table 11). All streams were measured for an array of physical and biological parameters both before harvest (2001), and after harvest (2002 and 2003). Our approach is to examine differences in several biological and physical factors pre- and post- harvest, as well as differences above and below the cut block (Figure 30).

SUMMARY OF NEW RESULTS

Stream temperature

In each of the 15 study streams we deployed 6 automatic temperature recorders at 100-m intervals along a 500-m study reach (Figure 30). Our greatest challenge for monitoring water temperature in this study has been stream drying. Rainfall in 2001 (pre-treatment) and 2002 (first post-treatment year) was unusually low. In each of those years, most of the streams began to dry as the summer progressed. As a result, temperature probes “de-watered,” resulting in measuring air temperature instead of water temperature. In addition, the path of water in such small streams “wanders” laterally throughout the season, requiring occasional re-positioning of probes to keep them immersed. Interestingly, although 2003 was a more normal rainfall year, most of the streams still ran dry late in summer, just as they did in the 2 prior dry years. We are beginning to suspect that this may be normal behavior for small headwater streams.



Using various techniques, including stream inspections and temperature data trace inspections, we have removed temperature data that were either suspect of representing air temperature or known to be measuring air temperature. Data filtering methods will be outlined fully in our forthcoming manuscripts.

Because overall climate can be different each year, it is not appropriate to report absolute stream temperatures for the pre- and post-harvest years. For example, the average daily maximum air temperature during summer was about 1°C cooler in the first post-harvest year (2002) compared to the pre-harvest year (2001). Any stream warming that might have occurred as a result of the streamside harvest might have been mitigated by the cooler climate.

One solution to this problem is to plot daily maximum stream temperature vs. daily maximum air temperature (shaded mature forest)(Figure 31). This procedure effectively controls for daily maximum air temperature. In other words, we can ask “What was the daily maximum water temperature in the pre-harvest year as compared to the post harvest year, only on those days in both years when the daily maximum air temperature was 25 °C (or any specific temperature)?” If there is no treatment effect, we expect daily maximum water temperature to be the same in both years for any given daily maximum air temperature. Plots for each temperature probe in one stream from each of the 5 treatments are shown (Figure 31)

It is worth carefully inspecting the graphs in figure 31 to understand treatment (buffer) effects on water temperature. Examine the results for the 0-m buffer stream (top row of graphs, figure 31). Above the harvest block (500-m Station, far right) there was no difference in the relationship between daily maximum water temperature and daily maximum air temperature between the pre- and post-harvest years (the two clusters of points, and regression lines are basically overlapping). Stream water temperature at this station behaved the same in relation to air temperature in both years. Follow the graphs to the left (i.e., “downstream”). As the water moves through the cut block, the two regression lines separate, with the post-harvest year clearly showing warming relative to air temperature. By the time the water has travelled 100 m back into the forest below the cut block (Figure 31, far left graph), the 2 regression lines are back in congruence, indicating temperature recovery.

Inspect the same series of graphs for other treatments in figure 31 (11-m buffer, 23-m buffer, partial cut treatment, Control). All of the 11-m buffer graphs (Figure 31, second row) show the data (regressions) from the two years as virtually overlapping; streams in other treatments

show the same overlapping pattern. This graphical presentation suggests that the only substantial temperature change was observed in the 0-m buffer treatment.

Even though it was slightly cooler in the summer of 2002, in 2002 we recorded minor to moderate changes in water temperature (2 - 5 °C increase, on average) in the harvest zone of the 0-m buffer (no buffer) treatment, compared to the pre-harvest year. Only on a few very warm days did water temperature within the cut block exceed the prolonged-exposure temperature limit of brook trout. Water temperature 100-m below the cut block of 0-m buffer streams returned to within 0 - 2 °C of pre-harvest temperature. There is variation among streams in response to the treatments, but the three 0-m buffer streams clearly have showed the greatest temperature response. Water temperature increases in the cut blocks of the other treatments was minimal or non-existent. With only the first year of post-harvest data available for analysis at this time, we are not yet prepared to say whether buffers are important along small headwater streams to protect stream temperature.

Water Chemistry

Simple summaries of water quality (pH, dissolved O₂, turbidity, and conductance), which include the 2003 data from June, are shown in Figure 32. Our conclusions have not changed with a second year of post-harvest data; we see no substantive changes in any of these parameters as a result of the harvest treatments (during the window of time in which we collected water quality data [late May, early June]). Slight year effects are apparent in some of the plots, but these seem to influence all streams in much the same way, regardless of the buffer prescription. Turbidity, one of the parameters of most concern, was no different in the post harvest year and extremely low for natural water bodies.

Table 11. List of experimental treatments.

Treatment	Harvest	Replicates
1	Clearcut with 0-m buffer	3
2	Clearcut with 10-m partial cut buffer	3
3	Clearcut with 23-m partial cut buffer	3
4	200-m partial cut block	3
5	No harvest	3

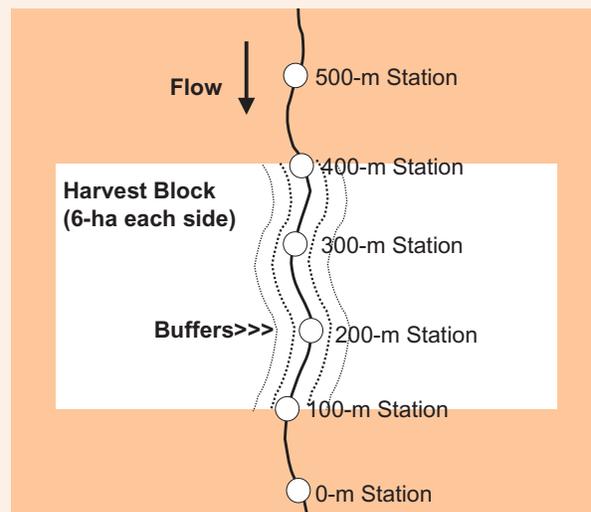


Figure 30. A 500-m reach was established on each of 15 study streams. Temperature recorders were deployed at 100-m intervals.

Treatment (stream)

0-m buffer (Kibby)

11-m buffer (Caratunk)

23-m buffer (Sanderson)

Partial Cut (Up Cup)

Control (Appleton)

100 m Above Harvest

Harvest Zone

100 m Below Harvest

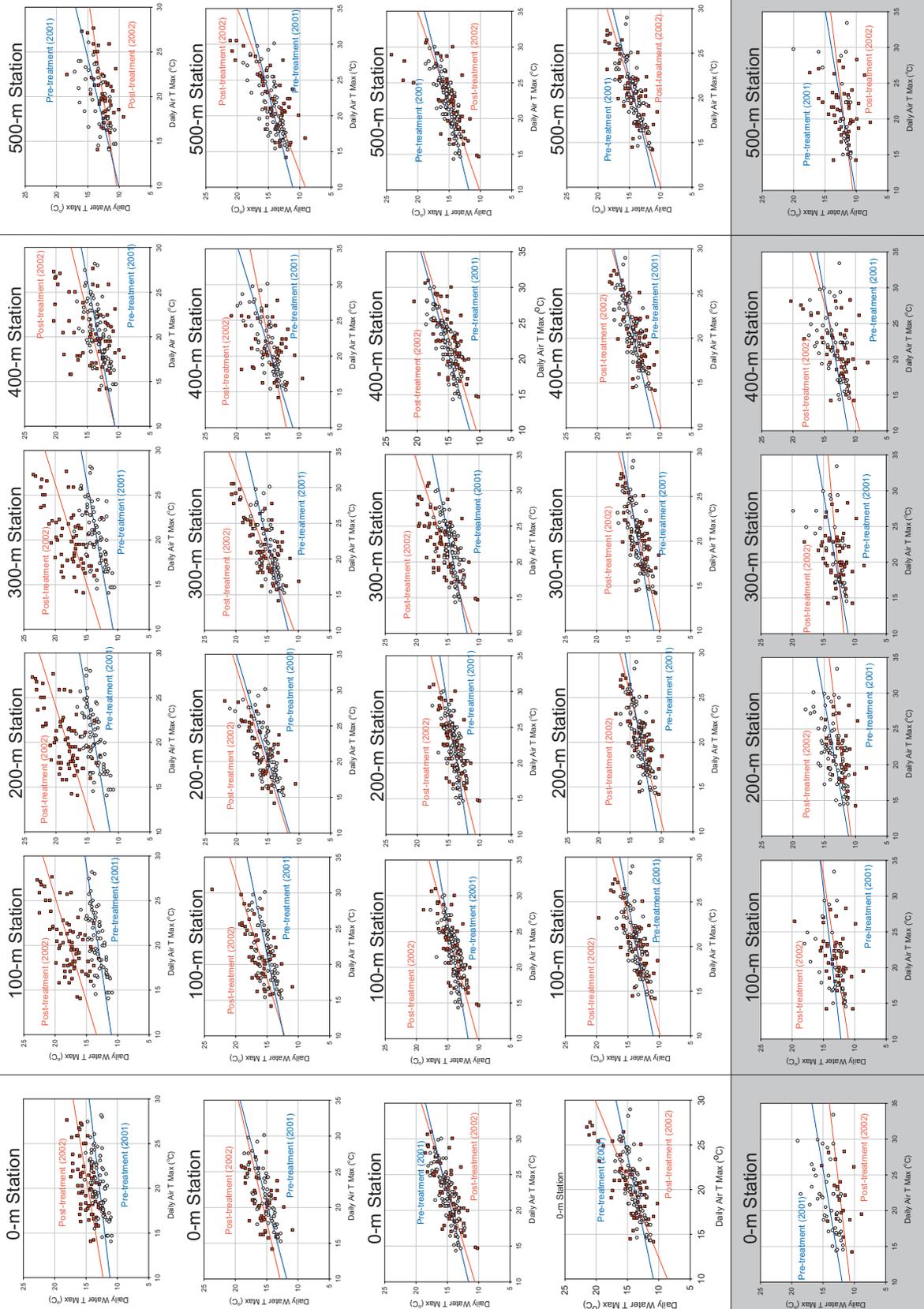


Figure 31. Relationship between daily maximum water temperature and daily maximum air temperature for each temperature probe (0, 100, 200, 300, 400, and 500-m stations) on one stream from each of the 5 treatments. Effect of the treatments on water temperature is shown by the degree of separation of the pre-treatment and post-treatment regression lines on each graph.

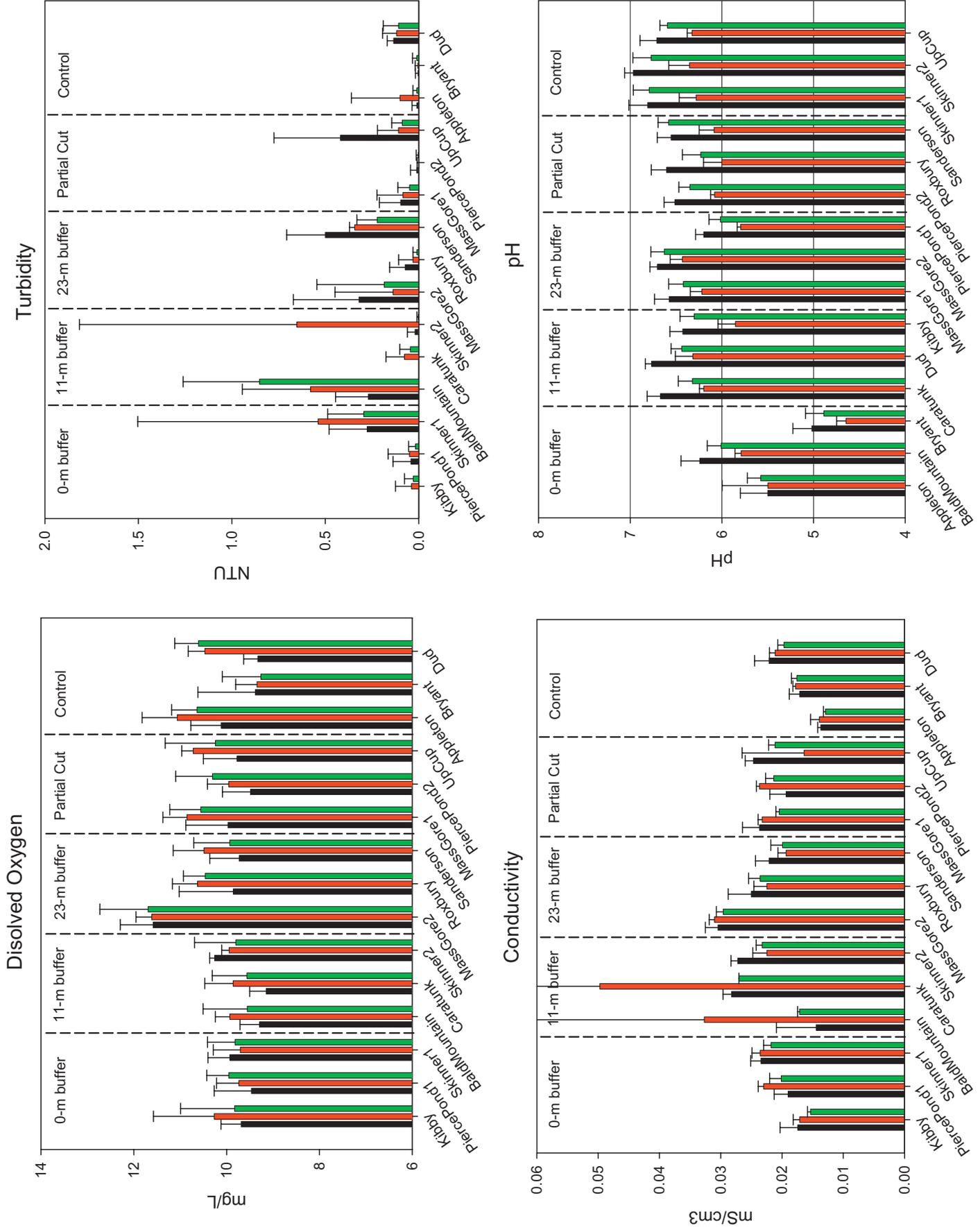


Figure 32. Water chemistry changes in each of the 15 streams in the pre-treatment year (2001) and the two post-treatment years (2002 and 2003). Although we collected data at 100-m intervals (see Fig. 1), data shown here are for the 100-m station (lower end of the cutblock) only.

Ortho-Phosphate

In 2001-2003 analysis of water samples for concentrations of ortho-phosphate was completed with assistance of the Maine Department of Environmental Protection (DEP). Ortho-phosphate measures the concentration of phosphorus that is in a form available for use by biota. Results of ortho-phosphate concentrations for samples taken at the lower edge of the cut block are shown in figure 33. The concentration of ortho-phosphate in all streams is very low and does not show a marked increase or decrease after forest harvest. The small concentrations indicate a low availability of nutrients within the stream system for aquatic plant growth. Fluctuations in concentrations of aquatic ortho-phosphate can be influenced by many factors including precipitation, overland runoff, sediment input, and levels of biota consuming nutrients.

Chlorophyll-a/Periphyton

Maine DEP also analyzed rock scrapings for concentrations of chlorophyll-a. Chlorophyll-a is used to measure the amount of periphyton and other algae in aquatic systems. Chlorophyll-a data from 2001-2003 are shown in Figure 34. The concentration of chlorophyll-a increased in all streams in the 0m, 11m, and partial harvest treatments in at least one of the post-harvest years. Only one stream within the 23m treatment showed any increase in concentrations. The increase in chlorophyll concentrations indicates an increase in periphyton population as a result of increased sunlight reaching the streambed. It is unknown if the increase in periphyton will effect the stream ecosystem. Increases in periphyton may indicate a shift in the stream community from an allochthonous to autochthonous system. If such a shift is occurring, it may be observed in the macroinvertebrate data from 2003 (samples being processed now).

Macroinvertebrates

In 2002 and 2003 we deployed standard mesh bags filled with cobbles for 4 weeks (late May - late June) at the top of the cut block and the bottom of the cut block in each of the 15 streams. Because of stream drying in 2001, we do not have pre-treatment data on macroinvertebrates. (NOTE: we changed the sampling window to May/June in 2002 and 2003 when streams are certain to be flowing). Analysis of 2003 samples is expected in January of 2004. At that time, 2003 and 2004 data will be compared to statewide macroinvertebrate data collected by the Department of Environmental Protection (DEP).

As a general rule, macroinvertebrate species richness and species diversity was greater at the lower end of the cut block (100-m station) than at the upper end of the cut block. This was true regardless of the treatment. We suspect this was a result of the streams being slightly wider and more structurally diverse at the 100 m station relative to the 400 m station. Data from 2003 will help us understand whether there were any effects on macroinvertebrates as a result of the increases in stream temperature that we observed after the harvest. Overall,

the macroinvertebrate species present in our samples indicate very high quality aquatic systems.

Blowdown

In the first post-harvest year (2002) we recorded 50 blowdown trees over all 15 streams, and within 23-m of the stream channel (or to the outer edge of the buffer for the 11m treatment) (Table 12). In 2003 we recorded 40 blowdown trees. Because we were sampling effectively one-half the area in the 11m buffers as compared to the 23m buffers, there may be greater blowdown per unit area for the 11m buffer than the other treatments (18 trees in 2002). More detailed analysis of blowdown will be provided in our forthcoming final report (e.g., tree species and sizes).

Table 12. Number of trees blown down in the first (2002) and second (2003) post-harvest year within the buffer strips. We sampled the a 23m zone on either size of the stream channel, except for the 11m treatment in which we sampled to out to the edge of the buffer only (~11m).

Treatment	2002	2003
0-m	6	14
11-m	18	7
23-m	8	9
Partial	5	5
Control	13	5
Total	50	40

PLANNED ACTIVITIES

This winter and spring we will be completing the final report for the original 2001-2003 study period, and submitting several manuscripts for publication. In May, 2004, we will begin a third post-harvest field season, but we will only be measuring water temperature. We will be monitoring recovery of water temperature as streamside vegetation begins to recover. Even after only 18 months post-harvest, we already are seeing rapid growth of streamside shrubs (Figure 34).

ACKNOWLEDGEMENTS

Our work in 2003 was made possible by the great cooperation and support from **Plum Creek Timber Co, Seven Islands Land Co.**, International Paper, and MeadWestvaco. We thank the Maine Department of Environmental Protection for analyzing ortho-phosphate and chlorophyll-a/periphyton data. We thank the CFRU, NCASI, and Manomet Center for financial support of this project.

Comments or questions about this report are welcomed. Contact John Hagan at 207-721-9040 or by e-mail at jmhagan@ime.net.

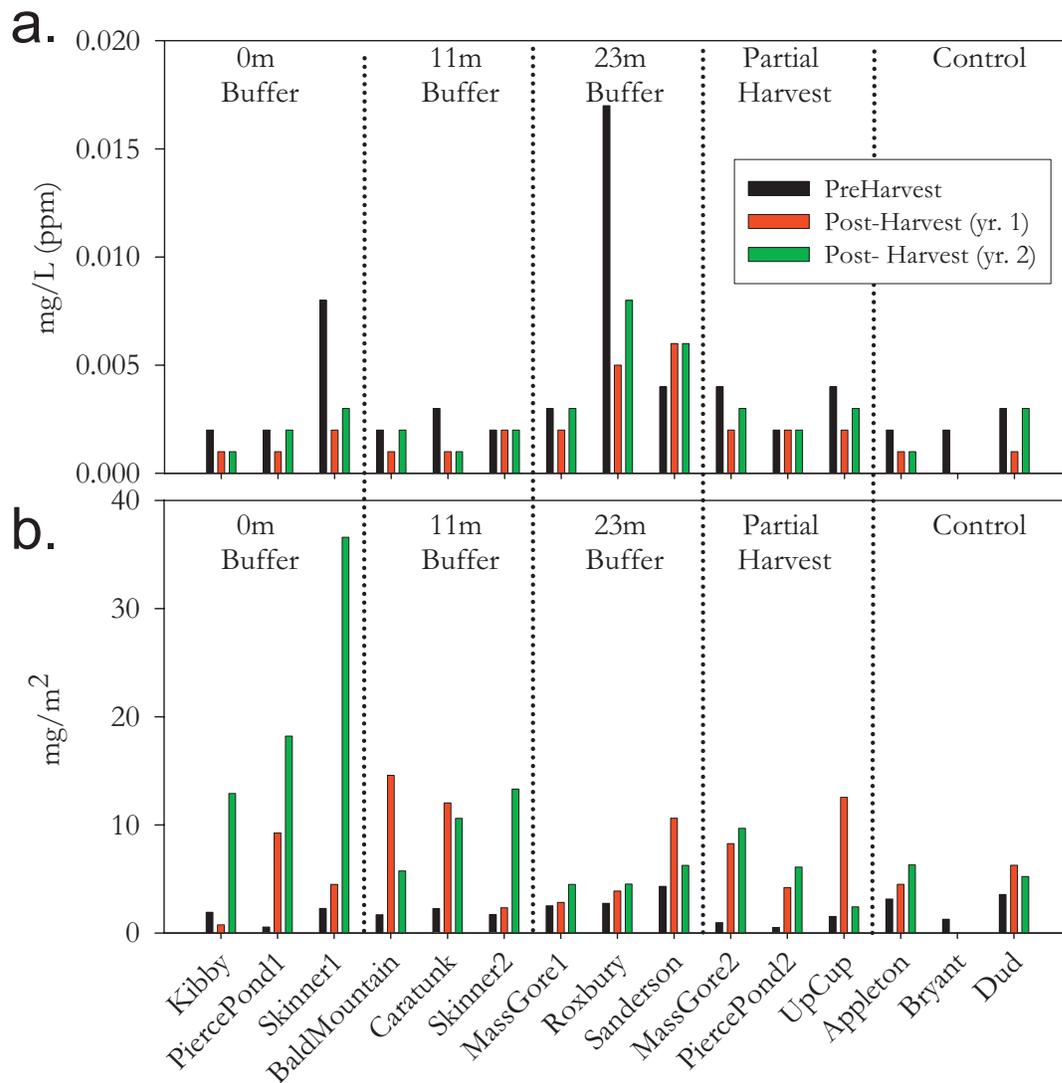


Figure 33. Changes in ortho-phosphate (a) and (b) chlorophyll-a concentrations and at each of the 15 streams in the pre-treatment year (2001) and the post-treatment years (2002 and 2003). Samples were taken near the 100m stations, at the lower end of the cutblock.



Figure 34. Just 16 months following harvest in the 0-m buffer treatment shrubs and sapling trees are beginning to recover the site and aid in buffering the stream. Hobblebush, a common understory shrub in Maine, along with maple, ash and balsam fir are already beginning to shade the stream channel.

Outreach

Communicating our research accomplishments to a wide audience is a critical component of the CFRU. Over the past year CFRU staff and scientists produced more than 80 new articles, theses, reports, proceedings, and presentations to state, regional, national, and international audiences.

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Appendices

APPENDIX A.

SPECIES LIST

Trees

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

Animals

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

APPENDIX B.

Contact Information

- R. Justin DeRose** Graduate Student, Department of Forest Ecosystem Science, University of Maine, Orono
207-581-2839; densitymanager@yahoo.com
- Michael S. Greenwood (Ph.D.)** CFRU Cooperating Scientist, Ruth Hutchins Professor of Tree Physiology, University of Maine, Orono
207-581-2838; greenwd@umenfa.maine.edu
- John M. Hagan (Ph.D.)** CFRU Cooperating Scientist, Program Director
Manomet Center for Conservation Science, Brunswick, Maine
207-721-9040; jmhagan@ime.net
- Daniel J. Harrison (Ph.D.)** CFRU Cooperating Scientist, Professor of Wildlife Ecology, University of Maine, Orono
207-581-2867; harrison@umenfa.maine.edu
- Julieann Kahler** CFRU Administrative Assistant, University of Maine, Orono
207-581-2893; Julie_Kahler@umenfa.maine.edu
- William B. Krohn (Ph.D.)** Leader, Maine Coop. Fish and Wildlife Research Unit, Assistant Professor of Wildlife Ecology, University of Maine, Orono
207-581; wkrohn@umenfa.maine.edu
- Daniel J. McConville** CFRU Research and Communications Coordinator, University of Maine, Orono
207-581-2861; dan_mcconville@umenfa.maine.edu
- Timothy McGrath (Ph.D.)** Leader, Growth and Yield Group, Nova Scotia Department of Natural Resources, Truro, Nova Scotia, CA
902-893-5683; tpmcgrat@gov.ns.ca
- Spencer R. Meyer** Graduate student, Department of Forest Ecosystem Science, University of Maine, Orono
207-581-2897; spencer_meyer@umenfa.maine.edu
- Ralph D. Nyland (Ph.D.)** Distinguished Service Professor, SUNY College of Environmental Science and Forestry, Syracuse, NY
(315) 470-6574; rnyland@syr.edu
- Robert S. Seymour (Ph.D.)** CFRU Cooperating Scientist, Curtis Hutchins Professor of Forest Resources
207-581-2860; seymour@umenfa.maine.edu
- Robert G. Wagner (Ph.D.)** CFRU Director, Professor, Department of Forest Ecosystem Science, University of Maine, Orono
207-581-2903; bob_wagner@umenfa.maine.edu
- Andrew A. Whitman** Forest Ecologist, Manomet Center for Conservation Science, Brunswick, Maine
207-721-9040; awhitman@prexar.com