

COOPERATIVE FORESTRY RESEARCH UNIT

2000 Annual Report



College of Natural Sciences, Forestry,
and Agriculture

Maine Agricultural and Forest Experiment Station
Miscellaneous Report 424



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Highlights 1999-2000

Organizational

- The restructuring of the CFRU, which was begun in 1999, was completed in mid 2000
- The final draft of the CFRU Prospectus, which includes the objectives and organizational design for 2000-2005, was completed
- The filling of new support positions was completed. The new organizational design substantially reduced the overall administrative expenses for running the CFRU
- Dan McConville was hired as CFRU Field and Data Coordinator
- KaDonna Randolph was hired to lead the modeling effort for the commercial thinning study
- Mike Greenwood and Dan Harrison completed their first year as Cooperating Scientists
- This year, administrative expenses were reduced to less than 40% of the dues base. As a result, the CFRU has been able to substantially increase the amount of operating dollars available for new research projects
- A number of other new project scientists, research technicians, and graduate students are associated with new and ongoing CFRU projects
- Construction on a new CFRU website is providing a new focus and approach for communications with cooperators, as well as reduced costs.
- Development of strategies to integrate CFRU field coordination across all projects was targeted through discussions with scientists and field visits to new CFRU study sites

Research

- Five *new* projects have been funded in keeping with the guiding principle of interdisciplinary and collaborative research
- The Commercial Thinning Research Network, led by Bob Wagner and Bob Seymour, is addressing one of the CFRU cooperators biggest concerns--finding improved strategies for commercial thinning
- John Hagan and Andy Whitman of the Manomet Center for Conservation Sciences are principal investigators on new projects addressing concerns about the effect of forestry practices on water quality and the effect of patch retention on harvested sites to support several biodiversity components
- Cyndy Loftin of the USGS, is working on a study that seeks to summarize the body of existing literature on effects of forest management practices on riparian and in-stream animal biota of North America
- A new partnership was explored and developed for shared funding of research projects with National Council for Air and Stream Improvement (NCASI) on riparian zone research that is of common interest
- Recent concerns about the Canada lynx and the effect of precommercial thinning in Maine's forests has stimulated a study by Dan Harrison to examine the relation between stand density and predator food sources, with special emphasis on snowshoe hare
- Marten populations were examined as a means for evaluating landscape effects of forest harvesting and as a coarse filter to assist in long-term forest planning at the scale of townships or larger landscapes
- Funding for the establishment of a Hardwood Silviculture Research Advisory Committee to develop ways to improve the management of the hardwood resource was initiated
- Bill Ostrofsky addressed the need to better understand the effects of precommercial thinning on rooting characteristics of spruce and fir in Maine
- A project to assess the effects of precommercial thinning on the properties of wood harvested at future intervals was completed by Bob Shepard
- The Austin Pond Study is the CFRU's oldest research site and is providing one of the best opportunities to document the long-term effects of herbicide treatments and precommercial thinning (PCT) on spruce-fir stands in the region
- Substantial reductions in the number of needle primordia was found in red spruce and balsam fir as a result of seasonal applications of imazapyr
- A conversion of the Maine Forest Service's wood supply model from Atlas to a Woodstock platform was completed successfully in an effort to evaluate silviculture research priorities for the state

Makeup of the Organization

Major Cooperators 2000

Baskahegan Corporation
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
Mead Corporation
Plum Creek
Prentiss & Carlisle
Seven Islands Land Company
The Nature Conservancy
Ste. Aurelie Timberlands Company

Other Cooperators 2000

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
Penley Corporation
Pride Manufacturing Company
Robbins Lumber Company
Saunders Brothers
Timberlands Enterprises /Pinebelt, Inc.
Western Maine Nurseries

CFRU Staff

Director

Robert G. Wagner, Associate Professor of Forest Ecosystem Science

Professional Staff

H. E. "Chip" Griffin, Communications and Financial Coordinator
Daniel J. McConville, Field and Data Coordinator
KaDonna Randolph, Research Associate

Cooperating Scientists

Michael S. Greenwood, Professor of Forest Ecosystem Science
Daniel J. Harrison, Professor of Wildlife Ecology

Project Scientists

John M. Hagan, Manomet Center for Conservation Sciences
Cynthia S. Loftin, Assistant Professor of Wildlife Ecology, USGS
Robert S. Seymour, Professor of Forest Ecosystem Science
Robert K. Shepard, Professor of Forest Management
William D. Ostrofsky, Associate Professor of Forest Management
Andrew A. Whitman, Manomet Center for Conservation Sciences

Chair's Report

The first year of the new millennium has been a very successful and productive one for the CFRU. It has been the first full year of working with the new structure and although there have been a few growing pains, it appears to be working well. I am very pleased to be able to report that all staff members who were displaced during the restructuring process have found satisfactory re-employment and appear to be doing well in their new positions.

To accompany the new structure, the CFRU Prospectus and by-laws were revised to outline responsibilities of positions and agencies involved and to develop procedural guidelines required to accomplish the goals and objectives of the unit.

Contained in the Prospectus are new, 5year research priorities or objectives to guide the direction of research 2000-2005. It is encouraging to see that research now being funded by the unit and new projects that have been proposed go a long way in working toward accomplishment of these objectives.

The staff of the restructured unit became at full strength with the addition in May of **Dan McConville** as "Field and Data Coordinator". Dan is a Maine native who had been working at the Jones Ecological Research Center in Georgia. He joined the CFRU on May 15 at the beginning of field season, hit the ground running, and has been a great asset to the unit.

Great strides have been made in the communications aspect of the Unit during the year with the development and continual upgrading and improvement of the CFRU website. Now, thanks to the ingenuity of the Unit's Communications and Financial

Coordinator, **Chip Griffin**, virtually all information relating to meetings, annual reports, research proposals and reporting is now, or soon will be, available on the web site. This has greatly reduced paper handling by all involved and has resulted in a substantial savings in printing and mailing costs.

The concept of Cooperating Scientists appears to be working well. Special thanks to **Dan Harrison** and **Mike Greenwood** who presently occupy these positions. Two additional scientists have been recommended to bring the compliment to four. Hopefully the process can be completed soon and they will be on board early in the coming year.

Another important achievement for the year has been the establishment of a Hardwood Silviculture Research Advisory Committee. In recent years there has been much interest by many of the cooperators in improving the management of the hardwood resource. In August a meeting was held by interested parties at **Henry Saunders'** lodge in New Hampshire. The meeting was organized by **Max McCormack** and **Bob Wagner** and was attended by representatives of several of the cooperators, and researchers from the University of Maine and the US Forest Service. The purpose of the meeting was to develop a proposal for establishment of the committee which would include: objectives, terms of reference, research priorities, and membership. The proposal was presented and approved at the October meeting of the Advisory Committee, and Bob Wagner is in the process of setting it up. Many thanks to Henry Saunders for the use of his lodge, his participation, his hospitality, and his continued interest in and promotion of responsible management of the hardwood resource.

On the downside, as everyone is aware, much forest land in Maine has changed hands in recent years; a trend that appears to be continuing. For the most part new owners have continued to support the CFRU, but this has not always been the case. The net result has been a loss of some \$67,000.00 in dues. This situation inspired the establishment of a new dues structure that would allow/encourage participation by non-landowning agencies such as mills and various corporations. To date we have had no new members but hopefully this can change in the coming year.

All in all I would rate 2000 as a very successful year for the CFRU. On behalf of the Advisory Committee I would like to thank **Bruce Wiersma** for his participation and the University's continued support of the unit; **Bob Wagner** and the CFRU staff for the excellent work they have done during the transition to the new structure in making it a success; and the cooperating and project scientists for the timely and pertinent research they are carrying out in working toward achieving the goals and objectives of the unit.



Brian Higgs
Chair, CFRU Advisory Committee

Dean's Report

The year 2000 marks completion of the first year of a five year research plan established as a result of the 1999 restructuring of CFRU. The support of the members of CFRU continues to be unwavering and impressive. Without that support the CFRU could not function. The time and effort expended by the members has proven to be well spent as we look at the accomplishments of last year.

The CFRU has a different look with new faces and new projects. Under the able leadership of **Bob Wagner**, and with the help of Communications and Financial Coordinator **Chip Griffin** and new staff members **Daniel J. McConville**, Field and Data Coordinator and **KaDonna Randolph**, Research Associate, the *new* CFRU is a successful reality. A website is up and running that provides cooperators and others with both historical and up-to-date information on CFRU. Five *new* projects have been funded. In keeping with the guiding principle of interdisciplinary and collaborative research, I am

very pleased that **John Hagan** and **Andy Whitman** of the Manomet Center for Conservation Sciences are principal investigators on two of the new projects established in 2000. The first project addresses concerns about the effect of forestry practices on water quality in Maine's forests. The second project, part of the Shifting Mosaic Project, tests the capability of patch retention on harvested sites to support several biodiversity components. **Cyndy Loftin** of the USGS, is working on a study that seeks to summarize the body of existing literature on effects of forest management practices on riparian and in-stream animal biota of North America. Recent concerns about the Canada lynx and the effect of precommercial thinning in Maine's forests has stimulated a study by **Dan Harrison** to examine the relation between stand density and predator food sources, with special emphasis on snowshoe hare. Finally, the Commercial Thinning Research Network, led by **Bob Wagner** and **Bob Seymour**, is addressing one of the CFRU cooperators biggest concerns--finding improved strategies for commercial thinning.

We still face the same challenges year after year. Major shifts in land ownership patterns and reluctance of new owners to commit to long-term research on forest resources issues continues to strain the funding base of the CFRU. I will continue to work with **Bob Wagner** and other CFRU leaders to help minimize or eliminate this funding problem. The revitalization of the general forest resources advisory committee is underway and the new CFRU will have a significant role to play in the renewed FRAC as we attempt to more closely integrate our base forest resources research programs with those of CFRU.



Bruce Wiersma
Dean, College NSFA

Director's Report

This year was the first full year of operation since the 1999 restructuring. It has been an exciting and productive year for the newly reformed unit. Completion of the CFRU Prospectus this year concluded restructuring of the unit. Implementation of the new organization also made significant strides with the filling of two core support staff positions. **Chip Griffin** was hired at the beginning of this year as CFRU Communications and Financial Coordinator. In May, we hired **Dan McConville** as CFRU Field and Data Coordinator. Both Dan and Chip are proving to be invaluable as we fully implement the new organization.

For example, Chip has done a great job getting the financial affairs of the unit into shape and getting the new CFRU on line with a new web page. The Advisory Committee voted this year to stop printing CFRU publications on paper and making everything we produce available primarily online. This move has significantly reduced our overhead expenses and provided for more rapid communication of research results and other CFRU matters to our members. Chip also has introduced a new Research Note and Research Report formats based on cooperator feedback that has worked well with our shift to online publishing.

Dan has spent most of his first months implementing the field portion of the new CFRU Commercial Thinning Research Network. Dan installed seven new study sites across the state this summer as part of this effort. During the coming year, Dan will be developing a data bank so that all data from CFRU research projects can be documented and archived for long-term use.

My thanks to **Mike Greenwood** and **Dan Harrison** who as Cooperating Scientists for the unit have been invaluable as we moved the CFRU into a new realm. **Bill Ostrofsky** and **Bob Shepard** continued to contribute significantly to the program with a couple of ongoing research projects.

As part of the restructuring, we also have been able to develop new partnerships. For example, **Bob Seymour** has been crucial to the development and implementation of the Commercial Thinning Research Network, CFRU's largest new project. We have been able to develop a closer relationship with **Manomet Conservation Sciences** through a partnership with **John Hagan** and **Andrew Whitman** on a couple of new research projects. We also explored and developed new opportunities for shared funding of research project with **National Council for Air and Stream Improvement (NCASI)** on riparian zone research that is of common interest. **Cyndy Loftin, USGS** took the lead in developing a literature review on the effects of forestry practices on the riparian zone. As part of the thinning project, we were able to hire a fixed-term Research Associate, **KaDonna Randolph**, to serve as a modeler for Phase I of the commercial thinning project.

As always, the strength of the CFRU comes from its member organizations. We continue to experience dynamics in this regard as Maine forestlands continue to be bought and sold. I am happy to report that this year has been relatively stable. The most significant change to our membership has been with the sale of **Champion International Corporation** lands to **International Paper Company**. As long-standing members of the CFRU, IP generously agreed to increase their membership support to reflect their purchase of Champion lands. On behalf of CFRU members, I thank IP for their continued support through this transition. We also want to thank Champion for the many years of support that they have provided to the CFRU. I am happy to report that most of the Champion representatives that interacted with the CFRU will still be doing so under the IP name. I also thank **Brian Higgs (Baskahegan Co.)** for his leadership as Chair of the Advisory Committee as we implement the new organization.

A significant advantage to restructuring the CFRU was allowing a substantially larger proportion of our dues based go into to new research projects. I am happy to report that this expectation was realized this year. The new partnerships I describe above come from the initiation of several new research projects that address the 2000-2005 CFRU research priorities. This annual report describes the details of these projects.



Robert G. Wagner
CFRU Director

Introduction

Formed in 1975, the CFRU is one of the oldest industry/university forest research cooperatives in the United States. Funding for the CFRU 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 first quarter century, CFRU cooperators and researchers saw 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. Research in the fields of site classification, growth and yield, vegetation management, nutrient cycling, wildlife, tree improvement and genetics, beech bark disease, and spruce budworm are particularly noteworthy. These projects resulted in the publication of over 475 CFRU sponsored research articles and other publications. Several long-term research sites (e.g., Weymouth Point and Austin Pond) were established and continue to be maintained.

For reasons described in last year's annual report, the CFRU went through a major restructuring in 1999. The purpose of this restructuring was to provide cooperators with a more flexible and efficient research organization. Details of the new organizational design are provided in the *2000-2005 Program Prospectus* that can be found on our web site. Details of the CFRU's current objectives and guiding principles are provided in this Prospectus, and form the basis for the work presented in this annual report.

As we enter the new century, the mission of the CFRU is *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 over 30 member organizations across the state of Maine, CFRU research is focused on a variety of problems facing Maine forest managers and landowners. Specific research projects (described in this report) are focusing on commercial thinning, buffer-strip management in riparian zones, snowshoe hare and marten habitat issues, the long-term effect of herbicides and precommercial thinning, precommercial thinning influences on root rots and wood quality, Maine's wood supply, and the ecological value of patch retention in harvested stands.

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 has been a hallmark of the organization since its earliest days. Results from CFRU research are rapidly communicated to cooperators via 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 1999-2000 and is the first annual report under the new organizational design.



Organization Accomplishments

Restructuring

Robert G. Wagner
University of Maine

The restructuring of the CFRU, which was begun last year, was completed this year. The final draft of the CFRU Prospectus, which includes the objectives and organizational design for 2000-2005, was completed. The filling of two new support positions was completed. The new organizational design substantially reduced the overall administrative expenses for running the CFRU. Before the restructuring, over 90% of the CFRU dues base was consumed by administrative expenses. This year, administrative expenses were reduced to less than 40% of the dues base. As a result, the CFRU has been able to substantially increase the amount of operating dollars available for new research projects. The new projects described in this report reflect this increase in available funds and the enhancement to the program that has resulted from restructuring.

Five-Year Objectives

One of the final tasks required to complete the 2000-2005 CFRU Prospectus was the development and approval of the five-year research objectives for the unit. The objectives, compiled largely from a 1999 research priorities survey of CFRU Cooperators, was refined, submitted to cooperators for review, and approved at the May 17, 2000 Advisory Committee meeting. The approved research objectives for the CFRU from 2000-2005 are to:

- A. improve strategies for commercial thinning, including a better understanding of growth and yield responses to thinning, optimum timing of stand entry, appropriate spacing standards, criteria for prioritizing stands, and other decision-making criteria;
- B. increase information about the influence of forest management practices on water quality, including the effects of buffer strips on watershed protection and wood production;
- C. provide better growth & yield models for conifer, hardwood, and mixedwood stands;

- D. improve silviculture for hardwood stands, especially methods that increase the regeneration success of high value tree species;
- E. increase understanding about the effects of forestry practices on wildlife, biodiversity, and landscapes, with special emphasis on wildlife species that are of strong public concern; and
- F. improve understanding about public perceptions and attitudes about forest management, including developing better ways to communicate and resolve conflict with the public about important forestry issues.

These objectives have helped guide the solicitation of new research proposals, most of which were implemented this year. The projects included in this annual report are addressing most of these five-year objectives.

New Dues Structure

Another task required to complete the CFRU Prospectus was development of a new dues structure for CFRU members. Apart from landowner members, the CFRU had no dues standards for other classes of members or potential members. As a result, four new membership categories were developed, reviewed by members, and approved at the Advisory Committee at the May 17 meeting.

Four categories of membership are provided for those organizations and individuals wanting to advance forest management practices in the state of Maine by supporting CFRU research (Table 1).

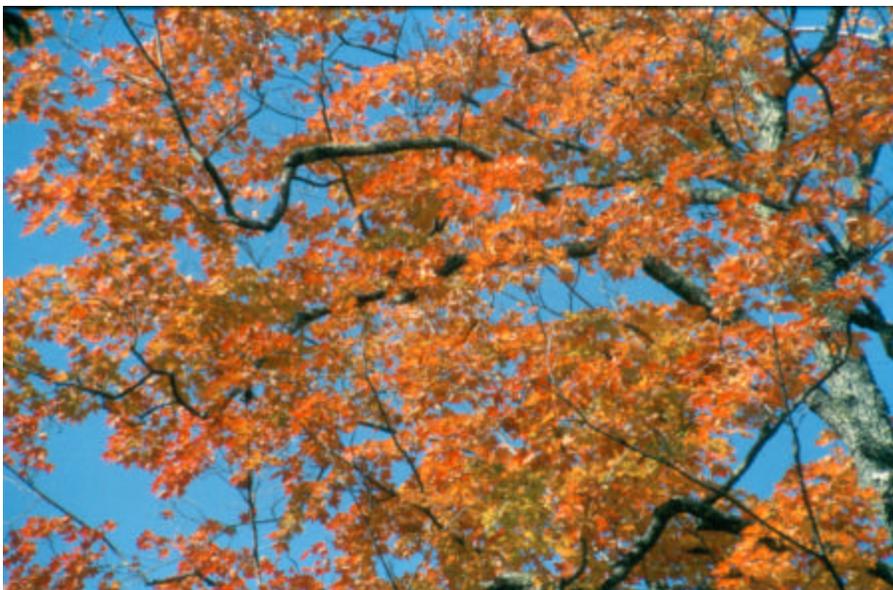


Table 1. CFRU Categories of Membership

Category	Description	Services received	Annual dues
Forest Landowner / Manager	Owner or manager of commercial forestlands in the state of Maine	<p>Voting representation on CFRU Advisory Committee that directs all CFRU research and activities (for landowners / managers with $\geq 50,000$ acres)</p> <p>Immediate notification to all frontline forest managers in your organization as new CFRU research notes, reports, and other materials are released</p> <p>Internet password access to all CFRU publications (including research notes, full research reports, and annual reports)</p> <p>Quick access to CFRU scientists for technical advice and support</p> <p>Participation in quarterly Advisory Committee meetings and annual field tour</p> <p>Listing of your company name as a CFRU cooperator on all publications, poster displays, and web page</p> <p>Opportunity to have CFRU research projects conducted on your lands</p> <p>Access to CFRU databank</p>	<p>\$0.05 per acre per year of owned and/or managed forestland (includes all lands and waters less acreage of water bodies ≥ 10 acres in size)</p> <p>(\$1000 minimum)</p>
Millowner / Wood Processor	Owner of pulp and paper mill or sawmill in the state of Maine that does not own or manage commercial forestland	<p>Voting representation on CFRU Advisory Committee that directs all CFRU research and activities (for mills processing $\geq 200,000$ tons of pulp, paper, or other wood products)</p> <p>Immediate notification when new CFRU research notes, reports, and other materials are released</p> <p>Internet password access to all CFRU publications (including research notes, full research reports, and annual reports)</p> <p>Participation in quarterly Advisory Committee meetings and annual field tour</p> <p>Listing of your company name as a CFRU cooperator on publications, poster displays, and web page</p> <p>Access to CFRU databank</p>	<p>\$0.0125 per ton of pulp, paper, and other wood products processed per year</p> <p>(\$1000 minimum)</p>

Table 1. continued

Category	Description	Services received	Annual dues
Corporate	Corporation, business, or other organization that does not meet either the Forest Landowner / Manager or Millowner / Wood Processor categories above	Voting representation on CFRU Advisory Committee that directs all CFRU research and activities (for medium and large corporations) Immediate notification as new CFRU research notes, reports, and other materials are released Internet password access to all CFRU publications (including research notes, full research reports, and annual reports) Participation in quarterly Advisory Committee meetings and annual field tour Listing of your company name as a CFRU cooperator on publications, poster displays, and web page	Small: \$1,000 per year if gross revenue <\$100,000 Medium: \$3,000 per year if gross revenue is \$100,001 to \$1,000,000 Large: \$5,000 per year if gross revenue is >\$1,000,000
Individual	Individual person who does not meet any of the above categories	Immediate notification as new CFRU research notes, reports, and other materials are released Internet password access to all CFRU publications (including research notes, full research reports, and annual reports) Participation in quarterly Advisory Committee meetings and annual field tour Listing of your name as a CFRU sponsor on all CFRU publications, poster displays, and web page	\$500 per year

All dues are to be paid one year in advance of the fiscal year in which the funds are used. Billing by the CFRU occurs each January.

2000-2005 CFRU Prospectus

Approval by the Advisory Committee of the revised CFRU Bylaws at the February meeting and approval of the five-year objectives and new dues structure at the May meeting completed the final components needed to finish the 2000-2005 CFRU Prospectus. In addition to these components, the prospectus provides all details about the CFRU mission, guiding principles, organizational design, roles, responsibilities, policies, procedures, guidelines, and other matters necessary for governance of the CFRU. For the first time in the history of the CFRU, all details for running the unit are compiled into a single document. The 2000-2005 CFRU Prospectus was completed and posted on the new CFRU web site in the summer of 2000 (Figure 1). This prospectus will be revised every five-years, or earlier if modifications are needed.

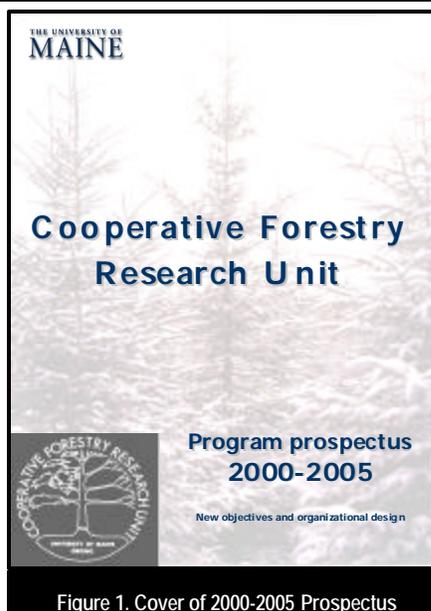


Figure 1. Cover of 2000-2005 Prospectus

Staff Changes

A final stage of implementing the new organizational design was the filling of the two full-time coordinator positions. The Communications and Financial Coordinator position is responsible for all technology transfer activities, communications, and financial affairs for the CFRU. **Chip Griffin** filled this position in October 1999. Chip has done a great job this year getting the financial affairs of the unit in order, developing a communications plan, creating a new CFRU web site, assisting with conferences, publishing a number of CFRU reports, and a variety of other accomplishments.

Dan McConville filled the second position as Field & Data Coordinator in May 2000. Dan has a MS degree in silviculture from U. Maine in 1997 and then spent the last few years as a research technician at the Jones Ecological Research Center in Georgia. He is responsible for installing and maintaining CFRU research sites, coordinating field

crews and logistics, managing the CFRU databank, conducting statistical analyses, and supporting technology transfer activities for the unit. Dan hit the ground running this spring and summer, spending most of his time installing and measuring the CFRU Commercial Thinning Network study sites.

In addition, a fixed-term Research Associate position as was filled by **KaDonna Randolph** to lead the modeling effort for the commercial thinning study. KaDonna comes to the project well qualified, with a recent MS degree in forest biometrics from Purdue University.

Mike Greenwood (Dept. of Forest Ecosystem Science) and **Dan Harrison** (Dept. of Wildlife Ecology) completed their first year as Cooperating Scientists. Dan and Mike are providing leadership within CFRU for the wildlife ecology and genetics/tree improvement efforts, respectively. With the approval of the five-year objectives (above), two additional Cooperating Scientists will be sought during the coming year to the lead research efforts addressing these objectives.

A number of other new project scientists, research technicians, and graduate students are associated with new and ongoing CFRU projects. Their names and contributions are identified throughout this report.

For more information about the restructuring of the CFRU, please contact **Bob Wagner** at 207-581-2903 or bob_wagner@umenfa.maine.edu.



Financial Report

Chip Griffin University of Maine

The unit began a restructuring process in early 1999 that was completed in mid 2000. The new structure substantially reduced the amount of fixed salary dollars and increased funds available for discretionary spending on projects. This action allows the unit to easily respond to changing research priorities and changes in the land base. Scientists, who come from both inside and outside the University of Maine, submit proposals for Advisory Committee approval, based on established research priorities.

In the last five years, CFRU representation has unfortunately decreased from a high of 8,648,670 represented acres to the current level of approximately 7,300,237 acres. Recent events represent a loss in potential research funds of at least \$67,254.00 per year below those historical funding levels. Despite this loss of income, the unit has continued to operate at financially ambitious levels in FY2000, spending 116% of its 1999 contributions, and committing 140% of its 2000 contributions.

Sound fiscal management by all the project scientists and CFRU staff has resulted in returning \$61,945.00 to the general fund at year end. These savings were the result of the following practices:

Table 2. FY 2000 Expense Report by Project

CFRU Report of Assets: 10/01/1999-09/30/2000	
Balance on Hand	\$ 201,533.00
Investments	\$ 40,755.00
Contributions FY00	\$ 322,334.00
Vehicle Sale	\$ 3,150.00
Unspent FY99 Budget Returned to Control	\$ 40,330.00
FY 2001	\$ (450,429.00)
Unspent FY00 Budget Returned to Control	\$ 61,945.00
Unallocated Balance on Hand 09/30/00	\$ 219,618.00

Project savings (Table 3)

42801	Lower printing costs due to online delivery
42802	Lower summer student salaries and travel costs than expected
42803	Less money needed for travel
42804	Funds not needed
42805	Contractor could not be hired
42806	Frugal management
42807	Keiser's resignation & Randolph's late start, only 1 crew needed, no leased vehicle was needed, graduate student late start, less equipment needed
42808	Project continued until 12/30/00

To successfully reinvigorate the CFRU field research following restructuring, spending on research projects has remained high against an unforeseen drop in the dues base. The CFRU will continue in principle to commit more funds toward its research objectives than it will receive from dues through FY2003.

Table 3 . FY 2000 Asset Information by Category

Account	Project Coordinator	Budget	Expenses	Unspent
5-6-42801	Administration-Griffin	\$ 152,950.00	\$ 135,686.00	\$ 17,264.00
5-6-42802	Silviculture-Wagner	\$ 59,445.00	\$ 54,832.00	\$ 4,613.00
5-6-42803	PCT and Root-Ostrofsky	\$ 27,719.00	\$ 22,446.00	\$ 5,273.00
5-6-42804	Wood Quality-Shepard	\$ 2,170.00	\$ -	\$ 2,170.00
5-6-42805	Hybrid Larch-Greenwood	\$ 4,400.00	\$ 1,951.00	\$ 2,449.00
5-6-42806	Pine Marten / Snowshoe Hare-Harrison	\$ 51,550.00	\$ 46,473.00	\$ 5,077.00
5-6-42807	Thinning-Wagner and Seymour	\$ 64,535.00	\$ 43,354.00	\$ 21,181.00
5-6-42808	Literature Review-Loftin	\$ 10,000.00	\$ 6,082.00	\$ 3,918.00
	Patch Retention-Hagan and Whitman	\$ 40,000.00	\$ 40,000.00	\$ -
	Buffer Strip-Hagan and Whitman	\$ 40,000.00	\$ 40,000.00	\$ -
Total Expenses		\$ 452,769.00	\$ 390,824.00	\$ 61,945.00

Table 4. FY00 dues by acre and payments received

Cooperator	2000 Acres	Rate/acre	2000 Dues	Paid
Baskahegan Lands	83,700	0.05	\$ 4,185	\$ 4,185
Bethel Furniture Stock	2,500	0.05	\$ 125	\$ 125
Bouchard, H. O., Inc.	4,000	0.05	\$ 200	\$ 200
Champion International	910,260	0.05	\$ 45,513	\$ 45,513
Field Timberlands	2,000	0.05	\$ 100	\$ 100
Finestkind Tree Farms	2,000	0.05	\$ 100	\$ 100
Fraser Papers	238,880	0.05	\$ 11,944	\$ 11,944
Great Northern Paper	328,200	0.05	\$ 16,410	\$ 16,410
Hancock Timber Resource Group	343,140	0.05	\$ 17,157	\$ 17,157
Haynes, H. C., Inc.	4,000	0.05	\$ 200	\$ 200
Huber, J. M. Corporation	320,000	0.05	\$ 16,000	\$ 16,000
International Paper Company	449,187	0.05	\$ 22,459	\$ 22,460
Irving, J. D. Ltd.	1,550,000	0.05	\$ 77,500	\$ 38,750
Landvest	4,000	0.05	\$ 200	\$ 200
Madden, F. A., Inc.	4,000	0.05	\$ 200	\$ 200
Maine Bureau of Parks and Lands	378,000	0.05	\$ 18,900	\$ 18,900
Mead Corporation	550,200	0.05	\$ 27,510	\$ 27,510
Peavey Corporation	170	0.05	\$ 137	\$ 137
Penley Corporation	12,500	0.05	\$ 625	\$ 625
Plum Creek Timberlands	863,000	0.05	\$ 43,150	\$ 43,150
Prentiss and Carlisle	81,500	0.05	\$ 4,075	\$ 4,075
Pride Manufacturing	no forest	0.05	\$ 468	\$ 468
Robbins Lumber Company	30,000	0.05	\$ 1,500	\$ 1,500
Ste. Aurelie Timberlands	60,000	0.05	\$ 3,000	\$ 3,000
Saunders Brothers	10,000	0.05	\$ 500	\$ 500
Seven Islands Land Company	880,000	0.05	\$ 44,000	\$ 44,000
Timberlands Enterprises/Pinebelt	2,000	0.05	\$ 200	\$ 200
The Nature Conservancy	185,000	0.05	\$ 9,250	\$ 4,625
Western Maine Nurseries, Inc.	2,000	0.05	\$ 100	\$ 100
TOTAL	7,300,237		\$ 365,708	\$ 322,334

** reflects late payment from FY99

Advisory Committee

The CFRU Advisory Committee governs all the affairs of the CFRU. In addition to addressing restructuring issues (see pgs. 10-12 of this report), the Advisory Committee helped ensure that ongoing research efforts continued and that new research ideas were developed and implemented. We thank the officers, **Brian Higgs (Baskahegan Co.)** - Chairperson, **Peter Etheridge (JD Irving)** - Vice Chairperson, **Peter Triandafillou (Huber Corp.)** - Financial Officer, and **Carl Haag (Plum Creek)** -- Member-at-Large for their hard work and dedication to the CFRU.

The Advisory Committee met three times in FY2000 (October 12, 1999; February 2, 2000; and May 17, 2000). A highlight of the year was the annual CFRU field tour conducted on October 13, 1999. Tours of hardwood silviculture experiments on Bartlett Experimental Forest were lead by Bill Leak, Dale Solomon, Mariko Yamasaki, and John Brissette. Stops at sites included long-term growth and yield, group/patch selection, shelterwood and clearcut, single-tree selection and economics, long-term PCT results, and succession: softwoods to

hardwoods and back again. The CFRU would like to extend its appreciation to Bill, Dale, Mariko, John and the USFS Bartlett Experimental Forest Station personnel for the opportunity to share results from their excellent research. We extend a special thanks to Matsuye Mairs for her help with making the facility and meal arrangements that made this meeting a success.

Advisory Committee Members 2000

Brian Higgs, Baskahegan Company (Chair)
Peter Etheridge, J. D. Irving, Limited (Vice Chair)
Peter Triandafillou, Huber Cooperation (Financial Officer)
Carl Haag, Plum Creek Maine Timberlands, LLC (Member at Large)
Anthony Filauro, Great Northern Paper
Si Balch, Mead Corporation
John Brissette, USFS Northeast Forestry Experiment Station
John Cashwell, Seven Islands Land Company
Chuck Gadzik, Irving Woodlands LLC
Henry Whittemore, Hancock Timber Resource Group
Phil Malerba, International Paper Company
Jacques Morin, Ste. Aurelie Timberlands Company
Bill Miller, Prentiss and Carlisle
Thomas A. Morrison, Maine Bureau of Parks and Lands
Nancy Sferra, The Nature Conservancy
Kevin Topolniski, Fraser Papers Inc.
G. Bruce Wiersma, Dean, College of Natural Sciences, Forestry and Agriculture



Figure 2. CFRU Advisory Committee during a field tour in Bartlett Experimental Forest in New Hampshire

Field and Data Report

Daniel J. McConville
University of Maine

Field Coordination

Most of the field coordination resources this year were directed toward establishing phase II study sites for the Commercial Thinning Research Network (see pg. 23). However, the development of strategies to integrate CFRU field coordination across all projects was targeted through discussions with scientists and field visits to new CFRU study sites. The objectives of these discussions were to (1) more clearly define the role of the data coordination effort to all projects and (2) determine ways in which the data coordination could lead to increased efficiencies through creative uses of labor and resources between projects. These discussions will continue during the coming year with the intent of finding ways to reduce field costs across all projects.

In the coming year, field coordination efforts will focus on continuing the data collection for the Commercial Thinning study and maintaining the long-term research sites at Austin Pond and Weymouth Point. CFRU staff, under the guidance of former Weymouth Point principal investigators, are developing a maintenance plan for the Weymouth Point study area. Tony Filauro, of Great Northern Paper, is drafting an agreement between GNP and the University of Maine to prohibit disturbing the study areas in both the managed and unmanaged watersheds. Although no new research is scheduled at Weymouth Point, GNP along with CFRU staff will be monumenting the site and maintaining access so that future work may be done.



Data Coordination

Over the past 25 years, valuable CFRU data from studies such as Weymouth Point and Austin Pond have accumulated in the absence of a data management system. Thousands of data files are currently being stored on obsolete storage media, such as reel and floppy tapes. It is vital to CFRU that these data are converted to modern media in a readable format and assembled into a CFRU databank.

A two-tiered approach is underway to establish the databank. First, a standardized data archival system will be designed based on long-term data management systems developed nationwide. Data, metadata (information about the data), graphics, maps, and program files will be organized in a clearly mapped directory structure that can be easily navigated by any of the cooperators. The second tier involves transferring data files stored on a variety of media to compact disc, and converting them to a universal language such as ASCII. The updated files will be inserted into the databank and will be available to CFRU cooperators either via our website (password protected) or compact discs.



Communications Report

Chip Griffin
University of Maine

Introduction

The objective of the new CFRU communications plan is to provide cooperators with a regular output of research results from CFRU projects in a form that cooperators find most useful. A 1999 survey of all CFRU cooperators revealed that research notes, field guides, field tours, and workshops were the most preferred methods of receiving research results. Based on these preferences, the CFRU communications effort will emphasize these preferred methods wherever possible. Where appropriate, traditional and other methods also will continue to be used.

An outside firm conducted a marketing study for the University of Maine in the spring of 1998. This study established a plan to standardize and improve the image of the university projected internally and to the public. The university began implementing the resulting marketing plan in fall 1999. Printed and web based publications have been standardized and updated to reflect a more contemporary look. An emphasis is placed on publications that are more user friendly and image conscious. The CFRU logo will continue to be used under the new plan, as well as the new University of Maine logo in Figure 3 below.



Figure 3. New approved Umaine publications logo.

Web Page

The worldwide web is expected to continue growing as a communications vehicle for research. Therefore, CFRU communications must stay up to date with this technology. In the past, the CFRU Web page was updated on a sporadic basis. It was designed to function principally as an electronic brochure with hyperlinks to University of Maine faculty and cooperators home pages. In February, construction on a new website was initiated to conform to the new university marketing plan (Figure 4). The website was given a new look, incorporated

more responsive software, and updated its hyperlinks. Completed and launched in June, the new CFRU web became not only a site showcasing research and educational material; it also became a vehicle to service the desires of our cooperators. Future annual reports, research notes, research reports, and other research results will be available exclusively on-line. Efforts also are underway to enter abstracts of past CFRU publications for website access.

The use of limited access pages has allowed both frontline foresters and Advisory Committee members 24 hour, 7 days a week access to publications and meeting materials. This move alone revealed efficiencies by means of reduced printing costs, postage costs, and faster publication cycles. Information Distribution Lists utilizing email, mail, and fax lists are used to notify cooperators when new postings are available on the web. The following

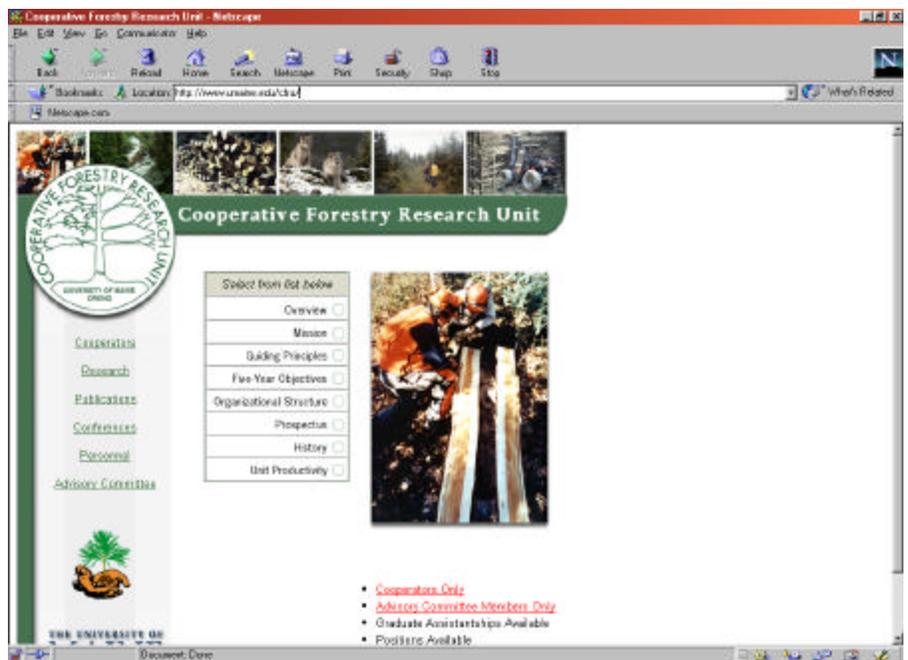


Figure 4. New CFRU home page at <http://www.umaine.edu/cfru>

CD ROMs

As technology improves and publication costs increase, nontraditional avenues become attractive to provide deliverables to cooperators. One approach is the use of CD ROMs as an alternative publication vehicle for those cooperators with limited web access.

Research Notes Series

In August, CFRU scientists began providing cooperators with 1-4 page research notes of ongoing and new research projects. These research notes provide quick updates by researchers and in a more readable form for cooperators. This ongoing series is in web format only.

Quarterly Advisory Committee Meetings

Quarterly CFRU Advisory Committee meetings have been and will continue to be the most important form of communications about ongoing and completed CFRU research. We will continue to strive to make these meetings as effective and informative as possible.

Annual Field Tours

Annual field tours have been a CFRU tradition and will continue to be a highlight of the first quarterly Advisory Committee meeting of the fiscal year. These 1-2 day tours focus on visits to CFRU research sites, cooperators lands, and other locations where forest research and management issues are of interest to cooperators. Details of the 1999 tour of Bartlett can be found on page 17.

Annual Reports

The annual report provides a summary of the research conducted each year by the CFRU. Financials, publications, and other administrative reports are also highlighted. These reports will be standardized and updated to reflect a more user friendly, consistent and contemporary look for the web. Annual Reports will continue to carry MAFES publication numbers as well.

Conferences, Meetings and Workshops

Conferences and workshops provide a valuable means of focused communication among cooperators, scientists, and others about topics of common interest. The CFRU organizes conferences, workshops, or other major meetings when:

- CFRU researchers have completed a body of research on a particular subject and a large meeting would provide the most effective means of communicating these results to cooperators and the public;
- The CFRU is embarking on a new area of research and a conference or large meeting about the subject helps cooperators determine the state of knowledge about the subject and helps CFRU researchers identify specific information gaps based on the state of knowledge about the subject; or
- CFRU cooperators have identified a critical issue affecting forest landowners that would benefit from a dialog among forestry professionals and/or the public.

Thinning in the Maine Forest

The identification by CFRU cooperators of the need for better information about commercial thinning as a top research priority prompted this state-of-the-art conference entitled "Thinning in the Maine Forest." Held from November 15-16, 1999 in Augusta, this event brought together Maine forest landowners, managers, technicians, loggers, and researchers for a discussion about designing and implementing successful thinning operations in the state. The conference was organized by **Bob Wagner**, **Andy Egan**, **Bill Ostrofsky**, and **Bob Seymour**, and jointly sponsored by the CFRU and the College's Office of Professional Development. Eighteen leading experts from the Northeastern US, Canada, other US regions, and Europe shared their experiences and results from thinning research experiments. About 170 people attended this successful conference and a 116-page proceedings was published (Figure 5) and distributed at the conference. Copies of the proceedings can be found on the CFRU web page.

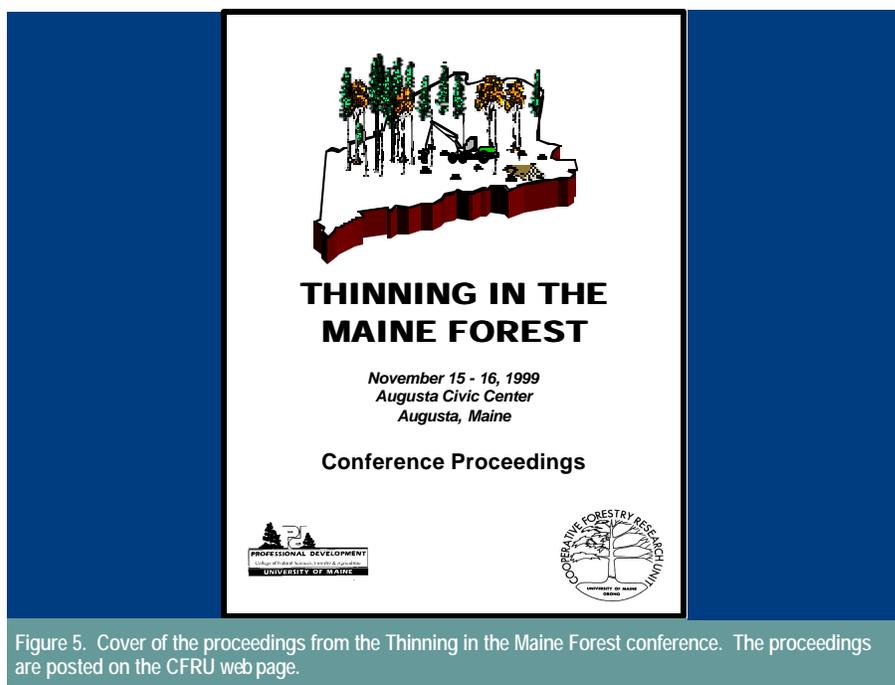


Figure 5. Cover of the proceedings from the Thinning in the Maine Forest conference. The proceedings are posted on the CFRU web page.

Joint Maine and New Brunswick Forestry Organizations Meeting

In an effort to stimulate better communications between forestry organizations and researchers between Maine and New Brunswick, **Bob Wagner** and **Dave MacLean** (University of New Brunswick) organized a joint meeting of leaders from Maine and New Brunswick forestry organizations. A list of organizations represented are included in Table 5. The meeting was held December 6-7, 1999 in St. Andrews, New Brunswick. The purpose of the event was to identify common problems, information gaps, and future concerns for forest management and research. Discussions were initiated about how to improve communication, collaboration, and coordination on key forest research issues. Although each of the organizations represented had a wide array concerns and there seemed to be limited financial resources on which to build a formal cross-border effort, there was a vote by all attending that there should be continued cross-border communications of this sort. The University of Maine and the University of New Brunswick jointly sponsored the meeting. Efforts during the coming year will focus on developing possible options for continued joint meetings of this type.

Table 5. List of organizations represented at the December 6-7, 1999 joint meeting of Maine and New Brunswick forestry organizations

Maine	New Brunswick
Cooperative Forestry Research Unit	Canadian Forest Service
Maine Forest Service	Environment Canada
Maine Department of Inland Fisheries and Wildlife	Fundy Model Forest
Maine Forest Products Council	New Brunswick Dept. of Natural Resources
University of Maine	New Brunswick Environment
USDA Forest Service	New Brunswick Forest Products Association
	Université de Moncton
	University of New Brunswick

CFRU Collaboration with The Forest Ecosystem Information Exchange

This year the CFRU developed a collaborative effort with The Forest Ecosystem Information Exchange that is led by **John Hagan** and **Manomet Conservation Sciences**. This new forest science forum began in the fall of 1999 to create a mechanism whereby forest stakeholders can come together to obtain the latest scientific information on various current topics about forest ecosystems and sustainable forestry in the northeastern U.S. and southeastern Canada. The Exchange is designed to be an interface between those who generate information and those that need information about the region's forests. **Bob Wagner** (as CFRU Director) is a member of the Exchange Steering Committee, which has representation from the environmental, industry (including several CFRU cooperators), agency, media, and research communities.

In 2000, **Chip Griffin** and CFRU graduate students participated in two Exchange meetings:

Landscape Forestry

October 29, 1999

Black Bear Inn in Orono, Maine

This first Exchange meeting focused on what we know about managing forests at large spatial scales. At this meeting, participants and presenters worked through focus groups to identify remaining information gaps that can be filled to improve management of forest landscapes for biodiversity in the region. About 150 people attended this meeting.

Greenbacks and Green Goals: Economics and Environmental Forestry

May 4, 2000

Wells Conference Center at the University of Maine in Orono, Maine

Jointly sponsored by The Forest Ecosystem Information Exchange and University of Maine's Munsungan Conference, this meeting explored the inter-relationships between economic and environmental goals in forest management. The purpose of this meeting was to provide participants with an understanding about the varied opportunities and constraints of different forest landowners for achieving economic and environmental goals in the northeastern U.S. and southeastern Canada. A variety of landowner examples were presented to provide an integrated understanding of the forces that shape the regions forests. Over 150 people attended this meeting.

Posters and Portable Exhibits

Posters and exhibits at public meetings, scientific conferences, and other meetings communicate the mission and activities of research organizations. A portable display highlighting the research unit's past, ongoing and planned research was designed and constructed

for use at university events, conferences, and workshops. Plans to incorporate a more permanent and multi media version will be implemented in FY2001.

Journal Articles

Scientific journals are a vital form of scientific communications around the world. Peer-reviewed journal articles from CFRU research provide important functions including:

- validation from the scientific community that the methods and interpretations used in CFRU-sponsored research are sound;
- research results become part of the established scientific literature and therefore, available worldwide for a long time;
- researchers increase their chance of leveraging funds from other funding agencies by demonstrating their productivity in the scientific community; and
- scientists affiliated with CFRU become recognized as experts in their field, allowing them a reputation to publicly speak (e.g., to the press, to policy makers, in litigation, and forest certification) as experts about issues they are researching.

Therefore, the CFRU encourages and supports the publication of CFRU research results in peer-reviewed scientific journals. Where appropriate, the CFRU Advisory Committee is encouraged to use productivity in this area as a criterion for evaluation of scientists submitting research proposals to the CFRU. FY 2000 publications by CFRU scientists are listed on page 17 of the Publications section.

For more information on CFRU communications, contact **Chip Griffin** at 207-581-2893 or email at chip_griffin@umenfa.maine.edu.



Research

Silviculture

Commercial Thinning Research Network

Robert G. Wagner and Robert S. Seymour
University of Maine

In the July 1999 survey of research priorities for the CFRU, a better understanding of commercial thinning strategies and growth and yield responses from commercial thinning were identified as the top two priorities among 68 research topics presented. In the 1998 "Timber Supply Outlook for Maine: 1995-2045" report by the Maine Forest Service, commercial thinning was identified as a crucial aspect of intensive forest management regimes for enhancing state wood supplies. So, commercial thinning is clearly a top silvicultural issue for CFRU cooperators and forest management for the state of Maine.

Although some data exist on the effects of pre-commercial and commercial thinning in the Northeast (Wilson et al. 1999; Seymour 1995), the availability of data for understanding subsequent stand responses and for making sound growth and yield predictions is severely lacking. Recent efforts by Wagner et al. (1999) brought together current information about forest thinning from Maine, regional, national, and international experts on the subject.

This document is serving as a guide for development of the CFRU's new Commercial Thinning Research Network.

The CFRU Commercial Thinning Research project is divided into two phases. Phase I is seeking to develop a set of interim commercial thinning guidelines and Phase II is establishing a statewide network of research sites that can address specific operational, silvicultural, and ecological questions about commercial thinning in Maine's forests. Approval of the Commercial Thinning Research Network proposal submitted to the CFRU Advisory Committee in January 2000 initiated work on this project this year.

The first step was to establish a subcommittee (Table 6) of the CFRU Advisory Committee that could help provide guidance, technical recommendations, and study sites for both phases of the study. The subcommittee met twice this year (May 31 and September 18) to refine the proposal, assist with site selection, and provide technical recommendations. We thank all members for their contributions this year.

Phase I of the study called for the hiring of a modeler who would use existing data and models to develop the set of interim guidelines. We were very fortunate to hire **KaDonna Randolph**, who recently obtained a M.S. degree in forest biometrics from Purdue University. KaDonna started work in mid-May and has made significant progress in only a few months (described below in Phase I report).

Implementation of Phase II was initiated with the hiring of **Dan McConville** this May. Dan has a M.S. in silviculture from U. Maine and several years of experience as a research



Table 6. Names and affiliations of the CFRU Commercial Thinning Subcommittee

Name	Affiliation
Bob Wagner	U. Maine (CO-CHAIR)
Bob Seymour	U. Maine (CO-CHAIR)
Si Balch	Mead Corp.
Tom Brann	U. Maine
John Brissette	US Forest Service
Tom Charles	Maine Bureau of Public Lands
Mike Dann	Seven Islands Land Co.
Peter Etheridge	JD Irving
Tony Filairo	Great Northern Paper Co.
Carl Haag	Plum Creek Timber Co.
Jim Hatch	Plum Creek Timber Co.
Brian Higgs	Baskahegan
Kirk MacDonald	Plum Creek Timber Co.
Phil Malerba	International Paper Co.
Dan McConville	U. Maine
KaDonna Randolph	U. Maine
Paul Sendak	US Forest Service
Dale Solomon	US Forest Service
Kevin Topolniski	Fraser Papers
Peter Triandafillou	Huber Corp.
Jim Ward	International Paper Co.

technician in Georgia. Leading the field portion of Phase II is just one of the duties that Dan has as the Field and Data Coordinator for the CFRU. Dan also has made substantial progress with Phase II this summer (described below in Phase II report).

The following sections describe the progress made in Phase I and II of the project this year:

Phase I: Interim Guidelines for Commercial Thinning in Spruce-fir Stands

Robert S. Seymour, Robert G. Wagner,
and KaDonna C. Randolph

Introduction

Phase I focuses on developing a set of practical commercial thinning guides that will assemble available Maine-applicable literature, unpublished data, and computer models regarding commercial thinning. This phase concentrates on assembling all we know about commercial thinning into a practical field guide and/or software product. The overall goal of this phase of the project is to rapidly compile available information into a form that can guide CFRU cooperators with commercial thinning prescriptions. These guides are intended as a stop-gap measure that will be tested and refined with data from Phase II as they become available. The initial effort will focus on commercial thinning in spruce-fir stands.

Objectives

The objectives for Phase I are to:

- assemble available data from remeasured plots that capture individual tree and stand growth responses to controlled density reduction treatments
- compare existing methods for growth prediction (e.g. FVS, GNY, FIBER) against these data sets and against one another; and
- produce an easy-to-use field guide or software that includes the best available information for commercial thinning prescriptions in Maine's spruce-fir forest.

Approach

Work began on Phase I at the end of May 2000. At that time we elected to focus on objective three and develop a thinning guide prototype. Reasons for skipping to objective three were twofold. First, we needed a target guide that would allow us to determine the critical areas of development for the final product; and secondly, we wanted to avoid unnecessary digressions that might prolong the model evaluation and data analysis process. The success of our efforts to develop this example guide is outlined below.

Accomplishments

Variables of Interest

Five variables reflecting management objectives were identified. These are mean annual increment (cords/acre/year), piece size (trees/cord), final harvesting cost (\$/cord), total wood cost (\$/cord), and present net worth (\$/acre). The final harvest cost variable incorporates forwarder and harvester machine productivities and the condition of the stand being harvested, i.e. size of the trees and intensity of removal. These costs were modeled using an adaptation of PPHARVST, a harvesting cost estimator developed by the US Forest Service for ponderosa pine plantations (Fight et al. 1999). Total wood cost is the expense of growing the wood over the entire rotation and includes the price of precommercial thinning (PCT), profit from commercial thinning, and cost of the final harvest. The present net worth is the total revenue at rotation's end discounted to year zero. Several assumptions underlie the financial calculations, including an interest rate, value of wood roadside, and cost of the PCT.

Response to Commercial Thinning

Stand growth response after commercial thinning was modeled with the Nova Scotia Softwood Growth and Yield Model (GNY) version 1.0 (NSDNR 1993). Efforts focused primarily on stands with a history of PCT. These stands were modeled as plantations; variables were site index, age of commercial thinning, and percent removal. After thinning, the residual stand was grown and the value of each variable calculated every five years through age 100.

From the resulting series of data points, nomograms for each variable were created from repeated thinnings of a given stand to different residual densities. The nomograms consist of a three-dimensional graph with stand age and residual stand density on the main axes, and a "contour map" of a variable of interest relative to the main axes (Figure 6). These 3D nomograms allow the user to work backward from a desired future condition and arrive at a target residual stand density.

The limitation with this approach is that often we are interested in more than one objective or variable of stand performance. It was necessary, therefore, to combine all the nomograms for different variables to provide the user with a method for evaluating different thinning prescriptions based on a set of management objectives.



User Interface

Given a set of nomograms, the user can exclude (by shading out) unacceptable outcomes. When this is done for several different variables and the results overlap on each other, the zone that remains unshaded on all graphs represents the range of residual densities and final harvest ages that meet all objectives. Because this use of multiple nomograms has properties similar to those found in GIS problems, we found that ArcView GIS 3.2 (ESRI 1999) software was able to provide a visual user-interface for determining acceptable commercial thinning prescriptions given a set of management objectives.

This graphical interface allows acceptability limits to be set for each variable and then highlights the region or polygon where all objectives are met (Figure 7). The range of residual densities and rotation ages that will meet all management objectives can be read off the axes. In Figure 7, residual densities between 355 and 210 trees per acre and a final harvest between ages 59 and 81 will satisfy the objectives. Note that for a given residual density, there is a time frame in which the final harvest must be made: after the stand "grows into" the region and before the stand "grows out" of the region.

When to thin a stand is determined by examining acceptable regions given different commercial entry timings (Figure 8). Management objectives are set and the nomograms are queried for regions meeting the criteria. If the criteria are met, the areas are highlighted. In some instances, no areas will be highlighted, indicating that the thinning scenario is unacceptable. Users then can examine the remaining scenarios and determine which entry timing, residual density, and final harvest age best fits their management schedule.

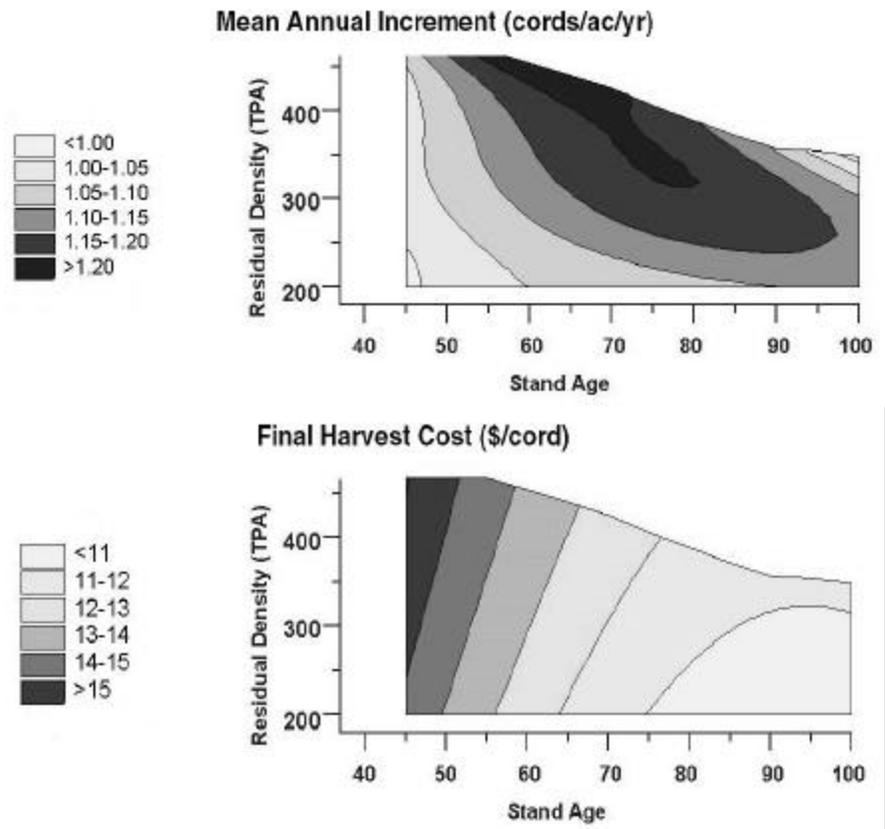


Figure 6. Example nomograms for mean annual increment and final harvest cost from a series of commercial thinnings using the Nova Scotia Softwood Growth and Yield Model.

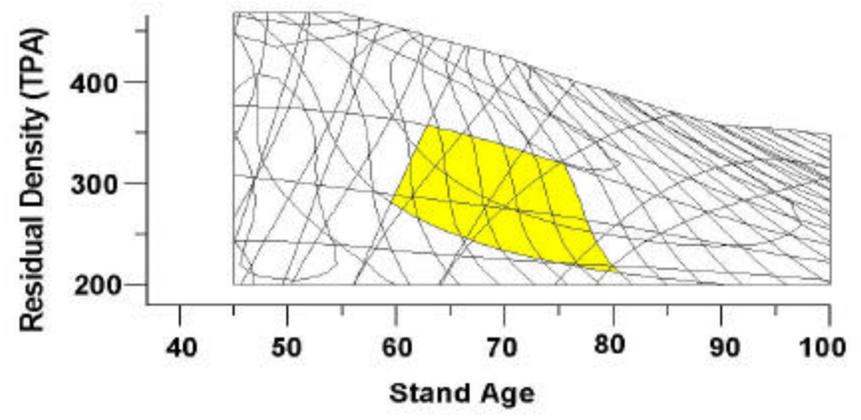


Figure 7. Example of overlain nomograms where a polygon (yellow shaded area) reveals a combination of residual densities and final harvest ages where all defined management objectives are met when thinning a spruce-fir stand at 40 years old

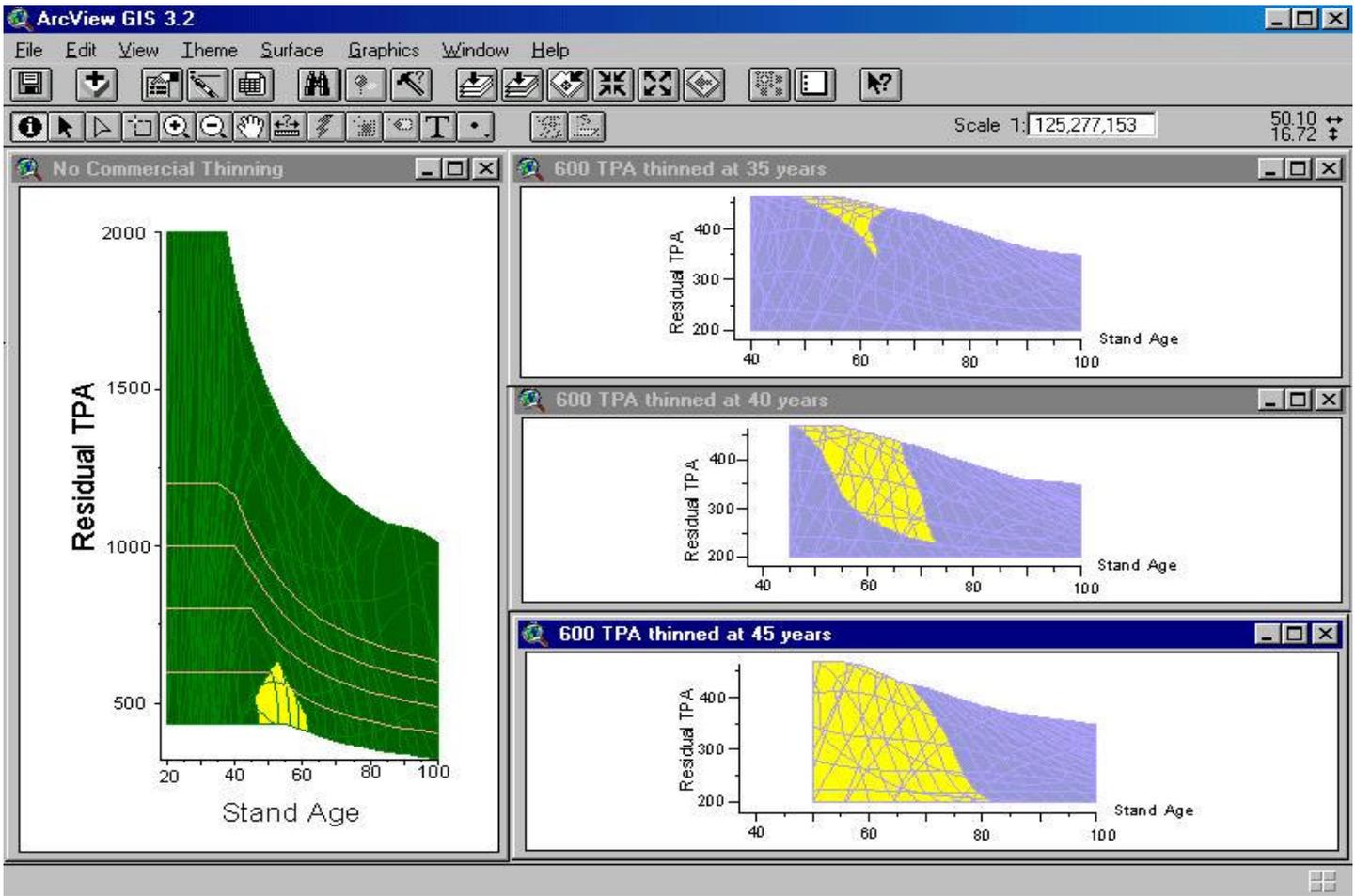


Figure 8. Example of ArcView GIS 3.2 screen showing where the acceptable regions at different timings of commercial thinning entry can be compared

Next Steps

Now that the overall conceptual approach for the commercial thinning guides has been developed, efforts during the coming year will focus on evaluating available growth & yield models and available data sets to ensure that the best available information for thinning Maine spruce-fir forests is included.

Growth and Yield Model Comparison

Three models have been selected for comparison: GNY, the US Forest Service Forest Vegetation Simulator-NE TWIGS variant (FVS), and FIBER. The growth response (basal area and volume) following commercial thinning as predicted by each of these models will be compared. Data collected during the 2000 field season for Phase II will be used as input for FVS and FIBER. Remeasured plots from study sites at Austin Pond will be incorporated as an additional way to evaluate the growth

and yield models. The best model identified after the evaluation will be used to develop the final nomograms.

Nomogram Creation

Nomograms will be created for each thinning scenario selected through consultation with the Commercial Thinning Subcommittee. Depending upon the growth and yield model selected, each thinning prescription nomogram may be specific for some or all of the following: age of commercial thinning entry, site index level, removal level, percent stocking, and type of thinning (whether from above or below, etc.). Financial assumptions also will be refined before the first version of the commercial thinning guide is produced.

Thinning Guide Production

Version 1.0 of the Softwood Commercial Thinning Guide is scheduled for completion in May 2001 with distribution thereafter. The format for distribution to CFRU cooperators will probably be on a CD containing various ArcView projects and a customized interface that will allow the user to make decisions as previously described. Further analysis of the thinning scenarios may result in general guidelines that will accompany the CD guide in written format.

Phase II: Influence of Thinning Method, Residual Density, and Timing on Growth Responses of Spruce-Fir Stands in Maine

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

Introduction

The purpose of phase II is to design, install, and maintain a network of research plots on CFRU cooperator lands that will help forest managers improve strategies for commercial thinning in the state of Maine. The primary emphasis is on developing a database that can be used to help optimize 1) timing of entry, 2) spacing standards, 3) prioritization of stands, and 4) improve regional growth and yield modeling efforts related to commercial thinning. Data from this phase will help further refine the thinning guides developed in Phase I, improve growth and yield models related to thinning responses, and address other silvicultural and ecological questions of interest.

Installed at different times over a period of years, three types of installations (Types A, B, and C) were proposed to address specific objectives and work in a complementary manner. Each type varies in size and complexity depending upon the objectives. Type A installations are intended to provide general growth and yield data for commercial thinning under a wide range of site and stand conditions across the state. Type B installations explore more specific questions or hypotheses that develop from Phase I and from Type A installations. Type C installations are intended to be large-scale installations designed to examine larger ecological and operational questions that may arise. The Commercial Thinning Subcommittee decided that initial efforts for Phase II should focus on establishing a set of Type A installations in spruce-fir stands across the state.

Objectives

The general objectives for Type A installations are to:

- provide a network of commercial thinning plots on CFRU cooperator lands under a range of stand conditions, site conditions, and approaches to commercial thinning;
- provide data that can be used to quantify growth and yield responses to commercial thinning based on spacing treatments, entry times, stand composition, stand age, and site productivity; and
- provide data on operational costs of thinning treatments, product quality and values removed, and machine productivity.

Work over the past year has been directed at developing and refining the highest priority and researchable questions about commercial thinning for the first Type A installations. Based on discussions with CFRU cooperators, tours of potential study sites during the summer of 2000, and input from the Commercial Thinning Subcommittee, the following questions were identified as most important to address with the first Type A installations:

- For natural spruce-fir stands that have never received PCT, what is the influence of (a) method of thinning and (b) residual density on subsequent stand response?
- For natural spruce-fir stands that have received previous PCT, what is the influence of (a) timing of first commercial thinning entry and (b) residual density on subsequent stand response?

Approach

The first set of Type A installations will have 12 study sites that are selected across the state of Maine on CFRU cooperator lands. Six sites will have been previously PCT and approximately 20-30 years old. The remaining 6 sites will have originated from a stand-replacing disturbance approximately 30-70 years prior and will not have been previously thinned. At each site, seven 0.9-acre (200 x 200 ft.) treatment plots will be established. Four 0.05-acre (50.0 x 43.6 ft.) measurement plots are to be placed at the center of each treatment plot.

All plots will be measured immediately before and after treatment, and periodically thereafter. Measurements include species, dbh, tree location (azimuth and distance from plot corner), total height, and height to live crown. On the PCT sites, all trees greater than 2.5 inches dbh will be measured. Four 8-foot radius plots will be installed in each plot corner to measure the dbh of trees taller than 4.5 ft. but with dbh less than 2.6 inches. On the non-PCT installations, all trees greater than 4.5 ft. tall will be measured for dbh, and tree location will be subsampled on one of the four measurement plots. On both types of installations, tree height and the height to the live crown will be measured on a subsample of trees stratified by dbh and species. The post-treatment measurements will be the same as with the pre-treatment sample except that all living trees > 4.5 ft. tall will be permanently num-



Table 7. Treatment descriptions for the non-PCT and previous PCT sites as approved by the CFRU Commercial Thinning Subcommittee

Natural Stands-Non-PCT		Thinning Method		
		Low	Crown	Dominant
Relative Density Reduction	50%	Trees will be removed only from smallest diameter classes to reduce RD by 50%	Spacing of crop trees based on mean 0.3 spacing to height ratio; upper-crown competitors of crop trees removed until RD reduced by 50%	Trees will be removed only from largest diameter classes to reduce RD by 50%
	33%	Trees will be removed only from smallest diameter classes to reduce RD by 33%	Spacing of crop trees based on mean 0.3 spacing to height ratio; upper-crown competitors of crop trees removed until RD reduced by 33%	Trees will be removed only from largest diameter classes to reduce RD by 33%
	Self-thin	Untreated check		

Natural Stands - Previous PCT		Relative Density Reduction	
		33%	50%
Timing	Now	Evenly-space residual stand and reduce RD by 33% now	Evenly-space residual stand and reduce RD by 50% now
	Wait 5 years	Evenly-space residual stand and reduce RD by 33% in 5 years	Evenly-space residual stand and reduce RD by 50% in 5 years
	Wait 10 years	Evenly-space residual stand and reduce RD by 33% in 10 years	Evenly-space residual stand and reduce RD by 50% in 10 years
	Never	Untreated check	

Table 8. Pre-treatment descriptions of seven Type A commercial thinning sites established during the 2000 field season. Data includes DBH (quadratic mean dbh in inches), TPA (trees per acre), BA (basal area, ft²/acre), wood volume (cords/acre), and RD (relative density).

Cooperator	Site name	PCT	DBH	TPA	BA	Volume	RD
Huber	Golden Road	No	5.2	1299	183	44.7	0.55
Seven Islands	Sarah's Road	No	4.3	1796	213	43.6	0.65
St. Aurelie	208	No	3.7	2466	179	33.8	0.47
BPL	Schoolbus Road	No	6.4	1460	230	63.5	0.75
IP	Alder Stream	Yes	5.8	544	109	22.3	0.28
IP	Lake Macwahoc	Yes	5.7	761	144	28.5	0.36
Plum Creek	Ronco Cove	Yes	4.6	746	114	21.5	0.29

bered and measured for tree location.

For the non-PCT sites, a factorial design including 3 methods of thinning (low, crown, and dominant) and 2 levels of relative density reduction (33 and 50 percent) *sensu* Wilson et al. (1999) plus an untreated check will be randomly assigned to the 7 plots on each of the 6 sites (Table 7). On the PCT sites, the factorial treatment design will be 3 timings of entry (1-year, 5-year, 10-year) and 2 levels of relative density reduction (33 and 50 percent), plus an untreated check. Prescriptions for each treatment will be based on analysis of plot-level pre-treatment data. Trees will be marked for removal based on prescriptions immediately following pre-treatment measurement and analysis.

Harvested merchantable volume will be determined by measuring all piled logs in the plots prior to removal. Data also will be collected to estimate harvesting costs and product quality. Financial analyses will be performed to compare operational costs for each of the treatments.

Accomplishments

Beginning in May 2000, we visited numerous sites on cooperator lands and found 7 suitable sites (4 non-PCT and 3 PCT) (Figure 9). Stand descriptions for the 7 sites are presented in Table 8. All plots were installed and measured on each of the 7 sites during the summer of 2000. More than 11,000 trees were measured on 49 plots. After the data were entered and analyzed, we developed details of the treatment prescriptions. The Commercial Thinning Subcommittee approved all details of the experimental design before the trees were marked for removal.

Next Steps

During the winter and spring of 2000-2001, all trees will be marked according to the prescriptions in Table 3 and harvesting will begin. We will observe the harvesting operations and measure logs harvested from each plot immediately after it is stacked. During the spring of 2001, two additional non-PCT and three additional PCT sites will be selected. Plot installation and measurement of these new sites will occur during the summer of 2001 and harvesting will occur during 2001-2002. In addition, we will make the first-year post treatment measurements for all sites harvested during the winter and spring of 2000-2001.

Thinning Study Site Locations

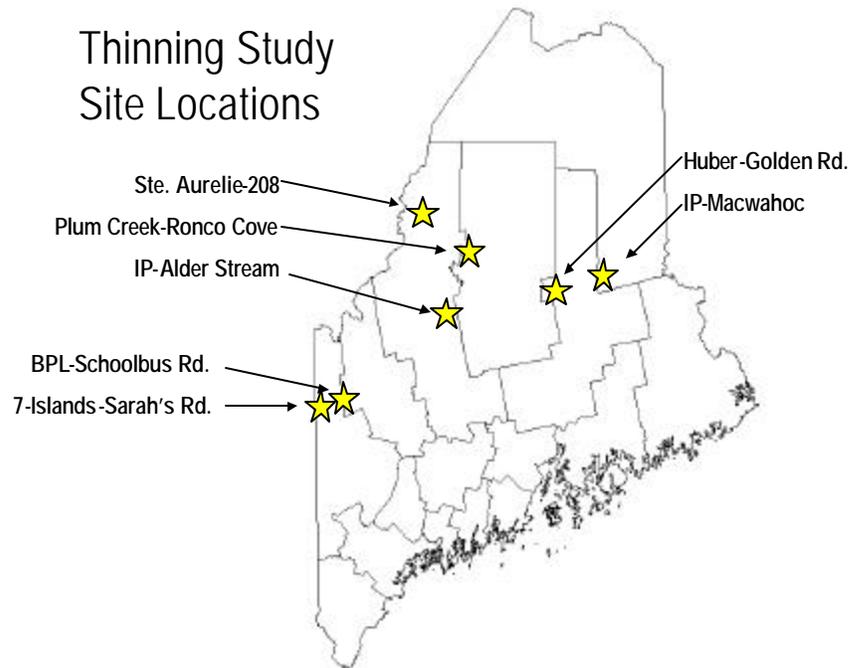


Figure 9. Locations of seven study sites for CFRU Commercial Thinning Research Network established for phase I during FY2000

For more information about commercial thinning study, please contact **Bob Wagner** at 207-581-2903 or bob_wagner@umenfa.maine.edu, or **Bob Seymour** at 207-581-2860 or seymour@umenfa.maine.edu.

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Condition and Development of Root Systems of Balsam Fir and Red Spruce in Precommercially Thinned and Unthinned Stands

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University of Maine

This project was developed to address a need to better understand the effects of precommercial thinning on rooting characteristics of spruce and fir in Maine. The study was initiated in 1998, and was developed by S. Tian as the basis for his Ph.D. thesis. Research has been conducted in three major phases. The first phase has compared the physical rooting characteristics of spruce and fir in thinned and unthinned stands now nearing commercial thinning size. The second phase was also conducted in stands at or near commercial thinning size. The second phase has directly assessed rooting strength by mechanically winching precommercially thinned and unthinned trees to estimate relative wind firmness. The final phase, conducted during the 2000 field season, is assessing root and butt decay characteristics in precommercially thinned and unthinned stands. This last phase of the project has been conducted in

recently thinned stands, as well as in stands that were precommercially thinned between 10 and 24 years ago.

Crop tree selection during precommercial thinning of softwood stands relies primarily on spacing recommendations, and on judgment by the thinning technicians to leave crop trees with the highest potential for survival and growth. Root and butt decays of fir and spruce are not easily detected, especially in young stands. Balsam fir is known to be especially susceptible to a considerable amount of root and butt rot; red spruce is less susceptible and generally much less damaged. Fungi causing these decays are native pathogens, and occur naturally on any sites where spruce and fir will grow. Precommercial thinning may reduce the percentage of infected trees in a stand, may increase the percentage, or may have no overall effect, depending on which trees are selected for crop trees.

In addition, the long-term effects of precommercial thinning on development of root and butt decays are not well known. Crop trees with pre-existing root and butt decay will be more vulnerable to volume loss if wounded during a commercial thinning phase. They could also be more susceptible to windthrow or to direct mortality resulting from stem breakage. Because these factors can affect the growth and yield of treated stands, it becomes important to assess, anticipate, and eventually predict the effect of root and butt decays on thinned stands.

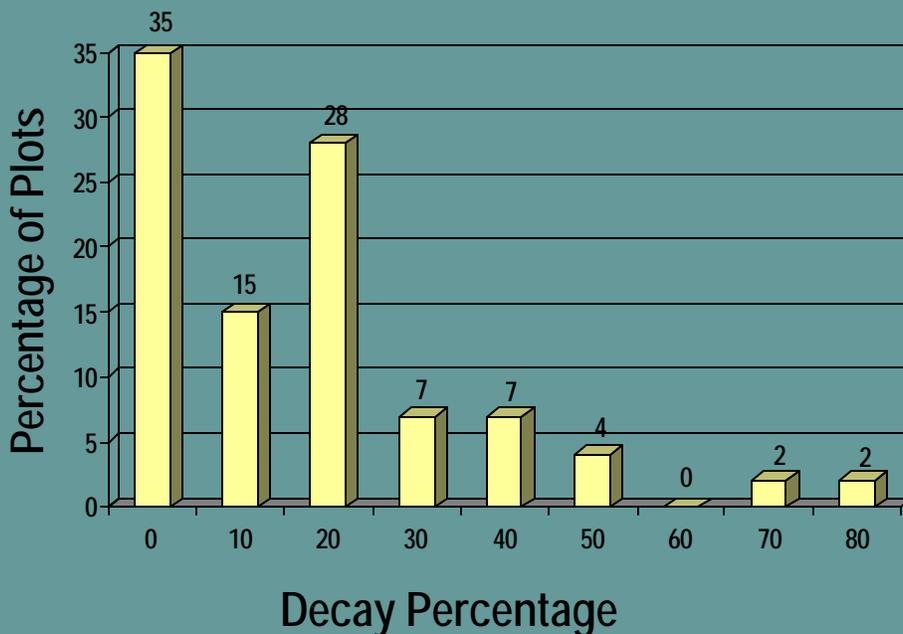


Figure 10. Decay incidence by plot,% of 55 sample plots of young precommercially thinned balsam fir stand.

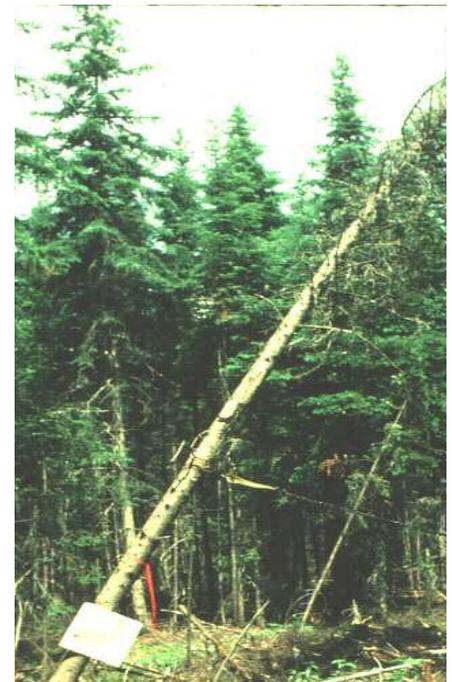


Figure 11. Mechanical winching

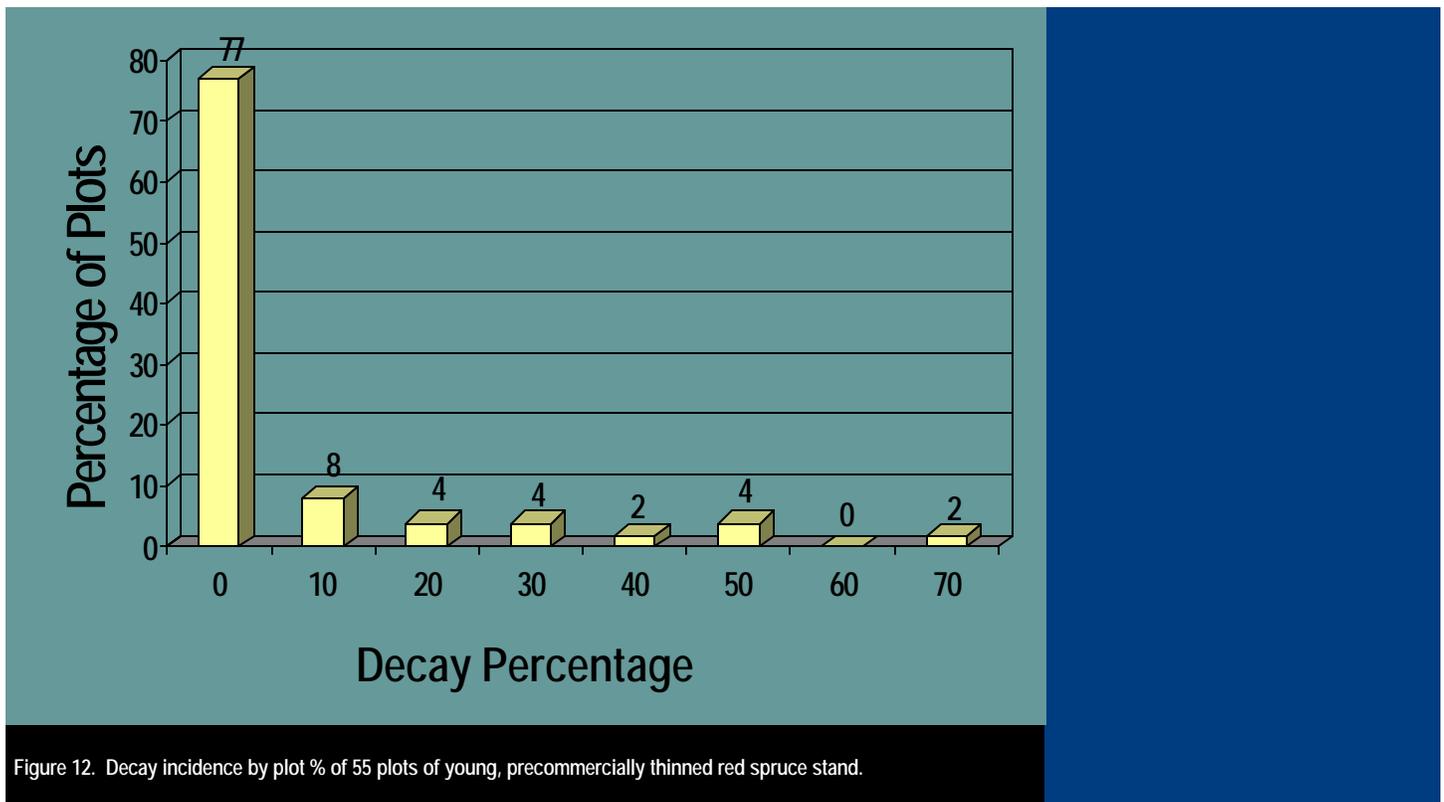


Figure 12. Decay incidence by plot % of 55 plots of young, precommercially thinned red spruce stand.

A total of sixteen softwood stands that had been precommercially thinned within the past two years were selected for study on lands owned by Champion International (now International Paper Co.). Depending on stand size, between two and seven 10 m X 10 m plots were established to assess stems for decay. Stumps of precommercially thinned trees were recut with a brushsaw, and examined directly for decay. Approximately 2,470 stumps of balsam fir, and 1,425 stumps of spruce were examined. Living trees in the plots were assessed for decay using standard methods developed for the Shigometer. Approximately 418 balsam fir crop trees, and 440 red spruce crop trees were assessed for decay.

Trees in an additional seven stands precommercially thinned ten to twenty-three years earlier, and in four unthinned stands of commercial thinning size and age were also assessed for decay using the Shigometer techniques. In these older stands, a total of fifty red spruce and fifty balsam fir were selected for sampling in each stand.

Results are still being analyzed, but some trends are indicated. In stands precommercially thinned recently, 15.8% of the balsam fir crop trees were determined to have at least some decay, but only 5.6% of the removed balsam fir were decayed (Figure 11). Red spruce was much less affected by decay, but a similar trend was also observed, with 5.7% of the crop trees containing decay, but only 1.6% of the cut stumps showing decay (Figure 12).

Decay incidence was considerably more variable in older stands that were precommercially thinned, or left unthinned. In stands precommercially thinned between 14 and 23 years ago, decay incidence in balsam fir ranged from 8% to 62% of the crop trees. Decay incidence of only 6% was found for red spruce. Decay incidence in older unthinned stands ranged from 44% to 52% for balsam fir, and from 4% to 8% for red spruce.

Earlier work at the Penobscot Experimental Forest has shown that as root diameters increase, incidence of decay also increases. Larger trees are more likely to be selected as crop trees, and this may be a partial explanation for why precommercially thinned young stands have a slightly higher level of decay incidence at that stage of development. However, as stands mature the overall decay incidence increases, making the differences which may have been related to treatment less significant. Site differences also likely play an important role in determining decay incidence. Further analysis is being conducted to understand these effects more clearly.

For more information about this study, contact **Bill Ostrofsky** at 207-581-2877 or email at ostrofsk@umenfa.maine.edu.

Effect of Thinning on Wood Quality

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Precommercial thinning followed by commercial thinning at a relatively young age will substantially reduce the properties of the wood at the time of the final harvest, and wood harvested in the commercial thinning will have relatively poor quality. Precommercial thinning affects wood properties primarily by increasing the growth rate at an early age, which results in a greater proportion of juvenile wood in the bole. Precommercial thinning may also extend the length of the juvenile period and lower the specific gravity and strength of the wood produced in individual growth rings. The purpose of this project is to assess the effects of precommercial thinning on the properties of wood harvested at future intervals.

During 1999-2000, work was carried out on a study involving the possible effects of precommercial thinning on the wood properties of red spruce and balsam fir. The properties being evaluated are

specific gravity, modulus of rupture, and modulus of elasticity. Data collection from a red spruce stand that was precommercially thinned in 1976 is nearly complete, and data are being collected from a balsam fir stand that was precommercially thinned in 1985. Two other suitable balsam fir stands were located. Because data collection is still ongoing, final results are not available for any of the precommercially thinned stands. However, it is possible to present some indication of what the effects of precommercial thinning in balsam fir stands may be by referring to data recently collected from a mature balsam fir stand.

Figures 13, 14, and 15 show how specific gravity, modulus of rupture (bending strength), and modulus of elasticity (stiffness) in a balsam fir stand changed with increasing tree age (number of rings from the pith). Referring to these figures, it is evident that each of the properties increased until about age 25 (i.e., the juvenile period lasted until about age 25), after which time there was very little change in any of the properties.

An increase in growth rate following precommercial thinning at an early age would increase the proportion of low quality, early juvenile wood in the bole, because growth rings close to the pith would be wider. Where specific gravity is important (Fig. 13), as for the pulp and paper industry, precommercial thinning will lead to lower pulp yields per unit volume of wood. Where strength properties are of primary concern (Figures 14 and 15), precommercial thinning will lead to wood which is weaker on average, because more of the wood in

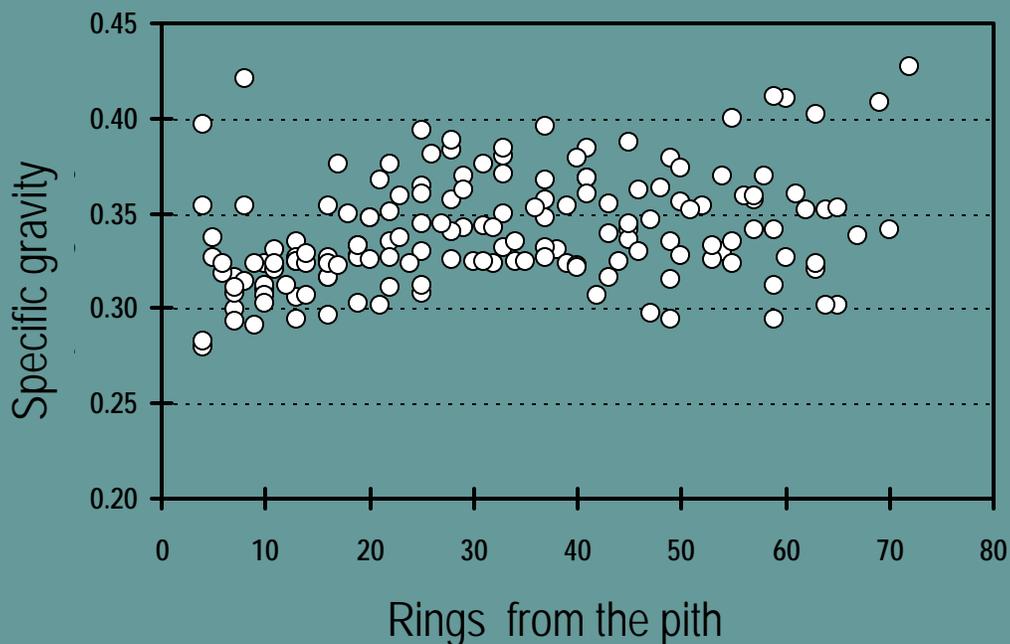


Figure 13. The relationship of specific gravity to growth ring position from the pith at breast height in a balsam fir stand.



the bole at the time of harvest will have been produced in growth rings prior to the twenty-fifth ring from the pith. The effect of precommercial thinning on modulus of rupture and modulus of elasticity will be greater than on specific gravity, because those properties increase relatively more during the juvenile period than specific gravity does.

The greatest effect of thinning on wood properties will occur when precommercial thinning at an early age is followed by a commercial thinning part way through the juvenile period. The material removed in the thinning will be of poor quality, and the increase in growth rate will further increase the proportion of juvenile wood in the bole at the time of the next harvest. To the degree that precommercial thinning extends the length of the juvenile period or reduces the properties of wood in individual growth rings during the juvenile period, its effect will be increased. For more information contact **Bob Shepard** at 207-581-2859 or email robert_shepard@umenfa.maine.edu.

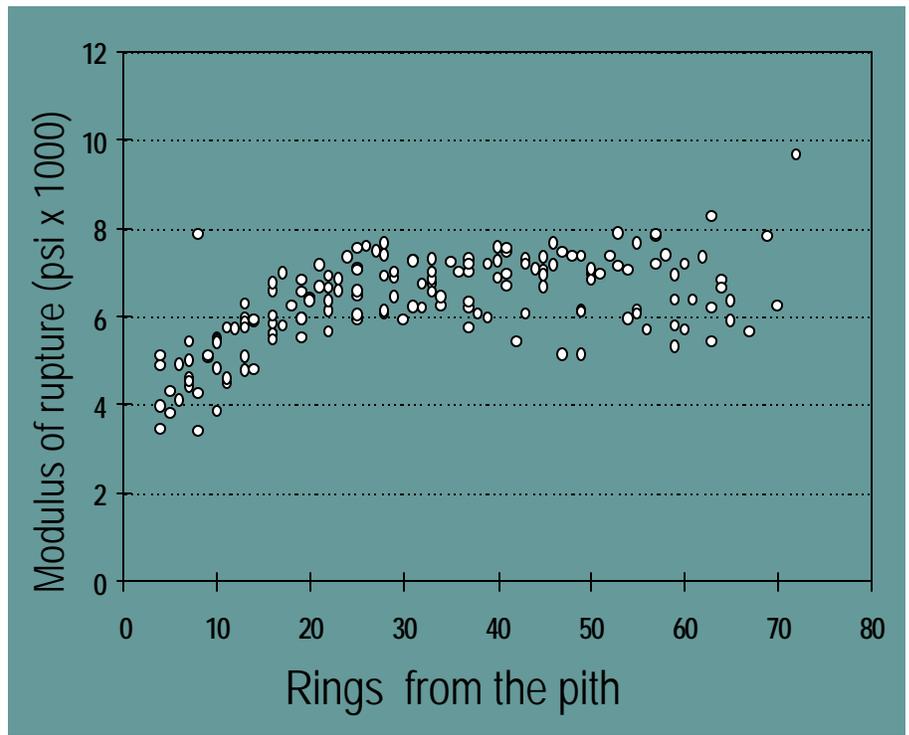


Figure 14. The relationship of modulus of rupture to growth ring position from the pith at breast height in a balsam fir stand.

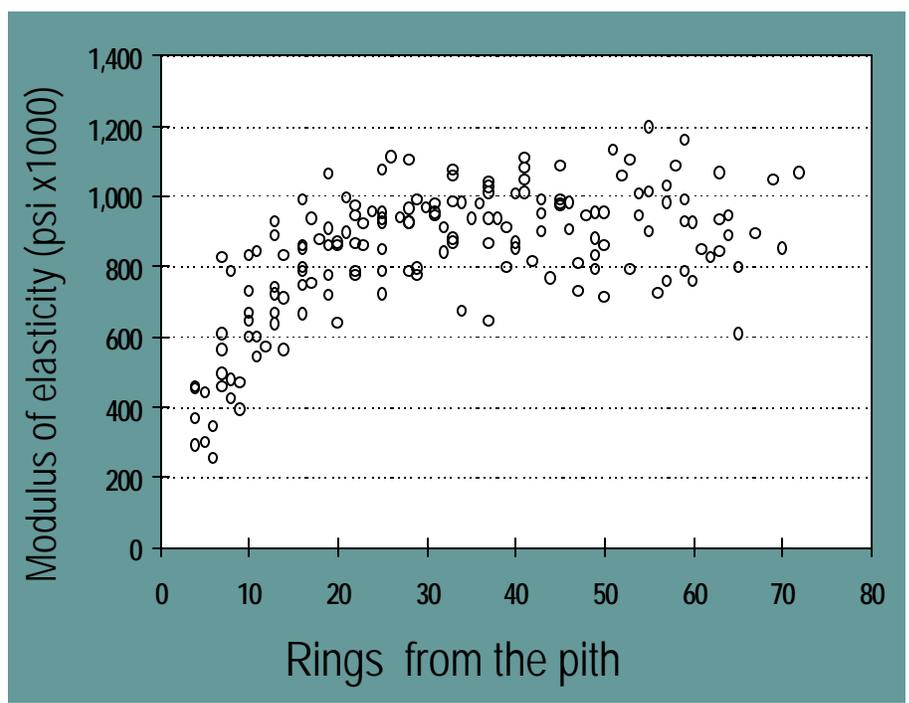


Figure 15. The relationship of modulus of elasticity to growth ring position from the pith at breast height in a balsam fir stand.

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

Robert G. Wagner
University of Maine

The Austin Pond Study is the CFRU's oldest research site and is providing one of the best opportunities to document the long-term effects of herbicide treatments and pre-commercial thinning (PCT) on spruce-fir stands in the region. During 1999, we re-located, re-marked, and the GPS located all plot corners from the original 1977 study. Four 1/20-acre permanent sample plots were installed inside

inside each half (PCT and no PCT) of the original 28 herbicide treatment plots. During the summer of 1999, we measured species and DBH of all trees in the plot. All trees >3.5 inches DBH had their azimuth and distance from plot center, DBH, and species recorded. All trees less than 3.5 inches DBH were classed into <0.5, 1, 2, and 3-inch DBH classes by species. The species and DBH of all standing dead trees were recorded. The total height and height to live crown of a subset of trees of the major species across all DBH classes also were measured to develop height/DBH relationships by treatment plot.

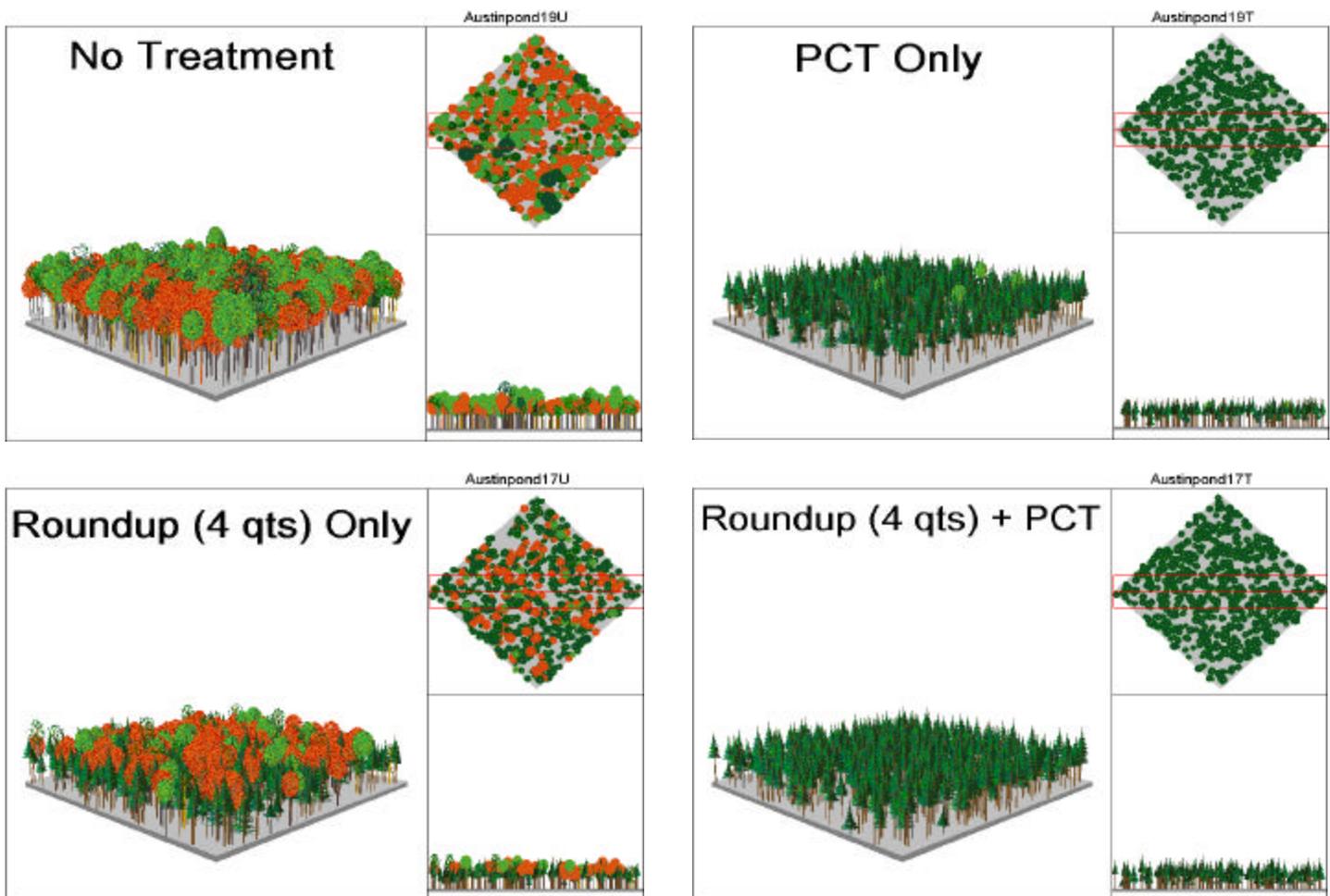


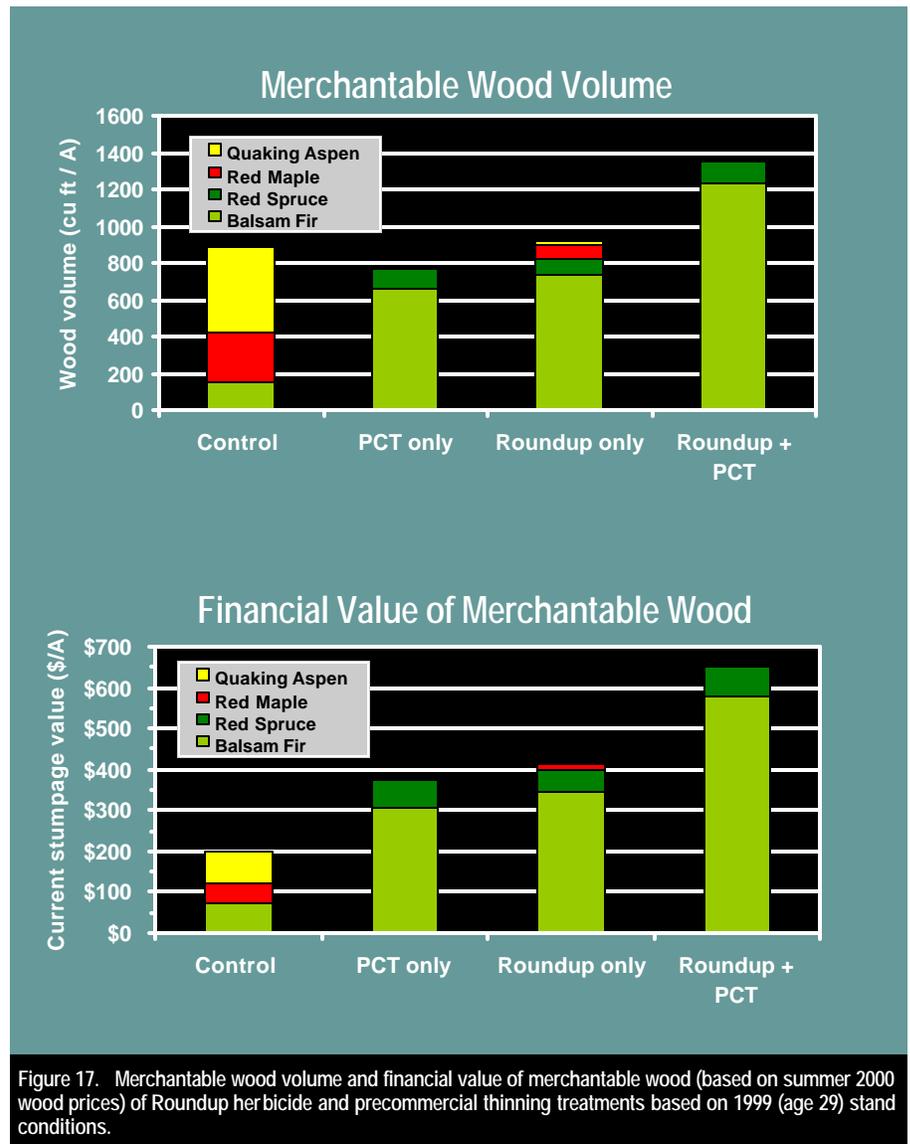
Figure 16. Computer-generated images of blocks 17 and 19 from the Austin Pond study depicting the long-term effects of Roundup herbicide (applied in 1977) and pre-commercial thinning (applied in 1985) on stand development in 1999 (age 29). The Forest Vegetation Simulator (FVS) was used to generate these images based on individual-tree data collected from sample plots in 1999. Key to tree species: red hardwood trees = red maple; light green hardwood trees = trembling aspen; dark green conifers = red spruce; light green conifers = balsam fir.

Accomplishments for this year included entering all data collected during the 1999 field season. We also found a graduate student (Howard Daggett) who will make analysis of the Austin Pond study the focus of his M.S. thesis. Howard is a recent University of Maine forestry graduate who led the field crew for the 1999 plot establishment and data collection at Austin Pond. During the summer of 2000, Howard and a botanist (Matt Montgomery, U. Maine Biology grad student) established 2 x 2 m subplots at all permanent sample plot locations to examine the effect of the treatments on the understory shrub and herbaceous species that were not sampled in the 1999 collection. Preliminary analysis of the 1999 data also was begun.

Preliminary analysis confirms what is quite visible on the ground; the herbicide treatments and PCT have had a substantial influence on stand development. We have briefly examined several of the treatments combinations that represent the treatment extremes in the data. Using the Forest Vegetation Simulator, we used the tree lists derived from the 1999 sample to construct how four of the plots look today (Figure 16). The untreated control plot is clearly dominated by hardwood trees (primarily red maple and aspen). The Roundup (4 qts/A) only treatment clearly increased the proportion of spruce and fir, but still permitted the long-term development of maple and aspen, forming a mixedwood stand at 22 years after treatment. PCT was clearly more than just a thinning. It also had a cleaning effect, substantially reducing the composition of maple and aspen as well as spacing the residual spruce and fir. The FVS simulations indicate a similar appearance between the PCT only and Roundup+PCT treatment.

From these projections, a principal question is whether there was any advantage to the herbicide treatment before PCT. There is more total wood volume on the Roundup+PCT plots than on the PCT only plots. Based on a preliminary analysis of the stem diameter distributions, there also appears to be a greater number of spruce and fir stems in the larger diameter classes in the sprayed plots relative to the unsprayed plots. As a result, there is nearly double the merchantable volume on the Roundup+PCT plots than on the PCT only plots (Figure 17). About 70% of the total wood volume is merchantable on the Roundup+PCT plots compared to only 58% on the PCT only plots. Differ-

ences in merchantable wood volume and species composition among these treatments have produced substantially different financial values at age 29. The Roundup+PCT plots have a current value of about \$650/A (year 2000 prices) compared to only \$197 for the untreated control. The PCT only and Roundup only plots are similar and fall midway be-



As part of his thesis research, Howard Daggett will 1) do a complete statistical analyses of treatment effects on the overstory and understory, 2) use existing growth models to project future stand development among the treatments, and 3) conduct a financial analysis of herbicide and PCT treatments based on current and future stand conditions. Results from this analysis will be used to quantify differences and similarities among the study plots, and using this information refine the experimental design so that new treatments (e.g., commercial thinning, additional vegetation management, and/or fertilization) can be added to the current silvicultural prescriptions in the coming years. For more information about this study, contact **Bob Wagner** at 207-581-2903 or bob_wagner@umenfa.maine.edu.

Seasonal Tolerance of Red Spruce and Balsam Fir to Glyphosate, Imazapyr, and Triclopyr Applications

Robert G. Wagner
University of Maine

Seasonal tolerance of red spruce and balsam fir to applications of glyphosate (Accord®, Vision®), imazapyr (Arsenal Applicators Concentrate®), and triclopyr (Garlon 4®) were reported in the 1999 CFRU Annual Report (pgs. 10-13). We noted at that time that imazapyr (Arsenal) produced no visible foliage injury to either spruce or fir. However, by dissecting buds at the end of the growing season we found substantial reductions in the number of needle primordia (Figure 18) in treated trees when the imazapyr was applied before mid August. The pattern of bud primordia injury was similar to the pattern of foliage injury produced by both glyphosate and triclopyr at the same times of application. We also observed that the 4 oz / A rate of imazapyr caused greater reduction in primordia than the 2 oz / A rate. No difference in degree of bud primordia injury by imazapyr was found between spruce and fir.

The question we asked this year was whether the injury to the bud primordia caused by the Arsenal would reduce height growth in the following years? We revisited the plots in the fall of 1999 and again in fall 2000 to measure the height increment on 10 spruce and 10 fir in each of the Arsenal treated plots plus the untreated control plots (894 trees total).

The results are presented in Figure 19. The reduction in needle primordia in the buds showed a strong relationship with timing of Arsenal application for both fir and spruce and both rates of Arsenal application. Applications from mid August on showed no difference in bud primordia number relative to the untreated control plots (i.e., not different from 100% of the control). Despite this apparent lack of injury to the bud primordia, however, height growth in 1999 was only about 80% of the control (or a 20% reduction) for the 2 oz rate. Height growth in 1999 with the 4 oz rate was reduced to about 60% of the control (40% reduction), fir being injured slightly more than spruce.

During the re-measurement in the fall of 2000, we had expected to see height growth begin to recover to a rate similar to that of the untreated trees.

However, height growth in the second year after treatment was reduced even further (Figure 19). Height increments of balsam fir were less than 20% of untreated trees (80% reduction) for all timings of Arsenal application in the second year after application. The only exception is the late June application that is beginning to show some level of recovery, despite the fact that the buds at this timing were more injured after treatment than at any other timing.

Spruce also showed a continued reduction in growth during the second year after treatment, but the decline was not as great as with fir. Spruce height growth in 2000 was about 50% of the control plots for the August and later timings at the 2 oz rate, and about 30% of the untreated controls with the 4 oz rate. The spruce are showing earlier signs of recovery than the fir in that the proportion of trees with lateral branches taking over for the leader across all Arsenal treatments is greater for the spruce (39%) than the fir (18%).

It is clear from these latest data that Arsenal applications for release of fir and spruce need to be seriously reconsidered. The 2 oz / A rates during the typical conifer release windows (mid August to mid September) have reduced height growth in balsam fir by about 25% in the first year, and over 80% in the second year, after treatment. At the 2 oz rate, spruce height growth has been reduced about 35% in the first year, and about 50% in the second year, after treatment. With only 9% of the fir and 18% of the spruce showing evidence of lateral branch takeover with the 2 oz rate during the mid August to mid September timings, it appears that height growth reductions are likely to continue for at least several more years. We will revisit the site in fall 2001 to track the 3rd-year results.

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

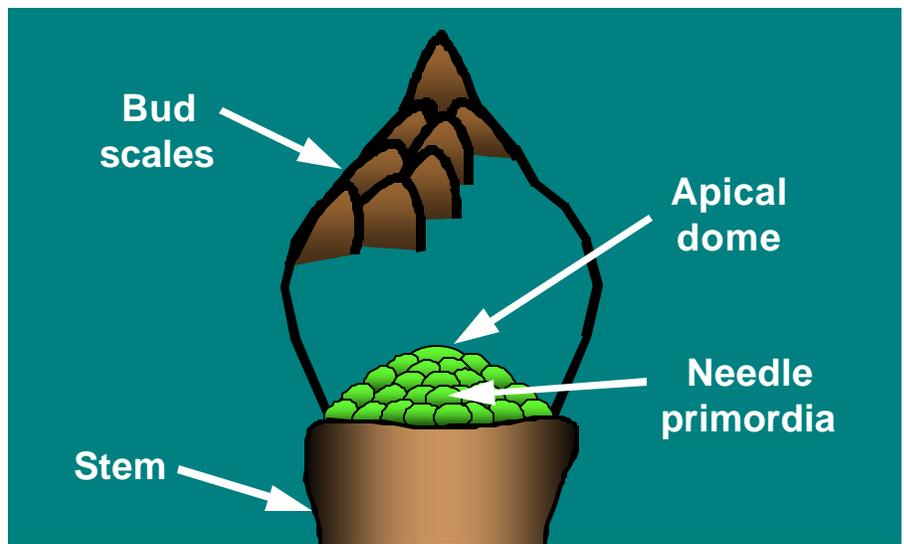


Figure 18. Diagram showing location of needle primordia in a conifer terminal bud.

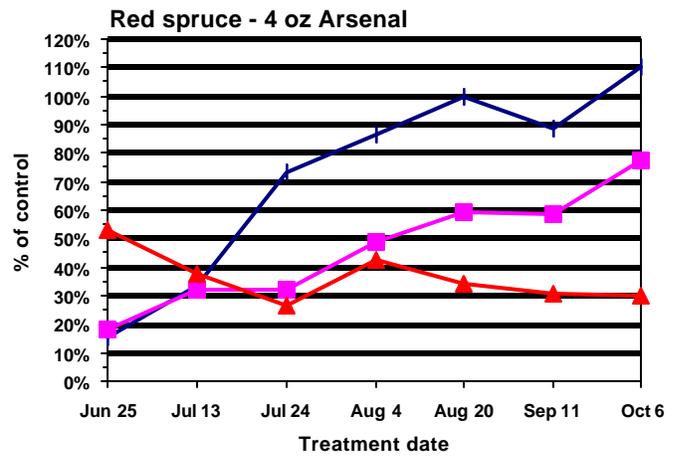
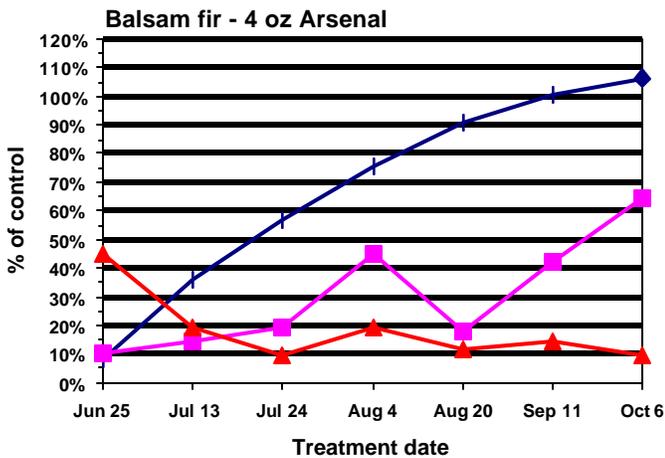
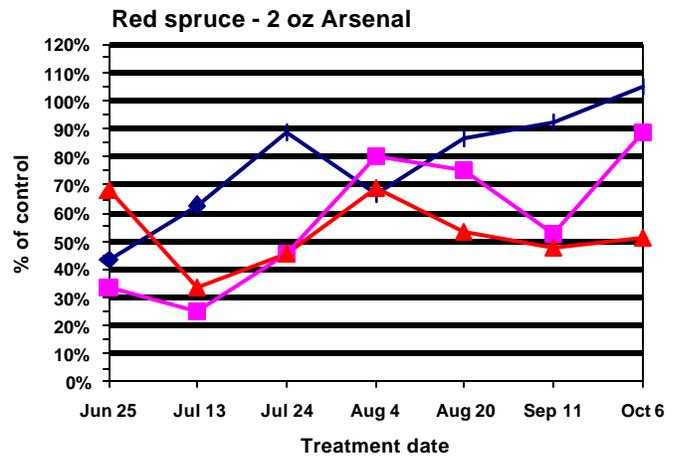
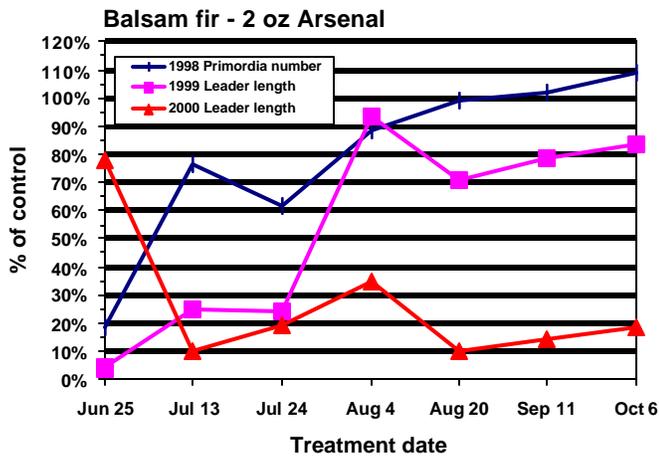


Figure 19. Number of needle primordia in buds in 1998, leader length in 1999, and leader length in 2000, expressed as a percentage of that observed for untreated control plots, for imazapyr herbicide (Arsenal) applications to red spruce and balsam fir at seven timings of application during the growing season.



Using Wood Supply Analysis of Maine's Forest to Identify the Most Productive Areas of Silviculture Research for the CFRU

Robert G. Wagner,¹ Robert S. Seymour,¹
and Ernest Bowling ²
¹University of Maine
²J.W. Sewall Company

The 1998 report *Timber Supply Outlook for Maine: 1995-2045* by Maine Forest Service (MFS) brought much attention to the issue of Maine's wood supply. Part of this analysis included an evaluation of the wood supply implications for increased use of silvicultural practices such as thinning, plantations, and vegetation management. At the same time, CFRU cooperators were debating about which areas of silvicultural research would provide the greatest benefit to them and contribute most to improving the management of Maine's forests.

So, we asked the question whether sensitivity analysis of silvicultural inputs could be used with the Maine Forest Service's wood supply model to determine the absolute and relative importance of various silvicultural practices on Maine's wood supply, and from this assess the value of various silvicultural research priorities? With combined financial support from the CFRU (\$35,000), Maine Forest Service (\$15,000), and College of Natural Resources, Forestry, and Agriculture (\$10,000), we were able to develop a joint collaboration with J.W. Sewall Company to conduct this modeling effort.

Atlas to Woodstock Conversion

Our first task, to convert the MFS model from Atlas to a Woodstock platform, was completed successfully early in the project. This conversion was necessary to provide a model that was in a form that could be used to develop the sensitivity analysis.

Initially, the Atlas harvest framework was translated directly to Woodstock, however this approach was abandoned in favor of an approach that was more silviculturally based. The model formulation features even and uneven-aged management systems. The even-aged systems feature the clearcut and shelterwood regeneration methods, with intermediate treatments that may or may not be applied. Intensive precommercial silviculture is modeled in a similar fashion to the Atlas model.

Our Woodstock model uses acres by habitat type and volume class from the MFS Atlas INVEN file to create the Woodstock area file. These data, in combination with the data from the MFS Atlas

MANAGE file (base yield curves, density change data), were used to create aggregate yield curves (aggregated by habitat type, harvest intensity, and management intensity). Yield curves were aggregated in some cases by fitting nonlinear regression lines through the predicted yields, and by computing weighted averages in other cases. The 10-year MFS Atlas volume classes were then converted to 5 year classes assuming that acres were uniformly distributed within volume classes; yield curves were developed by predicting yield at the midpoint of the volume class using the nonlinear regression lines fit to the 10-year volume class data. A comparison of the initial inventory for the MFS Atlas model with our Woodstock model indicated that the projections were within 1.6% for all habitat types.

Structure of Woodstock Model

The objective function we used initially was maximization of total harvest over the projection length (100 years). We set total harvest constraints equal to the Atlas level (2.7975 billion cubic feet per 5-year period) in periods 1-4, even flow harvest in periods 5-20, and total softwood harvest is limited to a maximum 50% increase and 10% decrease from one period to the next. Other constraints were ending inventory constraints by habitat type, limits on the acreage of overstory removal harvesting in deer wintering areas by period, and other constraints depending on the goal of the run. All harvest levels for these runs were set equal to the even-flow level attained in period 5 plus.

At this point it became evident that our choice of constraints was affecting the results, especially with regard to the yield sensitivity runs (described below). Due to the even-flow constraint in periods 5 plus, the models were unable to harvest the extra wood grown at high levels of silvicultural treatment. To address this issue, alternative constraints were evaluated. The even-flow constraint on the harvest for periods 5 plus and the constraint on softwood harvest limited to no more than 50% increase and 10% decrease from period to period were replaced with new constraints. The revised constraints were that total harvest must equal the Atlas level (2.7975 billion cubic feet per 5-year period) in period one, could



increase by no more than 30% or decrease by more than 20% from period to period. In addition, the total inventory could not decline by more than 5% from period to period. These revised constraints allowed more flexibility, allowing the model to harvest more of the wood grown, especially at high levels of silvicultural treatment. However, the constraint that harvest could not decline by more than 5% from period to period became binding, as the ending inventories were still high for aggressive treatment scenarios.

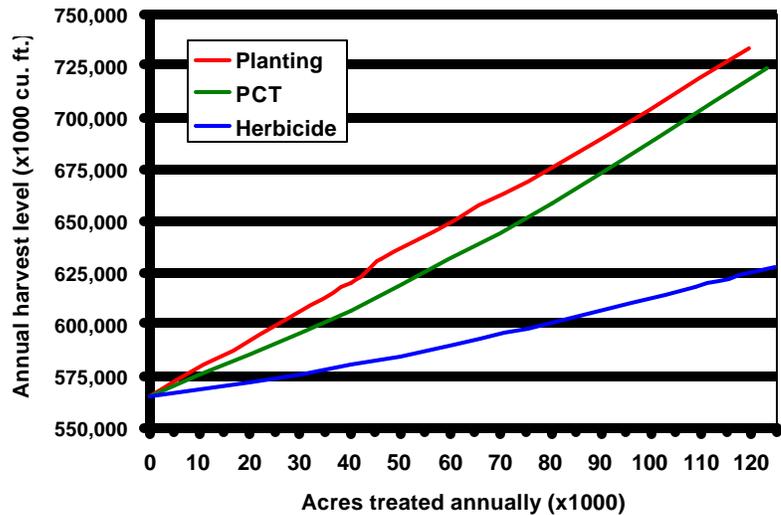
At this point, we shifted to an objective function based the above harvest constraints but added discounted cash flow objectives that considered treatment costs, net present value (NPV), and the financial value of the ending inventory. The resulting model behavior was reasonable and stable, nicely balancing both wood flow and economic considerations over the length of the projections. We believe this model structure more appropriately models management behavior and gives the model outputs with more economic credibility. As a result this model structure formed the basis for our sensitivity analysis.

Sensitivity Analysis

Using the above structure for the Woodstock model, we were then able to begin the sensitivity analysis. We focused this analysis on simulating the effects of increasing the acreage treated with tree planting, herbicide treatments, and precommercial thinning (pct) on annual harvest levels and NPV of the forestland. We examined one-way, two-way, and three-way interactions among these silvicultural inputs.

In addition, sensitivity of the model outputs to changing the growth and yield assumptions was examined. We did this by modifying the slope of the normal yield functions for planting, herbicide, and PCT from -20% to +20% to determine the effect on annual sustainable harvest levels and net present value. We also have examined the effect of varying the growth rate of stands harvested by partial harvest techniques, such as commercial thinning and selection harvesting, in the same way.

(A)



(B)

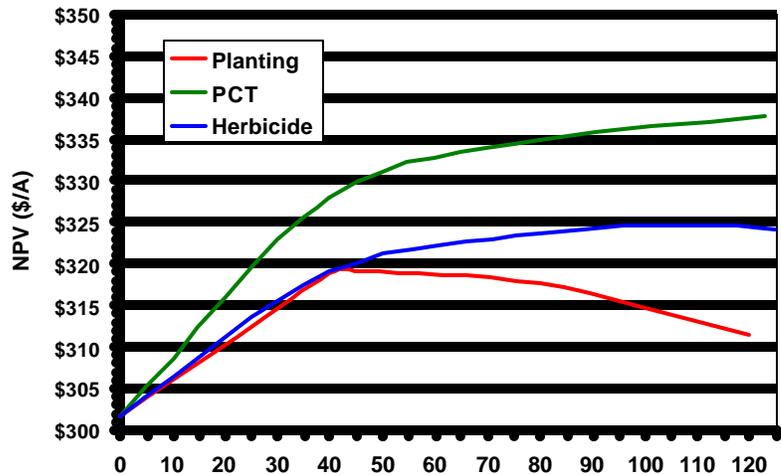


Figure 20. Influence of increasing annual acres treated for planting, PCT, and herbicide application on (A) sustainable annual harvest levels and (B) net present value of forestland in Maine. Results are from a one-way analysis where planting, herbicide application, and PCT were each considered separately in the model, i.e. acres treated were set to zero for all factors except the one being evaluated. Two-way and three-way interactions among all factors also are being evaluated in the project.

The relative influence of increasing acres treated for each silvicultural input on annual harvest levels and net present value, as well as the overall effect of raising and lowering the slope of the growth and yield assumptions, formed the basis for the sensitivity analysis. From this analysis, we were able evaluate the importance of better research information about these silvicultural activities.

One example of the output we are currently evaluating is presented in Figure 20. Tree planting and PCT had a larger effect on annual statewide harvest levels than herbicide application in the model

(Figure 20A). Under the maximum runs, if either planting or PCT were applied to about 120,000 acres of Maine's forest per year, annual harvest levels could increase as much as 30% statewide. However, the economic benefit from this level of investment tells a different story (Figure 20B). The NPV of Maine's forestland increases as planting, herbicide application, and PCT acres increase until about 50,000 acres are treated annually with each treatment. NPV levels off or declines above this level of investment. PCT has the greatest influence on NPV, while planting and herbicide application have a lesser effect. The NPV for planting begins to decline when more than 40,000 acres are planted per year. Interactions among these silvicultural investments (not shown here) change the relationships and conclusions, and are part of the analysis being conducted.

Results of this study will be released in early in 2001. For more information about this study, contact **Bob Wagner** at 207-581-2903 or bob_wagner@umenfa.maine.edu.



Wildlife and Biodiversity

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

Jeffrey A. Hepinstall and Daniel J. Harrison
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Marten are the most area-sensitive, forest specialized mammal inhabiting forest landscapes in northern Maine (Figure 21). They require large areas of relatively intact forest, are sensitive to forest fragmentation, but are tolerant to a wide range of forest types within their territories. Thus, this species is an ideal "umbrella species" to use for evaluating landscape effects of forest harvesting and can be used as a coarse filter to assist in long-term forest planning at the scale of townships or larger landscapes.

This project has several objectives. First, to develop and evaluate habitat models that will reliably predict the distribution of habitat for marten in the Telos (T4 R11 WELS and T5R11 WELS) and Baxter State Park study areas using field data gathered over 11 years and vector databases on vegetation type, age, and structure. Second, to modify this local area model to be able to predict marten habitat for all of the species' range within the state of Maine. Implicit in this objective will be an evaluation of whether the predicted habitat available will be sufficient to achieve the objective population sizes resulting from MDIFW's species assessment process. Third, to develop a spatially-explicit, long-term habitat projection for northern Maine using marten as an area-sensitive umbrella species, while also incorporating habitat requirements of other forest dependent vertebrates with smaller area requirements than marten.

This project will develop several products that will complement and enhance the landscape habitat planning and urban sprawl initiatives of the Maine Department of Inland Fisheries and Wildlife (MDIFW) and the State Planning Office, and would provide opportunities to integrate volunteer habitat planning across the diverse ownerships and management objectives in northern, western, and eastern Maine.

This project has begun the process of developing and evaluating models designed to predict marten habitat in the Telos and Baxter State Park study areas. We have been analyzing marten home range data gathered previously in the industrial

forest ($n = 150$) and Baxter State Park ($n = 109$) from 1989 to 1998. Standardized cover maps were developed that allowed for translation across the 10 years of data collection.

Because we knew what areas marten occupied and what areas were not occupied, we could combine used versus unused areas to analyze habitat thresholds for marten at the scale of the forest landscape. To do this we developed a method to populate the unused areas with simulated marten home ranges. These ranges were designed to simulate approximate size and shape observed within home ranges of male and female marten. The marten home range data from previous studies in the industrial forest have been paired with these simulated home ranges to 1) estimate thresholds of forest types (e.g., mature closed canopy forest, young forest) that will accurately predict the presence or absence of marten (i.e., habitat currencies); and 2) build the database required to model marten occurrence. For example, Figure 22 depicts differences in the proportion of young forest between home ranges of marten and home ranges that were randomly generated in areas unused by marten. This and related analyses are being used to define habitat currencies for marten.

To determine if marten are responding to landscape configuration, FRAGSTATS software is being used to calculate landscape metrics. Special consideration of the habitat currencies used as input into the software has required further exploration of the types of forest stands used and unused by marten. Landscape metrics are currently being developed for two different habitat classification systems to determine which more accurately predicts habitat occupancy by marten.

In addition to developing thresholds for marten habitat, the marten home range data and simulated home range data and derived landscape metrics will be used as input for at least two different modeling strategies. We are using logistic regression to build and test models that will predict the presence and absence of marten in the local study area. These models



Figure 21. American marten.

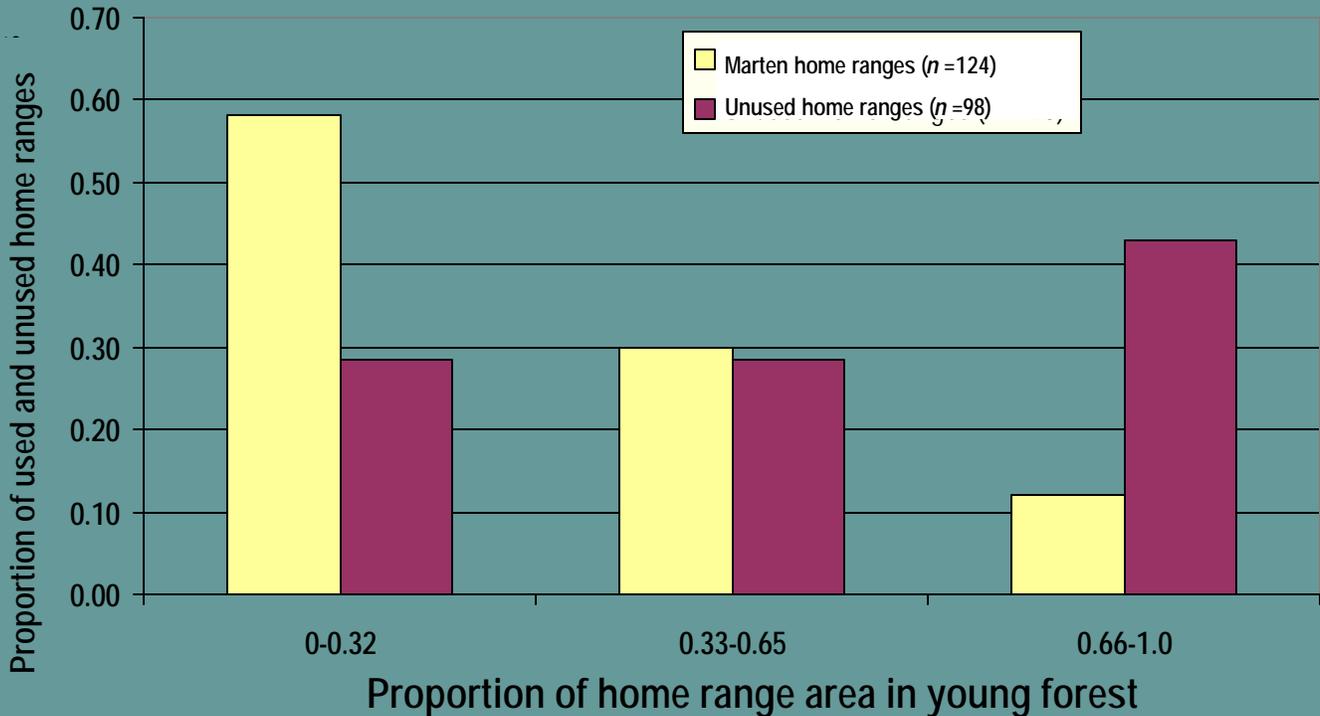


Figure 22. Differences in the proportion of young forest between home ranges of marten and home ranges that were randomly generated in areas unused by marten.

will then be adapted to run on raster-based vegetation maps and satellite imagery available for Maine. We have statewide data for vegetation and land cover of 1993 developed for the Maine Gap Analysis Project, as well as unclassified satellite imagery from 1991, 1993, and 2000, and study area imagery for 1995, 1997, and 1998. The many dates of satellite imagery will be used to better understand the relationship between vector stand maps and classifications derived from the imagery.

It is expected that we will have objective 1 completed by early 2001. Objective 2 will require approximately 6-8 months to complete, and simulation modeling for objective 3 will be completed by summer, 2002.

In addition to the CFRU funding for this project, funding is being provided by Maine Department of Inland Fisheries and Wildlife, Maine Outdoor Heritage Fund, the Maine Chapter of The Nature Conservancy, the College of Natural Sciences, Forestry, and Agriculture and the Department of Wildlife Ecology at the University of Maine.

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



Effect of Precommercial Thinning on Selected Wildlife Species With Special Emphasis on Snowshoe Hare

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Introduction

In March 2000, the U.S. Fish and Wildlife Service listed the Canada lynx as a threatened species under the Endangered Species Act (ESA). Maine is the only state in the northeast with a verified population of resident lynx. However, the relationships between lynx habitat and forestry practices are not well-studied. Lynx are a specialized predator (O'Donoghue et al. 1998) of snowshoe hare and hares reach their highest densities in stands with exceptionally high densities of conifer saplings (Litvaitis et al 1985). It is possible that extensive areas of regenerating forest, and the hare populations supported by these habitats, will turn-out to be an important component of lynx habitat in Maine and that precommercial thinning (PCT) could be challenged as a habitat issue influencing lynx recovery.

During 1997 to 1999, 63,619 acres of forest were precommercially thinned in Maine and acreage of both commercial and precommercial thinning are projected to increase substantially (Maine Forest Service 2000, 1999, 1998). Forest managers will be challenged to justify those approaches based on wildlife habitat and biodiversity. There is insufficient information to evaluate the influence of thinning on snowshoe hares, small mammals, and other potential prey species for lynx and other forest carnivores. Thus, we are currently investigating the temporal effects of PCT on hare and small mammals and forest structure in the industrial forests of northern Maine.

This study is funded by the CFRU, the National Council of the Paper Industry for Air and Stream Improvement (NCASI), the 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 provided access to their lands.

Objectives

The study was initiated to clarify the effects of PCT on selected wildlife species and stand structure for 0-15 year post-PCT treatment. We are giving special attention to the snowshoe hare because of this species' strong association with forest structure, high stem densities of saplings, and because of its importance as a food source to lynx and other predators, including barred owl, bobcat, fisher, fox, great horned owl, goshawk, and marten. The two-year study addresses the following objectives:

- to quantify and compare overstory, understory, coarse woody debris (CWD), and vertical and horizontal structure between herbicide treated clearcuts, with and without PCT, across a temporal gradient;
- to document the stand-level effects of PCT on densities of snowshoe hare and small mammals across a temporal gradient and relate to vegetation changes associated with thinning, and
- to use existing data on forest structure and hare densities from other forest types and silvicultural treatments in Maine that are available in our labs (Long 1995, Lachowski, Fuller 1999) to develop a predictive relationship of hare density in relation to overstory, understory, coarse woody debris (CWD), and structural variables. This will provide a predictive tool for evaluating effects of alternative silvicultural and harvesting options on hares at the scale of the forest stand.

Approach

The study sites are distributed among seven townships in northern Maine. We examined site quality, tree density, dbh of dominant trees, and spatial independence of stands before selecting them as study sites. We paired treatments with a control that has similar dates of harvest, dates of herbicide, and site quality. The treatment blocks are comprised of stands that have been clearcut, herbicided, and precommercially thinned. The study design



Figure 23. Jessica Homyack, Graduate Research Assistant, records information from a red-backed vole that was captured in a treatment stand that was clearcut in 1970, herbicided in 1976, and precommercially thinned in 1986 (15-year treatment site).

includes 24 precommercially thinned stands at 5 year intervals since thinning (1 year post thinning, $n = 6$; 5 years, $n = 6$; 10 years, $n = 7$, 15 years, $n = 6$) and 13 paired control stands (1 year, $n = 5$; 5 years, $n = 5$; 10 years, $n = 3$).

Results

We established 24 small mammal grids on stands treated with PCT from four age classes, zero years since PCT ($n = 6$), five years since PCT ($n = 6$), 10 years since PCT ($n = 6$), and 15 years since PCT ($n = 6$). Thirteen small mammal grids were established on stands with similar site histories, but without subsequent PCT. We trapped mice, voles, and shrews on 36 stands during summer 2000 (Figures 24 and 25). Trapping periods lasted for six trap nights and small mammals were captured in Bolton live-traps baited with oats and peanut butter. Each grid had 64 trapping locations. We recorded age, sex, reproductive condition, and presence of external parasites of each individual. Mice and voles were ear-tagged with a uniquely numbered ear tag (monel no. 1005-1). We captured 558 individual small mammals. Preliminary results of the effects of PCT on densities of small mammals are unclear (Figure 25).



Figure 24. 558 small mammals were ear-tagged and released during 13,051 trap-nights of effort on 24 treatment and 13 control stands during summer 2000.

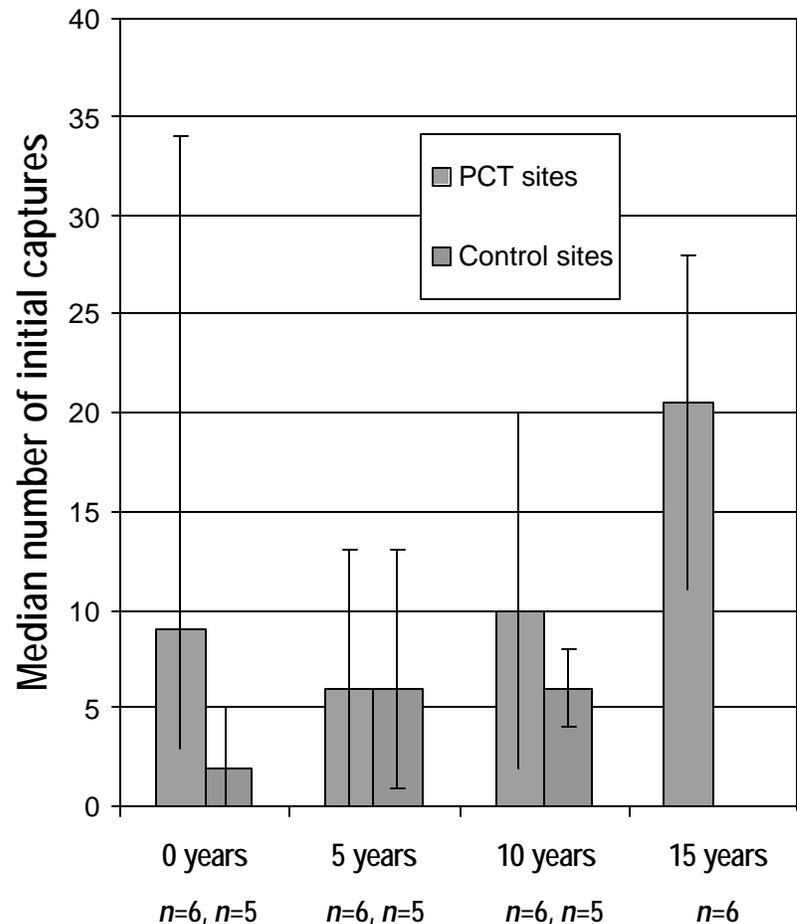


Figure 25. 558 individual small mammals were captured. Preliminary results of the effects of PCT on densities of small mammals are unclear.

We completed microhabitat analysis of thirteen small mammal grids. Sixteen of the 64 trapping locations per small mammal grid were randomly selected to intensively measure vegetation characteristics. A 10 x 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 saplings, volume of coarse woody debris, canopy closure, basal area, and other measurements.

Snowshoe hare densities will be calculated from hare pellet counts. We set up hare transects on 17 treatment stands (0 years since PCT, $n = 5$; 5 years since PCT, $n = 5$; 10 years since PCT, $n = 7$) and on 13 control stands. We marked individual pellet plots at 20 m intervals and randomly oriented them along the transect. In the entire study, a total of 2,480 pellet plots were distributed on 46.68 km of transect. Most study sites have 1.6 km of transect and 84 pellet plots. The pellet plots are 5 x 30 cm (Fuller 1999) and were cleared of pellets in October 2000.

A second year of fieldwork will be conducted in summer 2001. Hare pellets will be counted and cleared in early spring and again in fall. We will verify the relationship between pellet density and hare density with live trapping of hares on a sub-sample of stands (Long 1995). Extensive vegetation characteristics will be measured on the hare transects. A second year of small mammal trapping will occur and we will complete the intensive vegetation measurements within the small mammal grids to quantify microhabitat characteristics.

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

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Figure 26. A treatment stand that was precommercially thinned in 1999.

Can Patch Retention Maintain Biodiversity in Clearcuts and Partially Harvested Forest?

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

Variable tree retention has become a popular tool for maintaining biodiversity in managed forests (Franklin et al. 1997). The variable retention harvest system retains trees as key structural elements of a harvested stand for at least the next harvest rotation in an effort to maintain both species and forest processes. Either few trees or many trees can be retained under this system, and trees can be retained in clumps (patches) or left uniformly throughout a stand (hence the name 'variable'). There has been much debate about which strategy works best for biodiversity. Variable retention may maintain biodiversity by: (1) *servicing as refugia* for species so they can persist through the next rotation period, (2) *maintaining structure* by providing a constant supply of features important to biodiversity, such as large trees, snags, and woody debris, (3) *retaining vulnerable or rare species and/or features*, and (4) *maintaining habitat patches* that can serve as stepping stones for dispersing individuals and propagules.

Timber harvesting affects forest species in different ways, depending on an array of life history traits. The ability of a species to disperse may be the most critical trait that determines a species' vulnerability in dynamic landscapes. Large organisms, such as birds and large-bodied mammals, are able to move and/or readily disperse into suitable habitat. Smaller organisms, such as herbaceous plants, lichens, mosses, invertebrates, and terrestrial amphibians may not fare as well in the face of industrial forestry because their dispersal and recruitment rates are low and can be inhibited by timber harvesting. Harvesting may affect these species at the stand level: (1) by temporarily changing structure and eliminating critical habitat features, and (2) by creating large areas of unsuitable habitat for years or decades.

The idea of variable retention originated from the observation that natural forest disturbances such as fire, blow down, and insect infestation typically leave patches of forest or isolated trees intact. Indirect evidence suggests that retaining such stand "legacies" can help maintain small mammals (Carey and Johnson, 1995), birds (Hansen et al.

1995), and lichens (Sillet 1995) typically found in mature forest. Nonetheless variable retention must be considered a hypothesis since the scientific basis is not yet established. This study tests whether patch retention can maintain biodiversity elements in northern Maine's forests.

The objectives of this study are to:

- Determine the contribution of new patches to maintaining populations of herbaceous plants, lichens, mosses, red-backed salamanders, and ground beetles.
- 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.

To accomplish these objects, we have initiated 3 substudies. Substudy I is an experiment that follows 30m-radius patches before and two years after harvesting. The goal of Substudy I is to determine the short-term (2 year) impacts of harvest on species and forest structure in retention patches and harvest area. In June-August 2000, we established 60 experimental plots that were sampled for forest structure, herbaceous plants, mosses, and macro-lichens. Twenty plots were placed in patches to be created this winter, 20 plots were placed in sites to be harvested this winter, and 20 were placed in sites that will remain unharvested for the duration of the study. Sites were matched among treatments based on visual estimates of forest structure, presence of indicator species, seeps, and intermittent streams and are ready for harvesting.

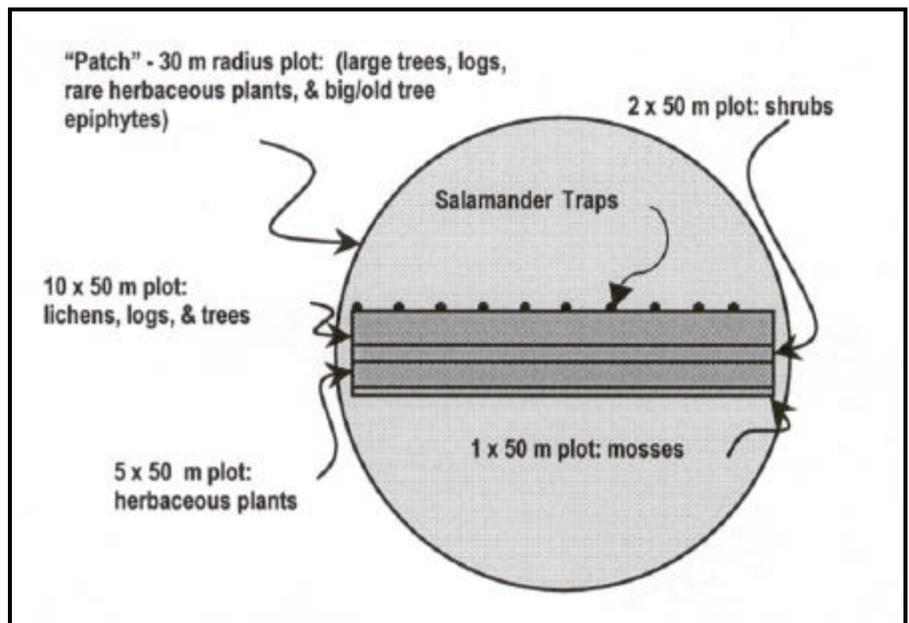


Figure 27. Plot layout for Substudy I and II.

We modified our plan to conduct the partial harvested part of the experiment on hardwood sites instead of mixedwood sites. We will compare the percent change species diversity and abundance in retention patches in both partial harvested hardwood sites and clearcut mixedwood sites to determine the relative benefit of patch retention in each treatment. We were not able to sample for beetles and salamanders because of constraints associated with finding suitable experimental units but will be sampling these groups in 2001. We also added a 30-m radius sample plot to improve our abundance estimates of rare herbaceous plant species, large logs, large trees, and large trees with epiphytic macro-lichens and moss (Figure 27).

Forest structure and species survey data from summer 2000 are being entered and checked. Later in the fall, we will statistically verify if our assignments of sites to treatments were statistically appropriate.

Substudy II is a retrospective study that samples upland forest buffer strips that were created 8 to 10 years ago between clearcuts. We will use these upland buffer strips to determine which species are likely to be retained and which are likely to be lost from the patches within 8-10 years. We added a study of 80-year-old fire remnants to address the usefulness of patch retention over the long-term.

For Substudy II, we were able to establish 40 sites and sample 15 for forest structure, herbaceous plants, and macro-lichens. In 2001, the remaining Substudy II sites will be sampled. We sampled 15 buffer strips of various widths (65' to 1300'), clearcuts, and intact forest (all mixedwood forest) in order to better understand what is gained by patches of different sizes. We focused on buffer width as a factor because our advisory team has expressed a strong interest in learning how big patches must be in order to maintain ecological features and species.

Data are being entered and error checked and will be available for analysis later this fall. Analysis of this year's data will focus on the relationship between buffer width and forest structure, macro-lichens and herbaceous plants. A preliminary assessment of four variables suggest that buffers $\geq 200'$ wide appear to have densities of large trees and logs, and percentages of trees with big/old tree epiphytes (moss and lichen species) that were similar to large tracts of intact forest.

Numbers of forest herbaceous plant species were not influenced by buffer width.

In the study of remnants in the 80 year old burn, it was noteworthy that all remnants contained big/old tree epiphytic species and that several remnants about ≥ 1 acre in size contained herbaceous plant species considered rare in Maine and sensitive to timber harvesting. This suggests that remnants may have the long-term capacity to retain herbaceous plant, lichen, and moss species that may be vulnerable to timber harvesting.

Substudy III is an economic assessment of patch retention that seeks to assess the economic costs of employing patch retention on a scale beyond the experimental work. Work on Substudy III will begin this winter and be completed in 2002.

An advisory team has been formed and is comprised of Carl Haag (Research Forester, Plum Creek Timber Company), Peter Etheridge (Research Forester, J.D. Irving, Ltd.), Hugh Crammond (Forester, J.D. Irving, Ltd.), and Sue Gawler (Plant Ecologist, Maine Natural Areas Program). We have canvassed team members for proposal comments and are planning a meeting by early winter to review progress and solicit suggestions for work in 2001.

Year 2001 Tasks

- Report: Plant species and biodiversity features in upland forest buffers of different widths, mature forest, and clearcuts in western Maine.
- Report: Plant species and biodiversity features in remnants and surrounding forest of a 1925 burn in western Maine.
- Field evaluation of costs of patch retention
- Sample 105 points in 8-10 year old buffer strips, clearcuts, and mature forest for Substudy II
- Sample ground beetles and salamanders in sites of Substudy I
- Sample 80-year-old fire remnants for forest structure, lichens, and plant species.
- Microclimate studies of sites in Substudy I

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

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Water Quality

Literature Synthesis of Effects of Forest Management Practices on Riparian and In-Stream Animal Biota of New England

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University of Maine

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Background

Although it is common to retain forested buffer strips along streams to protect lotic environments and water quality during and following forest harvest, utilization and value of these remaining forested areas by wildlife are unclear. At a stand scale, structure, species composition, and forest density are important components of the overall value and function of riparian buffer strips (DeGraaf and Yamasaki 2000). Landscape characteristics and physical attributes of the watershed such as land-use practices, land-cover types, and geological and hydrological conditions also play important roles in shaping the wildlife communities found in riparian forested areas (Kelsey and West 1998).

Much of the research examining the effects of riparian forest harvest on the value of riparian forest buffers to wildlife has been conducted in northwestern and southern North America; similar research in northeastern North America has been limited. Although the basic paradigms of stream continuity and watershed ecology and function apply throughout these regions, differences exist in the regional geomorphology, climate, stream conditions, stream-side and watershed land-use activities, and biotic composition of riparian habitats across North America.

The temporal and spatial variability of streams, adjacent riparian areas, and the watersheds in which they occur create a complex environment utilized by a wide array of animal species that is not uniformly tolerant of riparian disturbances due to their diverse and complex life histories and mobilities (e.g., microbial communities to migrating birds). Temporal responses to these disturbances may also vary from immediate to spanning decades (Harding et al. 1998). In-stream temporal and spatial physical gradients affect the stream-dwelling organisms

existing within the stream environment (Gosselink et al. 1990); these environments are not isolated from temporal and physical gradients or the inhabiting organisms found in the surrounding riparian landscape (Huryn 2000). This physical connectivity and the differing dispersal abilities of the inhabiting organisms should be considered in defining riparian protection zones. The functions of riparian areas vary with watershed, stream-side and in-stream conditions, and the inhabitants of these environments. The effectiveness of riparian buffers will depend on the functions that the buffers are intended to protect. This variability in site conditions, landscape, temporal dynamic, and wildlife response must be recognized when predicting potential effects of riparian forest manipulations. To date, these effects have received little study in northeastern North America.

Literature Search Methods And Results

During May-August 2000 we searched 18 online databases with approximately 20 combinations of the following search words: riparian, forest, wildlife, invertebrates, stream, birds, amphibians, mammals, fish, biodiversity, buffer, management, insect, policy, exotic, hyporheos, groundwater, watershed, aquatic (Table 9). The searches included literature published during 1967-June 2000, although not all databases index publications from the entire interval. Reference lists published in approximately 20 recent riparian ecology books were also compiled. The criteria used to select references followed those used in the online database search, i.e., the literature addressed some aspect of riparian forest ecology primarily in northeastern North America, or the citation was for an important paper in riparian ecology research conducted in other regions of the world but considered relevant to riparian forest ecology and management in the Northeast. Several thousand citations were reviewed, and two databases were developed in EndNote citation management software, with approximately 500 citations from northeastern North America and approximately 1000 citations of published research conducted outside this region but considered important papers in riparian ecology research. Currently the databases are being cross-checked for duplicates, typographic errors, and content. Database editing will be complete by early December 2000.

We retrieved few citations (<2% of the saved citations) of publications addressing effects of specific forest harvest manipulations on New England riparian wildlife; most of the published research in this region has examined bird responses to riparian forest manipulations (primarily buffer width), whereas reptiles and amphibians are the least-represented of the surveyed taxonomic groups (Table 10). Few studies address specific forest manipulations; most are general discussions of stream-side forest disturbance. Birds have received more study of effects of changes in buffer widths, whereas studies of invertebrates concentrate on stream-side, clear-cutting effects.

Table 9. Databases and selected references reviewed for literature survey.

Database
Agricola
Agris
America: History and Life
Aquatic Sciences and Fisheries
Biosis
Caris
Ecology Abstracts
Electronic Theses and Dissertations
Entomology Abstracts
Forestry Abstracts
Forest Products Abstracts
Georef
Government Periodicals Online
PaperChem
Water Resources Abstracts
Wildlife Worldwide
Wilson Biological and Agricultural Index
Zoological Record

Wildlife Use Review Methods and Results

In addition to reviewing the available literature citations, we have used software developed by the University of Maine Forest Management Research Cooperative (Hansen 2000) to tally wildlife use of New England riparian forests compiled by DeGraff et al. (1992) and DeGraff and Rudis (1986). Our summary of New England wildlife species utilization of riparian forests was prompted by our review of the literature: with the limited research of riparian harvest effects on New England wildlife (less than 40 papers published in the primary literature during 1967-2000), predictions of wildlife response to riparian habitat manipulation must be made based on descriptions of wildlife use of riparian areas rather than from results of studies applying controlled, riparian forest manipulations. We supplemented our northeastern wildlife response research database described above with this wildlife use information to identify potential responses of forest riparian wildlife to manipulations of this habitat.

We summarized northeastern riparian forest habitat use with counts of obligate species (forested riparian habitat required) of mammals, birds, amphibians, and reptiles. Use was designated as utilized (used occasionally) or preferred (used most often), and riparian forests were separated by type (riverine, palustrine, lacustrine), wetland location (stream, river, beaver ponds, lake, seep, bog or fen, ephemeral pool), structure type (in red maple swamps: seedling, poletimber, sawtimber, large sawtimber), and in Maine by forest composition (deciduous forest, coniferous forest, scrub-shrub) and biophysical region (Krohn et al. 1999). Riverine, palustrine, and lacustrine habitats are used for winter foraging and shelter by at least 30% of bird and mammal species occurring in New England. Lacustrine riparian areas are preferred by 65% of mammal species; although birds show less specific wintering preferences, 60-70% do utilize lacustrine riparian areas during the winter. Most amphibians and reptiles occurring in New England are riparian forest obligates, preferring streams, rivers, and beaver-created wetlands over other wetland types (lake, seep, bog or fen, ephemeral pool) (Figure 28). Use of red maple swamps varies by taxa (23% amphibians, 41% birds, 50% reptiles, 71% mammals) and is generally even across timber size classes. For those species showing preferences for timber size classes in red maple swamp habitat, however, preference varies by taxonomic group, with amphibians (27%) preferring age classes beyond seedling stage, whereas birds (17%) prefer seedling and saw timber size classes, and mammals (16%) and reptiles (10%) show no size class preference.

Table 10. Number of retrieved citations addressing effects of riparian forest manipulations on wildlife in northeastern

Taxonomic group	Citations retrieved	Treatment studied
Amphibians	3	disturbance, general
Birds	15	width, forest type, general
Fish	4	general
Invertebrates	8	clear-cutting, disturbance
Mammals	4	general, width, disturbance
Reptiles	0	

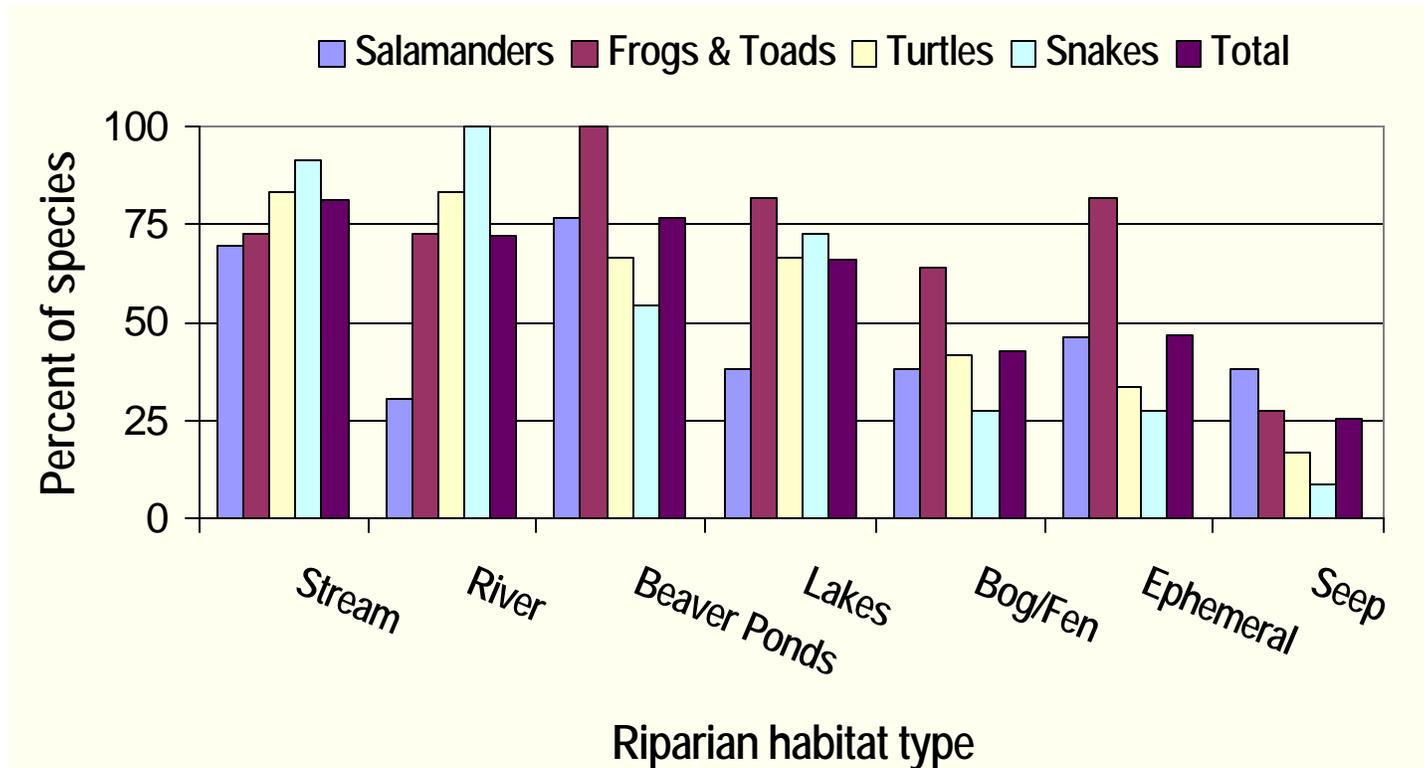


Figure 28. Percent of amphibians and reptiles using riparian habitats in New England. Data are based on preferred habitat use, from DeGraaf & Yamasaki (2000). Species counts are salamanders (13), frogs and toads (11), turtles (12), and snakes (11).

Conclusions

Research examining wildlife responses to forest management activities across temporal, spatial, and taxonomic gradients is needed in order to develop a comprehensive conservation strategy for riparian animals. Research on the effects of forest manipulation on riparian biota in northeastern North America has concentrated on the response of local communities of birds to selected buffer widths. Studies of other taxa have addressed differences in composition of biota among forest types, effects of clear-cutting, or disturbance in general. However, research addressing effects of specific riparian forest harvest techniques on these taxa is absent from the published literature.

Although watershed-scale studies of effects of specific forest manipulations on stream water quality have been conducted in northeastern North America, responses of the riparian biota to these manipulations have not been reported. The intended functions of a riparian buffer should be considered

when designating the buffer width. Criteria to consider in determining appropriate buffer dimensions include the functional value of the resource, intensity of the adjacent land use, characteristics of the site and watershed, and the specific desired functions of the buffer (Castelle et al. 1994). These functions might be water quality or water temperature protection, conservation of the woody debris flow, protection of areas inhabited by riparian vertebrates and invertebrates, or ideally a combination of these uses and values.

Spatial and temporal variation in climate, topography, elevation, vegetation cover types, species density, and species mobility (i.e., the taxonomic mobility gradient) should also be considered when establishing riparian management plans for animal biota. Stream density, land-use patterns, and watershed characteristics should be analyzed prior to designating buffer widths for stream habitats. Since streams are dynamic in nature, riparian buffers need to be tailored to the conditions of the site and surrounding landscape, and should be sized and located to protect the stream and riparian area from the potential cumulative effects of watershed disturbances on buffer functions. Future research should adopt a systems perspective: studies should recognize the spatial and temporal variability within and among watersheds, and responses to riparian forest manipulations across the taxonomic gradient should be documented.

For more information on this study, contact **Cyndy Loftin** at 207-581-2843 or email cyndy_loftin@umenfa.maine.edu.

References

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Assessing the Effectiveness of Different Buffer Widths for Maintaining Ecological Values of Headwater Streams in Managed Forests of Western Maine

Darlene Siegel, John M. Hagan
and Andrew A. Whitman

Manomet Center for Conservation Sciences

Objective

The objective of this project is to understand the effectiveness of different buffer widths for protecting various riparian values on small headwater streams in managed forests.

Experimental Design

We will study 15 perennial headwater streams in western Maine. Each of these streams will be randomly assigned to one of 5 treatments (Table 11). We replaced the original treatment of a 3 m buffer surrounded by clearcuts with a no-buffer treatment. We made this change in order to learn more about the implications of a worst-case scenario in riparian management.

Each harvest block will follow a 300-meter reach of the stream and will extend 200 meters perpen-

Table 11. Experimental design treatment assignments.

Treatment	Harvest	No. of Replicates
1	Clearcut with No Buffer	3
2	Clearcut with 10 m Partial Cut Buffer	3
3	Clearcut with 23m Partial Cut Buffer	3
4	200 m Partial Cut Unit	3
5	No Harvest (Control)	3

dicular to each side of the stream (Figure 29). The experiment follows a before-after-control design in which treatment and control sites will be sampled before and after the treatment is applied (Figure 29). Harvests will be carried out following standard BMP operations in the fall (September – November) of 2001, with the exception that sites designated as inoperable due to wet conditions will be harvested in the winter (December 2001 – January 2002).

Methods

We will measure an array of variables to determine the effects of the harvest treatments. Water quality variables will be collected in locations above, within, and below the treatment harvest (Figure 29 as represented by the stars). All other variables will be measured

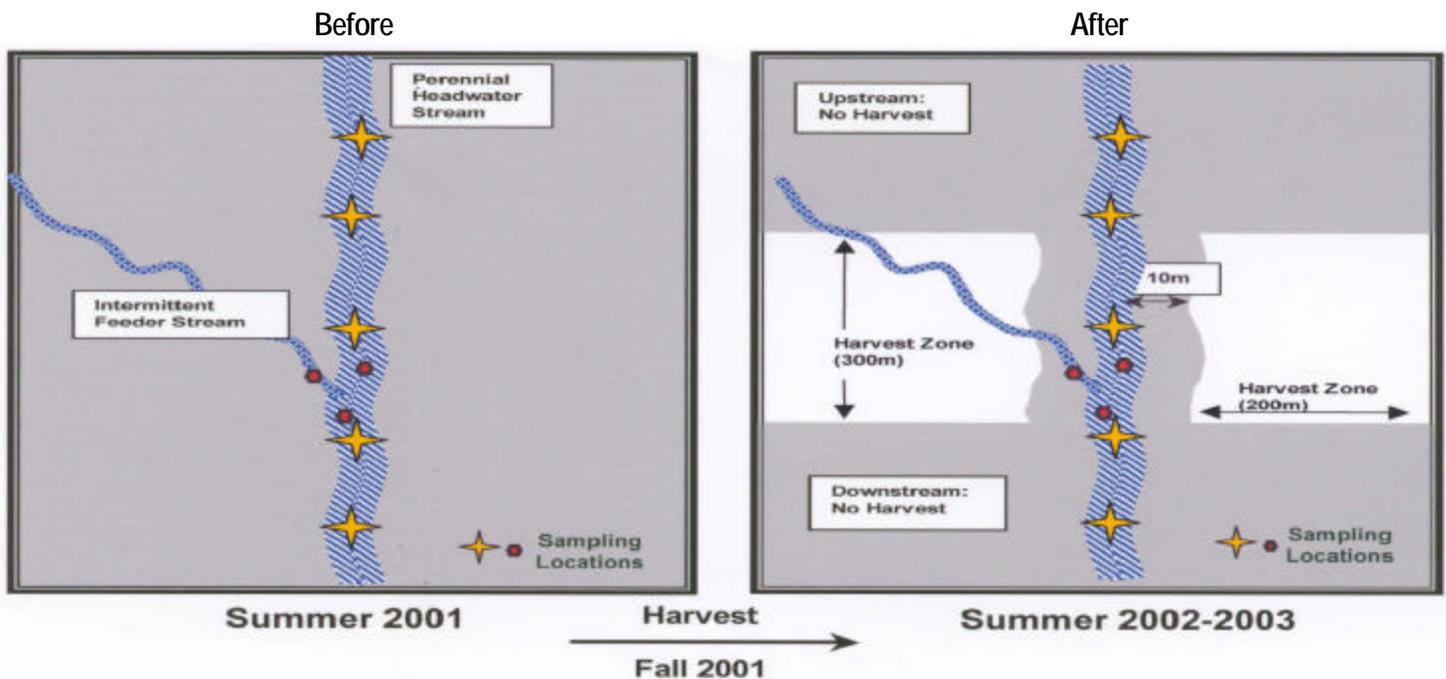


Figure 29. Before and after experimental design and sampling locations using an example treatment of a clearcut with a 10 m buffer strip.

over the length of stream surrounded by the treatment (Table 12)

Intermittent Feeder Streams

We also will determine what influence intermittent feeder streams located within the harvest block have on the main perennial channel. We will measure water quality parameters and macroinvertebrates within the feeder stream and compare data from sampling locations above and below where the feeder enters into the perennial channel (in Figure 26 represented by circles). Loggers will be instructed to treat these streams per standard BMP protocol.

This section of the study has been modified from the original study design. Initially we planned that each site would consist of a perennial stream that is fed by at least four intermittent streams. The two upstream feeders would have been treated with filter strips and the two downstream feeders would have been harvested without a filter strip. This would have created separate upstream and downstream experimental blocks. Together, the two blocks would have spanned a distance of 600 to 800 m. However, it was impossible to find enough replicates with four feeder streams and 600 m of intact forest. Our new design retains the ability to rigorously evaluate the effectiveness of buffer width, but we have sacrificed the experimental assessment of intermittent feeders. Still, the basic information we collect on intermittent feeders will help us understand whether further experimentation is warranted.

Site Selection

Our work from June through October has concentrated on the selection of 15 study streams. This has been a three-step process. First, we established relationships with ownerships interested in providing study sites in the western Maine study region. Second, we met with area foresters, reviewed their harvest plans for fall 2001 and stand maps to identify potential research sites. Third, we conducted field evaluations of potential sites and measured the following criteria to determine the suitability of the stream for the study:

- Watershed Area: Perennial/Non-Perennial
- Gradient: Elevation
- Aspect: Land Use History
- Slope: Stream Source
- Bankfull Width: High Water Mark
- Substrate Composition: Channel Morphology
- Canopy Cover: Forest Stand Type
- Soil Type

Table 13 includes the averages of some of these parameters measured at several potential sites.

We visited 85 potential streams in 30 townships covering 6 ownerships. Only 8 met our selection criteria. These 8 streams are located in 11 townships incorporating 6 ownerships (Figure 30). Eleven additional sites may become suitable if we relax our selection criteria slightly (Table 14). We plan to discuss this issue with our Advisory Committee this coming January.

Finding suitable sites was slowed by four challenges: (1) Relationships with landowners took time to develop. (2) Stream ecosystems are highly variable, so finding similar replicates took time and careful consideration. (3) The number of perennial headwater streams that drain intact forest is low. Determining whether the stream is perennial is challenging and requires a field visit to each stream. (4) The study criteria excludes short-term future harvesting near replicates. This may have caused some foresters to be reluctant to make sites available for the study.

Table 12. Riparian value and variables to be measured.	
Riparian Value	Variables
Water Quality	Dissolved Oxygen, pH, Conductivity, Turbidity
Aquatic Habitat	Water Temperature, Physical Habitat, Large Woody Debris
Aquatic Biodiversity	Macroinvertebrates, Amphibians, Fish*
Terrestrial Biodiversity *	Woody Plants, Herbaceous Plants
*Measurement contingent on funding.	

Table 13. Averages and ranges for a subset of the site selection criteria variables.		
Parameter	Average	Range
Wetted width (m)	1.9	0.9-3.8
Bankfull width (m)	4.9	2.9-7.2
Slope (%)	25	13-36
Gradient (%)	9	4-16
Watershed area (acres)	393	111-1020
Elevation (ft)	1831	1420-2130

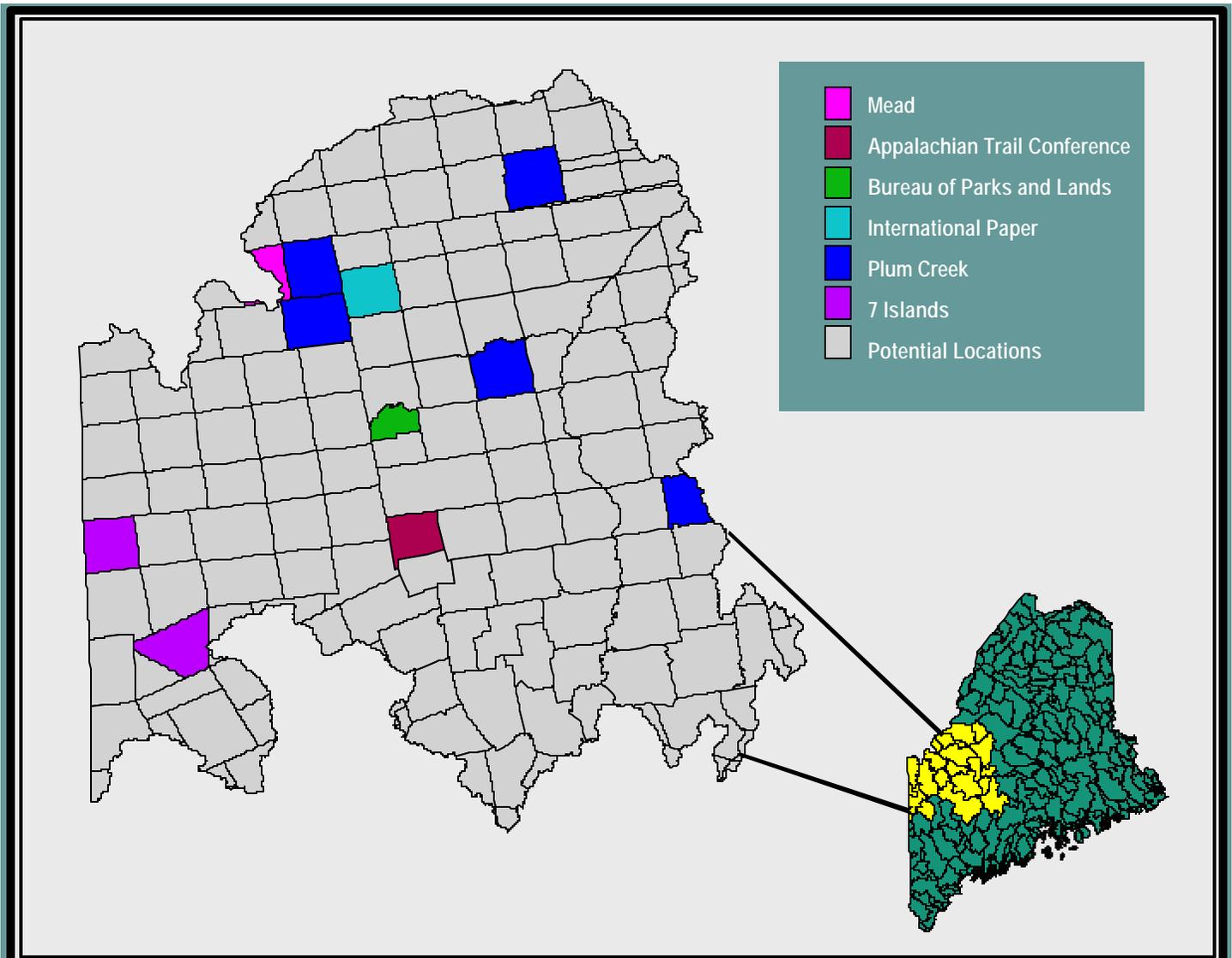


Figure 30. Locations of confirmed sites and the corresponding ownerships throughout western Maine.

Table 14. Number of confirmed and potential sites listed by ownership.

Ownership	Confirmed	Secondary
Plum Creek	7	3
Seven Islands	1	2
Mead	0	2
International Paper	0	1
Bureau of Parks and Lands	0	2
Appalachian Trail Conference	0	1
Total	8	11

Project Advisory Committee

We set up an advisory committee comprised of professional foresters and scientists. The members of the committee include: Si Balch (Mead Paper), Dave Courtemanch (Maine DEP), John Hagan (Manomet), Carl Haag (Plum Creek), Jim Hornbeck (US Forest Service), Steve Kahl (University of Maine), Jeff Light (Plum Creek), Morten Moesswilde (Maine Forest Service), Darlene Siegel (Manomet), and Ron Steiner (Plum Creek). The committee has met twice during the field season. The first meeting was used to introduce the project, solicit comments on the design and methods, and to discuss site selection. The second meeting was conducted in the field to discuss the appropriateness of selected streams. The committee members have provided valuable advice that has led to design modifications.

Upcoming Plans

We have four goals for this winter: (1) We will confirm treatment plans with each area forester so that the study will be integrated into harvest plans for the fall of 2001. (2) We will identify additional sites to be evaluated in the spring of 2001. We will use these sites if an original candidate stream can no longer be used and/or if funding allows us to increase treatment replication. (3) We will be developing the sampling protocols for each parameter to be measured. This will be accomplished by consulting primary literature and specialists. (4) We will continue to pursue additional collaborations with other scientists and agencies including those that follow.

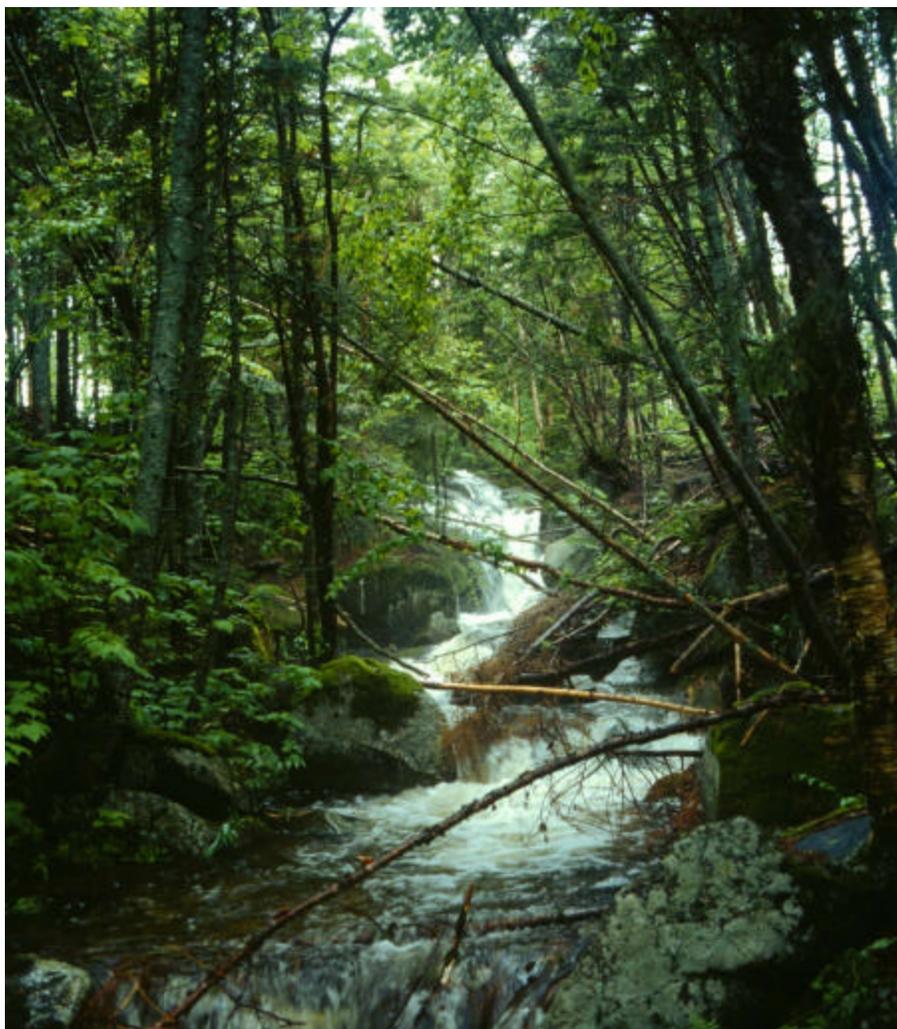
Project Timeline

- June-October 2000: Site Selection
- October 2000-April 2001: Protocol Development
- May-September 2001: Pre-Treatment Data Collection
- September-November 2001: Treatment Harvest
- October 2001-April 2002: Data Analysis and Report Writing
- May-September 2002: First Year Post-Treatment Data Collection
- October 2001-April 2003: Data Analysis and Report Writing
- May-September 2003: Second Year Post-Treatment Data Collection
- October 2003-May 2004: Data Analysis and Report Writing

Other Project News

- We have submitted a proposal to the National Fish and Wildlife Foundation to fund amphibian and terrestrial plant studies in collaboration with Dr. Malcolm Hunter (University of Maine).
- We have submitted a proposal through the Maine Forest Service to the USDA Forest Service to provide funding for 5 continuous water chemistry monitors. We are submitting a proposal with Steve Kahl at the Water Research Institute to place continuous monitors in all 15 streams.
- We are working with the Maine DEP Biomonitoring staff to develop a collaborative effort for macroinvertebrate sampling.
- The Maine Department of Inland Fish and Wildlife has agreed to aid in the collection of fish population data by electrofishing the experimental stream reaches.

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



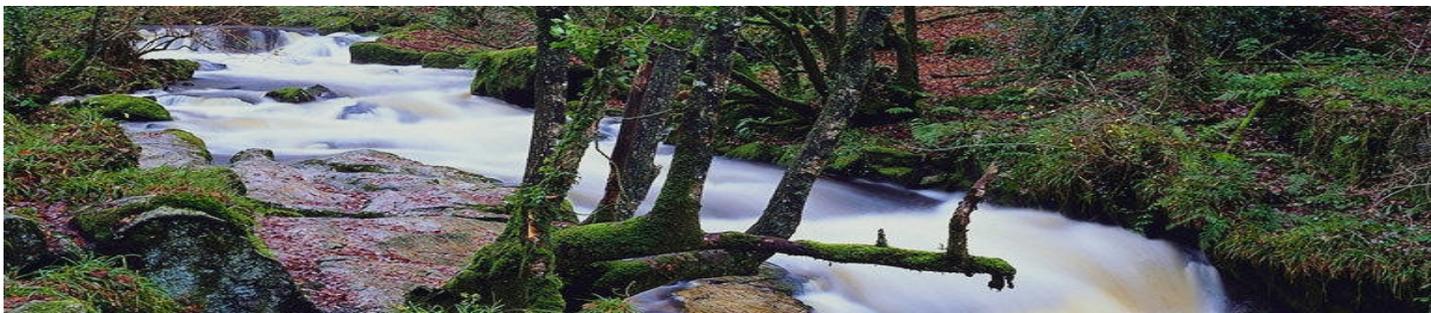
Technology Transfer

Journal Articles, Research Reports, and Technical Publications

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- Harrison, D.J.** 1999. Response of wildlife to thinning in forests of the northeastern U.S. pp. 35-40. *In Proc. Thinning in the Maine Forest Conference*, November 15-16, 1999, Augusta, ME.
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- Cobb, R.C.** 2000. Silvicultural impacts on soil functional processes in a 17-year-old whole tree harvest. Unpubl. M.S. thesis. University of Maine, Orono, 96 p.
- Fuller, A.K.** 1999. Influence of partial timber harvesting on American marten and their primary prey in northcentral Maine. M.S. Thesis, University of Maine, Orono, 141pp.



Presentations

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Fuller, A.K. and D.J. Harrison. Influence of partial harvesting on habitat selection by American marten in an industrially forest landscape. . Paper presented at 3rd International *Martes* Symposium, Corner Brook, Newfoundland, August 14.

Fuller, A.K., H.J. Lachowski, and D.J. Harrison. 2000. Stand-level responses of American marten and prey to forest management: do marten respond to distribution of prey? Paper presented at 3rd International *Martes* Symposium, Corner Brook, Newfoundland, August 15.

Fuller, A.K. 1999. Influence partial timber harvesting on American marten and their primary prey in northcentral Maine. M.S. Thesis Seminar, Department of Wildlife Ecology, University of Maine, Orono, December 2.

Harrison, D.J. 1999. Effects of thinning on wildlife habitat. In: Thinning in the Maine Forest Conference, November 15-16, Augusta, ME. pp. 35-40.

Harrison, D.J. 2000. Served as Program Chair and provided opening comments for 3rd International *Martes* Symposium, Corner Brook, Newfoundland, August 14.

Harrison, D., D. Payer, A. Fuller, J. Hepinstall, D. Katnik. 2000. Landscape thresholds and response to fragmentation by American marten. Paper presented at 3rd International *Martes* Symposium, Corner Brook, Newfoundland, August 14.

Harrison, D. 2000. Served as chairperson for session titled: Planning and Managing Landscapes for *Martes*, 3rd International *Martes* Symposium, Corner Brook, Newfoundland, August 14.

Harrison, D. 2000. Served as an invited panelist for discussion of : What is suitable habitat for North American *Martes*? 3rd International *Martes* Symposium, Corner Brook, Newfoundland, August 15.

Harrison, D. 2000. Chaired plenary session titled: Status of *Martes* and their habitats from a global perspective. 3rd International *Martes* Symposium, Corner Brook, Newfoundland, August 15.

Harrison, D.J. and D.C. Payer 2000. Presented a seminar of final results of 10 year study on effects of forest harvesting and tapping on American martens to Advisory Committee, Cooperative Forestry Research Unit, University of Maine, Orono, February 2.

Ostrofsky, W.D. 1999. Managing residual stand damage from thinning operations. In: Thinning in the Maine Forest Conference, November 15-16, Augusta, ME. pp. 55-60.

Payer, D.C., and D.J. Harrison. 2000. Influence of forest structure on habitat use by American marten. Paper presented at 10th Northern Furbearer Conference, Fairbanks, Alaska, April 17.

Payer, D.C., and D.J. Harrison. 2000. Effects of timber harvesting and trapping on demographic characteristics of marten. 10th Northern Furbearer Conference, Fairbanks, Alaska, April 18.

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Tian, S., and W.D. Ostrofsky. 2000. Effect of precommercial thinning on root and butt decay of red spruce and balsam fir - Preliminary results. Presentation to the Northeastern Forest Pest Council, March 1-2, Portsmouth, New Hampshire.

Tian, S., and W.D. Ostrofsky. 2000. Effects of precommercial thinning on root structure and on root and butt decay in spruce-fir stands. Poster presentation, Winter Meeting, New England Society of American Foresters, March 22-24, Lowell, Massachusetts.

Wagner, R.G. - Organizer and Moderator. Greenbacks and Green Goals: Economics and Environmental Forestry, Forest Ecosystem Information Exchange, May 4, 2000, Wells Commons, Orono, ME

Wagner, R.G. - Research Updates: CFRU Advisory Committee meeting (May 2000)

- Hiring
- Proposed new dues structure
- Revised 5-Year Objectives
- Approval of Prospectus
- Carter referendum white paper
- Wood supply project update
- Commercial thinning Phase I & II update
- Herbicide tolerance study: 1 year Arsenal effects
- Herbicide Tank Mix Toxicology Project Update

Wagner, R.G. - Conifer tolerance to herbicides. Pesticide Applicator Recertification Training, University of Maine Cooperative Extension, Pest Management Office, Brewer, ME. (April 2000)

Wagner, R.G. - Forest vegetation management: Principles and practice. Instructor for ½day session, Module II: Silviculture - Regeneration, Alberta Advanced Forest Management Institute, Hinton, Alberta (February 2000)

Wagner, R.G. - Research Updates: CFRU Advisory Committee meeting (February 2000)

- CFRU Prospectus
- Commercial thinning project
- Herbicide tank mix project update
- Past and future CFRU budgets
- U. Maine overhead on external project funding
- Hiring update
- Maine / New Brunswick meeting
- Thinning conference
- Wood supply analysis project
- Hardwood Site Guide

Wagner, R.G. 2000. The Cooperative Forestry Research Unit (CFRU). Poster presented at 80th Winter Meeting of the New England Society of American Foresters, March 22-24, 2000. Lowell, MA.

Wagner, R.G. - The role of vegetation management in increasing forest productivity. Forestry Seminar Series, University of Maine, Orono. (November 2000)

Wagner, R.G. - Program Chair and Organizer, Thinning in the Maine Forest Conference, Augusta, ME, November 15-16, 1999, Cooperative Forestry Research Unit, U. Maine.

Wagner, R.G. - Research Updates: CFRU Advisory Committee meeting (October 1999)

- CFRU re-structuring
- Research priority survey results
- Interactive effects of herbicide tank mixes on aquatic ecosystems
- Maine Commercial Thinning Research Network
- FY99-00 CFRU budget
- Organizer - Bartlett Experimental Forest Tour

Wagner, R.G. - Organizer and Moderator. Managing Forested Landscapes, Forest Ecosystem Information Exchange, October 29, 1999, Black Bear Inn, Old Town, ME

Wagner, R.G. - Vegetation management with herbicides, FES 408 Silviculture class lecture, U. Maine, Orono, ME (October 1999)

Appendices

List of Scientific Names

Common Name

Scientific Name

Plants

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

Animals

Goshawk	<i>Accipiter gentilis</i>
Great horned owl	<i>Bubo virginianus</i>
Red-backed vole	<i>Clethrionomys gapperi</i> Vigors
Snowshoe hare	<i>Lepus americanus</i> Erxleben
Canada lynx	<i>Lynx canadensis</i>
Bobcat	<i>Lynx rufus</i>
American marten	<i>Martes americana</i> Turton
Fisher	<i>Martes pennanti</i>
Barred owl	<i>Strix varia</i>
Fox	<i>Vulpes vulpes</i>

Insects

Spruce budworm	<i>Choristoneura fumiferana</i> Clemens
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