Cooperative Forestry Research Unit

2002 Annual Report

MAFES
MISCELLANEOUS
REPORT 431

COOPERATIVE FORESTRY RESEARCH UNIT
UNIVERSITY OF MAINE

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COOPERATIVE FORESTRY RESEARCH UNIT

University of Maine

2002 ANNUAL REPORT

MAFES Miscellaneous Report 431

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
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Cover photo: Fresh Canada Lynx tracks in a pre-commercially thinned spruce-fir stand

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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 to conduct applied scientific research that contributes to the sustainable management of Maine's forests for desired products, services, and conditions. 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 marten habitat issues, the long-term effect of herbicides and pre-commercial thinning, and the ecological value of patch retention in harvested stands 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. Additionally, 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 2001-2002.

Silviculture ***Wildlife*** ***Biodiversity***



HIGHLIGHTS

Organizational

- The CFRU was selected as one of the top accomplishments of the Forestry Program at the University of Maine over the past 100 years and is being celebrated as such at the centennial celebration this coming year
- Five new projects were approved for funding this year, in addition to the funding of five ongoing projects reflecting a strong commitment to new ideas
- CFRU project scientists leveraged approximately $183,000 from outside funding sources (46 percent of research expenses) to augment the research effort
- To reduce staff expenses and increase efficiency we combined the positions of Field and Data Coordinator and Financial and Communications Coordinator to create a Research and Communications Coordinator position, which was filled by **Dan McConville** in August
- **Joanna Silva** was hired as a half-time Administrative Assistant to manage the Unit's administrative duties
- The Unit website, which was overhauled during the summer to improve design and efficiency, continues to be an important means of technology transfer

Research

Silviculture

- The Commercial Thinning Research Network, led by **Bob Wagner** and **Bob Seymour**, will continue this year with two new graduate students who will address growth and yield responses to thinning
- The Austin Pond study, which documents the long-term effects of herbicide and pre-commercial thinning (PCT) on spruce-fir stands is completed and a final report will be available during the summer of 2003
- Third-year results from a study analyzing the effects of imazapyr (Arsenal®) on balsam fir and red spruce height growth applied at 7 timings and two rates suggest that negative impacts of the herbicide persist for at least three years following treatment
- Bob Wagner and Bob Seymour completed a state-wide wood supply analysis to analyze silviculture research priorities using a model of Maine's future wood supply
- First-year results were summarized in study to address the factors that affect red spruce regeneration

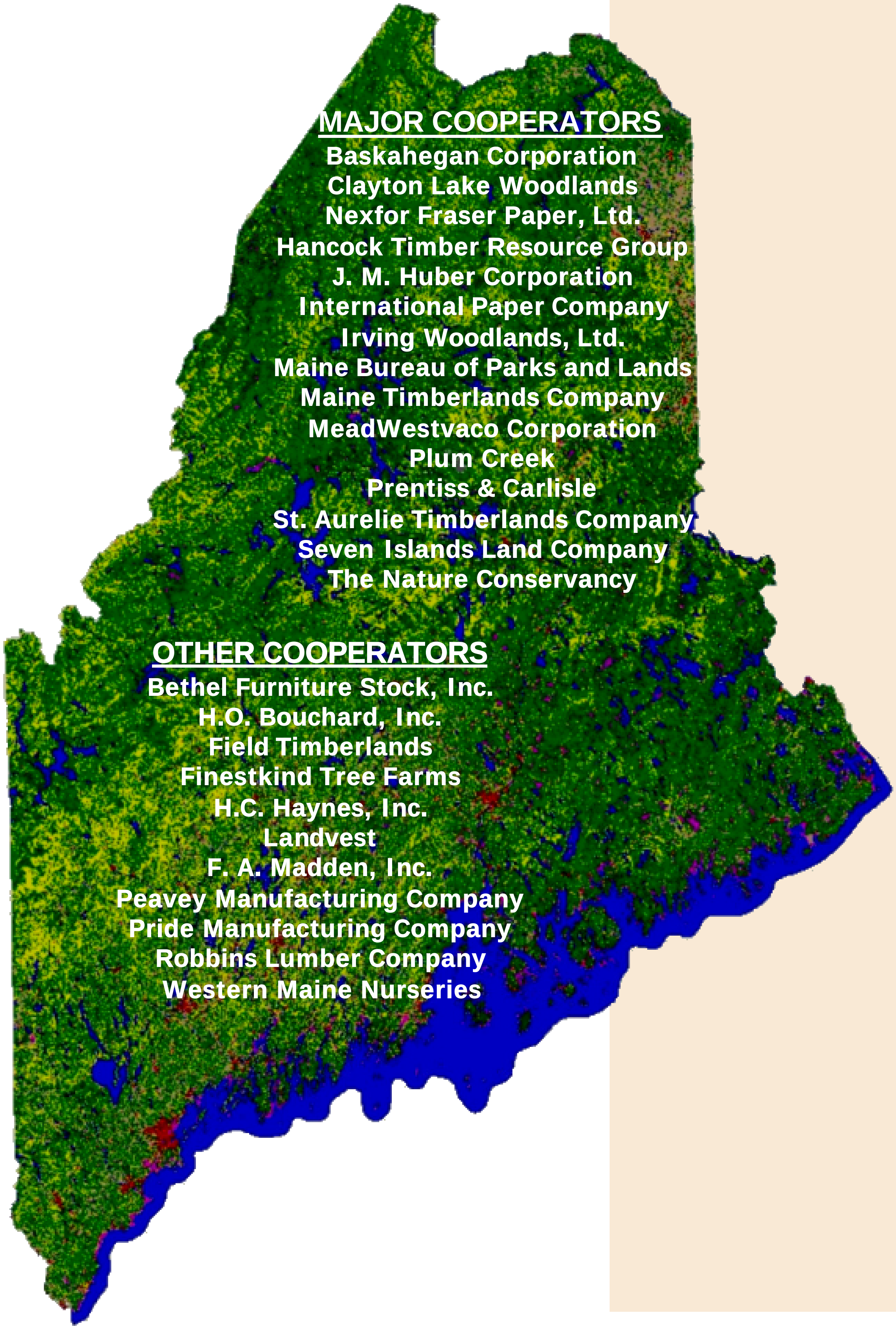
Wildlife Conservation

- **Jessica Homyack** and **Dan Harrison** completed the final field season for their research investigating the effect of pre-commercial thinning on snowshoe hare, small mammals and forest structure; a final report is due next summer
- **Angela Fuller** and Dan Harrison continue their work examining the influence of forest practices on Canada lynx
- **Jeff Hepinstall** and Dan Harrison completed a project to evaluate the effects of habitat loss and fragmentation on marten and to build predictive models of marten occurrence for use in forest planning

Biodiversity Conservation

- **John Hagan** and **Andy Whitman** completed the third and final year of a study to test the ability of forested patch retention to retain vulnerable species and features in a managed forest
- John Hagan's study to evaluate the effectiveness of different buffer widths for protecting riparian values on headwater streams continues to provide insight into how buffer strips along headwater streams influence biodiversity and water quality

MEMBERSHIP



MAJOR COOPERATORS

Baskahegan Corporation
Clayton Lake Woodlands
Nexfor Fraser Paper, Ltd.
Hancock Timber Resource Group
J. M. Huber 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
H.C. Haynes, Inc.
Landvest
F. A. Madden, Inc.
Peavey Manufacturing Company
Pride Manufacturing Company
Robbins Lumber Company
Western Maine Nurseries

PERSONNEL

STAFF

Robert G. Wagner
Director and Professor of Forest Ecosystem Science

Daniel J. McConville
Research and Communications Coordinator

Joanna Silva
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

William B. Krohn
Cooperative Fish and Wildlife Research Unit and Professor of Wildlife Ecology

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 REPORTS

Chair's Report

Until becoming Chair this past year, I had relatively little direct contact with the CFRU except to adopt applicable areas of its many research initiatives. This year has, for me, been a real opportunity to become familiar with a very worthwhile and productive organization. I hope that my "on the job training" has not hindered the CFRU in any way.

Before writing this report, I reviewed several previous reports written by different Chairs and was struck by several recurring themes. It is apparent that nearly constant change is the norm. Whether it is a change in staffing, dues structure or bylaws we will be constantly challenged to alter the way we conduct the CFRU. These changes can be disruptive and time consuming but appear to be a necessary way of life in order to successfully confront challenges, survive and invariably make CFRU more productive. It is equally obvious that CFRU provides a service that is well worth the attention and cost required to maintain it as a functioning program. Enthusiasm for the products delivered by CFRU keeps us all at the table working to make it a success.

Several events this past year stand out as being particularly noteworthy:

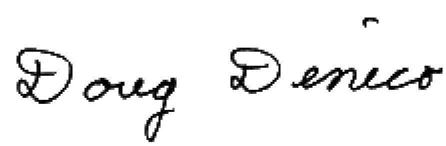
- The loss of **Chip Griffin** from staff was taken on as a challenge by **Bob Wagner** and **Dan McConville** to once again reconfigure staff accountabilities. Dan taking on additional responsibilities as Research and Communications Coordinator helped accomplished this. The end result was a fully functioning staff accomplishing its goals at a substantial savings to the CFRU membership.

- Selection of the CFRU program to be featured by the University of Maine as one of its top accomplishments during the 100th anniversary of the forestry program is certainly a singular honor. The accomplishments of CFRU have obviously drawn the attention and respect of the University.

- It was particularly rewarding to see a potentially divisive issue as dues restructuring to be addressed through a process that was respectful and sensitive to the concerns of the membership. Given the ever-changing circumstances of the CFRU membership, the subject of dues structure will likely be further reviewed within the next two years. The dues issue is a symptom of many factors such as a decreasing land base assessed by CFRU, ownership consolidation, and decreasing forest industry profitability. In recognition of such profound changes within the industry, key industry personnel will be brought together in 2003 to discuss and reach consensus on the long-term future of forest industry related research. With the ever-increasing economic pressures being placed on forest industry, the need for well-researched information is clear. How we choose to provide this information, however, appears to need a continuing dialogue.

- The Hardwood Silviculture Research Subcommittee has successfully culminated two years of work by funding of two research proposals. The sequence of activities leading to this stage has required very diligent work by the Committee members and their efforts are much appreciated. Interestingly, the research proposals came from outside of Maine and were authored by **Ralph Nyland** and **Tim McGrath**. Both these individuals are well known and respected by the membership. Their selection demonstrates the ability of the CFRU to draw on regional expertise. **Dan Harrison, Mike Greenwood, Bob Seymour John Hagan, Andy Whitman, Bob Wagner** and **Dan McConville** have continued to provide timely and relevant research on a wide range of projects encompassing wildlife, silviculture, water quality, and biodiversity.

Finally, a note concerning excellent budgetary constraint. This is an area that all too often requires a Chair's attention in other organizations. In the CFRU, I am pleased to say that both project and administrative portions of the budget are very well managed. Bob and all the project leaders have excelled in operating within their budgets. We struggle to provide a consistent level of funding, but fortunately we have prudent management of funds once collected. My sincere thanks.



Doug Denico
Chair, CFRU Advisory Committee

Dean's Report

The Cooperative Forestry Research Unit continues its mission of solving problems that Maine's forest land managers are facing through practical research under the able leadership of **Bob Wagner**.

The CFRU is about foresters who are responsible for millions of acres of Maine's forest sitting around the table with university researchers, defining the most important problems facing this vital resource, and then designing and implementing research that will work to solve these problems. The CFRU has become a signature forestry program at The University of Maine and is being recognized as one of the top accomplishments being celebrated during the 100th anniversary of the forestry program at the University of Maine (1903-2003).

The support of the members of CFRU has, as always, been steadfast and impressive. We deeply appreciate all the time and effort that the members expend to make the CFRU a success. The opportunities and responsibilities for executing forestry research in Maine in the future are both exciting and daunting.

Land sales to financial investors, poor markets, and increase in non-industry extramural research funds pose certain threats to industry-sponsored research. In response to some of these concerns, a group of industry leaders will be drawn together in early 2003 to focus on the longer-term future of forest industry-based research and development at The University of Maine. The objective is to create a vision of the future, develop potential mechanisms, and oversee implementation of best options. I believe that this summit of forestry leaders is an important step towards assuring a strong and healthy forest resources industry in the 21st century.

My thanks, again, to the CFRU cooperators, faculty, and staff for their excellent work during the past year. I invite all of you to participate in the many activities associated with the 100th anniversary celebration of the forestry program in 2003.

G. Bruce Wiersma
Dean, College NSFA

Director's Report

Fiscal 2001-02 was another productive year for the CFRU. The staff, scientists and graduate students serving the unit continue to be central to the unit's success. Their efforts are documented in this annual report. **Dan Harrison's** excellent team had a productive year with an ongoing wildlife research effort focused on forestry issues affecting marten, snowshoe hare, and lynx. **Bob Seymour** and I continued to work closely together on silviculture research, especially on the now fully installed Commercial Thinning Research Network sites for spruce-fir. **Mike Greenwood** also is working on these sites, studying conifer seed production and regeneration associated with commercial thinning. **John Hagan** of Manomet Conservation Sciences continued leading two excellent projects with **Andy Whitman** examining buffer strips and patch retention for maintaining biodiversity.

In addition to this ongoing research, I am happy to report that we were able to develop a number of new research proposals for consideration by the Advisory Committee. As a result of these efforts, five new projects were approved for funding next year. Our focus continues to be identifying forest management problems facing CFRU Cooperators and then developing new research ideas that can help solve those problems. Toward that end, the new **Hardwood Silviculture Research Subcommittee** was instrumental in helping us put more emphasis on hardwood management issues this year. Two of these approved projects also involve new CFRU collaborations with the Nova Scotia Department of Natural Resources and SUNY College of Environmental Science and Forestry.

I thank **Brian Higgs** (Baskahegan Corp.) for his excellent leadership as Chair over the past two years. A special thanks goes to **Doug Denico** (Plum Creek) who quickly filled the role of Chair when our incoming Vice Chair could not serve. Doug's crucial leadership during a number of meetings around the dues issue cannot be overstated. Thanks also go to **Peter Etheridge** (J.D. Irving) for his outstanding service to CFRU over the past several years. We all wish him the best in his future career pursuits.

Dan McConville did an excellent job this year coordinating field activities for the unit and was invaluable as we redesigned CFRU staff positions after the departure of **Chip Griffin** during midyear. Dan's contributions to the success of the unit grow steadily and I look forward to working with him in his new position as Research and Communications Coordinator. We believe this move will improve the efficiency of the unit's technology transfer mission. I also look forward to working with **Joanna Silva**, new CFRU Administrative Assistant, during the coming year. I also want to thank **Nora Ackley** for the outstanding job she did filling in as the unit administrative assistant from June through September.

Finally, I extend a special thanks to all members of our **Advisory Committee** for their support, patience, and hard work in dealing with the dues restructuring issue this year. It was the last and clearly most difficult phase of the organizational restructuring we have accomplished over the past few years. I am very pleased that we were able to develop a satisfactory solution. While the CFRU still faces major challenges from continuing land sales and a poor wood market, I am confident that we can work together to meet the challenge of funding a vital and long-term research effort. I look forward to another productive year, working closely with CFRU staff, scientists, and member organizations to keep the CFRU moving forward and advancing forest management practices for the state and region.

Robert G. Wagner
CFRU Director

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FINANCIAL REPORT

Continued sound fiscal management by CFRU project scientists and staff resulted in coming $50,544 (or 11.6%) under budget during FY2001-02 (Table 1). The savings came primarily from mid-year departure of a full-time employee, finding alternative funding to support a CFRU graduate student, and efficiencies gained for several research projects by combining field crews and transportation needs. These savings were returned to the central account for future use on other CFRU projects.

CFRU spent 16% of its budget on silviculture research, 18% on wildlife habitat related research, and 21% on water quality and biodiversity research. Substantial funds (approximately $183,000) were leveraged from outside finding sources, including NCASI, to support primarily the wildlife, water quality, and biodiversity research projects. Therefore, leveraged funds covered approximately 46% of total expenses for CFRU research projects this year. In-kind contributions from the University of Maine also contributed substantially to the overall effort. About 45% of total CFRU expenditures were spent on administering the CFRU, including salaries of two full-time employees and part-time Director, stipends for cooperating scientists, plus expenses for vehicles, travel, supplies, and other costs related to administering the unit.

Member contributions to CFRU continued to be strong, bringing a total of $385,381.55 in dues contributions (Table 2). The loss of member acreage, however, continues to be a concern, even with the addition of Clayton Lake Woodlands last year. Well-publicized financial difficulties with Great Northern Paper also affected the CFRU this year, reducing our planned dues base by $17,980. Nexfor Fraser Papers generously donated an additional $3,195 in support of the CFRU wildlife research projects. For the first time in a number of years, CFRU spending was 10.8% less the dues received during the previous year (FY2000-01) and was therefore able to carryover $224,422 into FY2002-03.

Table 1. CFRU project expenditures and balances for FY2001-02 (as of September 30, 2002).

Project	Approved amount	Amount spent	+ / -	%
Administration	$208,062	$173,455	$34,607	-16.6%
A habitat supply assessment for marten (Harrison)	$16,350	$16,350	$0	0.0%
Influence of forest practices on habitat selection of lynx in northern Maine (Harrison)	$25,000	$24,983	$17	-0.1%
Austin Pond: Long-term effects of herbicide application and pre-commercial thinning on spruce-fir stands (Wagner)	$20,020	$13,414	$6,606	-33.0%
Effect of pre-commercial thinning on selected wildlife species with special emphasis on snowshoe hare (Harrison)	$29,260	$29,250	$11	0.0%
Commercial Thinning Research Network (Wagner/Seymour)	$53,234	$46,221	$7,013	-13.2%
Factors affecting regeneration and early growth of balsam fir and red spruce (Greenwood)	$4,000	$1,710	$2,290	-57.3%
Effect of buffer and filter strips on water quality and aquatic biodiversity (Hagan)	$40,000	$40,000	$0	0.0%
Patch retention as a tool for maintaining biodiversity in a northeastern industrial forest (Hagan)	$40,000	$40,000	$0	0.0%
TOTAL	**$435,926**	**$385,382**	**$50,544**	**-11.6%**

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Table 2. CFRU cooperator contributions during FY2001-02.

COOPERATOR	Reported acres for FY2001-02	Amount invoiced in 2002	Amount received in FY2001-02	Balance due for FY2001-02
Irving Woodlands	1,550,000	$85,250	$85,250	$0
International Paper Company	1,302,883	$71,659	$71,659	$0
Seven Islands Land Company	880,000	$48,400	$48,400	$0
Plum Creek Timberlands	863,000	$47,465	$47,465	$0
MeadWestvaco Corporation	529,158	$29,104	$29,154	$50
Maine Bureau of Parks and Lands	349,414	$19,218	$19,218	$0
Maine Timberlands Company / GNP	326,915	$17,980	$0	-$17,980
Huber, J. M. Corporation	320,000	$17,600	$17,600	$0
Hancock Timber Resource Group	289,460	$15,920	$15,920	$0
Clayton Lake Woodlands	245,000	$13,475	$13,475	$0
Nexfor Fraser Papers	231,802	$12,749	$15,944	$3,195
The Nature Conservancy	187,788	$10,328	$10,328	$0
Baskahegan Lands	101,629	$5,590	$5,590	$0
Prentiss and Carlisle	84,574	$4,652	$4,652	$0
Ste. Aurelie Timberlands	60,000	$3,300	$3,300	$0
Robbins Lumber Company	30,000	$1,650	$1,650	$0
Pride Manufacturing	0	$468	$468	$0
Bouchard, H. O., Inc.	0	$200	$0	-$200
Haynes, H. C., 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
TOTAL	**7,351,601**	**$408,172**	**$391,233**	**$-14,937**

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ADVISORY COMMITTEE

The CFRU Advisory Committee is comprised of 18 members representing private industrial and non-industrial organizations, the US Forest Service, the state of Maine, and the University of Maine. Advisory members guide and govern all CFRU affairs and ensure that ongoing and new research is conducted to the highest standards. We thank all committee members and the officers, **Doug Denico** (Chair), **Hugh Crammond** (Vice-Chair), and **Brian Higgs** (Financial Officer).

Our Advisory meetings continue to serve as an important communications outlet. A number of research reports were presented at our quarterly advisory meetings and fall field tours over the past year. Detailed meeting minutes are available online in the Advisory section of our website. Meetings were held:

- October 17, 2001 Field Tour
- January 22, 2002
- May 2, 2002
- July 16, 2002
- October 9, 2002 Field Tour

The October 2001 fall field tour was graciously hosted by **Huber Corporation**, **International Paper Company**, and **Nexfor Fraser Papers, Inc**. **Bob Wagner, Bob Seymour,** and **Dan McConville** presented results from the Commercial Thinning Research Network study. **Dave Wilson** of Nexfor Fraser Papers gave an overview of his company's habitat management program, and **Dan Harrison** and **Jeff Hepinstall** provided a summary of how forest management affects marten habitat.

The October 2002 field tour, which took place in the Telos area focused on forest management effects on wildlife and ecological integrity. Dan Harrison and graduate student **Jessica Homyack** presented the latest findings on snowshoe hare habitat in pre-commercially thinned stands (Figure 1). We visited a partially harvested mixed-wood stand where Dan Harrison examined the effects of a partial overstory on marten habitat. The tour concluded at the Baxter State Park Scientific Forest Management Area where **Jensen Bissell** described his management objectives in mature mixed-wood stands (Figure 1).

2002 Advisory Committee

Doug Denico (Chair), Plum Creek Maine Timberlands
Hugh Crammond (Vice-Chair), JD Irving Limited
Brian Higgs (Financial Officer), Baskahegan Company
Si Balch, MeadWestvaco Corporation
John Brissette, USFS Northeastern Forest Research Station
John Cashwell, Seven Islands Land Company
Tom Charles, Maine Bureau of Parks and Lands
Anthony Filauro, Maine Timberlands Company/ GNP
Phil Malerba, International Paper Company
Bill Miller, Prentiss and Carlisle
Jacques Morin, St. Aurelie Timberlands Company
Nancy Sferra, The Nature Conservancy
Bill Sylvester, Clayton Lake Woodlands
Kevin Topolniski, Nexfor Fraser Papers, Inc.
Peter Triandafillou, Huber Corporation
Henry Whittemore, Hancock Timber Resource Group
Paul Van Deusen, National Council for Air & Stream Improvement (NCASI)
G. Bruce Wiersma, Dean, College of Natural Sciences, Forestry and Agriculture

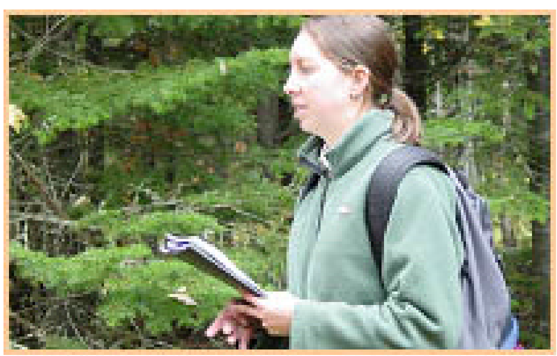


Figure 1. Graduate student Jessica Homyack (left) speaks about the effects of PCT on snowshoe hare habitat, and Baxter State Park forester Jensen Bissell (right) describes the Park's management objectives at a recent field tour.

Hardwood Silviculture Research Subcommittee

In late 2000, several CFRU members felt that a group of hardwood experts was needed to provide a critical mass of hardwood expertise that could initiate and guide CFRU research to improve the management of Maine's hardwood resource and advance northeastern hardwood management in general. During 2001, a Hardwood Silviculture Research Subcommittee was formed by the Advisory Committee. Members of the Subcommittee are shown in Table 3. The mission of the Subcommittee is to *"promote applied scientific research that can improve the quality and productivity of Maine's hardwood forest resources and the northern hardwood forest."* A set of objectives and functions were developed for the Subcommittee (Table 4). A list of top hardwood silviculture research priorities also was established (Table 5).

One of the first events developed by the Subcommittee was the Hardwood Silviculture Field Tour held in Woodstock, New Brunswick on September 27-28, 2001. The workshop was organized by Bill Ostrofsky and attended by over 100 foresters from Maine and New Brunswick. Topics covered included pre-commercial thinning, effects of past harvesting practices and silvicultural treatments on stand development, species composition, and stem quality changes, and site quality evaluation methods. The workshop was sponsored by the Cooperative Forestry Research Unit, Henry W. Saunders Professorship in Hardwood Silviculture, the Maine Hardwood Association, and the University of Maine.

Based on the list of research priorities (Table 5), the Subcommittee also prepared and distributed a Request For Proposal in October 2001 to researchers at the University of Maine and other forest research institutions around the region. During the winter of 2002, six pre-proposals were received from six different institutions. The Subcommittee met and evaluated each of the proposals at the end of January. Only two of the six pre-proposals were recommended for development into full proposals. The full proposals were received and evaluated by the CFRU Advisory Committee at the May 2002 meeting. Both proposals were approved for funding for the 2002-03 fiscal year. The proposals are 1) development of a Northern Hardwood Growth and Yield Model by Tim McGrath of the Nova Scotia Department of Natural Resources (see page 68 for details) and 2) A Literature Review About the Role of Interfering Plants in Hardwood Regeneration by Ralph Nyland of the SUNY College of Environmental Science and Forestry (see page 68 for details). Subcommittee activities for the coming year will focus on monitoring the progress of these new projects.

Table 3. 2001-02 CFRU Hardwood Silviculture Research Subcommittee

Name	Affiliation
Hardwood researchers/experts:	
Peter Hannah **(Vice Chair)**	U. Vermont, retired
Max McCormack	U. Maine, retired
Ralph Nyland	State University of New York, ESF
Larry Safford	U.S. Forest Service, retired
Hardwood managers:	
Si Balch	MeadWestvaco Corp.
Kenny Fergusson	Huber Resources
Hugh Crammond	Irving Woodlands
John McNulty **(Chair)**	Seven Islands Land Co.
Organizational representatives:	
Brian Higgs	CFRU Executive Committee
Bill Leak	U.S. Forest Service, NE Research Station
Bill Ostrofsky	U. Maine, Saunders Chair
Henry Saunders	Maine Hardwood Association
Bob Wagner **(Secretary)**	CFRU Director

Table 4. Hardwood Silviculture Research Subcommittee objectives and functions
• **Identify and maintain a list of research priorities to develop new data, information, and knowledge that will improve the management of the hardwood resource in Maine and the Northern hardwood forest.**
• **Solicit research proposals through the CFRU from qualified researchers to address the above research priorities.**
• **Review research proposals on hardwood silviculture submitted to the CFRU for scientific soundness and recommend specific proposals for funding by the CFRU or other agencies.**
• **Review the progress of approved CFRU hardwood research projects and recommend them for continued funding.**
• **Regularly communicate information and knowledge (through the CFRU, Maine Hardwood Association, and other organizations) from current and past research about hardwood silviculture to a broad audience of forest landowners, forest managers, the media, and others interested in forest management.**
• **Promote the establishment of demonstration areas exhibiting a wide range of approaches to hardwood silviculture for education about hardwood management.**

Table 5. Hardwood Silviculture Research Priorities
• Develop improved vegetation management strategies for understory vegetation (including diseased beech, striped maple, and other interfering plant species) to promote the regeneration and growth of desirable hardwood species.
• Develop improved silvicultural strategies to regenerate, rehabilitate, or increase the productivity of stands that have been high-graded or subjected to diameter-limit cutting.
• Develop effective intermediate treatments for young, even-aged stands of northern hardwoods to improve species composition, stem quality, growth, and shorten sawlog rotations.
• Develop improved silvicultural strategies for growing and maintaining quality northern hardwoods as an integral component of mixed-wood stands.

Restructuring CFRU Dues Rate

The Advisory Committee spent considerable time this year discussing and eventually restructuring the way that CFRU members will pay their dues in future years. The dues issue was the last phase of restructuring the CFRU that began in 1998 (see 1999 and 2000 CFRU Annual Reports). It was recognized during this restructuring that the dues calculation on which the CFRU was based needed to be reevaluated. The dues rate had been fixed at $0.05/A since 1992 when the dues rate was reduced from $0.055/A. The decision to lower dues in the early 1990s came from a large budget surplus that had accumulated. The Advisory Committee decided at that time to lower dues and begin spending down this accumulated surplus.

During the next 14 years, the CFRU annually spent more than the dues being collected from members. By 2002, the entire surplus was depleted. During this period, inflation also had steadily eroded the purchasing power of the $0.05/A rate by about 31%. This problem was further exacerbated during the late 1990s by a 15% loss of contributing acres (from 8.5 million acres in 1998 to 7.4 million acres in 2002) from the substantial forestland sales to private investors who were not interested in supporting CFRU efforts. The combined effect of not increasing dues and the land sales has been a 38% reduction in overall purchasing power of annual CFRU dues contributions between 1990 and 2002. The organizational restructuring that occurred during 1999-2000 substantially reduced staff expenses, but some form of financial restructuring was clearly needed to secure long term and stable funding for the CFRU.

The Advisory Committee assigned a Financial Subcommittee to address the issue in early 2001. This subcommittee recommended a two-step increase in annual dues rate ($0.055/A in FY02 and FY03, and $0.060/A in FY04) and then tying future CFRU dues increases to an accepted consumer price index that would allow dues to keep up with inflation. After considerable discussion at the July 2001 meeting, the Advisory Committee strongly supported (by 8 to 1 vote) a dues increase for all members of $0.055/A (a return to the 1989 rate) with any future increases to be dealt with on a year-to-year basis.

Shortly thereafter, however, two of CFRU's largest members, International Paper Company and Irving Woodlands (who together provide 39% of the dues contributions), indicated a strong dissatisfaction with the increase. As a result, the Financial Subcommittee was asked by the Advisory Committee (at the Jan 22, 2002 meeting) to return to the table and develop a new set of recommendations.

The Financial Subcommittee met three times (Feb 21, Mar 12, Apr 4) and discussed a wide variety of options. Most of the discussion centered on developing a formula for a tiered dues structure (i.e., increasing the rate per acre paid for the first tier of acres owned and then systematically decreasing the dues rate per acre for additional tiers of acres owned). Unfortunately, a consensus could not be reached to support a specific formula. As a result, the subcommittee asked IP and Irving to jointly develop a proposal for consideration by the full Advisory Committee.

At the July 16, 2002 Advisory Committee meeting, IP and Irving representatives presented a three-tiered dues proposal that would be implemented in two phases during the 2002-03 and 2003-04 fiscal years. The Advisory Committee (by 9 to 5 written vote) agreed to implement only the first phase of the IP and Irving proposal. The new dues structure is presented in Table 6. This change in the dues structure will be reflected in the invoices sent to CFRU members in January 2003.

Sincere thanks go to all Advisory Committee members for their steadfast support during these long and sometimes difficult financial discussions. This support reflects the strong commitment that CFRU members have to improving the management of Maine's forests over the long term. To accomplish its mission, the CFRU clearly needs a dues structure that is relatively stable, supports a critical mass of research activity, can keep pace with inflation, is buffered against corporate mergers, and is perceived as equitable by all members. The Advisory Committee made substantial progress in this regard over the past year.

Table 6. New CFRU three-tiered dues structure to be implemented during 2002-03.

Land owned or managed	Rate paid per acre
First 500,000 acres	$ 0.0575
Next 500,000 acres	$ 0.0525
Acres over 1,000,000	$ 0.0500

ORGANIZATIONAL ACTIVITIES

Field and Data Report

Long-term data and field installations are the CFRU's most valuable capital assets. The maintenance and protection of these assets is critical to the success of this organization. This past year we made significant progress in ensuring the protection of three important studies: Weymouth Point, Austin Pond, and the Commercial Thinning Research Network.

Weymouth Point

One of the CFRU's most significant achievements, the Weymouth Point study has substantial historic and future value for forest management in the state (Figure 2). It is the only long-term research site in Maine, and one of the few watershed studies in New England that combines silvicultural and environmental research that is relevant to issues concerning sustainable forestry. Furthermore, Weymouth Point offers an excellent opportunity for new research projects that incorporate the issues of forest productivity and the maintenance of site quality in a framework of multiple-use forestry.

The ability to initiate new research at Weymouth Point requires that researchers have access to well-documented historic data and the locations of previous sample plots. In the fall of 2001 we assessed the state of the research site and data files and found both to be in danger of being lost. Thousands of data files were scattered throughout the region and stored on a variety of magnetic media including 9-track tapes, 5.25" and 3.5" floppy disks and zip disks. In the field, the boundary of the treated watershed was all but invisible and several plot markers had disappeared. It was evident that both the data and study site was in dire need of restoration.

During the summer of 2002 we re-marked the perimeter of each watershed with boundary paint and collected GPS positions for the grid system. In addition, we reestablished landmarks and

Figure 2. The Weymouth Point study (above) has substantial historic and future value for forest management in the state provided that the study area and data are preserved for future use.

collected GPS coordinates for all of the important study site features including: plot, soil pit, stream samples, weather station, and lysimeter locations. In the winter of 2002-03 we will digitize an old hard-copy site map and create a GIS that has locations for the features discussed above.

Over the past year we've spent a considerable effort locating and securing data files from throughout the region. To date, we have collected more than 75 files including stream nutrient data files that span more than a decade. Through the winter of 2002-03 we will organize and document these data to create a Weymouth Point database. Upon completion, the database and maps will be made available to our Cooperators on the CFRU website.

Austin Pond

Initiated in 1977 Austin Pond is the CFRU's oldest ongoing study. This past year we installed over 100 6-foot steel fence-posts at each plot corner, re-painted the perimeter of the study boundary and hung CFRU research area signs around the study area. In addition, we collected location data for each plot corner using GPS equipment and created detailed plot and access maps. We are working to restore several historic data files and will be incorporating these files with more recent data and our GIS to create a comprehensive project database.

Commercial Thinning Research Network

The Commercial Thinning Research Network represents a new generation of long-term CFRU research. As such, we have made a concerted effort from the outset to manage data and field installations for long-term accessibility. An important component to this effort is the development of a conventional system for managing and documenting data files. **Dan McConville** presented the vision for a new data management system at the January 2002 Advisory meeting and initiated a long-term data management strategy for the thinning project that was designed to be used as a conventional framework for managing all CFRU project data.

Over the past year considerable progress was made toward this goal. Last spring we researched several data management systems and found a suitable system for the CFRU that incorporates multiple data files with metadata (information about the data) in an easily retrievable system. The system was tested and implemented and the database will be available through the CFRU website in December 2002. We have begun using the system for other projects. Eventually, this data management and archival system will be used for all CFRU projects. including Weymouth Point and Austin Pond.

Given the long-term investment made in the commercial thinning project the protection of the field installations is a primary objective for the CFRU. Over the past 2 years we established 12 research sites that cover over 500 square miles of Maine. To date, eleven of the sites have received the initial thinning treatment (Figure 3). The remaining site is scheduled to be thinned in November, 2002.

The challenge for us is to protect these sites for at least 12-15 years—the projected length of the study. We collected coordinate data for each plot and created a GIS for the study to ensure our ability to locate plots into the future. Plot maps, access roads and directions to each study site are available on our website. In addition, more than 11,000 trees were numbered with aluminum tree tags; 336 steel fence-posts were installed (one at each plot corner); and more than 500 aluminum research study area signs were hung around the perimeter of each study area. By the summer of 2003 each site will have a 4' by 4' information poster describing the study objectives, methodology and results.

Figure 3. MeadWestvaco forester Dan Simonds (left) and Dan McConville assessing the width of a forwarder trail during a harvest operation on a Commercial Thinning Research Network plot.

ORGANIZATIONAL ACTIVITIES

Communications Report

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:

- Influence of forest structure on habitat use by American marten in an industrial forest
- Long-term effects of herbicide and PCT treatments on the development of spruce-fir stands: update on the Austin Pond study
- A user's guide to the forest vegetation simulator (FVS) and Suppose interface
- ThinME: development of commercial thinning guidelines for Maine spruce-fir forests
- 2001 annual report

In all, CFRU staff and scientists produced more than 50 new articles, reports and presentations over the past year (see “Technology Transfer, p. 71).

Field Tours

The annual Maine Society of American Forester's meeting, which took place at Austin Pond in May 2002 featured two CFRU studies; “Assessing Silviculture Research Priorities For Maine Using a Wood Supply Analysis,” and “Long-Term Effects of Herbicide and Pre-commercial Thinning on Young Spruce-Fir Stands: The Austin Pond Study.” These studies, presented by **Bob Wagner** and CFRU graduate student **Howard Daggett** highlighted the need for a better understanding of growth and yield responses in the spruce-fir forest (Figure 4). More than 200 participants were on hand to see the latest results of these key CFRU research studies.

Figure 4. Graduate student Howard Daggett presents the latest CFRU research findings to more than 200 forest professionals from around the state.

Web Page

In an effort to reduce mailing and paper printing costs and to give cooperators the convenience of 24 hour access to pertinent information we created a CFRU website in 2000. The move to web-based communications was an overwhelming success, both in reducing costs and providing greater access to information. However, as the volume of information increased limitations in the design became apparent.

This past summer we hired a consultant to overhaul the website to improve the overall design and function. New color-coded graphics improve the appearance and navigability of the site (Figure 5). Users can determine what section they are in based on the color scheme. Red graphics indicate the user is on the password protected part of the web page. Password access allows CFRU members early access to the latest CFRU research results and data. Green indicates users are on the public access part of the web page. Back-end improvements include a new file structure system that makes web updating more efficient and reduces the instances of broken links.

The new site was unveiled in September and will continue to grow as we add information. Our goals for the coming year include improving the frequency of updates and increasing the availability of project-level information on both sides of the website.

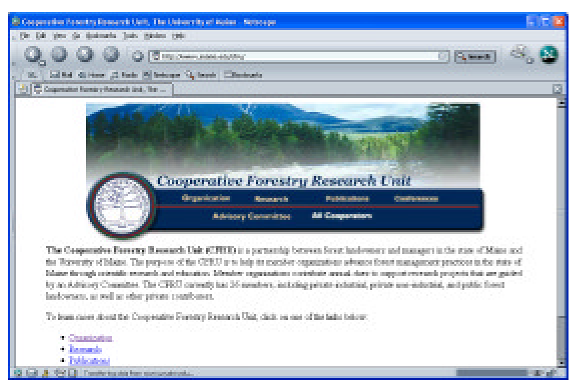

Figure 5. Visitors to the new CFRU website will notice the new look and organization by going to: http://www.umaine.edu/CFRU

ORGANIZATIONAL ACTIVITIES

Staff changes

Chip Griffin's departure as Communications and Financial Coordinator midyear provided us with an opportunity to reevaluate how to more efficiently deliver CFRU services. **Bob Wagner** and **Dan McConville** worked closely to evaluate essential functions and concluded all duties could be consolidated into a new Research and Communications Coordinator position, and a half-time Administrative Assistant position to manage payroll and purchasing. It was concluded that this change could maintain all essential services, improve efficiency, and significantly reduce staff expenses. Therefore, Dan McConville's job duties were re-written and a new half-time Administrative Assistant position was created. Dan McConville's reclassification was approved in September 2002 and we were very fortunate to hire **Joanna Silva** the new CFRU Administrative Assistant in October. Joanna is a native of Bangor, received a B.S. degree in Business from Liberty University in Virginia, and is well qualified for the position. Joanna will be in the office from Monday through Friday in the mornings. We also thank **Nora Ackley** (Dept. of Wildlife Ecology) for the excellent job she did filling in as the unit administrative assistant from June through September. We also wish Chip Griffin the best of luck in his new position with Jackson Labs at Bar Harbor.

SILVICULTURE RESEARCH

Commercial Thinning Research Network (click photo to read report)

Long-Term Effects of Herbicide and Pre-commercial Thinning on Young Spruce-Fir Stands: The Austin Pond Study (click photo to read report)

Height Growth Reductions in Red Spruce and Balsam Fir from Arsenal Herbicide Three Years After Application (click photo to read report)

Assessing Silviculture Research Priorities for Maine Using a Wood Supply Analysis (click to photo read report)

Factors affecting the Regeneration of Red Spruce and Balsam Fir
(click photo to read report)

Commercial Thinning Research Network

Robert G. Wagner, Robert S. Seymour, Daniel J. McConville, and Dawn M. Opland
University of Maine

Study Site Establishment and Measurement

Installation was completed this year for the twelve Commercial Thinning Research Network study sites planned for two separate studies in the spruce-fir forest type. Six sites with seven 1-acre plots (42 plots total) were established across the state in spruce-fir stands that have not received pre-commercial thinning (PCT) 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). Six sites with seven 1-acre plots (42 plots total) also were established in balsam fir stands that have received PCT 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). A total of 10,800 trees have now been tagged for long-term measurement across all sites (Figure 6). The location, descriptions, and experimental design details for all sites were reported in the 2001 CFRU Annual Report.

Plot installation, pre-treatment measurements, and thinning treatments were completed for the second set of sites selected in 2001. By the end of the 2002 field season, all scheduled pre-treatment measurements, thinning treatments, and harvested wood inventory measurements were completed for all sites. We thank the ten CFRU members that have provided study sites and indirect financial contributions to establish the Commercial Thinning Research Network (Table 7; Figure 7). Their substantial investment and long-term commitment to this project are much appreciated.

A proposal for continued work on network installations was presented by **Bob Wagner**, **Bob Seymour**, and **Dan McConville** at the May Advisory Committee meeting. The proposal provided a detailed plan for the periodic treatment, maintenance, and measurement of the twelve study sites for 2000 to 2010 (Table 8). Three years of continued work was approved for fiscal years 2002-03 to 2004-05. Work during the coming year will focus on these planned activities plus the ongoing and new projects associated with the study sites described below.

For more information contact **Bob Wagner** at bob_wagner@umenfa.maine.edu, or **Dan McConville**dan_mcconville@umenfa.maine.edu

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Table 7. CFRU members participating in the Commercial Thinning Research Network.

Contact	Organization
Brian Higgs	Baskahegan Co.
Kenny Fergusson	Huber Corp.
Phil Malerba	International Paper Co.
Hugh Crammond	Irving Woodlands
Tom Charles	Maine Bureau of Parks and Lands
Si Balch	MeadWestvaco Corp.
Doug Denico	Plum Creek
John Cashwell	Seven Islands Land Co.
Jacques Morin	St. Aurelie Timberlands
John Brissette	U.S. Forest Service

Figure 6. We will be closely monitoring the growth of more than 10,000 trees over the next decade to understand growth responses to commercial thinning.

Table 8. Approved plan for the establishment, treatment, maintenance, and measurement of current study sites in the CFRU Commercial Thinning Research Network Treatment for 2000-2010.

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

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

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

IM = Intensive post-treatment measurement (DBH, total height, and crown height on every tagged tree; measure ing-rowth; 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)

Figure 7. Generous in-kind support from our cooperating members made possible the use of state of the art harvesting equipment in remote locations. A Valmet processor (left) carefully follows the thinning prescription on Baskahegan land in northern Washington County; and a 16-ton Rotnne forwarder painstakingly lays each log in single file for easier measurement (right) in Parmachenee Township in Western Maine.

Projected Spruce-Fir Responses to Commercial Thinning Treatments

Work by CFRU graduate student **Dawn Opland** during the past year has focused on projecting the long-term growth and yield responses of each study plot following the commercial thinning treatments. This effort is intended to provide CFRU members with a preliminary estimate of how the commercially thinned stands in the network are likely to respond to various treatments, assess the likely economic feasibility of commercial thinning, and examine the ability of current growth and yield models to simulate commercial thinning responses.

Pre-treatment and first-year post-treatment data of each plot in the older unthinned stand experiment were used with the Forest Vegetation Simulator (NE TWIGS variant) to project future stand development for ten-year periods over the next 100 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 based on several merchantability standards. Stumpage prices from the Maine Forest Service (2000), 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 100-year simulation.

We calculated the difference in NPV produced between the thinned and unthinned scenarios for each plot as the basis for comparing treatment effects. Preliminary results indicate that dominant thinning treatments yielded a higher NPV than crown thinning treatments. Crown thinning treatments tended to produce a higher NPV than low thinning treatments. As expected, the NPV of the thinning treatment tended to increase as the number of large diameter trees removed by the treatment increased. Results for one of the study sites (Sarah's Road) are shown in Figure 8.

In addition, we compared differences in the NPV of the residual stands produced by each of the treatments. To make this comparison, we removed the value of the wood taken in the thinning treatment from the financial analysis to isolate the effect of each treatment on the future value of the residual stand. We calculated the difference in NPV produced between the thinned and unthinned scenarios as before (Figure 9). The treatments that removed larger diameter trees, as expected, tended to reduce the future value of the residual stand. To our surprise, however, the NPV of the heavy thinning treatments tended to increase rapidly after thinning, and within 10 to 30 years catch up to stands that were thinned much more lightly (Figure 9). This response is not what would be expected of a stand where most of the large diameter trees were removed.

Figure 10 shows the difference in growth between the thinned and unthinned scenarios for each treatment on the Sarah's Road site. The rapid growth of both dominant thinning treatments relative to treatments removing much less volume is unrealistic. The projections also indicate that the volume growth for some treatments and sites is reduced for a short time after thinning, but exceeds that of the unthinned scenario within 10 to 30 years.

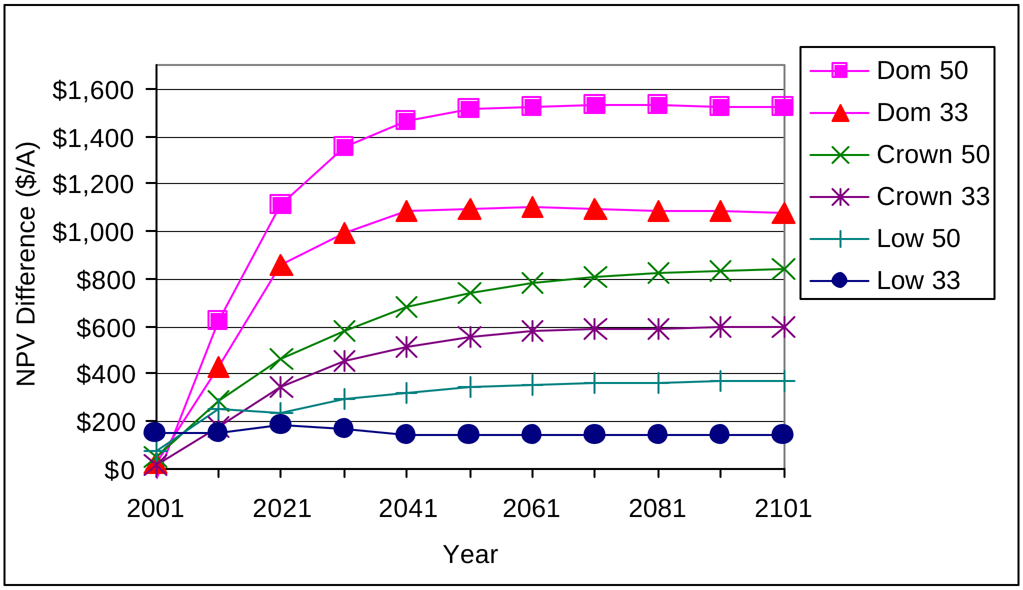

Figure 8. Difference in net present value of residual stand (i.e., revenues from wood removed by commercial thinning treatments not included) between thinned and unthinned scenarios for the six commercial thinning treatments applied in a natural stand (Sarah's Road site) that had not received PCT. A 4% discount rate was used.

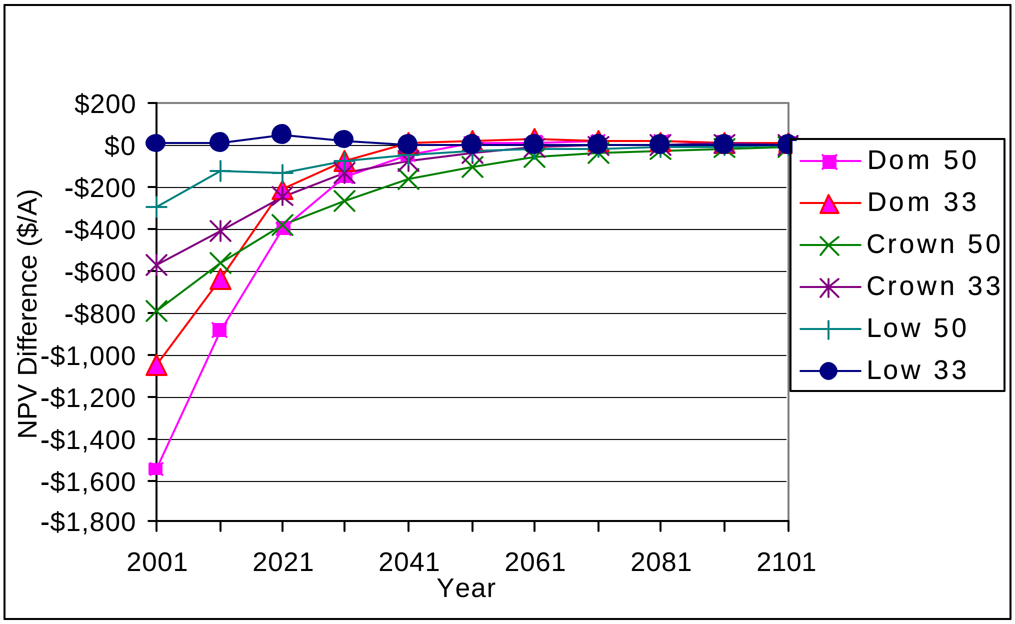

Figure 9. Difference in net present value between thinned and unthinned scenarios for the six commercial thinning treatments applied in a natural stand (Sarah's Road site) that had not received PCT. A 4% discount rate was used.

It was obvious from this analysis that the NE TWIGS growth model we are using did not produce realistic stand responses after some treatments. Since NE TWIGS was developed largely from data derived from unmanaged natural stands, it was uncertain how this model would handle a variety of commercial thinning scenarios.

After examining the model outputs more closely, we found that the model is growing previously suppressed and intermediate residual trees on the dominant thinned plots much more rapidly than expected. In contrast, trees in dominant and co-dominant crown classes should outgrow previously intermediate and suppressed individuals (Figure 11).

The Forest Vegetation Simulator (FVS) with NE TWIGS variant is a well-supported model by the U.S. Forest Service. Thus, it has the potential to be a mainstay growth and yield model for the state and region. Data from our network study plots have already been useful in identifying problems that will need to be addressed if FVS is to be useful for managed stands.

Continued work this coming year will focus on modeling responses of plots in the part of the study examining thinning in previously PCT'd stands. Completion of Dawn Opland's M.S. thesis is scheduled for mid 2003. For more information about this portion of the study, contact:

Dawn Opland: Dawn_Opland@umenfa.maine.edu,
Bob Wagner: bob_wagner@umenfa.maine.edu.

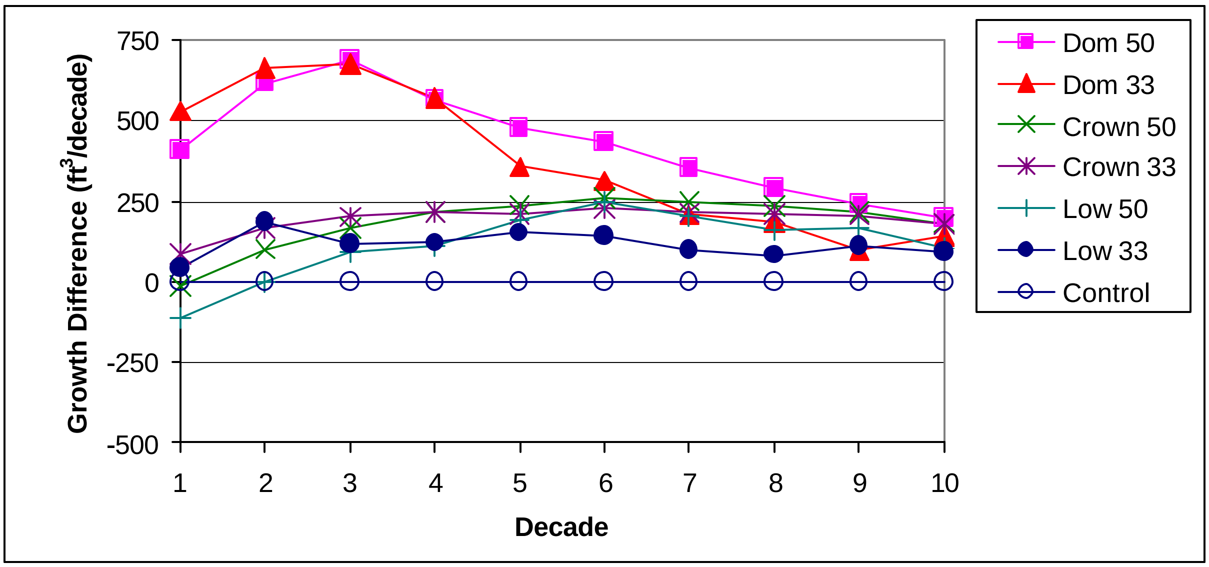

Figure 10. Difference in volume growth of residual stands between thinned and unthinned scenarios for the six commercial thinning treatments applied in a natural stand (Sarah's Road site).

Figure 11. Suppressed trees released from the dominant thinning treatments at the Huber Golden Road site (above left and right) showed sparse crowns, looked unhealthy, and in many cases died soon after thinning. However, the NE Twigs growth model projected little mortality and a strong response. Clearly, modifications to the model are required for accurate predictions of growth responses following thinning.

New Research on Network Study Sites

In addition to the continued maintenance and measurement work approved the commercial thinning plots described above, several new graduate student projects were proposed to address key questions associated with commercial thinning. These graduate student projects are intended to take full advantage of the new research plots and data that are now available through the network.

Last year's completion of the first version of the ThinME model identified a number of opportunities for improvements to the model. **Bob Seymour** will lead two new graduate student projects addressing modeling issues associated with commercial thinning. These projects will use data gathered from the existing plots, archived data sets assembled by **Ralph Griffin** and his graduate students over two decades (1965-85), and remeasured plot data from other available sources to improve the growth and yield components of ThinME. One of these students will be supported by the CFRU and the other sponsored by Bob's MAFES/McIntire-Stennis funding. Two new M.S. students (**R. Justin DeRose** and **Spencer Meyer**) were accepted and began their programs in September 2002. Work over the coming months will focus on the details of the specific work to be accomplished.

A new project proposed by **Bob Wagner** will focus on developing a better understanding of how well the commercial thinning treatments were applied in the two studies. One of the more interesting questions that can be asked early in the study is how efficiently each of the thinning treatments redistributed growing space. Since the primary objective of thinning is to reallocate growing space to individual trees, it is clearly important to know how well each of the thinning methods accomplished this objective. Documenting the spatial locations of all trees within the plots both before and after treatment has been part of the study protocol. Therefore, we have the necessary data to examine how each of the treatments redistributed growing space in two and three dimensions around individual trees in the study plots. Bob will be seeking a new graduate student to take on this project in the next fiscal year.

Two other projects also were proposed and funded this year that will use the research plots established under the network. **Mike Greenwood** proposed and began work documenting cone production and regeneration patterns following several of the thinning treatments. Details of this project can be found on pages 37 of this report. **Rakesh Minocha** of the USFS Northeastern Research Station received funding from the Agenda 2020 program to examine the effects of various silviculture treatments on physiological stress, carbon and nitrogen metabolism in trees, and their relationship to forest productivity. Her specific objective is to determine the influence various commercial thinning treatments has on biochemical stress indicators in thinned and unthinned trees in both thinning studies. Chemical analysis will be conducted on spruce and fir foliage collected from plots on two of the network study sites during the summer of 2003.

For more information about these new studies, contact **Bob Wagner** at 207-581-2903 or bob_wagner@umenfa.maine.edu, **Bob Seymour** at 207-581-2860 or seymour@umenfa.maine.edu, or **Mike Greenwood** at 207-581-2838 or greenwd@umenfa.maine.edu.

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Long-Term Effects of Herbicide and Pre-commercial Thinning on Young Spruce-Fir Stands: The Austin Pond Study

R. Howard Daggett and Robert G. Wagner

University of Maine

Steady progress was made toward the completion of Howard Daggett's M.S. thesis on Austin Pond. The objectives of the thesis research are to: (1) compare the effects of herbicide and pre-commercial thinning (PCT) treatments (22 and 13 years after treatment, respectively) on overstory composition and wood volume in 29-year old spruce-fir stands; and (2) project future stand development of all study plots and evaluate potential long-term financial returns associated with various combinations of herbicide and PCT treatment in spruce-fir stands.

Objective #1 was completed last year and the results published in a CFRU Research Note in April 2002 (Daggett and Wagner 2002). Work on the second objective was completed this year and the results reported below.

Methods

The Forest Vegetation Simulator (NE TWIGS variant) was used to project stand development on each Austin Pond plot for the next 100 years. Stand conditions measured on the 52 surviving Austin Pond plots during 1999 (29 years stand age) were used as the starting point and the model run using 10-year periods. Total stemwood volume, merchantable wood volume, wood value, net present value (NPV), and internal rate of return (IRR) were calculated at the end of each period for each plot. From these calculations, maximum NPV, age at maximum NPV, number of years of positive NPV, and the NPV integral (calculated numerically) also were calculated for each plot.

NPV was calculated as the difference between the sum of discounted revenues and the sum of discounted costs. The discounted revenues were calculated as the wood value at the end of the period discounted to the year 2000. Wood values were based on average stumpage prices paid to Maine landowners in Somerset County for the year 2000 that are published by the Maine Forest Service. The sum of the discounted costs was calculated using $50 per acre in 1977 for herbicide application and $200 per acre in 1986 for PCT and compounding these costs forward to the year 2000. A cost for PCT of $180 per acre was applied if the plot had received herbicide treatment. NPV was calculated at discount rates of 4, 6, 8, 10 and 12%. The influence of three merchantability standards (2" x 4", 3" x 5", and 4" x 6" minimum pulpwood top x minimum sawlog top) and differing future harvest costs as a result of treatment also were examined.

Based on treatment comparisons from the Objective #1 analysis, herbicide treatments producing similar results were pooled into three herbicide treatment groups for the Objective #2 analyses: Glyphosate-Triclopyr, Phenoxy, and Control (no herbicide). Each herbicide treatment group had a PCT and no-PCT treatment, providing six herbicide and PCT treatment combinations.

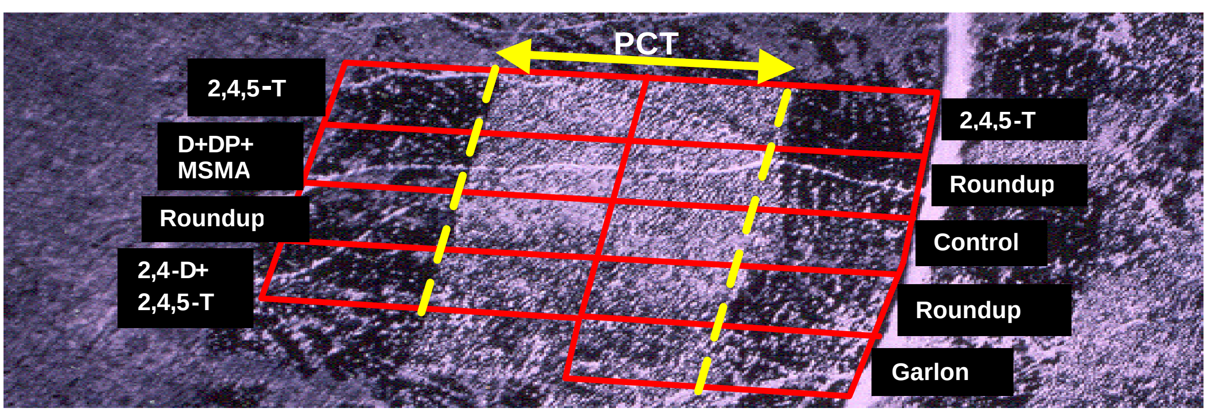

Figure 12. 1989 air photograph depicting Austin Pond experimental design 12 years after herbicide and 3 years after PCT.

Results and Discussion

Total stemwood volume over the simulation period was greater for the two herbicide-only treatment groups [Glyphosate-Triclopyr (Gly-Tri) and Phenoxy] than all other treatments (Figure 13). Although having similar volumes to the herbicide-only treatments before age 40, the Control-only volume diverges substantially at age 50, producing less volume overall. This leveling off is likely due to the high intolerant hardwood composition of the plots as a result of receiving no herbicide treatment early in stand development (Table 9). Total volume was lower on all plots receiving PCT, regardless of whether herbicides were used. There was some evidence of increasing growth on the PCT-treated plots in the simulation. At age 29, total volume with PCT was about 65% of that found in the herbicide treatments without PCT but about 75% of total volume by age 50. Despite this apparent increase, however, there was still a substantial reduction in total volume over the entire simulation period as a result of the PCT treatment.

Species composition throughout the rotation was influenced substantially by both herbicide and PCT treatments. At age 50, softwoods were projected to compose 77% and 66% of the total volume in the Glyphosate-Triclopyr-only and Phenoxy-only treatments, respectively, compared to only 32% for the Control-only (Table 9). PCT created a much larger dominance of softwoods; with fir and spruce comprising nearly 84% of total stand volume in the PCT-only treatment compared to 32% in Control-only treatment. Prior herbicide treatments further enhanced softwood composition in PCT-treated plots, with fir and spruce comprising 93% and 89% of total stand volume in the Glyphosate-Triclopyr + PCT and Phenoxy + PCT treatments, respectively, compared to 83% in the Control + PCT treatment.

Herbicide and PCT influences on projected merchantable wood volume were similar to those for total volume. There was little difference in merchantable volume between the two herbicide only treatments, and by 50 years, both herbicide only treatments had higher merchantable volumes than the Control only. Contrary to what we had expected, merchantable volume in plots receiving PCT was lower than herbicide-only treatments throughout the entire simulation. Between ages 70 and 80 years, merchantable volume in the Control only plots falls below that of plots that received PCT.

Maximum NPV occurred at about 50 years for all treatments. Treatments without PCT attained a higher maximum NPV than those treatments with PCT depending on the merchantability standards used.

Based on comments received from the Advisory Committee on preliminary results, additional computer runs are being made using several merchantability standards and discount rates.

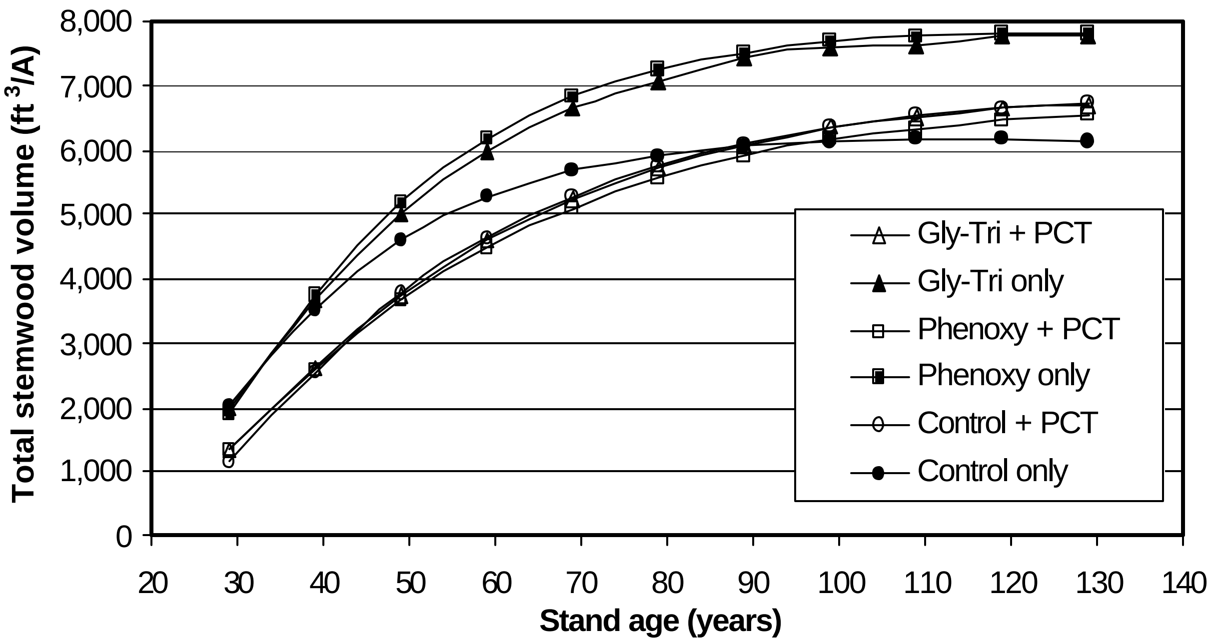

Figure 13. Projected stemwood volume for six combinations of herbicide and PCT treatments for 100-years using the NE TWIGS variant of the Forest Vegetation Simulator.

Table 9. Projected stemwood volume and tree species composition at age 50 years for six combinations of herbicide and PCT treatments.

Tree Species	Glyphosate-Triclopyr		Phenoxy		Control	
	Volume (ft^3/A)	% of total	Volume (ft^3/A)	% of total	Volume (ft^3/A)	% of total
No PCT						
Softwood	3,869	77.0	3,429	66.0	1,472	32.1
Hardwood	1,154	23.0	1,762	34.0	3,108	67.9
All species	5,023	100.0	5,191	100.0	4,581	100.0
PCT						
Softwood	3,469	93.0	3,282	89.4	3,142	83.6
Hardwood	259	7.0	389	10.6	615	16.4
All species	3,728	100.0	3,670	100.0	3,757	100.0

Conclusions

Our preliminary financial analysis of the Austin Pond plots suggests that the cost of PCT will not be recovered by the increased value of the larger stems, earlier merchantability, or shift to higher-value conifer species.

Some of this result may be due to the wide PCT spacing standards (700 TPA) of the 1980s that were used in this study. This wide spacing may have created more inefficiently used or unused growing space than with current tighter spacing standards for PCT. Herbicide treatments alone cost substantially less than PCT and produced similar improvements in species composition to PCT, thus producing a higher NPV.

It also should be noted that this analysis occurred at the stand level. The value of PCT and herbicide treatments also needs to be evaluated at the forest level where increasing spruce-fir composition and earlier wood flow over an entire forest can produce and overall improvement in harvest level and NPV. Recent results from the CFRU wood supply analysis provide an analysis of PCT and herbicide treatments at the state level (see page 34 of this report). The importance of PCT and herbicides was demonstrated in this forest-level analysis.

This project also represents one of our first efforts at using the NE TWIGS model to simulate future stand development following various silvicultural interventions. It is unclear at this point how well this model projects future stand development under these conditions. Since our conclusions are based on projecting stand conditions for a relatively short period (to age 50 from conditions at 30 years), however, we are reasonably confident in the overall conclusions presented here.

Howard Daggett plans to complete his M.S. thesis in 2003. For more information about this study contact **Bob Wagner** at **207-581-2903** or **bob_wagner@umenfa.maine.edu**.

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Daggett, R.H. and R.G. Wagner. 2002. Long-term effects of herbicide and PCT treatments on the development of spruce-fir stands: Update on the Austin Pond study. Cooperative Forestry Research Unit, University of Maine, Orono. CFRU Research Note, CFRU RN 02-01. 4 p.

Height Growth Reductions in Red Spruce and Balsam Fir from Arsenal Herbicide Three Years After Application

Bob Wagner
University of Maine

In the 2000 CFRU Annual Report (pgs. 34-35), results from remeasurement of the imazapyr (Arsenal®) herbicide plots in the CFRU seasonal tolerance study were reported (Figure 14). Previous results showed that Arsenal applications reduced the number of needle primordia in terminal buds immediately after treatment and subsequently reduced height increment in both balsam fir and red spruce for two growing seasons. To determine whether height increment was still being reduced in the third year, we measured the height increment of 10 spruce and 10 fir in all Arsenal treated and untreated control plots (894 trees total) during the fall of 2001.

Results for all years are shown in Figure 15. There is clear evidence of some recovery for height increment in the third growing season after treatment for both fir and spruce at the 2 and 4 ounce / A rates. However, height increments were still less than that of the untreated control trees for both herbicide rates and all application timings. Height increments in the third year (all application timings combined) were reduced 42.5% and 49.1% for balsam fir after the 2 and 4 ounce / A rates, respectively. Reductions for third-year height increment for spruce were less severe; 26.3% and 34.0% less for the 2 and 4 ounce / A rates, respectively.

Despite the reductions not being as severe for spruce, most of the timings for both herbicide rates were statistically less than the untreated controls (Figure 15). Higher coefficients of variation in the height increment for fir probably contributed to the lack a statistical difference among treatments.

Differences among the timings of application seen in the previous years were less apparent in the third season, suggesting that the longer-term effects of application timing are less important than whether the trees were treated or not. Differences between the herbicide rates also appear to be less important than in previous years.

Thus, the negative effects on height growth from using Arsenal herbicide in conifer release treatments appear to persist for at least three years following application. Based anecdotal reports from CFRU members, results from this study have led to reduced usage of Arsenal herbicide in aerial herbicide programs around the state. For more information about this study contact **Bob Wagner** **bob_wagner@umenfa.maine.edu**.

Figure 14. Red spruce and balsam fir height growth was monitored for three years following herbicide applications

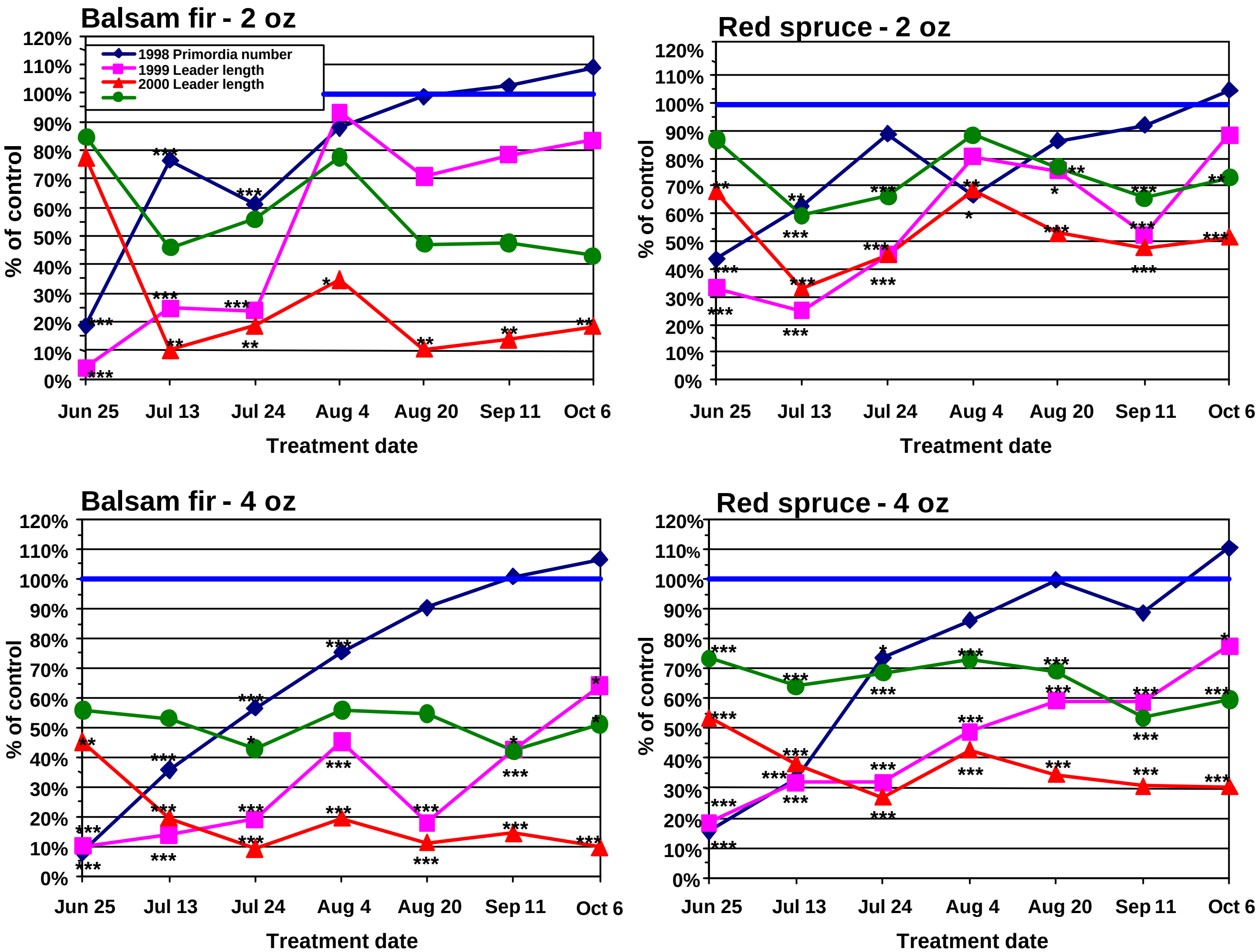

Figure 15. Number of needle primordia in terminal buds in 1998 (immediately after application) and leader lengths in 1999, 2000, and 2001 (first, second, and third growing seasons following application) expressed as a percentage of that observed for untreated control plots after imazapyr (Arsenal) herbicide applications to red spruce and balsam fir at two application rates and at seven times of application during the growing season. Means indicated by *, **, *** are different from the untreated control plots at p<0.1, p<0.05, p<0.01, respectively, based on orthogonal contrasts. Means without asterisks are not different from untreated controls.

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Assessing Silviculture Research Priorities for Maine Using a Wood Supply Analysis

Bob Wagner,[1] Bob Seymour,[1] and Ernest Bowling [2]
[1] University of Maine[2], James W. Sewall Company

The final report on an analysis of silvicultural research priorities using a model of Maine's future wood supply was completed this year. Several CFRU members provided a detailed review of the draft report. Their comments were incorporated into the final draft. We thank Ken Laustsen (Maine Forest Service), Si Balch (MeadWestvaco), and Peter Triandafillou (Huber Resources) for their review and comment. The following is the Executive Summary presented in the final report.

Problem

The 1998 "Timber Supply Outlook for Maine: 1995-2045" report by the Maine Forest Service (MFS) revealed the importance of understanding how various forces are likely to influence Maine's future wood supply. Much of the Maine's forest is currently in a young and vigorous condition, and opportunities for increasing the growth of this forest through more intensive silviculture have never been greater. The MFS report also identified that increasing the number of acres under intensive or high-yield management was needed to achieve more sustainable levels of harvest.

One of the principal limitations to projecting changes in wood supply under increasing levels of high-yield management has been a lack of information about how the component treatments of intensive silviculture chiefly tree planting, herbicide use, pre-commercial thinning (PCT), and commercial thinning are likely to alter growth and yield responses in forest stands (Figure 16). Silviculture research is the primary means used to provide this information. Since silvicultural research is a long-term and expensive proposition, identifying which silvicultural treatments are likely to have the greatest influence on future wood supplies is essential. This information is especially important for forest research programs, such as the University of Maine's Cooperative Forestry Research Unit, that must identify the highest forest research priorities to most effectively allocate limited research funds.

Project Objectives

To identify the highest priorities for silviculture research in Maine, we accomplished the following objectives:

- quantified the absolute and relative influence of future silvicultural investments (tree planting, herbicide application, and PCT) and commercial thinning on projected harvest levels and future wood supplies in Maine;
- quantified the absolute and relative importance of the growth and yield assumptions (via sensitivity analysis) used in estimating the influence of these silvicultural treatments on projected harvest levels and future wood supplies in Maine; and
- based on the absolute and relative importance of the growth and yield assumptions and on the influence of differing levels of future investment, ranked which areas of silviculture research are likely to be most important for improving Maine's future wood supply.

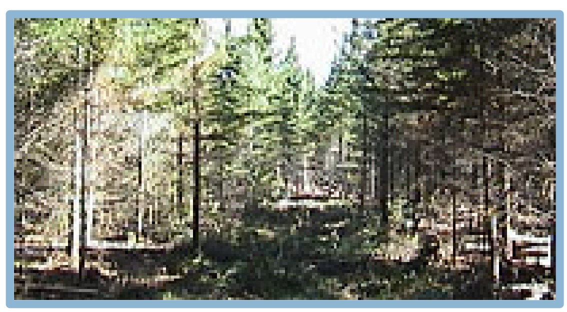

Figure 16. Maine's future wood supply can be met through intensive silviculture, such as planting (left), pre-commercial and commercial thinning. As the oldest PCT stands in the state approach financial maturity some landowners are meeting wood supply demands through commercial thinning (right).

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Modeling Approach

We used the analysis described in the 1998 MFS Timber Supply report for Maine as a starting point. Our intention was not to duplicate or reinterpret the 1998 MFS timber supply analysis. Instead, we used the original input files and modeling assumptions developed by the MFS as a platform for conducting a sensitivity analysis on 1) a range of future silviculture investment scenarios and 2) assumptions about growth and yield responses to specific silvicultural treatments.

Because the *Aggregate Timberland Assessment System* (ATLAS) computer simulation model used by the MFS in their analysis had several of shortcomings for our purposes, we chose the *Woodstock* forest modeling system. Every effort was made to ensure that our Woodstock model was able to reproduce outputs from the 1998 MFS ATLAS model. Due to differences between the models, however, we modified the objective function, constraints, yield functions, and other assumptions in order to produce reasonable model outputs and behavior.

We developed a discounted cash flow model with an objective function that maximized the sum of the discounted cash flows subject to constraints on period-to-period harvest levels and ending inventory. The combined cash flow objectives and wood flow constraints produced a model with rational and realistic behavior.

Growth, harvest, and inventory for Maine's forest were projected for a 100-year simulation period (1995 to 2095). Differences in the projections produced by the MFS 1998 ATLAS model and our Woodstock model were examined and are described in detail.

The primary response variables examined in the analysis were changes in the annual sustainable harvest level (ASHL) in ft^3/yr and net present value (NPV) in \$/A. Changes in ASHL and NPV were used as the basis for evaluating the influence of systematically modifying a variety of independent variables and model assumptions for the 100-yr model runs.

Analysis

Our analyses included quantifying the effect of increasing acres treated with tree planting, herbicide application, and PCT on ASHL and NPV. While conducting the analysis, a variety of questions arose about the magnitude of influence key model assumptions had on patterns of harvesting, ASHL, and NPV. We examined the influence of 1) different intensities of silvicultural treatment on harvest actions, 2) changing the clearcutting constraint, 3) factors affecting the use of commercial thinning, 4) management intensity on effective rotation age, 5) changing treatment costs, 6) changing discount rates, and 7) landownership classification. We also compared continuing current levels of planting, herbicide application, and PCT in Maine relative to the optimum selected by our model.

The final model provided the basis for accom-plishing the primary objective – quantifying the absolute and relative importance of the growth and yield assumptions for tree planting, herbicide application, and PCT on the Maine's future wood supply. We performed this sensitivity analysis by examining changes in the ASHL and NPV in 100-yr simulations resulting from ±10% and ±20% changes in the slope of the base yield functions describing stand responses to these treatments as well as the area treated annually.

In addition, we used the model to examine how various factors influenced the use of commercial thinning. Factors examined include: 1) slope of the post-thinning yield function, 2) volume requirement for first commercial entry, 3) financial value of the residual stand following thinning, and 4) the constraint on the maximum number of acres that could be clearcut in any period.

Based on the relative sensitivity of ASHL and NPV to changing the yield assumptions associated with tree planting, herbicide application, PCT, and commercial thinning, we ranked which areas of silviculture research are likely to be most important for improving Maine's future wood supply.

By comparing the relative effects of these three treatments in the analysis, we also concluded that the ranking for more precisely knowing the growth and yield response to these treatments should be PCT > herbicide > planting.

Key Findings

- Our model produced more optimistic projections of Maine's future harvest, growth, and inventory for the next 100 years than the 1998 projections by the Maine Forest Service. Our projections showed higher rates of growth, higher harvest levels, and a more stable inventory. The differing projections resulted from differences in model structure, solution methods, and a variety of other factors.

- The optimum future treatment scenario was zero A/yr of planting, and 21,458 A/yr of herbicide application, and 122,908 A/yr of PCT. The resulting ASHL was 740.7 MM ft^3 (31.1% or 176 MM ft^3 higher than if no further planting, herbicide, and PCT treatments were applied). The NPV of Maine's forestland under this optimum scenario was $338/A (12.1% or $36.42 higher than a no future treatment scenario). The total value of this optimum scenario for Maine's forest was $617,420,337.

- If the current acreage (based average 1995-2000 usage) of planting (11,232 A/yr), herbicide (14,052 A/yr), and PCT (19,887 A/yr) were applied annually over the next 100 years, the ASHL would be 613.0 MM ft^3 with a NPV of $325/A. This is 8.5% (48 MM ft^3) and 7.8% ($23.41/A) higher, respectively, than if no further planting, herbicide, and PCT treatments were applied to Maine's forest. The total value of this level of silvicultural investment for Maine's was $396,896,190.

- Limiting the use of herbicides and PCT only to large landowners (those owning >100,000 acres) reduced the ASHL by 11.7% and NPV by 1.6% under an optimum future treatment scenario.

- Increasing the amount of clearcutting in the model did not significantly alter future sustainable harvest levels or timberland financial values. Our model generally had the maximum acreage of clearcutting set at 30,000 A/yr. Lifting this constraint increased the acreage of clearcutting by two- to three-fold depending upon the amount of planting, herbicide treatment, and PCT applied. However, this increase did not alter the projected ASHL or NPV. ASHL remained unchanged or declined slightly, and the NPV increased less than 1%.

- Shelterwood harvesting (first entry in a two-stage system or overstory removal) was the principal harvest action selected by the model over the 100-yr simulations, and was independent of the levels of future tree planting, herbicide application, and PCT. Three-stage shelterwood was rarely selected. Uneven-aged management, as modeled by repeated partial harvests (selection system), was seldom chosen when even-aged methods (shelterwood and clearcut) could be used.

- A ±10% change in the slope estimate of the yield curves for the planting, herbicide, and PCT treatments produced a change in the ASHL calculation that is 56% to 81% of the projected gain from applying these treatments at current levels into the future. A ±20% change in slope estimate produced a change in the ASHL that was 117% to 141% of the entire projected gain from applying these treatments. Therefore, accurately calculating the allowable cut effect from continuing current levels of these treatments requires that the error in slope estimation be well below ±10%. The effect on NPV from a ±10% and ±20% slope deviation was less than on the ASHL.

- Based on current and the likely future acres of application, projected increases in ASHL and NPV, and the proportional influence of a ±10% and ±20% deviation in the slope of the yield curves, the suggested ranking of research priorities among the three silvicultural treatments examined is PCT > herbicide > planting.

- Commercial thinning was selected as a harvest option on less than 20,000 A/yr, substantially less than other harvest actions. Increasing the slope of the post-thinning yield curve, reducing the volume required for first entry, and enhancing the financial value of residual stand all increased the amount of commercial thinning done by the model. However, increasing the amount of commercial thinning had minimal influence on ASHL and NPV.

- Based on ASHL and NPV effects, understanding the yield responses to PCT, herbicide application, and tree planting should be a higher research priority than understanding the post-thinning yield responses following commercial thinning.

The final draft of the full report will be published as a Maine Agricultural and Forest Experiment Station Technical Bulletin and should be available early next year at: http://www.umaine.edu/cfru/. For more information about the study or report, contact **Bob Wagner** at bob_wagner@umenfa.maine.edu.

Factors affecting the Regeneration of Red Spruce and Balsam Fir

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University of Maine

Introduction

Post-harvest regeneration in the spruce fir forest has historically been dominated by balsam fir (Westvelde 1931) and this observation has been frequently confirmed (e.g., Place 1951, Randall 1976, Filauro 1976 and others). Even when there is ample mature, cone-producing red spruce in the overstory following partial harvest, balsam fir regeneration still predominates. For example Brissette (1996) reports that in all the treatment compartments at the Penobscot Experimental Forest (PEF) balsam fir regeneration (seedlings less than 15 cm tall) outnumbered spruce 17,239 to 6,635. This observation is surprising in that there are a total of 1,353 spruce and 1,128 fir trees greater than 11 cm in diameter that were potential seed producers. 628 of the spruce trees were greater than 21 cm in diameter, while only 25 balsam fir exceeded this diameter. Visual estimates over the last two years indicate that red spruce at the PEF has produced abundant cone crops both years, while balsam fir has produced virtually no cones this last year. This year (2002) balsam fir has produced a very heavy cone crop.

In this study we have examined the effects of moisture stress on germination (of red spruce and balsam fir seed obtained from the Canadian National Tree Seed Center) using polyethylene glycol, a metabolically inert osmoticum, to provide varying levels of moisture stress during seed germination in a relatively high (30^0 C day, 20^0 night) and low (20^0 C day, 10^0 night) temperature regimes. We also compared relative survival in response to drought of container-grown seedlings of both species 60 and 150 days after germination. In addition we have begun yearly surveys of cone production and regeneration by both species.

Effects of temperature, moisture stress on germination

The results of the germination study are shown in table 10. With no moisture stress, red spruce germinated much more completely in the cool regime, while balsam fir germinated somewhat more completely in the warm regime. The same trend was evident with 0.25MPa moisture stress, but germination was slightly reduced for both species. With the highest level of moisture stress, no germination was observed for red spruce, but a few seeds of balsam fir germinated. Overall, balsam fir exhibited slightly less germination that occurred over a longer period of time than that for red spruce.

Table 10. The effects of two temperature regimes at three levels of water stress on the percent germination and range of germination interval in days.

Moisture stress (MPa)	30^0 C day, 20^0C night		20^0 C day, 10^0C night	
	Red spruce	Balsam fir	Red spruce	Balsam fir
0	33%, 6-21	70%, 8-40	83%, 7-21	52%, 7-43
0.25	13%, 12-23	48%, 8-43	60%, 7-25	24%, 11-43
0.50	0	2%, 18	0	12%, 13

Effects of drought on seedling survival

Seedlings from the germination trials were sown in 115-cm³ conical plastic containers and grown in a heated greenhouse under 16h photoperiod with ample watering and fertilization. After 2 months (May 2002) and 5 months (August 2002) samples of 20 to 25 seedlings of each species were watered to field capacity, then water was withheld until seedlings began to show stress symptoms. At that time the seedlings were re-watered, and kept outdoors. Surviving seedlings were counted in late October, 2002.

Prior to each drought treatment, 7 to 10 seedlings of each species were destructively sampled to estimate root and shoot dry weight, total root system length and number of lateral roots. The seedlings as they appeared before each of the drought treatments are shown in Figure 17. After 2 months, the seedlings were about the same size with somewhat similar root/shoot ratios, but red spruce exhibits a much finer root system with more lateral roots. After 5 months of growth, red spruce seedlings have continued indeterminate shoot growth, and are now much larger than balsam fir seedlings. The dry weight of red spruce seedling is now almost 4 time greater than that for balsam fir, but the latter's root shoot ratio is more than twice as great as red spruce (see Table 11). When water was withheld from the 60-day-old seedlings until approximately half of them show symptoms of water stress, mortality in response to the drought treatment was almost exactly the same for both species, where the majority of seedlings of both species did not recover after re-watering. When water was withheld from 150 day-old-seedlings, red spruce was the first to show symptoms. After re-watering, only 12% of the spruce seedlings fully recovered, compared with 100% for balsam fir. At this writing, all of the balsam fir seedlings look healthy and have set large terminal buds.

Figure 17. 60-day-old balsam fir and red spruce seedlings (left), and 150-day-old balsam fir and red spruce seedlings (right). After 150 days the root:/shoot ratio is twice as high for fir as it is for spruce seedlings, perhaps enabling balsam fir to better withstand drought conditions.

Table 11. Morphological data and mortality following drought for 60 and 150-day-old red spruce and balsam fir seedlings. 7-10 seedlings of each species were destructively sampled before water was withheld.

Seedling age	60 days		150 days	
Species	Red spruce	Balsam fir	Red spruce	Balsam fir
Dry weight (mg)	57	40	850	230
Root/shoot ratio	0.30	0.44	0.29	0.69
Root length (cm)	11.8	13.0	13.9	13.1
# lateral roots	25	17	39	24
% mortality	70	80	88	0

Effect of Commercial Thinning on Cone Production

Cone production in crown thinning treatments: Cone production was estimated this fall by examining the residual red spruce and balsam trees in the low thinning treatments from the Commercial Thinning Research Network (see pages 23). On all trees with cones, the length of the crown bearing cones was measured with an hypsometer, and the density of cones estimated on a scale of 1 to 5 (low to high density).

Across all sites tallied, the majority of balsam fir trees (88%) were producing cones compared with only 29% fir red spruce (Table 12). Reproductive effort was estimated by multiplying the length of the cone bearing crown by the density of cone production. Also, when cones were present, they occurred at a relatively higher density on balsam fir. We estimate that the overall balsam fir reproductive effort may be at least 10 times higher than that for red spruce this year. At this writing, balsam fir seed are visible on the snow.

Table 12. Estimated reproductive effort across 5 thinning sites. A total of 161 trees were measured, including 85 balsam fir, 68 red spruce and 8 white spruce.

Site	Species	Percent trees with cones	Reproductive effort (density x height)
Alder Stream	Balsam fir	86	21.9
	Red spruce	0	0
Comp. 23A	Balsam fir	82	12.3
	Red spruce	20	0.3
Golden Rd.	Balsam fir	100	13.8
	Red spruce	13	0.9
Harlow Rd.	No fir present	-	-
	Red spruce	38	3.6
Weeks Brook Rd.	Balsam fir	92	21
	Red spruce	30	2.5
Mean across all sites	Balsam fir	88	17.2
	Red spruce	29	1.5

Conclusions

Based on these preliminary studies, we can tentatively conclude that:

- Relatively cool conditions favor germination of balsam fir.
- There is no difference in species early germination response to water stress.
- Drought resistance of seedlings may differ when red spruce seedlings have developed a relatively high shoot-root ratio.
- Over the last year, cone production by balsam fir appears to be more precocious than that for red spruce.

Predominance of balsam fir regeneration may therefore be due in part to relatively greater seed production by balsam fir in young stands, although several more years of observations on cone production may be required to confirm this possibility. In addition, 1-2-year-old balsam fir seedlings may be more drought resistant than red spruce seedlings, but the findings reported here must be evaluated with field trials, perhaps in the regeneration plots.

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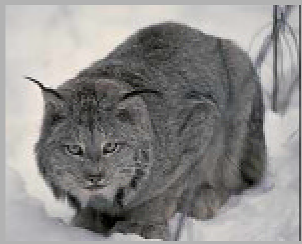
WILDLIFE CONSERVATION

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

(click photo to read report)

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

(click photo to read report)



Marten as a Tool for Landscape-Scale Habitat

(click photo to read report)

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

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

University of Maine

Introduction

Snowshoe hare are an important prey species and dominant herbivore across much of their wide geographic range. Forestry practices that degrade habitat may have a serious ecological impact on hare populations. Furthermore, the effects of pre-commercial thinning (PCT) on hare have been questioned in relation to indirect effects on recovery of the federally threatened Canada lynx. 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 at a regional scale, large areas of regenerating conifer stands is a habitat variable that predicts occurrences of lynx and describes relative abundance of snowshoe hare in Maine (Hoving 2001). Thus, extensive areas of regenerating forest may promote persistence of a population of lynx in the northeastern United States. 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.

Pre-commercial thinning is a silvicultural technique that decreases stem density in overstocked, regenerating stands and may reduce densities of hare relative to similar unthinned forest (Sullivan and Sullivan 1988). Since 1987 > 225,000 acres of forest have been pre-commercially thinned in Maine (Maine Forest Service annual reports). Although the total annual acres thinned each year only account for a small portion of the total silvicultural activity (3.5% in 2001), this practice may have large impacts on species that reach their highest densities in regenerating, early to mid-successional habitat.

Currently, there is insufficient information concerning the influence of thinning on habitat of snowshoe hare, 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 four years post-treatment (Sullivan and Sullivan 1988, de Bellefeuille et al. 2001), and most studies on the effects on small mammals lasted only two to three years (Lautenschlager et al. 1998, Sullivan et al. 1998). Because the structure of the understory and overstory changes dramatically in years after PCT, thinning may affect wildlife differently immediately after treatment than 6-16 years later. Thus, we are investigating the effects of PCT, at different intervals since thinning, on snowshoe hare, small mammals, and forest structure in the commercial forests of northern Maine.

This study is funded by the **Cooperative Forestry Research Unit** (CFRU), the **National Council of the Paper Industry for Air and Stream Improvement** (NCASI), the **U.S. Fish and Wildlife Service**, the **Maine Cooperative Fish and Wildlife Research Unit**, and the **Department of Wildlife Ecology, University of Maine**. **International Paper Company, Great Northern Paper Company,** and **Plum Creek** generated maps of stand type and management history and granted access to their lands.

Objectives

We examined the effects of PCT on selected wildlife species and stand structure 1-16 years post-PCT treatment. We are emphasizing the snowshoe hare because of its affinity for habitats with forest structure and high stem densities of conifer saplings, and because of its importance as a food source to Canada lynx and other predators. The specific objectives of this study were to:

- 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;
- 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;

- develop a predictive model of the relationship of hare density to overstory, understory, coarse woody debris, and structural variables.

Approach

We selected seven townships (Hersey, T4 R11 Wels, T5 R11 Wels, T4 R12 Wels, T1 R13 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 18) (Hoving 2001). Hersey Township is located in Aroostook County whereas the other six townships are located in Piscataquis County, Maine. **Great Northern Paper Company**, Millinocket, Maine, **Plum Creek Timber Company**, Fairfield, Maine, and **International Paper Company**, Costigan, Maine managed the study are for pulp and sawtimber production. We examined site quality, tree density, dbh of dominant trees, and spatial independence of stands before selecting them as study sites.

Treatment stands were clearcut 1967-1983, aerially treated with herbicide 1977-1988, and precommercially thinned with motor-manual brush-saws from 1984-1999. Similar unthinned stands were clearcut 1974-1982 and herbicided 1982-1988. We paired treatment stands with an unthinned reference stand with similar site quality, year of clearcut and year of herbicide. We did this 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. The study design includes 25 pre-commercially thinned stands at 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). 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.

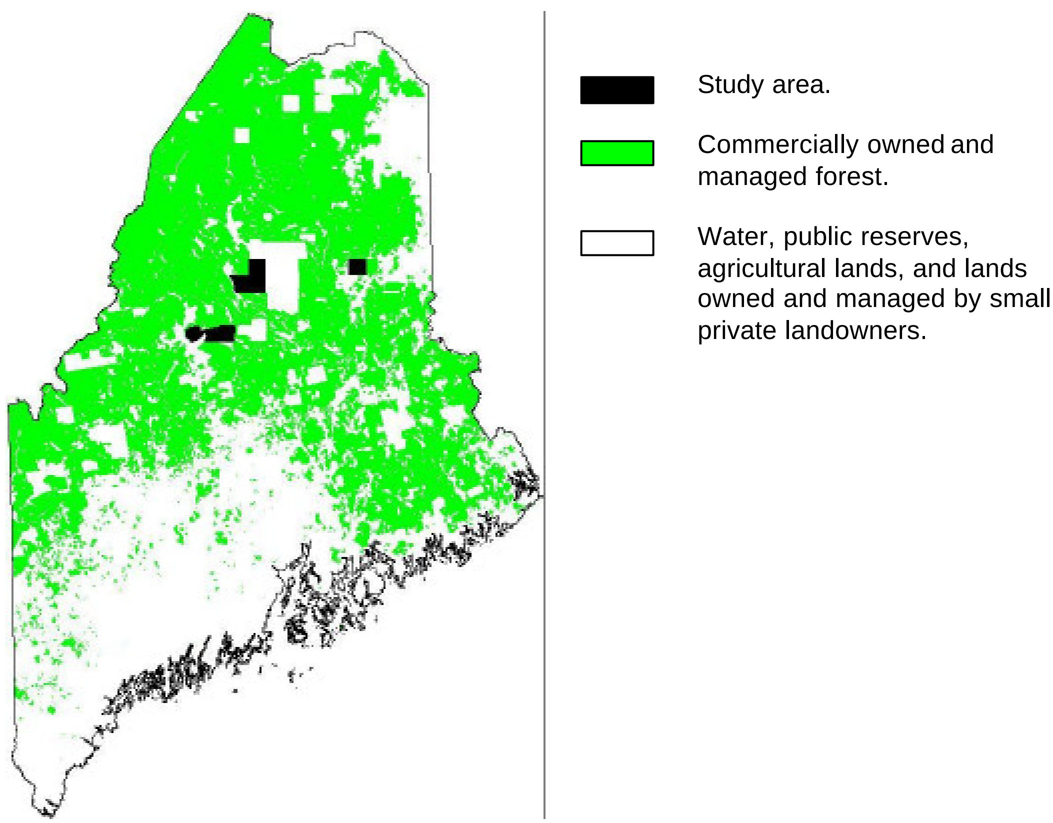


Figure 18. Location of study sites within 7 townships in the commercially owned and managed forests of northern Maine.

Methods

Snowshoe hare

We established 46.68 km of pellet transects in 30 stands including 17 treatment stands (1 years since PCT, n = 5; 6 years since PCT, n=5; 11 years since PCT, n=7) and 13 paired, unthinned stands. We established 1.6 km of transect in 28 stands and the remaining two stands had 1.18 km and 1.34 km. Transects were placed greater than 35 m from edges to minimize an edge-effect. When possible, we established four 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 for the entire study. We cleared all plots of hare pellets October 18th through 25th, 2000 so that only pellets deposited after leaf-off were counted during spring 2001. We counted and cleared pellets four times during the length of the study: May 17th through June 14th, 2001, September 13th through 29th, 2001, and May 10th through June 17th, 2002, and September, 13th through October 13th, 2002. Thus, spring pellet counts (May-June) were used to estimate hare abundance during the previous winter, or leaf-off season, and fall pellet counts (September-October) were used to estimate abundance during the previous summer, or leaf-on season.

To calibrate the relationship between pellet density and hare density (Krebs et al. 2001), we live-trapped hare on a sub-sample of four stands during May-June 2001 and 4 additional stands May-June 2002 (Figure 19). Single-door collapsible Tomahawk traps (Model 205) (Tomahawk, Wisconsin, USA) were set on a 390 m by 260 m grid, covering 10.14 ha. 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 a unique, individually numbered ear-tag or foot tag and released them on the trap-site. 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.

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 forest structure on 25 m^2 plots in thinned stands 10 m^2 plots in control stands. Larger plots were established on thinned stands because stem density was reduced in these stands and we wished to sample approximately 100 crop trees per stand. We measured several habitat measurements including the species of tree, diameter class at breast height, the height class, and the height of the crown base of every woody stem ≥ 1.0 m height in the plots. We also measured horizontal vegetation structure, the number and type (coniferous or deciduous)

Figure 19. During spring 2001 and 2002 we captured 242 snowshoe hare 772 times across 8 stands (4 treated with PCT, 4 unthinned) in northern Maine.

of woody stems between 0.2 m and 1.0 m height in a nested subplot, and the volume of downed logs. We estimated the percentage of ground covered by grasses and forbs, moss, bare ground, rock, litter, and other vegetation.

Small mammals

We established 24 grids for trapping small mammals on stands treated with PCT from four age classes, 1 years since PCT (n = 6), 6 years since PCT (n = 6), 11 years since PCT (n = 6), and 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 on 37 stands during June-August 2000 and 2001 (Figures 21 and 22). Trapping periods lasted for six nights and we captured small mammals in Bolton live-traps (B. N. Bolton, Inc. Vernon, B. C.) baited with rolled oats and peanut butter. The 70 m by 70 m trapping grids had 64 trap stations at 10 m intervals. We ear-tagged mice and voles with a uniquely numbered ear tag (Monel no. 1005-1) and recorded species, age, sex, reproductive condition, and presence of external macro-parasites for individuals. We captured 600 red-backed voles, 347 deer mice, 10 woodland jumping mice, 2 Southern bog lemmings, and 1 meadow vole during 2000 and 2001. Further, we had 399 captures of short-tailed shrews, 386 captures of masked shrews, 5 captures of smoky shrews, 15 captures of weasels, 51 captures of eastern chipmunks, and 11 captures of red squirrels. Capture success was only large enough for analysis of red-backed voles, deer mice, short-tailed and masked shrews.

We completed microhabitat analysis on all 37 small mammal grids. Sixteen of the 64 trapping locations per small mammal grid were randomly selected to intensively measure vegetation characteristics. A 10-m by 2-m rectangular plot was randomly oriented on each trapping location. We measured habitat characteristics including the number of trees greater than 7.6 cm dbh, number of understory saplings, volume of logs and stumps, canopy closure, basal area, number of herbaceous and woody ground stems, and other measurements.

Preliminary Results

Densities of snowshoe hare were linearly related to densities of fecal pellets during the leaf-off season and this functional relationship could reasonably predict abundances of hare at a stand-scale in Maine. Densities of snowshoe hare pellets were about 2 times greater in regenerating conifer stands than similar stands treated with PCT during 2 leaf-off and 2 leaf-on seasons, and up to 11-years post-PCT (Figure 22). 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 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. 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 had large inter-annual fluctuations, with greater numbers captured during the 2nd year of sampling.

Forest structure was dramatically different in thinned forest and was also strongly affected by time since treatment. Four of six *a priori* selected habitat variables that have been positively associated with densities of snowshoe hare in other studies were greater in unthinned stands than similar stands treated with PCT. Likewise, microhabitat variables that have been suggested to be important correlates of small mammal densities differed by treatment and age classes on our study sites

Status and Future Plans

All data tabulation is completed, as are many of the statistical analyses. Jessica is currently writing her thesis and the expected date of completion for the project is Spring 2003.

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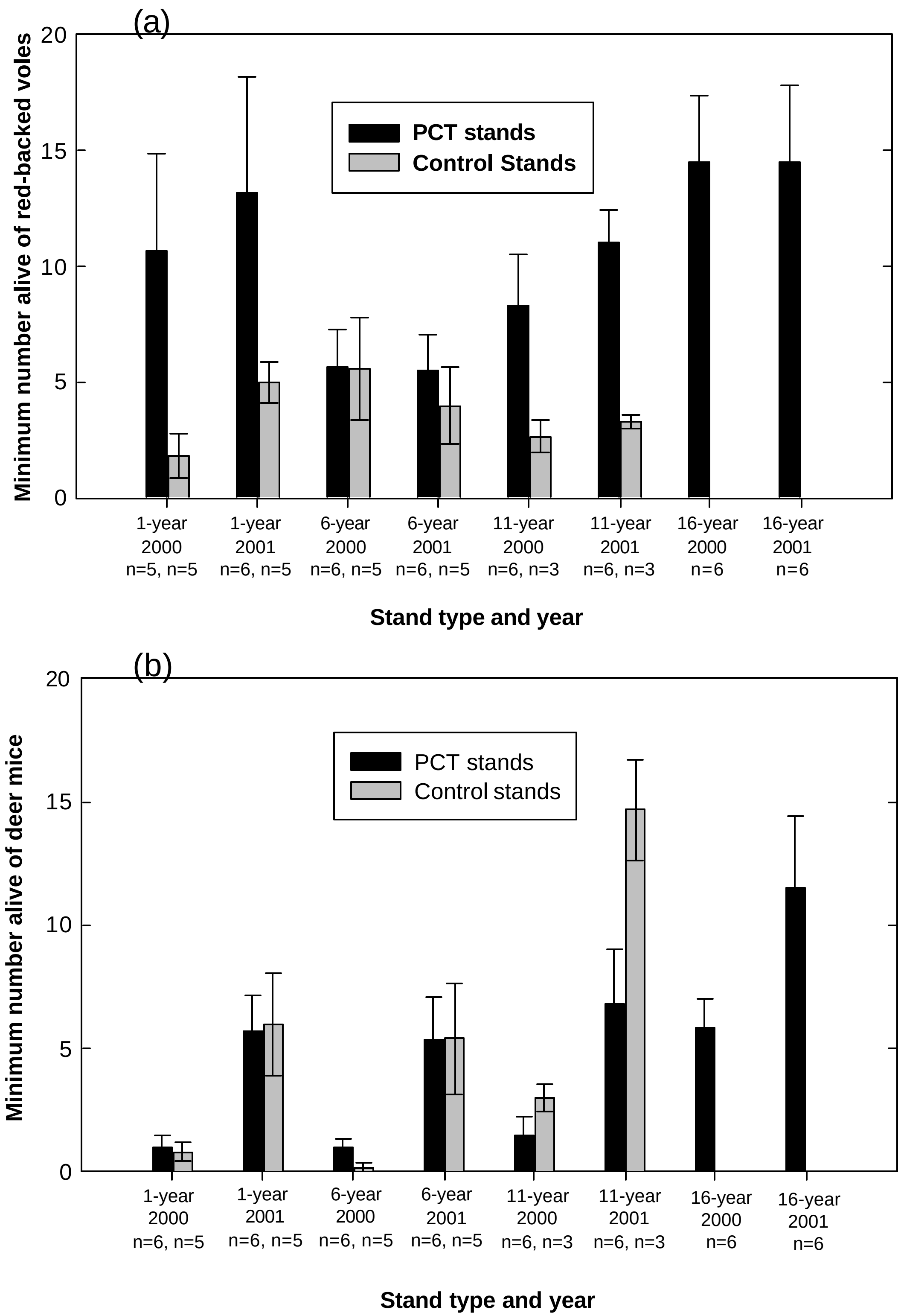

Figure 20. Mean minimum number alive (SE) of red-backed voles (a) and deer mice (b) in 24 stands treated with PCT and 13 similar control stands from 1 to 16 years post-treatment during summer 2000 and 2001 in northern Maine.

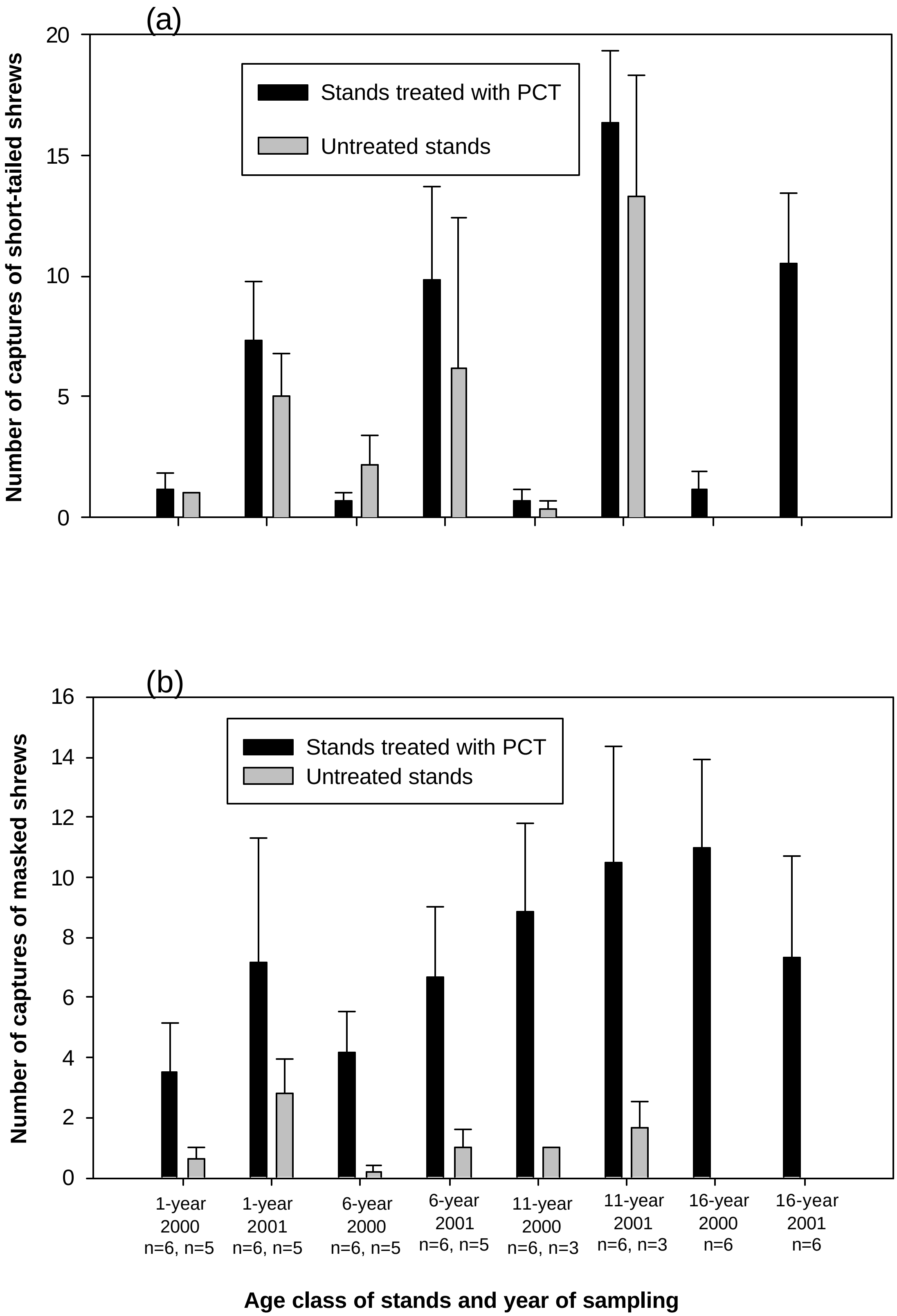

Figure 21. Total number of captures (SE) of short-tailed shrews (a) and masked shrews (b) in 24 stands treated with PCT and 13 unthinned control stands from 1-16 years post-treatment in northern Maine during summer 2000 and 2001.

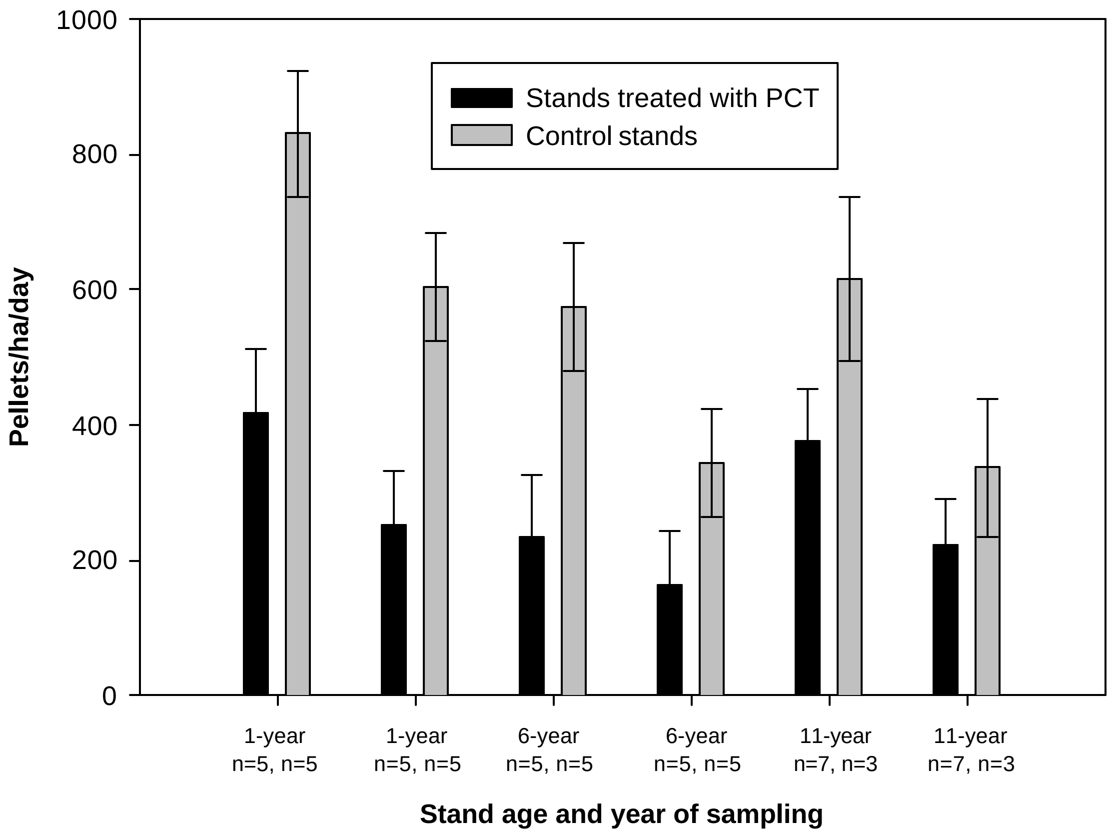

Figure 22. Mean (SE) number of snowshoe hare pellets/ha/day in PCT stands and similar unthinned stands in northern Maine during leaf-off seasons 2000-2002.

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

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Introduction

Canada lynx (Figure 23) occur across much of the northern United States and Canada, but little is known about lynx-habitat relationships in eastern North America (Ruggiero et al. 2000, Aubry et al. 2000). Most knowledge of habitat associations of lynx has been obtained from telemetry studies in the western portion of the species range (e.g., Koehler et al. 1979, Koehler 1990); only one habitat study has been conducted within the eastern range of lynx (Parker et al. 1983). Results of the few habitat studies conducted throughout the geographic range of Canada lynx have been extrapolated to areas with potentially unique (e.g., differences in climate, prey abundance, predator-prey communities, and rates of forest succession) ecologies (Buskirk et al. 2000); therefore, inferences about habitat ecology of lynx from studies conducted elsewhere are speculative and potentially unreliable.

Figure 23. Canada lynx are studied extensively across their range but little is known about lynx-habitat relationships in the Northeast.

Lynx are considered specialists on snowshoe hare (Saunders 1963, Brand and Keith 1979), and habitat use by lynx is closely associated with densities of snowshoe hare (Koehler et al. 1979, O'Donoghue et al. 1998, Mowat et al. 2000). In Maine, hare are closely associated with regenerating stands with abundant coniferous saplings (< 1.5 m height) (Lachowski 1997, Fuller 1999, Hoving 2001). Silvicultural practices that promote dense conifer regeneration (e.g., overstory removals followed by herbicide application) may create habitat for snowshoe hare and presumably, lynx. However, it has been hypothesized that some forms of forest harvesting might reduce structure and coarse woody debris required by denning lynx (Mowat et al. 2000). Various forms of partial harvesting represented >90% of the forest acreage harvested in Maine in 2001 and Fuller (1999) documented reduced densities of hares in partially harvested mixed stands (50-60% basal area removal, 3-4 years post-harvest). Further, PCT is a common silvicultural practice in Maine (63,620 acres PCT 1997-99) (Maine Forest Service), and has been hypothesized to reduce habitat quality for lynx (Mowat et al. 2000). Empirical studies have indicated that hare densities were reduced 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, Harrison, and Krohn, University of Maine, unpublished data). Pending litigation in U.S. District Court may require the U.S. Fish and Wildlife Service to declare critical habitat for lynx; therefore, it is important to understand the effects of alternative silvicultural practices on hare and lynx.

Habitat use can be evaluated at broad scales (i.e., geographic range), and at successively finer-scales, including placement of the home range on the landscape, use of overstory types within the home range, and use of structural features within the home range. Radiotelemetry is an important tool for evaluating habitat selection at the landscape- and stand-scales, and is the focus on ongoing field research in Maine being conducted by Maine Department of Inland Fisheries and Wildlife and the U.S. Fish and Wildlife Service. Radio telemetry is not an appropriate technique for evaluating fine-scale habitat selection by lynx; errors associated with location inaccuracy and the coarseness of habitat maps result in poor resolution for evaluating sub-stand scale choices. For example, the small average size (< 30 acres) of PCT stands in northern Maine, coupled with the error associated with telemetry locations (15-20 acres), precludes efforts to evaluate selection or avoidance of PCT stands based solely on radio locations. Habitat selection at the sub-stand scale can be best evaluated by measuring the structure of the habitat in the immediate vicinity of free-ranging lynx. Snowtracking using GPS technology can verify lynx presence with sub-meter accuracy and allows geo-referenced measurements of habitat structure and prey abundance in relation to lynx behavior.

Habitat use by lynx may be associated with more than just abundance of snowshoe hare; overstory and understory features that influence vulnerability of

Figure 24. Fresh lynx tracks leave evidence of male cat in a young pre-commercially thinned stand

hares to predation, or coarse woody debris hypothesized to be associated with denning sites (Mowat et al. 2000), may also influence habitat selection by lynx. There have been several studies that utilized snowtracking (e.g. Saunders 1963, Parker 1981, Murray and Boutin 1991, Murray et al. 1994, O'Donoghue et al. 1997) to evaluate selection for forest overstory types and to document lynx activities; however, no previous studies have included measures of sub-stand scale habitat selection in relation to prey encounters or structural characteristics of the forest. This study is funded by the **Cooperative Forestry Research Unit**, **U.S. Fish and Wildlife Service**, the **Maine Forest and Agricultural Experiment Station**, the **Nature Conservancy**, and the **Department of Wildlife Ecology at the University of Maine**. The goals of the project are to better understand sub-stand scale habitat associations of lynx, to determine whether sub-stand scale habitat choices made by lynx are related to relative abundance of snowshoe hare, and to evaluate the effects of alternative forest management activities on habitat use by lynx.

Objectives

Consistent with our goal of better understanding fine-scale habitat decisions by lynx, our study has been designed to evaluate the following objectives:

- Evaluate stand-scale habitat selection by lynx using GPS-referenced tracks in snow.
- Develop models for determining 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 radio collared lynx within verified home ranges.

Approach

Our methods for snowtracking of lynx have been previously tested on 20 km of actual and 45 km of random transects of radio-collared marten during winters 1997 and 1999. We locate radio-collared lynx, intersect their tracks, and backtrack on snow to evaluate habitat selection (Figure 24). 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 analyses 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 are installed 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, and snow depth) are collected. Habitat variables will be compared between areas used by lynx and control sites on random straight-line transects sampled within the home range of the lynx. We verify the locations of all rest sites used by lynx via GPS and take vegetation and structural measurements to characterize those sites (Figure 25). Lynx activities on trails are recorded, including travel, urination, scat, chasing prey, and killing prey. We also record all prey that cross or intersect the trail of a focal lynx. Scats found along the trail are collected and will be used for diet analyses.

Analyses of spatial-use and movement patterns will evaluate 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 archive all lynx trails with a GPS unit capable of continuous line sampling with real-time, sub-meter accuracy. We will compare path shape and characteristics of lynx in different overstory types to evaluate the effects of forest type on movement decisions. To determine which variables best distinguish lynx trails from random transects, we will develop *a priori* models based on variables suspected to influence lynx use of landscapes at the sub-stand scale. We will develop the models using logistic regression to determine which sub-stand scale variables best predict the areas used by lynx by comparing with the characteristics of the vegetation on random transects within the home range. The models that best describe behavior and habitat affinities of lynx will be chosen based on the information theoretic approach for ranking model performance (Burnham and Anderson 2002).

Figure 25. All lynx trails were mapped with a GPS unit capable of continuous line sampling with real-time, sub-meter accuracy.

Outcomes

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 and will quantitatively determine the spatial scales at which lynx respond to heterogeneity on the landscape. Our results will provide a better understanding of the effects of alternative forest management practices on habitat use by lynx.

Project Status

Three lynx (2F, 1M) were snowtracked for 31.8 km between 4 January and 28 March, 2002 and random straight-line transects were sampled for 55 km within the home ranges of those lynx. Vegetation was sampled within 341 plots along the lynx trails and within 605 plots along random transects. The second and final winter field season will be conducted during winter 2002-2003. The final report and presentations to CFRU and other project sponsors will be delivered in 2004.

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Marten as a Tool for Landscape-Scale Habitat Planning in Northern Maine

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Introduction

This project was initiated in May 2000 and utilizes a meta-analysis across 10 years of field data collected in northern Maine to evaluate the relative effects of habitat loss and fragmentation on marten, and to build predictive models of marten occurrence for use in forest planning.

Specific objectives of the project are to:

- evaluate and test habitat currencies that are useful for predicting occurrences of occupied home ranges by resident adult marten in managed landscapes;
- use the currencies derived in objective # 1 to map suitable and unsuitable patches of habitat based on low-level aerial photography, and then develop and evaluate vector-based habitat models for predicting marten occurrences, including variables such as amount of suitable patches, distance metrics between patches, patch size and density, and landscape shape metrics;
- redevelop and evaluate predictive habitat models for marten based on Landsat TM imagery (raster-based) and compare reliability of the coarser-grained models to vector models derived from aerial photography;
- apply the raster-based models statewide to map and inventory habitat supply for marten throughout Maine, and use habitat supply comparisons between 1993 and 2000 to evaluate change in amount and distribution of marten habitat in Maine; and
- quantitatively evaluate whether habitat conservation strategies for marten benefit other forest specialized and forest generalist vertebrate species.

All analyses for this project have been completed and a final report will be presented at the January 2003 meeting of the CFRU Advisory Committee. This project was funded by the **Cooperative Forestry Research Unit**, the **Maine Outdoor Heritage Program**, the **Maine Department of Inland Fisheries and Wildlife**, the **Maine Agricultural and Forest Experiment Station**, and **The Nature Conservancy**. Vector-based models developed during this project will allow forest managers to evaluate and predict effects of proposed cutting plans on habitat for marten and other forest-dependent wildlife based on ownership-specific forest maps. The broader-scale models will allow state agencies to monitor changes in amount and distribution of habitat supply for marten and other forest-dependent species throughout northern and eastern Maine, and will provide opportunities to enhance the integration of harvest management and habitat conservation missions within those agencies.

Objective 1

We evaluated many different potential currencies (i.e., human derived definitions of habitat that have the strongest biological significance for defining habitat quality to an animal) for defining suitable habitat patches for marten. Our approach was based on a quantitative comparison of the decline in probability of occupancy by marten in response to a decrease in the proportion of the landscape that was composed of each potential habitat currency (e.g., mature conifer forest). We quantitatively evaluated different currencies by comparing the amount of suitable habitat (as defined for each currency) in home-range sized (1-2 square miles) portions of the landscape that were occupied versus unoccupied by resident adult marten.

The best currency for defining suitable patches of forest for marten was forest > 20 feet in height with >40% canopy closure (Figure 26). We then used this definition of a patch to map suitable versus unsuitable habitat on our 60 mi^2 study area in northern Maine (Figure 27), which contained many patches of various sizes, shapes and configurations.

Objective 2

We developed vector-based habitat models to predict home range areas that were occupied versus unoccupied by resident adult marten. These models were derived from aerial-photography based forest maps and were designed to identify which habitat and landscape variables were most important in determining whether marten were present or absent at the scale of the home range (1-2 mi^2). Our models

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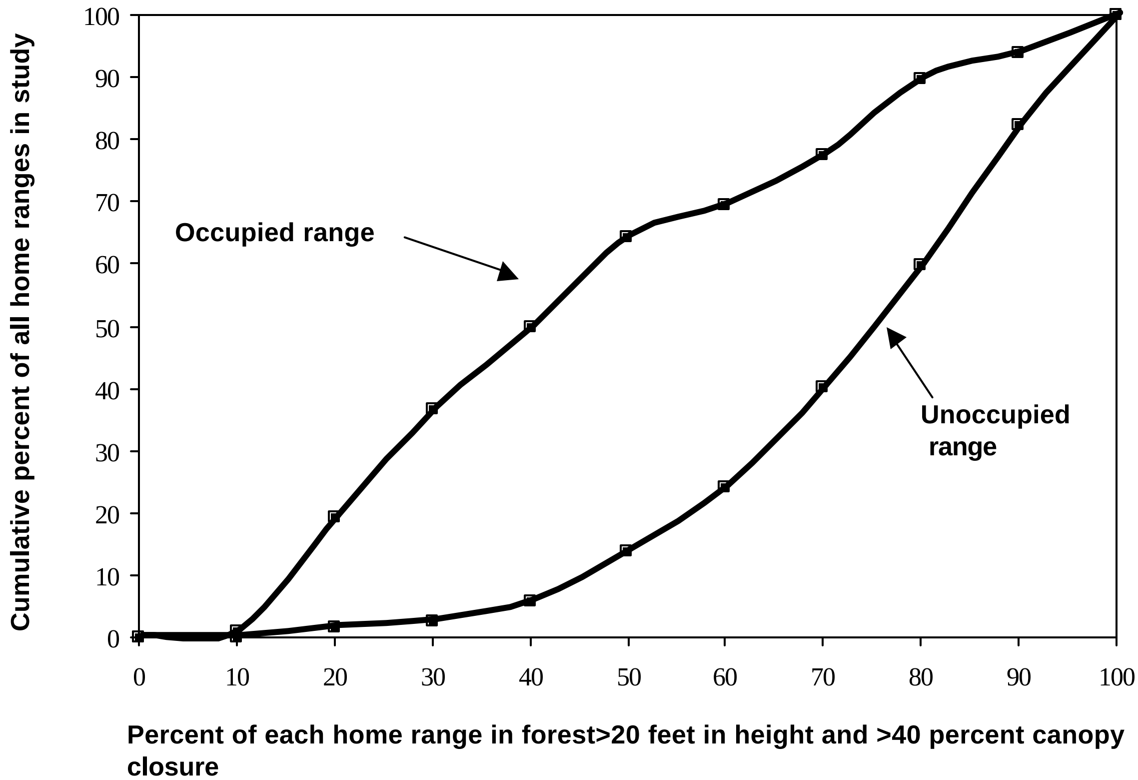

Figure 26. Curve depicting decline in occupancy rate (y-axis) of potential home ranges as the percentage of suitable habitat currency (defined as forest > 20 feet in height and > 40% canopy closure) declines (x axis) from 100 to 0%. A greater percentage of unoccupied ranges included a given level of unsuitable habitat than occupied ranges. The separation between unoccupied and occupied curves was greatest when habitat currency was defined as forest > 20 feet in height with canopy closure > 40 percent.

were developed using 124 home ranges that were occupied by radio collared adult marten and using 98 home range-sized areas that were not occupied. Variable considered in the models included extent of suitable habitat, patch characteristics (size and density), edge characteristics, and six frequently used fragmentation metrics. We used the information-theoretic approach to statistically rank 30 *a priori* logistic regression models (i.e., different combinations of variables based on marten biology) developed to identify the habitat characteristics and landscape metrics that determine occupancy versus non-occupancy by resident adult marten and to predict the distribution of marten home ranges across the landscape. Predictions of occupancy and non-occupancy based on the model were tested against reserved field data (n = 127 occupied and 41 unoccupied home ranges not used in the model building process) to evaluate each model's predictive capability.

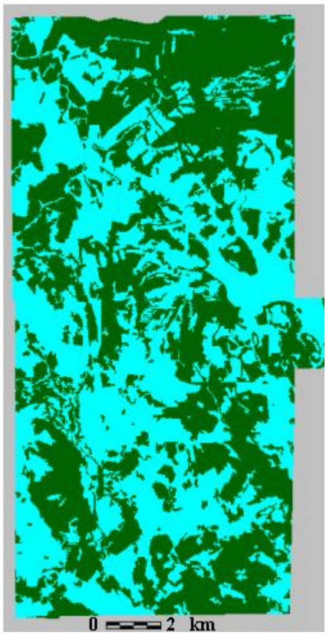

Figure 27. The distribution of suitable (green) and unsuitable (blue) patches of habitat for marten on our study site in T4 R11 and T5 R11, northern Maine, 1994. The habitat currency used for defining suitable patches was forest > 20 feet in height with canopy closure > 40 percent.

Our best raster-based model was highly reliable for predicting occupancy versus non-occupancy of home ranges by resident marten; 81% of home ranges were correctly classified as occupied or unoccupied in the managed forest landscape and 100% of home ranges occupied by radio collared marten in Baxter State Park were predicted to be occupied by the model. The dominant variable that influenced marten occurrence was the proportion of suitable (trees > 20 feet in height and > 40% canopy closure) patches in the home range; however, marten also responded to the density of patches (negatively related to probability of occupancy) and the distance between patches (negatively related). Thus, home ranges occupied by marten were characterized by a matrix of few, large patches of unfragmented forest. Unoccupied areas were more fragmented and had more and smaller patches of forest, less area in suitable habitat patches, and a greater mean and variance in inter-patch distances. Our results indicate that both habitat loss and fragmentation interact to influence habitat quality and distribution in managed forests. Our models can be used to evaluate silvicultural alternatives in relation to their potential effects on habitat occupancy by marten across township or multi-township areas.

Objective 3

Our vector-based models derived from Landsat TM imagery were built and evaluated using a similar approach as our vector-aerial photography models. Again, 30 potential models were evaluated *a priori* and incorporated different combinations of our variables that addressed extent of suitable habitat, patch size and density, distances between patches, shape indices, and interaction terms. Our best model reliably predicted 75% of occupied and unoccupied home ranges of marten in managed landscapes and again correctly predicted that 100% of home ranges occupied by radio collared marten in Baxter State Park would be occupied. Similar to our finer-grained vector models, the satellite-derived raster models indicated that the proportion of suitable patches in a marten home range was the dominant predictor (positive association) of marten nearly constant (2.5% increase) statewide from 1993–2000.

Objective 4

We observed only a 5% reduction in reliability using the raster based models; thus, we applied these models statewide to inventory and map the distribution of marten home ranges throughout Maine. Our models predicted habitat supply for 14,662 marten north of the species' southern geographic range limit in central Maine in 1993 (Figure 28). Potential habitat for marten is well distributed throughout northern and eastern Maine and density of potential home ranges varies based on landform, past cutting history, and silvicultural objectives of landowners. Our evaluation indicates that habitat supply for marten remained nearly constant (2.5% increase) statewide from 1993–2000.

Objective 5

American marten are the most area-sensitive, forest specialized mammal inhabiting northern Maine. Elsewhere, marten have been increasingly used as an indicator species of forest health (e.g., U.S. National Forests) and as an umbrella species for developing habitat conservation plans on crown-owned lands (e.g., New Brunswick, Ontario). Our final objective was the first quantitative evaluation of marten as an umbrella species for forest-wildlife conservation. We compared the predicted occurrences of 43 forest-specialized vertebrates and 68 forest generalists within the range of marten in northern Maine based on GAPS-derived models of vertebrate occurrences (Krohn et al. 1998). Our results indicate that approximately 75% of forest-specialist and 80% of forest-generalist vertebrates in Maine would achieve equal or greater benefit than the marten from planning efforts to conserve marten habitat. Our models provide the tools to predict extent and location of marten habitat on the landscape through time and provide a planning tool that could ensure habitat for many forest dependent vertebrates across large, managed landscapes. We hope to see these models applied as a coarse-filter approach for conserving biodiversity of forest dependent vertebrates in managed landscapes through an interactive process of habitat supply planning through time.

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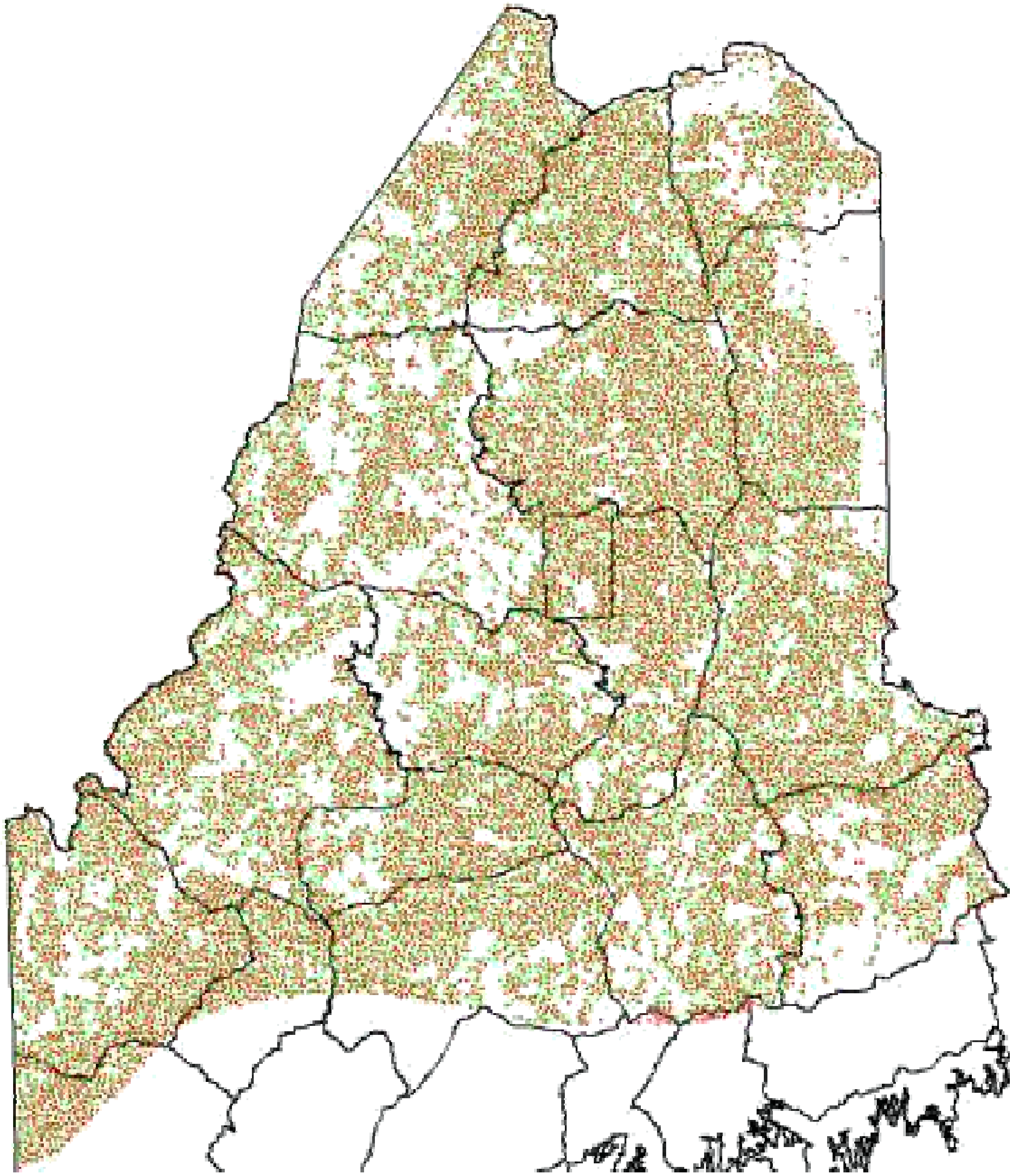
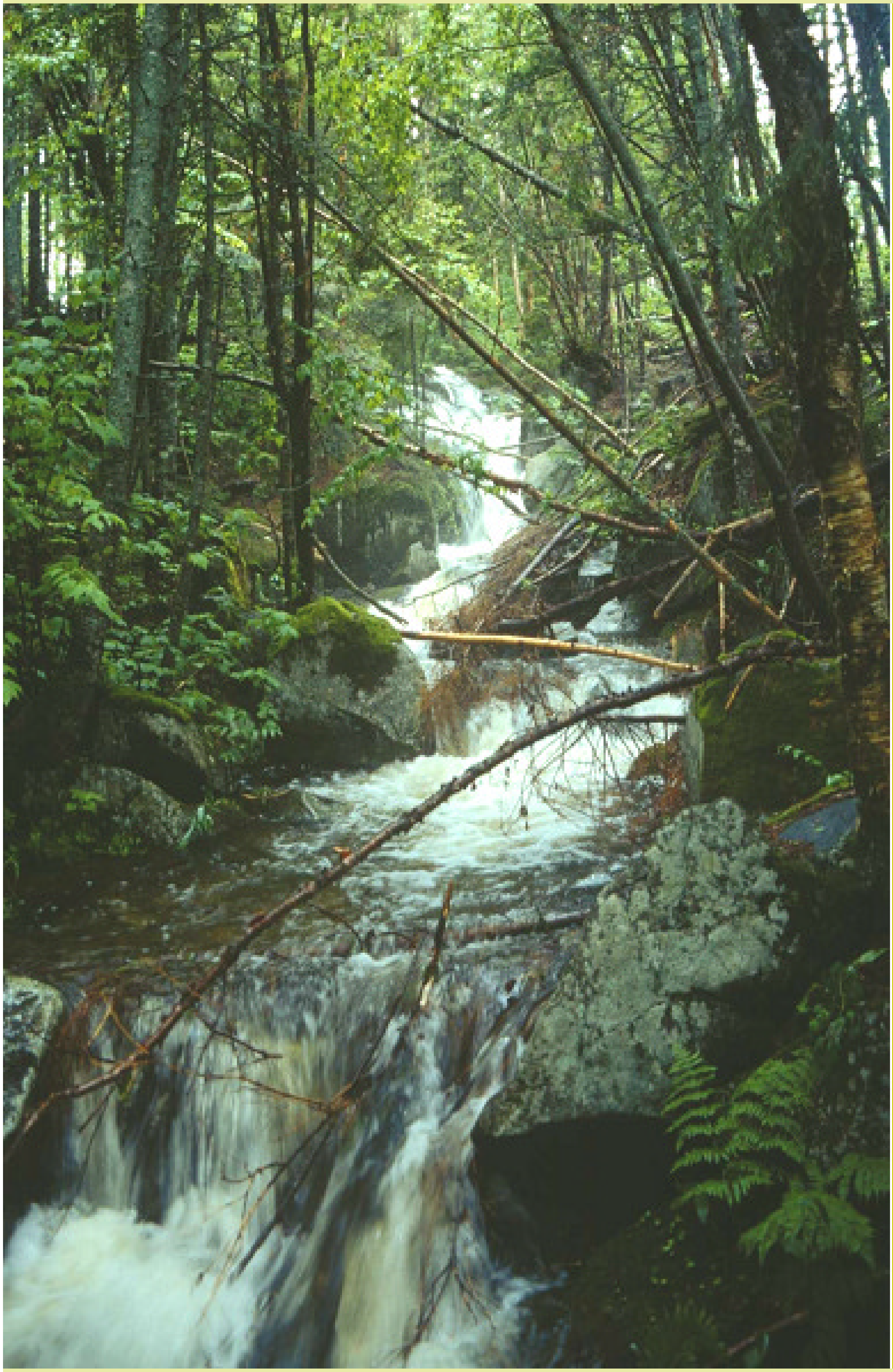


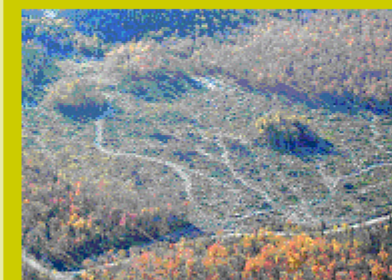
Figure 28. The distribution of potential female (centroid marked with red point) and male (green points) marten home ranges in northern Maine in 1993 based on logistic regression models developed from rasterized Landsat Thematic Mapper imagery. Occupancy of the landscape for marten was determined based on percent of the home range in patches of suitable habitat, density of suitable habitat patches in the home range, variation in size of patches, and the interaction between patch density and variation in patch size.

BIODIVERSITY CONSERVATION



Can Patch Retention Maintain Biodiversity in Clearcuts and Partially Harvested Forest (year 3)?

(click photo to read report)



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

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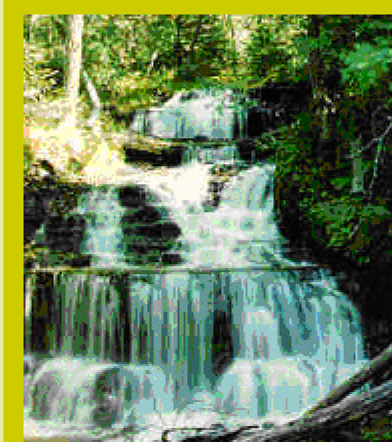

Can Patch Retention Maintain Biodiversity in Clearcuts and Partially Harvested Forest (year 3)?

John M. Hagan and Andrew A. Whitman
Manomet Center for Conservation Sciences

Introduction

This is a report on the third year of a three year project to test the ability of patch retention to retain vulnerable species and features in the managed forests of Maine. Patch retention is a new practice that involves retaining patches of mature forest in harvest blocks (Figure 29). Patches can be centered on vulnerable ecological features to maximize conservation benefits. These features may be large trees, snags, and logs, uncommon tree species, hard mast producing species, pockets of forest with little past harvesting history, vernal pools, springs, and/or populations of rare species associated with undisturbed forest.

Managed forests in northern Maine may be rich with these ecological features. However other managed forest landscapes, such as Sweden's, have had decades of intensive management and, as a result, features such as large trees, snags, and logs have become scarce (Ostland and Linder 1993). Forest plant and animal species that depend on these features account for over a third of Sweden's threatened species (Berg et al. 1994). Sweden is predicted to lose over 1000 forest species due to the loss of these features over the next 20 years (Hanski 2001). With changes in technology and markets, Maine's forests may be beginning to follow a trend that Sweden's forests began decades ago. Like Sweden, Maine's forest may become at risk to losing these features and the species that depend upon them. Patch retention may be an effective tool for maintaining Maine's forest biodiversity by accomplishing four objectives:

- *maintain forest structure* well distributed across the landscape;
- *provide refugia* for populations of sensitive species from which they can colonize the surrounding managed forest matrix;
- *maintain habitat patches* that can serve as stepping stones for dispersing propagules;
- *retain vulnerable ecological features and species*.

Figure 29. Substudy I retention patches in Skinner Township, western Maine.

Patch Retention Project

The objectives of the Patch Retention Project are to:

- determine the contribution of new patches in maintaining populations of herbaceous plants, lichens, mosses, and red-backed salamanders.
- determine the contribution of existing remnants toward maintaining populations of herbaceous plants, lichens, mosses, red-backed salamanders, and ground beetles.
- provide scientific information about patch retention to land managers, state authorities, and interest groups.

The Patch Retention Project is comprised of three substudies described below. Together the three substudies address the short- and long-term ecological and economic values of patch retention.

Substudy I

Substudy I was a before-and-after-control experiment that tested the ability of newly created retention patches to retain ecological features of interest (Figure 30). The goals of Substudy I were to: (1) determine the short-term (1-year) impacts of harvesting on species and forest structure in retention patches and harvest areas, and (2) establish a long term study of patch retention.

Status: In 2000 we established 60 experimental plots that were sampled for forest structure, macro-lichens, vascular plants, and mosses. Twenty plots were placed in patches to be created, 20 plots were placed in sites to be harvested, and 20 were placed in sites that will remain intact for the duration of the 3-year study. Sites were selected to maximize the number of ecological features found in a 30-m radius circle and were comparable across treatments. The patches were 60 m in diameter. Three sites were harvested in the winter of 2001 leaving five retention patches, harvesting through four to-be-harvested plots, and leaving five control areas containing five control plots. We sampled plots in these three sites during the summer of 2001 for microclimate, forest structure, mosses, vascular plants, and lichens. The remaining six sites were harvested in the winter of 2002 leaving 13 retention patches, harvesting through 12 to-be-harvested plots, and leaving seven control areas containing 13 control plots. These sites were sampled for microclimate, forest structure, mosses, vascular plants, and macro-lichens. Three hardwood sites were sampled for ground beetles in the summer of 2002. Data from 2002 have been entered and are being quality-checked.

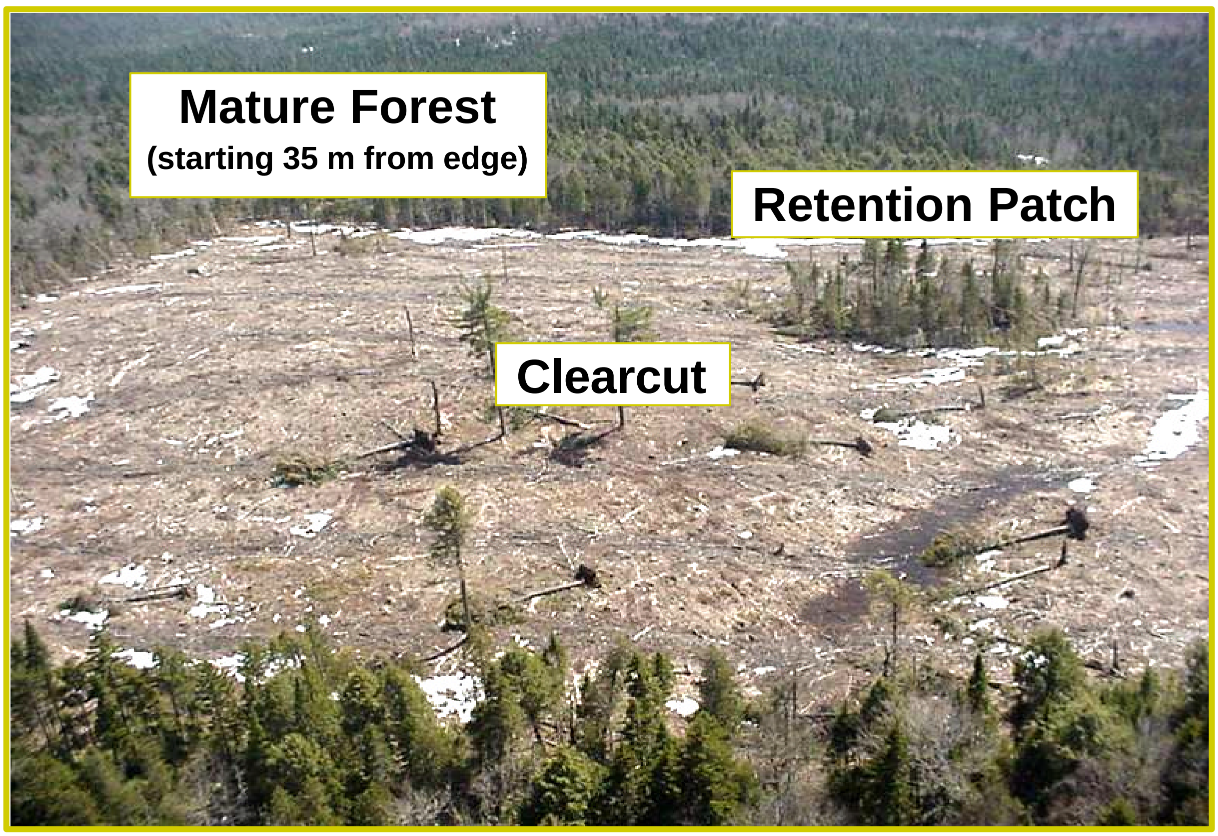

Figure 30. Sampling areas in a mature forest, a regeneration patch, and a clearcut (T14 R7 WELS, northern Maine).

We expanded our original plan to include experiments in hardwood forests (beyond planned treatments in mixed-wood forest), making our research results applicable to a larger portion of Maine's landscape. Hardwood sites received a partial-harvest treatment and mixed-wood sites received a clearcut treatment. Harvest intensity in hardwood sites ranged from a heavy shelterwood harvest to light improvement cut. We will compare percent changes in species diversity and ecological features in both harvest treatments to determine the relative biodiversity benefit of patch retention in each treatment. About 200 trees were tagged at the base before the harvest and the presence of epiphytic macro-lichens, epiphytic mosses and bark texture were recorded. Approximately 100 of these trees were cut, making it possible to sand the stumps and assess the minimum age of each individual tree in the summer of 2002.

Results to date: Although we will not have final results until post-harvest data are analyzed, we can make four points based on field observations. First, there was little immediate windthrow in new retention patches, although we expect to see more windthrow over time. Fortuitously, patches in mixed-wood sites varied in their hardwood composition and so it will be possible to see if there is a relationship between hardwood dominance and windthrow levels in retention patches. Second, there was no short-term loss of plant species or significant reduction in forest structure in patches though this very well could change with time. Third, the loss of species and forest structure varied depending on harvest intensity. Clearcuts and heavy shelterwood harvest blocks lost few vascular plant species but lost many epiphytic macro-lichen species and forest structure (trees and logs). Remarkably a few very common epiphytic macro-lichen species were found in clearcuts on scattered small trees left by loggers. In heavy shelterwood cuts, late succesional epiphytic macro-lichen ("old growth species" *in sensu* Selva 1994) still occurred on scattered, large trees but many of these species were slowly dying and may be lost. Many well-decayed logs were destroyed or heavily damaged in clearcuts and heavy shelterwood cuts leading to a reduction in log volume. Light improvement cuts lost few plant species or little forest structure. Fourth, the minimum age of harvested trees with *Lobaria pulmonaria* was 95 years old. Other epiphytic bryophytes only occurred on trees older than 95 years old. We will evaluate the relative importance of tree age, tree size, and bark texture in order to determine how these factors might limit populations of epiphytic bryophytes.

Major finding: Patch retention can retain vulnerable ecological features and species in hardwood and mixed-wood forests in the short term. Patch retention is one practice that can be applied in order to maintain epiphytic bryophytes that require old trees.

Figure 31. Jesse Twitchell measuring a large log in mature forest.

Substudy II

Substudy II is a retrospective study of upland forest remnants (buffer strips, retention patches, and fire remnants) that were created 2 to 70 years ago. The goals of Substudy II were to: (1) assess the long-term (2-70 year) ability of retention patches to retain forest structure and forest species and (2) establish a long term study of patch retention.

Status: In 2002 we completed a study of existing retention patches by sampling 92 plots in 2-4 year-old retention patches (n=50), adjacent clearcuts (n=21), and adjacent mature forest (n=21). Patches were selected by foresters or loggers. We sampled harvest blocks of **Irving Woodlands** (in northeastern Maine), **International Paper** (in eastern Maine), and **The Nature Conservancy** St. John Forest Management Area (in northwestern Maine). This study will evaluate how well patch retention can be applied in an operational setting. Sites were sampled for trees, logs, forested wetlands, macro-lichens, and vascular plants (Figure 31). Data from 2002 have been entered and are being proofed.

Results to date: We present the results from a preliminary analysis. Retention patches had the highest densities of intact large logs, large trees, and trees compared to clearcuts and mature forest (Figure 32). Clearcuts had greater large log densities than mature forest but 55% of large logs in clearcuts were severely damaged by logging equipment and site preparation equipment. Retention patches had a greatest number of vascular plant and moss species (Figure. 33). Retention patches also had the greatest densities of trees with epiphytes though not significantly greater than mature forest (Figure 34).

Small retention patches had much greater densities of large trees and large logs than large patches (Figure 35). Patches larger than 0.1 ha had more vascular plant species and moss species than patches smaller than 0.1 ha (Figure 36). Small patches have a much higher density of forest structure and of epiphyte species than large patches. Hence retention patches overall averaged greater plant species richness, densities of forest stru cture and epiphyte species compared to mature forest because most patches were small or were large and included areas with many plant species.

Major finding: Two-four year old retention patches $\geq$ 0.2 ha begin to resemble mature forest with regard to structure, plant diversity, and core temperature extremes. Small patches have a much higher density of forest structure and plant species richness than large patches suggesting that foresters and loggers are positively biased toward finding small "ecological hotspots" and retaining their ecological features using patch retention.

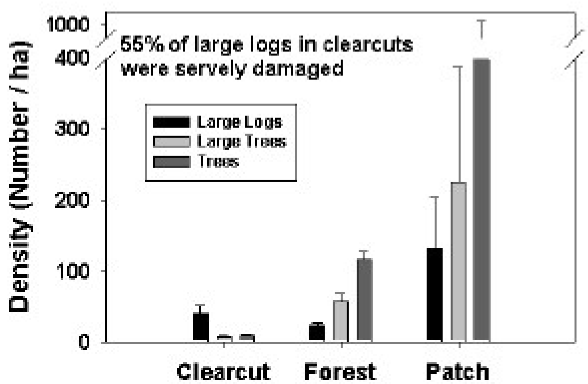

Figure 32. Density of large logs ($\geq$35 cm DBH), large trees ($\geq$ 40 cm DBH)), and all trees ($\geq$ 8 cm DBH) in clearcuts, mature forest, and retention patches (mean plus 1 *S.E.*).

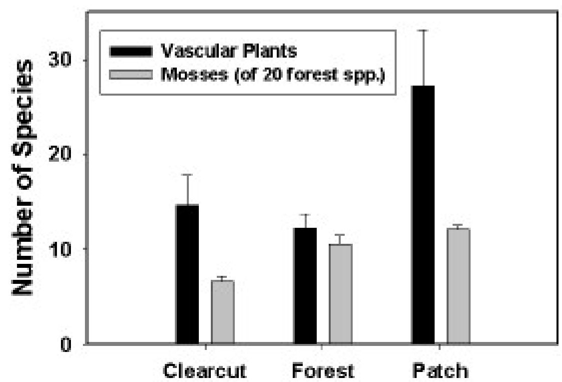

Figure 33. Number of vascular plant species and moss species in clearcuts, mature forest, and retention patches (mean plus 1 *S.E.*).

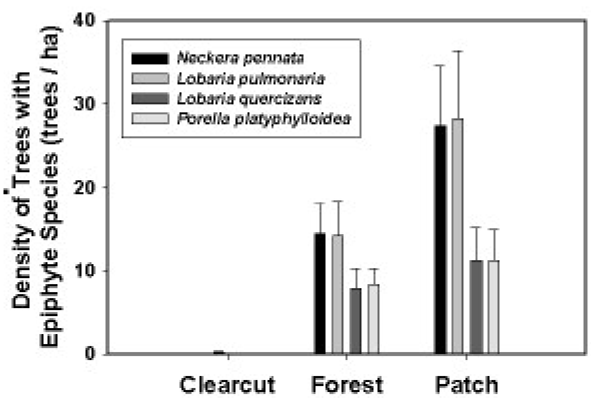

Figure 34. Density of trees with large tree epiphytes in clearcuts, mature forest, and retention patches (mean plus 1 *S.E.*).

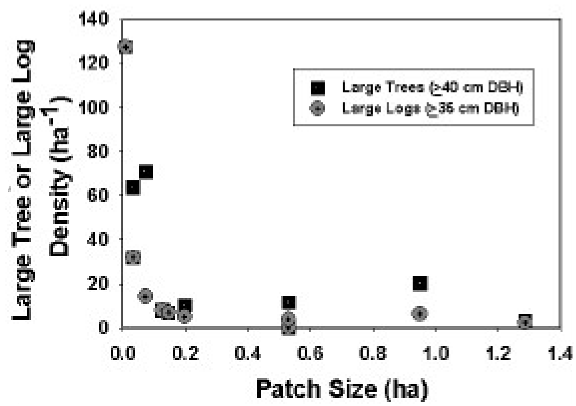

Figure 35. Relationship of retention patch size versus density of large trees and density of large logs in retention patches of different sizes. The density of large trees and large logs declines with retention patch size until the patches reach 0.2 ha.

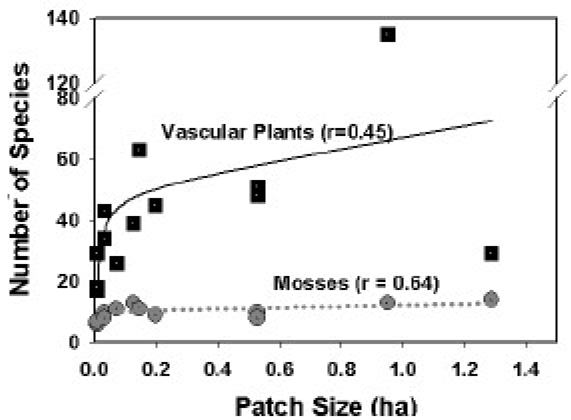

Figure 36. Relationship of retention patch size vs. number of plant and moss species in retention patches of different sizes. The numbers of vascular plant and mosses increase with retention patch size until the patches reach between 0.1 and 0.2 ha.

Substudy III

In Substudy III we are assessing the economic costs of employing patch retention on a scale beyond the experimental work. This work is being performed in collaboration with **Chris LeDoux**, Ph.D. (USDA Forest Service), a timber harvest operations and forest growth modeler. We have had two planning meetings with Dr. LeDoux to determine goals, data needs, and modeling strategies. We will use ecological data and GIS data collected from the retrospective study sites and to model and evaluate the costs of patch retention under real but different scenarios where patch size and density vary. These analyses will include sensitivity analyses to determine where patch retention costs are minimal and where they are likely to be high.

Outreach

The project has lead four major field workshops. We used sites from Substudy I (the before and after experiment) as demonstration areas for patch retention for field workshops for **Seven Islands Land Co.** (25 foresters attending), **Huber Corporation** (10 foresters attending), and a meeting of forestry school deans from across the US (60 people attending). A fourth field workshop was conducted for **MeadWestvaco** (25 foresters attending). Field workshops have been critical for communicating research results and for receiving invaluable feedback from users in the field.

Tasks

- Complete analysis and reporting of Substudy I (before and after experiment of patch retention)
- Complete analysis and reporting of Substudy II (retrospective studies of patch retention)
- Complete analysis and reporting of Substudy III (economic assessment of patch retention)

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

Acknowledgements

Ground beetle surveys were conducted jointly with Dick Dearborn (Maine Forest Service), Charlene Donahue (Maine Forest Service), and Hannah Gaines. Julia Briedis, Kari Van Allen, Charles Bevington, Devin Black, Lindsay Hawks, Liz Veazey, and Hannah Gaines assisted fieldwork. Substudy II was only possible through the assistance of **Hugh Crammond** (J.D. Irving), **Jim O'Malley** (Huber Corp.), **Joel Swanton** (International Paper), and **Paula Pelletier** (International Paper). Field Housing was provided in part by Russell Whitman and **J.D. Irving.** Funding was provided by the **Cooperative Forestry Research Unit** of the University of Maine, the **National Fish and Wildlife Foundation**, and **Manomet Center for Conservation Sciences.**

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

John M. Hagan
Manomet Center for Conservation Science

Introduction

As a review, the goal of this study is to understand what riparian values are protected with different forest buffer widths, especially water temperature. Fifteen streams in western Maine were assigned to one of five different treatments (Table 12).

During the fall and winter of 2001/2002, all harvesting along 12 treatment streams was carried out by the cooperating landowners (Plum Creek, Seven Islands, International Paper, and Mead-Westvaco). Three control streams remained unharvested. In 2002, we completed sampling for the first post-treatment year of this study.

The pre-treatment year (2001) was one of the driest years on record in Maine, and most of the 15 study streams went dry in late July or August. The first post-treatment year (2002) also was a dry year, especially in late summer. Most of the 15 study streams stopped flowing in 2002, but slightly later in the summer (early August, on average). Our most significant challenge in the study has been filtering out data from the automatic temperature recorders when the streams became dry; different streams went dry at different times, and some alternated between being wet and dry. This behavior may be more the norm than the exception for small headwater streams.

Table 12. Harvest 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 x 300m Partial Cut Block (both sides)	3
5	No Harvest	3

Data from the 2002 field season is being analyzed at present. However, this report provides some preliminary results from the first post-treatment field season, and gives us insight into the effectiveness of different buffer widths for protecting stream temperature.

Post-Harvest Assessment

In the 2002 field season (May 1 – September 24) we assessed whether harvests were carried out according to the study's specifications. We assessed the width of resultant buffers, residual basal area of buffer strips and cut blocks, and canopy closure over the stream channel.

Buffer Width

Buffer widths created by the harvest operation were very close to our treatment target widths (Figure 37). Buffers averaged 2-3 m greater than the target width because our post harvest assessment measured buffer width to the outer edge of the canopy (not tree trunks, which were flagged for harvesters). A few mistakes were made by harvesters due to misinterpretation of a complex array of flagging associated with the study, but we are nevertheless pleased with the precision with which harvesters met our buffer width specifications. A few scattered residual trees were retained along the 0-buffer treatment, which explains the average width of 1-2 m.

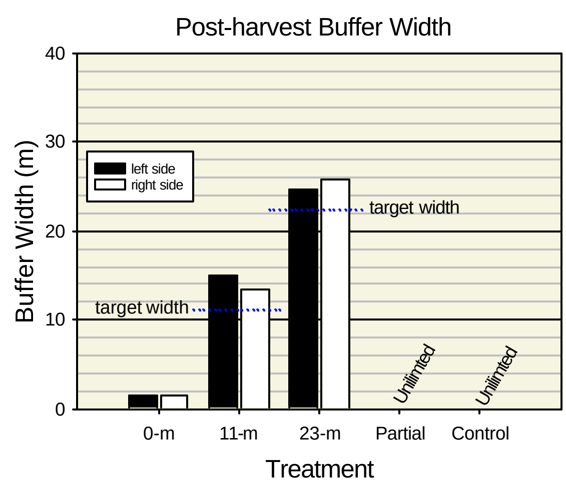

Figure 37. Mean buffer widths resulting from harvest operations on the right and left sides of the study streams.

Residual Basal Area

To ensure treatment basal areas were brought to study specifications, we repeated prism-plot sampling at the same locations along the stream and within the harvest blocks in 2002. Our goal was to partially cut the buffers to about 60 ft^2/ac residual basal area. Clearcut blocks should be less than 30 ft^2/A. All clearcut harvest blocks adjacent to study streams met the clearcut specification goal (Figure 38a). In the partial harvest blocks basal area was reduced from about 170 ft^2/A to about 98 ft^2/A. Stands adjacent to Control (no harvest) streams remained basically the same (Figure 38a). The target residual basal area in the streamside buffers was 60 ft^2/A, but the actual basal area tended to be higher (between 80 and 100 ft^2/A, Figure 38b). For whatever reason, we did not achieve the target residual basal area, but it is clear from Figure 38b that some harvesting was carried out in the buffer, based on comparing the pre- and post-harvest basal areas.

Canopy Closure

Canopy closure over the stream channel changed very little in all treatments except the 0-m buffer treatment (Figure 39). Prior to harvesting, all streams had over 90% canopy closure. Because of the proximity of the buffer edge to the stream, the 11-m buffer resulted in a slight opening of the canopy (84% closure) over the stream channel. The 23-m and partial-cut treatments changed very slightly, as did the control treatment. Based on the high degree of canopy retention, we would predict little change in water temperature regimes post-harvest, except in the 0-m buffer treatment streams.

Stream Temperature Changes

Stream temperature is arguably the most important parameter to monitor as an indicator of stream ecological change. Each of the 15 study streams had automatic temperature probes deployed at 100 m intervals over a 500 m study reach. Probes recorded temperature hourly throughout the summer. Interpretation of the stream water temperature data is complicated by the fact that most streams went dry in both years. It can be difficult to distinguish between when the probes were covered by water and when they were exposed to air. However, by trimming the water temperature dataset to a period for which we are confident water was flowing in both years (15 June – 15 July), we can begin to understand whether the different buffer widths protect water temperature.

The mean daily maximum water temperature increased for all three 0-m buffer streams in 2002 (post-harvest year) between 15 June and 15 July, even though the mean air daily maximum air temperature was slightly lower in 2002 (Table 13). Kibby stream increased the most (2.62°C, 4.72°F). However, the maximum daily maximum water temperature in Kibby during this period was 20.5°C, which is within the thermal tolerance zone for brook trout, a key biological indicator for cold water streams. Two of three 11-m buffer streams showed warming, and one of the three 23-m buffer streams warmed (Table 13). All of the partial-cut streams cooled, as did the three Control streams, reflecting slightly cooler air temperatures in the post-harvest year. These results suggest that 23-m buffers and partial cut blocks (with partially cut buffers) do a good job of maintaining water temperature at levels that would be observed with intact canopies. We presently are trying to understand what factors determine how much a stream warms in the 0-m and 11-m buffer treatments. Aspect of the stream may be a key factor because if affects the incidence angle of solar radiation. Streams that have a southerly aspect may therefore warm more than streams with a northerly aspect.

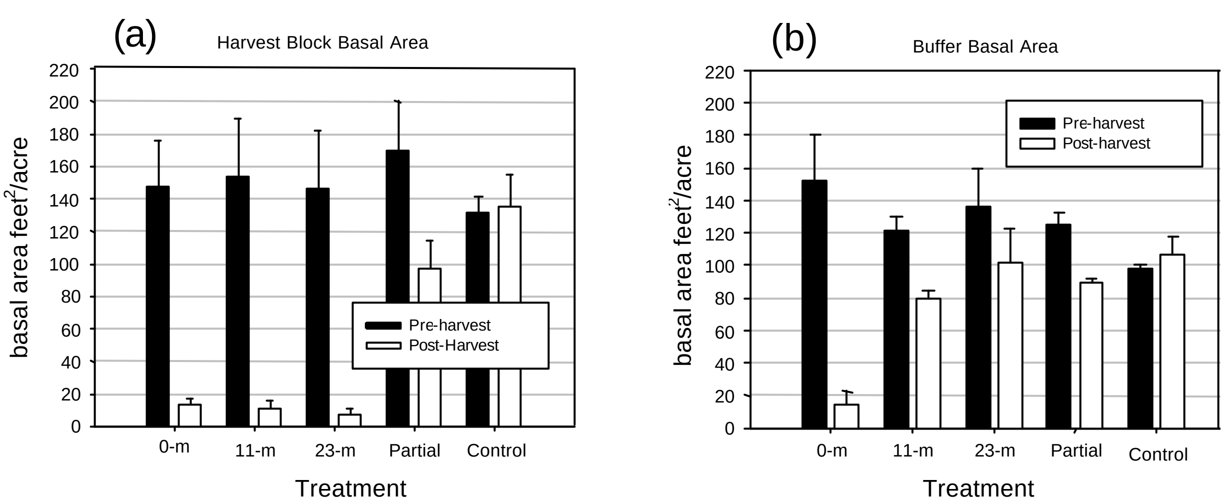

Figure 38. Residual basal area in harvest block (a) and in streamside buffer zones (b) pre- and post harvest

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Table 13. Mean daily maximum water temperatures (and air temperatures for 3 locations) in 2001 (pre-harvest) and 2002 (post-harvest) between 15 June and 15 July for each of the study streams. Mean temperature differences that were higher in the post-harvest year are shaded. Daily maximum air temperatures during this period were cooler in 2002 than in 2001.

		2001				2002				
Treatment	Stream	N (days)	Mean (°C)	Min (°C)	Max (°C)	N (days)	Mean (°C)	Min (°C)	Max (°C)	Daily Max Change (°C)
0-m	Kibby	31	12.60	10.73	14.60	31	15.24	7.95	20.52	2.64
0-m	PiercePond1	31	14.17	12.72	16.16	31	15.26	9.46	19.04	1.09
0-m	Skinner1	31	11.80	10.71	13.96	31	13.53	7.93	17.11	1.73
11-m	Bald Mountain	31	14.18	12.77	16.37	31	15.10	9.51	18.61	0.91
11-m	Caratunk	31	14.64	12.98	17.22	31	14.56	8.94	17.86	-0.09
11-m	Skinner2	31	10.79	9.62	13.35	31	13.42	8.21	17.09	2.63
23-m	MassGore2	31	5.46	4.86	6.26	31	5.75	4.23	9.04	0.29
23-m	Roxbury	31	14.44	12.74	17.30	31	13.28	8.97	16.46	-1.16
23-m	Sanderson	31	13.96	11.93	15.83	31	13.60	8.83	17.58	-0.36
Partial-cut	MassGore1	31	12.72	11.16	15.51	31	10.56	6.98	12.55	-2.15
Partial-cut	PiercePond2	31	13.53	12.14	15.56	31	13.02	8.42	16.35	-0.51
Partial-cut	UpCup	31	13.07	11.17	15.67	31	12.35	7.76	15.83	-0.72
Control	Appleton	31	12.52	11.08	14.96	31	11.47	6.79	14.99	-1.05
Control	Bryant	31	13.70	11.78	18.70	31	13.19	8.07	17.09	-0.51
Control	Dud	31	13.56	12.24	15.84	31	12.75	7.60	16.63	-0.81
AirT Sta. 1	Caratunk TWP	31	21.07	15.44	30.14	31	20.25	8.62	27.77	-0.82
AirT Sta. 2	Kibby TWP	31	19.06	11.92	28.21	31	18.91	7.43	27.66	-0.15
AirT Sta. 3	Roxbury TWP	31	22.60	15.79	32.52	31	22.35	9.42	30.97	-0.25

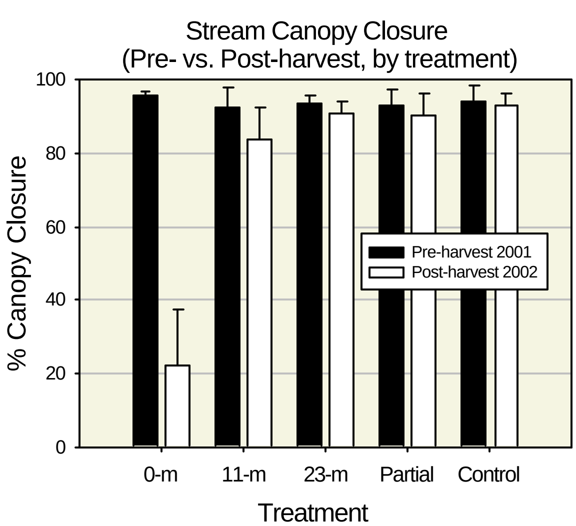

Figure 39. Mean canopy cover (percent) over stream channels pre- and post-harvest.

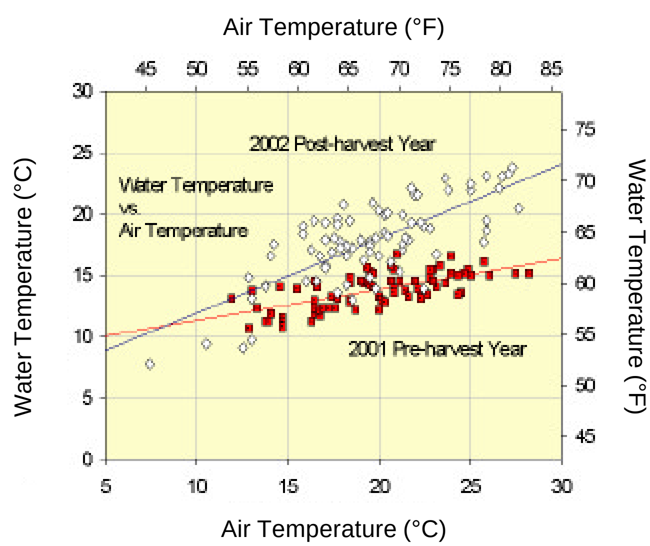

Figure 40. The relationship between daily maximum water temperature and daily maximum air temperature for Kibby stream (0-m buffer) in both 2001 and 2002. The change in slope of the relationship reflects the effect on water temperature of removing the canopy.

Another way to understand how canopy removal affects water temperature is to plot the relationship between daily maximum water temperature and air temperature for the pre-treatment and post-treatment years. This relationship is shown for Kibby stream in Figure 40. In the pre-treatment year, the daily maximum water temperature increased about 0.25°C for every 1.0°C increase in daily maximum air temperature (slope of regression line). After removal of the canopy over the stream, the daily maximum water temperature increased 0.60°C for every 1.0°C increase in daily maximum air temperature. Thus the stream water temperature was much more responsive to changes in air temperature after the canopy was removed.

The greater responsiveness of water temperature was also seen in the daily range in water temperature. Continuous traces of water temperature for the pre-treatment and post-treatment year are shown in Figure 41 for Kibby stream. It is clear from the traces that Kibby stream was much warmer in 2002 (despite the cooler overall temperature), and that the daily flux in stream temperature was much greater in 2002, with the stream channel exposed to the sun. Figure 41 shows that Kibby stream exceeded 21°C (unfavorable for brook trout) on a series of very warm days in mid August (2002). (NOTE: Kibby stream was non-fish-bearing due to a natural obstruction downstream). Although we do not yet understand the biological implications of these changes in thermal regime resulting from complete canopy removal, we are beginning to understand how abiotic conditions are affected.

Water Quality

We assessed four water quality parameters (in addition to water temperature) in the pre-and post-harvest years: (1) turbidity, (2) pH, (3) dissolved oxygen, and (4) conductivity. However, we were not able to record these parameters continuously because of cost. Water quality data are thus limited to June in both years when water was flowing in all streams.

None of these four water quality parameters changed as a result of the harvest in any of the treatments, at least during our 3 samples of each stream in June. In all cases, turbidity (Figure 42a) remained very low (less than 1 NTU) after the harvest. We also conducted an inspection of both sides of the stream for possible erosion inputs resulting from the harvesting operation (to be presented in a future report). Preliminary analyses show that natural scarification far exceeded harvesting scarification within 25' of the stream edge.

pH appears to have decreased slightly (but not statistically significant) among all streams, including Control streams in 2002 (Figure 42b). Dissolved oxygen appeared to increase (not significantly) in 2002 (Figure 42c), and conductivity remained the same after the harvest (Figure 42d). We point out that these data are taken at only 3 instants in time. Continuous data might have revealed different results. For 2 streams were have continuous data collected by Hydrolabs for these parameters. These data will be presented in a future report.

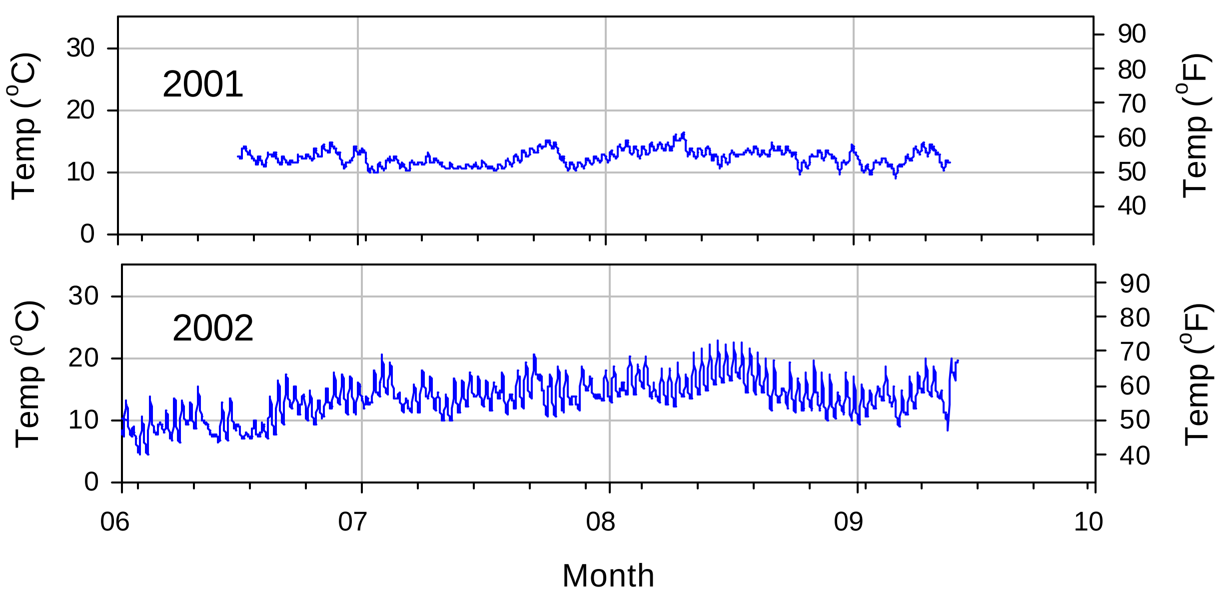

Figure 41. Continuous water temperature trace from Kibby stream in 2001 (pre-harvest year) and 2002 (post-harvest year). Kibby stream was a 0-m buffer stream. The temperature profile in the 2002 graph reflects the exposure of the stream to the sun.

Macroinvertebrates

Macroinvertebrates were sampled using standardized rock bags that are colonized by stream insects. These data are being analyzed by a 3rd-party lab, and results will not be available until summer 2003, due to a large backlog volume of work.

Planned Activities

Over the winter months we will be completing more thorough analyses of data collected to date, and preparing for the final (as currently planned) field season for this study in 2003. We intend to complete manuscripts on (1) herbaceous plant community gradients along small headwater streams, and (2) natural thermal dynamics of small headwater streams (data from the pre-harvest year). We will be meeting with our Headwater Stream Project Advisory Committee, and all interested participating foresters this winter to review and discuss the results of the study to date.

For more information about this report, contact **John Hagan** at 207-721-9040 (jmhagan@ime.net).

Acknowledgements

This report was prepared with the assistance of **Ethel Wilkerson**, Headwater Stream Project Manager. We thank our field assistants **Stephanie Hart**, **Tara Trinko**, **Josh Campbell**, and **Christa Straub** for their hard work and dedication to collecting quality data. **Darlene Siegel** (former Project Manager) also helped launch the 2002 field season and made our staffing transition smooth and seamless.

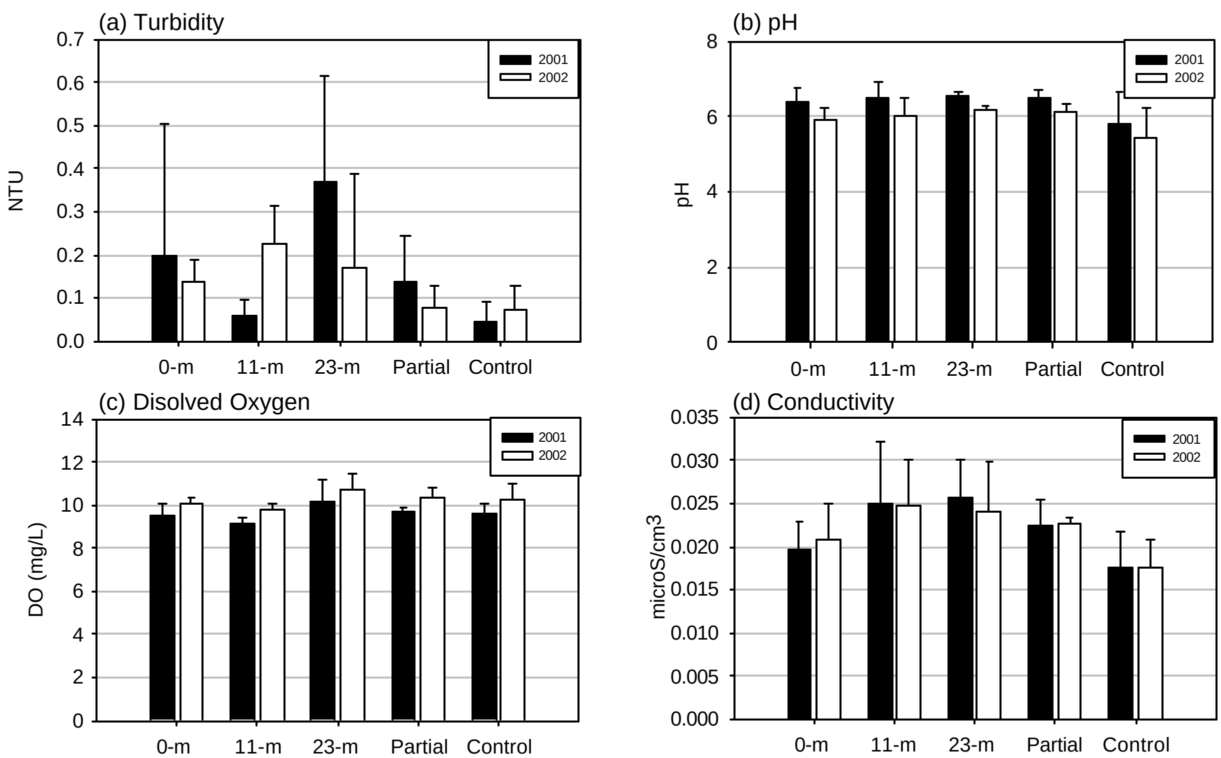

Figure 42. Four water quality parameters before and after harvesting. Bars represent the mean value of three streams per treatment. Means for each stream were derived from multiple readings taken during each three visits to each stream in June 2001 and 2002.

New CFRU Research Projects

CFRU scientists and staff are continually seeking to identify forest management problems facing CFRU Cooperators and then developing new research projects that can help solve these problems. During the past year a number of new proposals were presented to CFRU members for their consideration. The CFRU Advisory Committee and the new Hardwood Silviculture Research Subcommittee (see page 15) reviewed and evaluated all proposals. Among those reviewed, five new projects were approved for implementation in the next fiscal year (October 2002 to September 2003):

Northern Hardwood Growth and Yield Model

One of the highest CFRU research priorities for 2000 to 2005 is the improvement of growth and yield models as it relates to Maine hardwood stands. This new project led by **Tim McGrath** of the Nova Scotia Department of Natural Resources has three objectives: 1) remeasure 25-year-old hardwood experimental sites during the 2002 and 2003 field seasons, 2) use the remeasurement data to refine the Nova Scotia Hardwood Growth and Yield Model, and 3) publish a user manual and model description.

When complete, the model will be able to predict the yield of hardwood stands over time in both managed and unmanaged stands. The model is intended to allow users to evaluate the benefits of various silvicultural treatments by examining the outputs from the model. Of particular interest will be the ability to simulate the effects of pre-commercial thinning and commercial thinning for hardwood stands.

The Advisory Committee voted at the July 2002 meeting to fund this proposal in conjunction with the Nova Scotia Department of Natural Resources. This project was viewed as the best opportunity to improve growth and yield models for hardwood stands that are applicable to the state of Maine.

This two-year project is scheduled for completion in 2004. Regular progress reports will be provided to the CFRU Advisory Committee. For more information about this project, contact **Tim McGrath** at 902-893-5683 or by email at tpmcgrat@auracom.com.

Role of Interfering Plants in Hardwood Regeneration: A Literature Review

Improving management strategies for understory vegetation (including diseased beech, striped maple, and other interfering plant species) to promote the regeneration and growth of desirable hardwood species was identified by the CFRU Hardwood Silviculture Research Subcommittee as a top priority. This project, led by **Ralph Nyland** of the SUNY College of Environmental Science and Forestry, seeks to develop a literature review about interfering vegetation in hardwood forests and how to manage those interfering species in conjunction with silvicultural treatments to regenerate high-value hardwoods. The Advisory Committee approved this project at the May 2002 meeting.

This review is intended to serve as the foundation for drafting a management guide to aid in planning regeneration programs for the hardwood forests of Maine and adjacent areas of northeastern North America. Besides assisting forest managers in planning and prescription making, findings from the project will help CFRU to target critical factors that it must address through future investigations, while avoiding unnecessary duplication of past research. The annotated bibliography will be available will be available in fall of 2003.

For more information about this project, contact **Ralph Nyland** at 315-470-6574 or by email at rnyland@mailbox.syr.edu.

Indicators For Maintaining Biodiversity in Managed Forests

Efforts to develop, implement, and promote sustainable forestry practices by CFRU members are focused on several ongoing approaches: forest certification, outcome-based forestry, and adaptive management. Each of these approaches requires that the forest management programs explicitly manage for and maintain biodiversity.

Each approach, however, faces significant challenges to meeting biodiversity objectives. Forest certification relies on largely untested indicators, including the use of unproven biodiversity best management practices, to determine if a landowner is maintaining biodiversity. Outcome-based forestry relies on measuring management impacts to determine if a harvest practice or timber management strategy achieves the desired outcome with regard to biodiversity (irrespective of any particular approach). Adaptive management requires replicating highly detailed and expensive research programs over many sites to determine the impacts of different harvest and timber management strategies.

A primary limitation to these approaches is a lack of inexpensive tools to evaluate whether or not a landowner is succeeding or failing to maintain biodiversity. Inexpensive tools are critical for forest managers and landowners to economically and efficiently manage for biodiversity, and to assess progress toward meeting biodiversity goals.

To address this problem, **John Hagan** and **Andy Whitman** of the Manomet Center for Conservation Sciences developed a proposal to identify forest biodiversity indicators and evaluation tools that can be economically integrated into routine forest resource evaluations, including timber inventories, harvest block assessments, and landscape planning. Indicators and evaluation tools will be developed and tested using data collected at the stand- and landscape-level from managed and unmanaged stands in northern Maine.

This two-year project was approved at the July 2002 Advisory Committee meeting. More information about this project is available from **John Hagan** or **Andy Whitman** at 207-721-9040 or by email at jmhagan@ime.net, awhitman@ime.net.

Eastern CANUSA Forest Science Conference

Many millions of dollars are spent annually on scientific and other research in Maine, the northeastern states, and eastern Canada to advance knowledge about how to better the northern forest. Despite the importance of the forest and abundance of research being conducted, there is no regular cross-border forum where managers, landowners, researchers, students, and interested members of the public can meet to hear the latest information coming from this work. Further, there is no forum where US and Canadian researchers working on the same problems can meet regularly to present results, discuss common problems, develop collaborations, improve efficiencies, and learn from one another.

Bob Wagner (CFRU) and **Dave MacLean** (University of New Brunswick) proposed solving this problem by developing the Eastern CANUSA Forest Science Conference. The objectives of the ECANUSA 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 first of a continuing biennial conference hosted alternately by the University of Maine and University of New Brunswick is scheduled for October 2002. The one and half day meeting will include a half-day plenary session with prominent speakers addressing the latest issues affecting the northern forest. Following the plenary session will be a full day of concurrent technical sessions where attendees will hear presentations about the latest research in four theme areas: 1) silviculture and forest production, 2) ecology and wildlife, 3) wood products and forest operations/engineering, and 4) forest management, planning, and policy. In addition, there will be a poster session displaying results of other research projects from around the region.

The Advisory Committee at the May 2002 meeting voted to financially support this conference with several other organizations. For more information about the conference contact **Bob Wagner** at 207-581-2903 or bob_wagner@umenfa.maine.edu.

Growth Response and Economic Return From Fertilization of Pre-commercially Thinned Spruce-Fir Stands

Use of fertilizers to enhance the nutrient availability and growth of forest stands is commonplace in forestry in other regions around the United States. Unfortunately, relatively little forest fertilization research has been done in Maine, so it is still unclear whether the practice increases stand growth and is economically viable in this region. The work that has been done, primarily monitoring the response spruce-fir stands fertilized by the CFRU, has yielded mixed results. Two recent CFRU experiments

(Briggs/IP study and Weymouth Point) established in the 1990s were designed to test the effects of mid-rotation nitrogen fertilization on growth responses of spruce-fir. A preliminary measurement of the Briggs/IP study has shown up to 71% increase in height growth of these balsam fir stands. The Weymouth Point PCT and fertilizer study has not measured for several years. International Paper Co. also has established two fertilizer studies (Lhoist and Hersey) that are in need of remeasurement.

The objectives of this project proposed by **Bob Wagner** and **Dan McConville** (CFRU) are to 1) remeasure all study plots in two CFRU fertilization trials (Briggs/IP study and Weymouth Point) and two IP trials (Lhoist and Hersey studies), 2) compare volume growth of fertilized and unfertilized plots that have been pre-commercially thinned, 3) model future stand growth and perform an economic analysis based on response to fertilizer treatment, 4) compare biomass (foliage, stem and branch wood) development for fertilized and unfertilized pre-commercially thinned plots, 5) compare foliar nutrient content of fertilized and unfertilized plots, and 6) based on the results, identify future research needs related to fertilizing Maine's softwood stands.

This two-year project was approved by the CFRU Advisory Committee at the October 2002 meeting. A M.S. student has been identified to develop the project into a M.S. thesis. Work on the project will begin during the summer of 2003. For more information about this project, contact Bob Wagner at 207-581-2903 or
bob_wagner@umenfa.maine.edu or
Dan McConville at 207-581-2861
or **dan_mcconville@umenfa.maine.edu.**

TECHNOLOGY TRANSFER

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- Hardwood silviculture research proposals
- Eastern CANUSA Forest Science Conference

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Appendix A.

Species List

Trees

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

Animals

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

Appendix B.

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