

# CFRU Information Report 39

1996 ANNUAL REPORT AND  
RESEARCH SUMMARY OF THE  
COOPERATIVE FORESTRY RESEARCH UNIT

COLLEGE OF NATURAL RESOURCES, FORESTRY AND AGRICULTURE  
MAINE AGRICULTURAL AND FOREST EXPERIMENT STATION  
UNIVERSITY OF MAINE  
ORONO, MAINE 04469

## CONTENTS

FIGURES .....	iii
TABLES.....	iv
ADVISORY COMMITTEE CHAIR'S REPORT.....	1
DEAN'S REPORT .....	2
BALANCE SHEET.....	3
CFRU LEADER'S REPORT .....	4
SILVICULTURE - Dr. Maxwell L. McCormack, Jr.....	5
SILVICULTURAL TECHNIQUES FOR THE IMPROVEMENT OF TIMBER QUALITY	
Dr. William D. Ostrofsky.....	11
SITE QUALITY - Dr. James G. McLaughlin .....	17
TREE IMPROVEMENT - B. Baltunis, K. Peer, and Dr. Michael S. Greenwood.....	26
TREE IMPROVEMENT - Dr. Katherine K. Carter .....	29
GROWTH AND YIELD - Dr. Robert S. Seymour.....	31
SLUDGE AND ASH - Dr. Robert K. Shepard .....	34
EFFECTS OF TIMBER HARVESTING AND TRAPPING ON AMERICAN MARTENS IN NORTHERN MAINE	
Dr. Daniel J. Harrison .....	37
1996 PUBLICATIONS RESULTING FROM RESEARCH SUPPORTED BY THE CFRU .....	42
ADDITIONAL TECHNOLOGY TRANSFER ACTIVITIES BY CFRU PERSONNEL .....	43
COOPERATIVE FORESTRY RESEARCH UNIT ADVISORY COMMITTEE.....	45
CFRU STAFF .....	45
CFRU COOPERATORS.....	46
OTHER ORGANIZATIONS PROVIDING SUPPORT FOR CFRU PROJECTS.....	46
APPENDIX A - TERMINOLOGY ...	.. 47

This CFRU Annual Report and Research Summary provides information from research studies recently completed or in progress. To provide our cooperators with the most recent information available, some of the data and data analyses are preliminary, and should not be quoted without author permission.

## FIGURES

### FIGURE

1.	Retained smooth-bark beech in the partially harvested hardwood stand in Lakeview Plantation .....	6
2.	Skid trail within the partial cutting of the hardwood study site in Lakeview Plantation.....	7
3.	Seven seasons after aerial strip thinning treatment of young conifer regeneration .....	7
4.	Seven seasons after aerial strip thinning treatment of young conifer regeneration .....	8
5.	Locations of the 20 CFI plots and their representative harvest treatments used for the study on stand dynamics of beech saplings in beech bark disease affected stands .....	12
6.	T. Patton characterizing soils in Lambert Lake Township, Maine .....	13
7.	The height-age relationship for yellow birch and American beech regenerating after a heavy partial cut, Dyer Township, Maine .....	14
8.	Regeneration at the Lambert Lake study site five years after a final shelter-wood harvest and 13 years after the initial shelterwood cut and herbicide treatment for beech management.....	15
9.	Appearance of the advance regeneration in the glyphosate-treated blocks of the Lambert Lake study .....	16
10.	Beech sprouts developing from the resistant trees harvested in the final cut of the shelterwood .....	16
11.	Twenty-year-old even-aged hardwood stand regenerated from clearcutting located in Talmadge Township, Washington County, Maine .....	20
12.	Densities and basal area of dominant overstory trees (>2 in. dbh) for stands located at Talmadge and Waite Townships, Washington County, Maine.....	20
13.	Variation in height among families of European x Japanese hybrid .....	26
14.	Number of families ranked in the top twenty for height, 1993-1995 .....	27
15.	Number of families ranked in the bottom twenty for height, 1993-1995.....	27
16.	Average DBH at age 13 for each seed source of the larch species and hybrids at Talmadge, Maine.....	30
17.	Natural development of a young stand regenerated with the shelterwood method, projected to a top height of 65 ft in the year 2036, at which time the unthinned stand is expected to have an average stem volume of 10.9 cubic ft, an average dbh of 8.5 in., and a density of 497 trees per acre .....	31
18.	Distribution of white pine and eastern hemlock trees sampled in 1996, by crown class, crown size, and height .....	32
19.	Comparison in stemwood volume growth per unit of sapwood basal area, in a pilot study of four separate eastern white pine stands of widely differing ages.....	32
20.	Relationship between overstory basal area and canopy gap fraction (the percentage of the sky not obstructed by overstory leaf area) for five eastern white pine shelterwood overstories .....	33
21.	Relationship between height growth of the five most rapidly growing understory saplings (balsam fir, white pine, and red spruce) to canopy gap fraction .....	33
22.	1995 dbh of planted black spruce treated with a mixture of papermill sludge and wood ash at four rates .....	34
23.	1994 dbh of planted black spruce treated with a mixture of papermill sludge and wood ash at four rates ...	34
24.	Yearly diameter growth of planted red pine treated with a mixture of primary and secondary papermill sludge at two rates in early October 1989.....	35



25.	1995 dbh of planted red pine treated with a mixture of primary and secondary papermill sludge in late September, 1989.....	35
26.	1994 dbh of planted red pine treated with a mixture of primary and secondary papermill sludge in late September, 1989 .....	35
27.	Specific gravity at approximately breast height of dominant red spruce at four ages of wood formation.....	36
28.	Modulus of rupture at approximately breast height of dominant red spruce at four ages of wood formation.....	36
29.	Modulus of elasticity at approximately breast height of dominant red spruce at four ages of wood formation.....	36
30.	Number of resident marten captured on the Baxter State Park study area, 1991-95.....	38
31.	Seasonal home range sizes (median) of radiocollared martens on the Baxter State Park study area, 1991-95 .....	38
32.	Median volumes of four coarse woody debris classes in areas of high, low, and no observed use by resident martens on the industrial forest site, T5 RII WELS, Maine .....	39
33.	Median basal area of softwood and hardwood trees in areas of high, low, and no observed use by resident martens on the industrial forest site, T5 RII WELS, Maine .....	39
34.	Median tree height and canopy closure in areas of high, low, and no observed use by resident martens on the industrial forest site, T5 RII WELS, Maine .....	39
35.	Percentage occurrence, by season, of food items in 219 marten scats collected during 1991 through 1995 in T4 RII WELS, T5 RII WELS, T5 RIO WELS, northern Maine .....	40

## TABLES

### TABLE

1.	Volume index values for potential crop trees, fir or spruce, in residual strips between wide herbicide bands compared to potential crop trees in an adjacent untreated area.....	8
2.	Comparisons of differences in volume calculations using three methods of expressing diameters of tree components for ten selected sample trees from the Austin Pond Study Site.....	9
3.	Ecological phases inventoried for Talmadge and Waite Townships, Washington County, Maine.....	21
4.	Correlation matrix for density of selected tree species and environmental variables for Talmadge and Waite Townships, Washington County, Maine .....	22
5.	Correlation matrix for basal area of selected tree species and environmental variables for Talmadge and Waite Townships, Washington County, Maine .....	22
6.	Interpretations developed for classification of ecological phases .....	23
7.	Distribution of forest cover types across site types for Talmadge and Waite Townships, Washington County, Maine .....	24
8.	Average survival, total height age 4 (HT), and 1995 height increment (HI) for hybrid groups.....	26
9.	Analysis of variance (Height = B1 + Fam + B1 x Fam).....	26
10.	Species, hybrids, and seed sources included in the Talmadge larch trial.....	29
11.	Mean height (age 6) and DBH (age 13) for the six larch species and hybrids planted at Talmadge, Maine .....	30

12. Summary of overstory and understory stand components in the study of variable overstory pine densities .....	33
---	----

## ADVISORY COMMITTEE CHAIR'S REPORT

The past year has been challenging and has seen several changes that affect the CFRU and the College of Natural Resources, Forestry and Agriculture.

### Executive Committee

The Executive Committee changed officers in 1996. Si Balch (Chair), Everett Deschenes (Financial Officer), and Tom Morrison (Member-at-Large) completed their service on the Executive Committee. They are to be commended for their time and effort and for the fine service they rendered in our behalf.

New members of the Executive Committee are Peter Triandafillou (Vice Chair), and Brian Higgs (Member-At Large). Si Balch assumes the duties of the Financial Officer.

### New Personnel

On March 1, Dr. James W. McLaughlin joined the CFRU as an Assistant Research Professor. He assumed the research responsibilities of the Soils/Site Quality Program. Dr. McLaughlin will continue with the site classification work that was in progress under Dr. Briggs.

On June 1, Stephanie Arnold joined the CFRU as an Assistant Scientist in the Soils/Site Quality Program. She assumes the responsibilities previously held by Ron Lemin.

We are pleased that this important program is now back to full effort, and we look forward to working with Dr. McLaughlin and Ms. Arnold.

### CFRU Budget

At the April meeting, the Advisory Committee voted to increase the CFRU Reserve Account from \$400,000 to \$500,000. The change was made due to the increased size of the budget in recent years and a cash flow problem that needed to be addressed. The cash flow problem resulted from a change in accounting procedures at the University of Maine.

### College of Natural Resources, Forestry and Agriculture

In September, Dean Wiersma informed the Advisory Committee of plans to reorganize and expand in size the College of Natural Resources, Forestry and Agriculture. The change is required due to budget constraints and reorganization of seven colleges into five colleges at the University of Maine.

The Executive Committee met with Dean Wiersma concerning this matter, to discuss the effect this change will have upon the forestry curriculum within the college and the effect upon the CFRU. Additional concerns were discussed about the importance of the forest resource to the economic well-being of the state and the need for the forestry program at Orono to maintain a strong presence at the university level.

### Quantitative Silviculture Position

Dr. McCormack has indicated his intention to retire in 1997. In September, the Advisory Committee supported a recommendation from the Executive Committee to seek a candidate qualified as a quantitative silviculturalist to work with Dr. McCormack during the time he will remain on partial status with the CFRU. A preliminary job description for the new position is in the process of being drafted for formal administrative approval; however, it will be several months before a candidate is selected.

Compliments are due the CFRU scientists and staff, and the faculty of the college whose research projects are supported by the CFRU, for the work accomplished in 1996. I look forward to 1997 with anticipation of what will be accomplished in the coming year.

Anthony Filauro, Chair CFRU  
Advisory Committee

## DEAN'S REPORT

The College of Natural Resources, Forestry and Agriculture continues to adjust to a changing University. By July 1, 1997, the seven colleges of UM will be restructured into five. The effect of this change, resulting primarily from the continued difficult financial situation, will be that our college will be substantially larger. Several departments currently within other colleges will be incorporated into our college and may be additionally modified. The new college will be named the College of Natural Sciences, Forestry, and Agriculture, thus the forestry disciplines will maintain the appropriate visibility. Our cooperators should be aware that changes in college structure will not directly affect the operation or management of the Cooperative Forestry Research Unit.

An unusual political year was encountered, and a great deal of activity focused on providing the public with credible and accurate information regarding the health and productivity of Maine's forest resources. The CFRU played an important role in developing the research used in several of a series of white papers on forest management issues. In particular, the Weymouth Point Watersheds study data was critical in providing a baseline of information on which to discuss the important policy issues at hand. In addition, the recently published documents on the effectiveness of forestry Best Management Practices on water quality provide another example of how our research is and can be used in making the best management and policy decisions.

I have recently learned that Dr. Maxwell McCormack will be exercising his option for full retirement from CFRU within the next several months. Much of what the CFRU has accomplished over the past 20 years has been strongly guided by Max's competence, enthusiasm, and plain hard work. CFRU cooperators should be especially proud to have had his expertise at their command for this period of time. I will miss his direct involvement with the CFRU, but feel certain that he will maintain his strong forestry presence in Maine as he continues with his new opportunities. I wish him the best of luck.

The CFRU continues to be financially sound, through the efforts of the cooperators and the careful fiscal judgment of the scientists, and staff. It also has maintained a high level of productivity, as you will see by reading through the scientists' project descriptions contained in this annual report. We are ready for another outstanding year in 1997.

G. Bruce Wiersma, Dean  
College of Natural Resources, Forestry  
and Agriculture



CFRU cooperators examining a hybrid poplar plantation study during the September 1996 CFRU Advisory Committee field tour, Talmadge, Maine. The study was established by John Trobaugh, Georgia-Pacific Corporation, with assistance from ML. McCormack, Jr. and R. Dionne, CFRU.

MAINE AGRICULTURAL AND FOREST EXPERIMENT STATION MISCELLANEOUS REPORT 401

**BALANCE SHEET**

1995-1996 Period  
10/1/95-9/30/96

ASSETS:

BALANCE FORWARDED SEPTEMBER 30, 1996	630,808.64	
FUNDS RETURNED TO CONTROL AFTER adjustments on 09/30/96	60,672.95	
INVESTMENTS 10/01/95-09/30/96	38,617.27	
CONTRIBUTIONS 10/01/95-09/30/96	369,954.00	
TOTAL ASSETS:		\$1,100,052.86

**EXPENSES:** 10/01/95-9/30/96

ADMINISTRATION - OSTROFSKY	61,288.16	
SILVICULTURE - McCORMACK SITE	127,976.79	
QUALITY - McLAUGHLIN	83,297.62	
HARDWOOD/ASH - OSTROFSKY TREE	96,249.00	
IMPROVEMENT - CARTER	26,195.54	
GROWTH/YIELD - SEYMOUR PINE	19,031.98	
MARTEN - HARRISON SLUDGE &	21,211.85	
ASH - SHEPARD TREE	9,337.64	
IMPROVEMENT - GREENWOOD	8,707.99	
TOTAL EXPENSES:		\$ 453,296.57
ENCUMBRANCES: Vehicle		11,275.00
BALANCE WITH ENCUMBRANCES 09/30/95		635,481.29
LESS DEDICATED FUNDS:		500,000.00
BALANCE ENDING 09/30/96		135,481.29

## CFRU LEADER'S REPORT

The year started with very active participation by all faculty and staff in the CFRU as we assisted with hosting the Society of American Foresters National Convention, held in Portland, Maine, October 28 - November 1, 1995. Maxwell McCormack served as General Chair, Russ Briggs and myself served as poster session co-chairs, and Ron Lemin, Rick Dionne, and Peter Caron each provided assistance with numerous organizational tasks. The meeting was very successful and well received by the membership attending.

In January of 1996, Assistant Scientist Ron Lemin resigned from his position with CFRU to continue his career in the private sector. Ron is an exceptionally talented, productive, and personable individual. Although his presence in CFRU is greatly missed, we wish him the very best in his new endeavors.

With the resignation of Russ Briggs in 1995 and Ron Lemin in 1996, two positions in the Site Quality Program needed to be replaced. The CFRU was successful in filling both positions by national searches. On March 1, 1996, James McLaughlin was hired as Assistant Research Professor to lead the Site Quality Program, and on June 3, 1996, Ms. Stephanie Arnold was hired as Assistant Scientist in the program. We welcome both individuals and are very pleased to see this important program at full effort once again, with little time lost in the transition period.

During May, Maxwell McCormack conducted a very successful two-day conference and field tour on hardwood management. This effort was done in his capacity as Henry Saunders Professor of Hardwood Silviculture. This was another one of a series of hardwood workshops McCormack has organized that have been especially beneficial to CFRU cooperators.

On September 24, 1996, the CFRU Advisory Committee met in Calais, Maine, and cooperators

attended a field tour the following day. The tour was hosted by Georgia-Pacific personnel and featured intensive plantation management of hardwoods (Georgia-Pacific), site quality classification (McLaughlin), and timber stand improvement studies in beech-dominated stands (Ostrofsky). More than 50 cooperator personnel attended the tour.

Several changes to the CFRU Advisory Committee membership have occurred over the past year. Kevin Topolniski is the new representative for Fraser Paper, replacing Everett Deschenes, and Bob Barr will be representing Georgia-Pacific Corporation, replacing John Trobaugh. Both Everett and John have moved to new positions within their respective companies. Their service on the CFRU Advisory Committee is gratefully acknowledged, and we wish them the best of luck with their new positions.

The CFRU Executive Committee was busy with several cooperator visits during the year. Efforts have focussed on attempting to more fairly assess members, to maximize participation before consideration of a dues increase, and to prepare cooperators for an expected dues increase at some time in the next few years.

This has been a highly charged and politically active year for everyone in the forest resources arena. The forestry referendum on the ballot this fall will have a significant influence on Maine's forest resources, and on the management of that resource, regardless of the outcome. The projects described in this report summarize some of the activities occurring over the past year that will help to assist managers in making the best possible resource decisions. Although more changes are anticipated in the political environment, the university environment, and the CFRU for the coming year, the scientists and staff look forward to meeting the challenges ahead.

William D. Ostrofsky, Leader  
Cooperative Forestry Research Unit

## SILVICULTURE

Dr. Maxwell L. McCormack, Jr.

### Overview

This is my last contribution to a CFRU Annual Report. By mid-1997 I will have exercised my opportunity for full retirement from the university. Since joining CFRU as one of the first "three scientists" more than 20 years ago, it has been a challenging, satisfying professional experience. During the early years of CFRU, it was often stated that I had the best silviculture position in the country. I am sincerely thankful for the research opportunity and the experiences in working with the operational personnel among all the cooperators. I will continue pursuit of my interests in a new environment.

A few parting comments:

The need for realistic, long-term, applied research in forest production is greater than ever.

Full-time research personnel, coordinating resources among a number of landowners, housed in an academic institution, can be an effective and efficient means to carry out useful forestry research.

Overstocking from natural regeneration of spruces and fir in the forests of our region continues to be a dominant management challenge.

There is a need for better understanding and appreciation of forest understory vegetation dynamics and competition effects.

Harvesting systems are the "front line" of silviculture and should receive increased attention. Within this concept, landowners need to develop a deeper understanding of the classic silvicultural systems.

Site quality must be firmly established as the prerequisite base for executing silvicultural activities.

Production of high-quality hardwoods on appropriate sites should receive more attention and development.

Nothing is new. To a great extent, this is a reiteration of selected points in my first problem analysis prepared for the CFRU cooperators in 1976. The long-term research projects that I have established during my tenure with CFRU are briefly mentioned in the following paragraphs.

Activities over the past year were tempered by my reduced time from partial retirement and a disabling injury suffered in late January. General contributions from the silviculture program were sustained through CFRU Research Associate Rick Dionne's

consistent assistance provided to the research program of Dr. Robert Shepard. Also, assistance was provided in the spring of 1996 to John Trobaugh of Georgia-Pacific for establishing prepared sites and planting hybrid poplars. Initially, this was intended as a preliminary step in initiating a new project on high-yield forestry. My status and John's transfer to the western operations of Georgia-Pacific leave the future of this project in question.

As in past years, maintenance of the CFRU building on the University Forest and the trailer at Telos Camp have been carried out. A portion of the doctoral dissertation by Richard A. Lautenschlager, competition between forest brush and planted white spruce in north-central Maine, was published in the Northern Journal of Applied Forestry. Summary comments, with some information updates, on the projects of the silviculture program follow.

### Hardwood Silviculture

Activities in hardwood silviculture were continued within my responsibilities as the Henry W. Saunders Professor of Hardwood Silviculture. There is great need for continued and expanded efforts in developing effective silvicultural techniques to foster production of high-value hardwood species in Maine forests. A two-day workshop, attended by 130 persons, was held in late May. The first day was an indoor program of seminars covering hardwood planting stock, propagation of paper birch, ecology and management of hardwoods, and precommercial thinning in hardwood stands. Contributions to the program were provided by Bruce Fraser, Old Ridge Nursery; Michael Greenwood, University of Maine; William Leak, NEFES, USDA-Forest Service; Brian Higgs, Baskahegan Company; Jock Lees, Lakeshore Silviculture Systems; Tim McGrath, Nova Scotia Department of Natural Resources; and Lynn Wilson, S. D. Warren.

Also on the first day, John Herrington, American Chestnut Foundation, provided an update on the program for reintroduction of American chestnut, and Prof. Dr. Georg Kenk of the Baden-Württemberg Forest Research Institute presented an illustrated summary of silvicultural activities for production of hardwood species in western Europe. The second day was a field trip, with discussions, visiting young stands of a woodlot owned by Billy and Charlie Cleaves of Sangerville. The field tour was organized through assistance provided by John McNulty, Seven Islands Land Co., and Rod Kennedy of International Paper Co.

As announced at the workshop by Charles Gadzik, Director of the Maine Forest Service, organizational work is underway to form a Maine American Chestnut Task Force. This group will work toward

MAINE AGRICULTURAL AND FOREST EXPERIMENT STATION MISCELLANEOUS REPORT 401

applying the technical advances being achieved by the American Chestnut Foundation for restoring American chestnut as a component of the forest resources of Maine. The initial focus will be on the study of regeneration techniques so that as disease resistant material becomes available, seedlings can be successfully established. I will serve as Chairman with assistance from Gen. Clayton O. Totman (USMC, Ret.) of Waldoboro as Honorary Chairman.

The operational harvesting study, the establishment of which was reported in the 1995 CFRU Annual Report, was developed further. This study is located in a hardwood stand in Lakeview Plantation on land managed by Wagner Forest Management for the Hancock Timber Resource Group. A high proportion of the stand was poor-quality beech. It was harvested during the past winter. Because the diseased beech were removed in the harvest, the residual stand is relatively light. As part of the

study, the skid trails were located to provide an access network as well as to divide the harvested stand into blocks that would serve as plots for treatment. An effort was made to retain the smooth-barked beech, but it appears that because the harvest was relatively heavy, the residual beech stems have suffered from sunscald during the 1996 growing season. Figures 1 and 2 illustrate post-harvesting conditions in the study area.

Treatments are underway in the harvested stand. In an effort to improve species composition within the regeneration component, sugar maple seedlings have been hand planted on selected plots. Some additional maple seedlings from a different source will be planted in 1997. A variety of treatments to reduce beech sprouting and sapling development are being installed via backpack sprayer application of herbicides to stumps and understory brush. These treatments will be expanded during 1997.



Figure 1. Retained smooth-bark beech in the partially harvested hardwood stand in Lakeview Plantation. Opening of the stand has resulted in sunscald of these desirable beech trees.



Figure 2. Skid trail within the partial cutting of the hardwood study site in Lakeview Plantation. Poor quality beech have been removed. This area is typical of the plots where sugar maple seedlings have been introduced among the natural regeneration.

### Precommercial Thinning of Spruce-Fir

The aerial strip thinning studies, initiated in 1982, were continued. In follow-up to the data collections reported in the 1995 CFRU Annual Report, during 1996 some selected trees were measured to provide supplemental data. In cooperation with Ronald C. Lemin, Jr., Timberland Enterprises, Inc., a one-day field workshop was held in July. Sites were visited to illustrate conditions following treatments

applied over the past ten years and the plot locations where recent data have been collected.

Observations of the past treatments continue to reveal a lasting effect on stand structure of the developing spruce-fir regeneration. The last series of operational treatments applied in 1989 verify the desirability of wide (8-to 12-ft) chemical bands with narrow (2-to 4-ft) bands of crop tree residuals. Figures 3 and 4 illustrate typical conditions of two band



Figure 3. Seven seasons after aerial strip thinning treatment of young conifer regeneration. This band represents the acceptable narrow extreme of treatment, a band approximately 8-ft wide. The range pole markings are 1-ft increments.



Figure 4. Seven seasons after aerial strip thinning treatment of young conifer regeneration. This strip represents a wide band treatment, approximately 10 to 11 ft wide. The range pole markings are 1-ft increments.

widths seven growing seasons after treatment. The bands remain well defined with definite crop tree development within the residual strips. Visits to field sites also have found well-defined bands within hardwood patches, which illustrate potentials for treating young regenerating stands of hardwoods or mixed species.

Evaluation of crop tree growth responses is difficult because of a lack of appropriate unsprayed controls. However, some comparisons have been made using patches of regeneration in adjacent boundary areas of the 1989 banded sites. The volume index data prepared by Ron Lemin for the workshop are summarized in Table 1.

The data collected indicate that the crop trees in the strip-thinned areas are growing at a rate, based on volume index calculations, that is twice that of the untreated crop trees. In the strip-thinned-treated areas, balsam fir crop trees are growing at a rate 1.5 times that of the spruce crop trees. These data and past experiences with the strip thinning technique are being summarized for a paper to be presented at the 51st Annual Meeting of the Northeastern Weed Science Society.

Table 1. Volume index<sup>a</sup> values for potential crop trees, fir or spruce, in residual strips<sup>1</sup> between wide herbicide bands compared to potential crop trees in an adjacent untreated area. The 1988 values represent volumes in the year prior to treatment. The 1994 values represent volumes five growing seasons after strip thinning treatments.

Species & Treatment	Number of Trees Sampled	Volume Index 1988	Standard Error 1988	Volume Index 1994	Standard Error 1994
Balsam Fir - Untreated	10	3.23	0.85	42.50	8.56
Balsam Fir - Treated	48	2.26	0.42	72.70	5.27
Spruce - Untreated	10	0.76	0.31	19.41	4.08
Spruce - Treated	56	0.55	0.11	33.25	3.13

<sup>a</sup> Volume index = (Diameter at 0.5 ft above the ground)<sup>2</sup> X total height.

<sup>b</sup> Approximate spruce-fir density was 24,000 per acre in the untreated area and 4,000 per acre in the strip-thinned areas.

**Austin Pond Study Site**

The data collection described in the 1995 CFRU Annual Report was analyzed further. It was determined that some additional sample trees were needed for stem analyses in order to fill in some weak components of the data. These additional trees have been collected and the complete set of data will be organized for a planned report.

While evaluating sample tree volume procedures, a concern about stem radius measurements was addressed. When evaluating increment cores, radii, and growth rates from measurements on stem cross-sections, there is a question of procedure in selecting the location of the core or radius for measurement. In developing the volumes for sample trees at Austin Pond, an appraisal of radii selections

was conducted by Ron Lemin, former assistant scientist. Disks were removed from each sample tree at 0.5, 2, 4.5, 7, 10, and every 3 ft up the tree. Inside bark volumes were calculated for the 15-year study period using the formula for a frustrum of a cone to calculate bolt volumes which were summed to obtain total volumes.

The volume determined using the average of four radii was considered to be the "best" estimate of tree volume. Differences were compared using calculations based on a single average radius and an average of two radii for the volume components of each tree. Percentage difference comparisons are shown in Table 2.

Table 2. Comparisons of differences in volume calculations using three methods of expressing diameters of tree components for ten selected sample trees from the Austin Pond Study Site. The basis for each comparison is the volume determined using averages of four radii for each tree component.

Tree No.	Avg % Difference Volume Based on One Radius <sup>a</sup>	Avg % Difference Volume Based on Two Radii <sup>b</sup>	Absolute % Difference Based on One Radius <sup>c</sup>	Absolute % Difference Based on Two Radii <sup>d</sup>
Balsam Fir (6 trees)				
1	0.32	-1.02	2.64	1.02
2	-9.09	1.91	9.09	1.91
3	6.02	-0.60	9.44	0.69
4	1.97	-0.32	1.96	0.40
5	1.83	0.90	2.54	1.28
6	-25.30	-0.34	25.03	1.11
Mean	-4.04	0.09	8.50	1.07
S.E.	4.72	0.45	3.63	0.21
Red Spruce (4 trees)				
1	-5.07	-0.44	5.07	0.77
2	5.56	-0.63	6.44	1.16
3	24.30	-0.08	24.30	1.24
4	-3.88	-0.01	5.51	0.58
Mean	5.21	-0.29	10.32	0.93
S.E.	6.78	0.15	4.66	0.16
Total (10 trees)				
Mean	-0.34	-0.06	9.23	1.02
S.E.	3.98	0.27	2.72	0.14

<sup>a</sup> Avg % volume difference (actual difference in volume using one radius divided by the volume calculated using the average of four radii) for the sum of 15 years of volume.

<sup>b</sup> Avg % volume difference (actual difference in volume using two radii divided by the volume calculated using the average of four radii) for the sum of 15 years of volume.

<sup>c</sup> Absolute values of the avg % volume difference comparing volume based on one radius compared to volume based on the average of four radii for the sum of 15 individual years of volumes.

<sup>d</sup> Absolute values of the avg % volume difference comparing volume based on two radii compared to volume based on the average of four radii for the sum of 15 individual years of volumes.

These comparisons illustrate the importance of basic measurements for determining sample tree volume in young stands. Absolute percent differences were calculated because the positive and negative differences appeared to average out in the means. When comparing all ten trees together, there appears to be a significant difference in absolute percent when comparing volumes calculated using one radius and two radii. The confidence intervals are

absolute percent difference between volumes calculated with four radii averaged compared to volumes based on one average radius is

9.23 +/- 5.44 or 3.79% to 14.67%

absolute percent difference between volumes calculated with four radii averaged compared to volumes based on two radii averaged is

1.015 +/- 0.136 or 0.746% to 1.287%

This illustrates the value of using two radii averaged and thus, has determined the procedure used for processing the Austin Pond Study Site sample tree data.

Unfortunately, errant harvesting equipment traffic has moved across a portion of the study site. Intensified efforts will be carried out to ensure that further disruption of the study will be avoided. It is intended that the study area be maintained to provide valuable long-term data in the future.

#### **Long-term Spruce-Fir Thinning**

One of the original studies of the CFRU silviculture program was a crop tree-oriented, long-term study of merchantable and sapling-sized spruce-fir. Only two of the five original study sites remain. The most recent collection of data from the two sites will be summarized, but it is unlikely that the original study will be maintained. Recommendations regarding the study will be forthcoming with the possibility of a plan for maintaining the most valuable site of the remaining two.

#### **Weymouth Point Experimental Watersheds**

The Weymouth Point Experimental Watersheds remains a site of very high value. The study site has been maintained and negotiations are under way to

renew the agreement with the landowner, Great Northern Paper Co. During the summer, combined with a meeting with Great Northern, a joint visit to the study site was made to initiate a transition of responsibility in order to secure continuity of the study which originated in 1979. Jim Hornbeck, one of the original cooperating researchers from the USDA-Forest Service in Durham, NH, and I joined with Jim McLaughlin during this visit to facilitate Jim's assuming responsibility for coordination of the study.

#### **Surfactant Combinations with Glyphosate**

This study, with treatments applied on 31 August 1995, was reported in the 1995 CFRU Annual Report. There were 15 treatments established on the site in Great Pond Township on land of Champion International. Results of the treatments observed through the 1996 field season have been disappointing. In all cases, the levels of efficacy on undesirable vegetation have been less than would have been expected. It is likely that this is a reflection of the extreme drought conditions on the site at the time of treatment.

Given that the poor efficacy is consistent across all the treatments, observations of relative comparisons among the treatments might provide some meaningful information. Such observations, at this time clearly show that the standard treatment (i.e., 2 qts Accord® + 20 fl oz Entry II® per acre) was the most effective treatment causing suppression of undesirable vegetation. It is important to point out two frustrating principles in evaluating herbicide efficacy:

1. Actual efficacy of treatment is not apparent until three years or more after application of the treatment, and
2. It is a measurable improvement in growth and development of treated crop trees, as related to a valid comparison of untreated crop trees, regardless of the visual impression of suppressed target vegetation, which determines the true silvicultural efficacy of a given treatment.

Observations will be continued on these plots, but it is doubtful that the intended definitions of surfactant effects will be possible. Relative comparisons of effects within the general reduced levels of efficacy will be attempted.

## SILVICULTURAL TECHNIQUES FOR THE IMPROVEMENT OF TIMBER QUALITY

Dr. William D. Ostrofsky

### Introduction

Program emphasis over the past year has included a reexamination of the forest management problems associated with beech and the beech bark disease. Remeasurement was done of a study established 14 years ago, designed to test options for improving species composition in beech-dominated hardwood stands. However, the majority of time was spent on conducting a new study of the comparison of height development of American beech in stands managed by different levels of harvest intensity. This work is being led by T. Patton and will form the basis of her M.S. thesis. Our field work was conducted primarily in Washington County on Georgia-Pacific Corporation lands. Assistance with field work was again provided by P. Caron, CFRU Research Associate, and summer student Y. Ren.

Two workshops on forest health were organized and conducted: one in October of 1995 and one in September of 1996. Dr. K.T. Smith of the USDA Forest Service, Durham, New Hampshire, and H. Trial of the Maine Forest Service conducted a portion of both workshops. A high level of interest in this subject was indicated by the participants, and both workshops were well attended. The workshops were offered through the Office of Professional Development, College of Natural Resources, Forestry and Agriculture.

A book chapter was written and published which reviews general concepts of tree injuries resulting from harvesting practices. The draft of a manuscript entitled "Response and activity of a forest soil microbial population to application of papermill sludge ash" has been prepared and is in review prior to journal submission. The publication is coauthored by former graduate student Y. Ren and is based on a portion of her M.S. thesis work.

### Harvest Intensity and Development of American Beech

The improvement of stand quality is an important underlying goal of hardwood management in Maine because of the substantial value differential between low-quality and high-quality material. One effective way to improve timber stand quality is to favor species that are less prone to defect development and or less susceptible to chronic insect or disease pests.

Beech susceptible to the beech bark disease is one particular problem that affects many hardwood and mixedwood stands throughout much of Maine and the greater northeastern region. Aggressive development of beech, primarily from root sprouts but also

from seedlings, commonly occurs after harvesting. Dense beech thickets can become established and will often preclude development of other more desirable hardwood species. The situation is further *aggravated* because the majority of the developing beech are susceptible to the beech bark disease and will accumulate serious stem defects over time. Some mortality will occur from the disease, usually in older and larger trees, but young trees can survive and occupy valuable stand space for decades.

Harvesting prescriptions are needed that will result in the reduction of disease-susceptible beech in managed stands. Some general harvesting recommendations have been offered, based on observations made over many years (Ostrofsky and Houston 1989). However, many questions regarding successful beech establishment and development need to be quantified further if management improvements are to follow.

One issue that has not been extensively studied, particularly as it relates to disease-affected stands, is the dynamics of the development of beech saplings. Past studies have quantified beech regeneration only in terms of absolute numbers of seedlings and sprouts following harvest treatments. No studies have yet examined the competitive ability of beech regeneration during the stratification stage of stand development in comparison with associated species. This stage is crucial because it largely determines the composition and structure of the mature stand. An understanding of the interactions of sapling beech with cutting intensity, other desirable competitive species, and site quality will allow managers to "fine tune" prescriptions and will optimize species composition changes in the stands in question.

To this end, a study was initiated in the fall of 1995 by M.S. graduate student T. Patten entitled "Effects of overstory density and beech bark disease severity on height stratification patterns of American beech and associated species." The study objectives are (1) to evaluate differences in height growth patterns of sapling stage beech regeneration and of cohort yellow and paper birch growing under different residual overstory densities, and (2) to develop and evaluate an index for beech bark disease defect on beech saplings.

The study is being conducted with the cooperation of the Georgia-Pacific Corporation, which has generously allowed use of their CFI data and inventory plots. This information has been used to locate and test predesignated stand conditions on beech growth and development. Use of the CFI data has been invaluable in establishing past harvesting history and resulting changes in species composition.

Twenty CFI locations were selected based on harvesting history (Figure 5). Five plots were located in each of four harvest treatment groups representing four overstory density levels: uncut (control), light partial cut (> 60 ft<sup>2</sup>/A residual basal area), heavy partial cut (21 - 59 ft<sup>2</sup>/A residual basal area), and clearcut. In addition to the original CFI plot at each location, two satellite plots were also located in close proximity to more precisely estimate stand parameters.

Measurements taken included (1) overstory characteristics of species, height, diameter at breast height,

height to live crown, and beech bark disease defect, (2) understory characteristics of species, height, diameter at breast height, crown class, and beech bark disease defect, (3) site factors of slope, aspect, elevation, and climate zone, and (4) characterization of the soil and drainage (Figure 6). Assistance with soil characterization was provided by J. McLaughlin and S. Arnold. From each of the three plots at each location, three sapling trees were selected for stem analysis: one non-defective beech, one defective beech, and one associated competitor (yellow birch in the uncut and partially cut treatments and paper birch in the clearcut treatment).

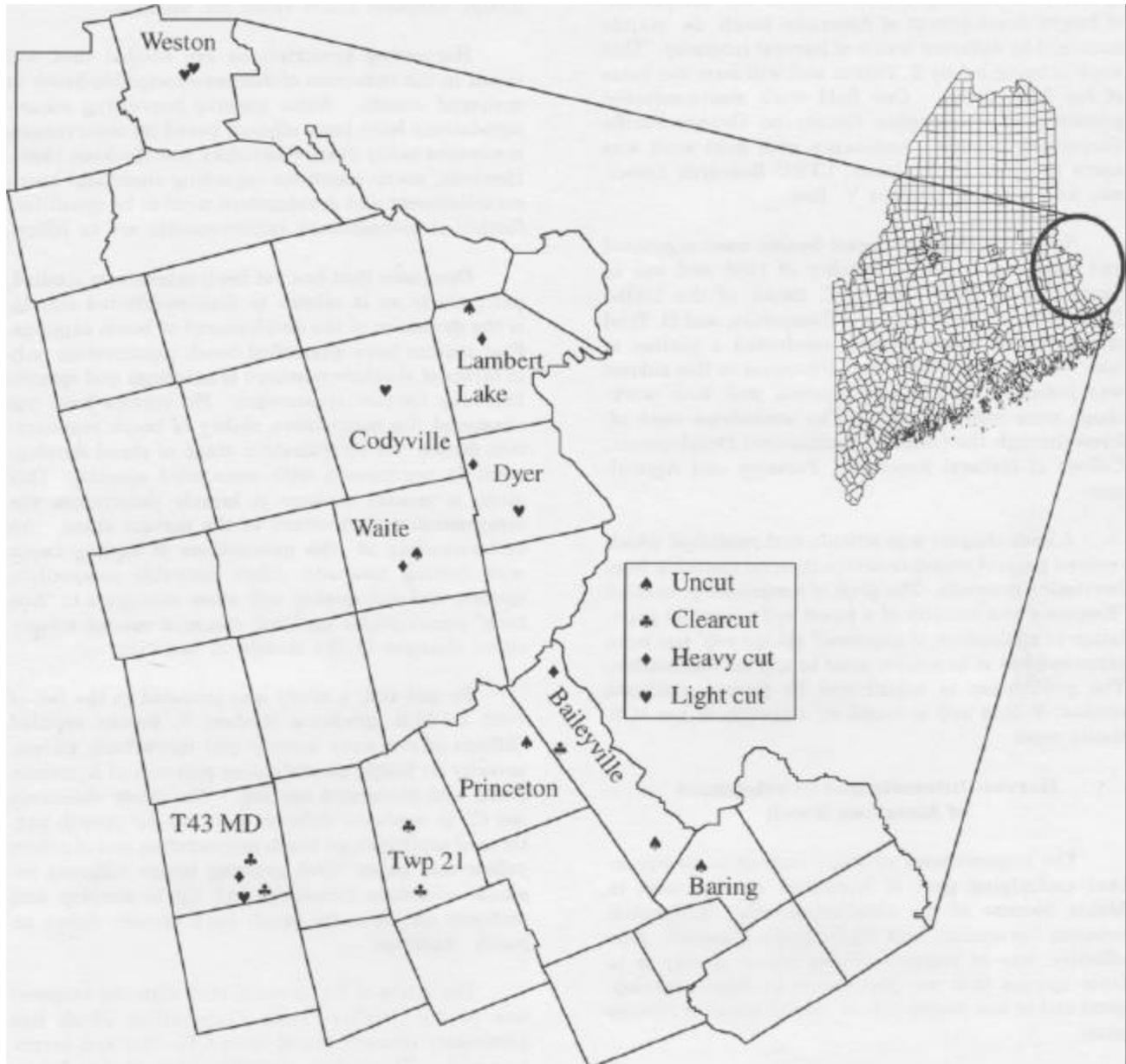


Figure 5. Locations of the 20 CFI plots and their representative harvest treatments used for the study on stand dynamics of beech saplings in beech bark disease affected stands.

Figure 6. T. Patton characterizing soils in Lambert Lake



Township, Maine.

The field work for this project is largely completed. Some limited stem analysis data has been collected and summarized, but the majority of this work is to be completed over the next several months. Preliminary stem development data from a single CFI location (Dyer Township) is presented as Figure 7. At this specific location, relatively light cankering by the beech bark disease has had an apparent negative impact on height growth.

Of the three oldest beech saplings, the one affected by disease has increased in height growth

more slowly than the two nondiseased stems for the past eight or nine years. Similarly, the diseased stem of the two younger stems has apparently undergone a reduction in rate of height growth for the past four or five years.

Yellow birch at this location was shown to outperform beech in height development (Figure 7). In one case, a yellow birch eight years younger than a nondiseased beech surpassed the beech in height growth after about 12 years. Another yellow birch the same age as a lightly cankered beech equaled the beech in height after ten years, in spite of the fact that the beech had an early and substantial lead in height growth.

Although accurate generalizations cannot be made from this single case, it clearly demonstrates important stand dynamics that will assist the manager in improving stand productivity. An analysis and summary of the complete data set, along with other observations on soil/site effects will be conducted during the coming months.

#### **Remeasurement of Regeneration at the Lambert Lake Study**

This study was initiated in 1983 to test a modified shelterwood system for rehabilitation of hardwood stands with a high component of beech damaged by the beech bark disease. The study site is located on lands owned by the Georgia-Pacific Corporation. Many individuals from Georgia-Pacific have assisted with this study during its several phases, and their cooperation is greatly appreciated.

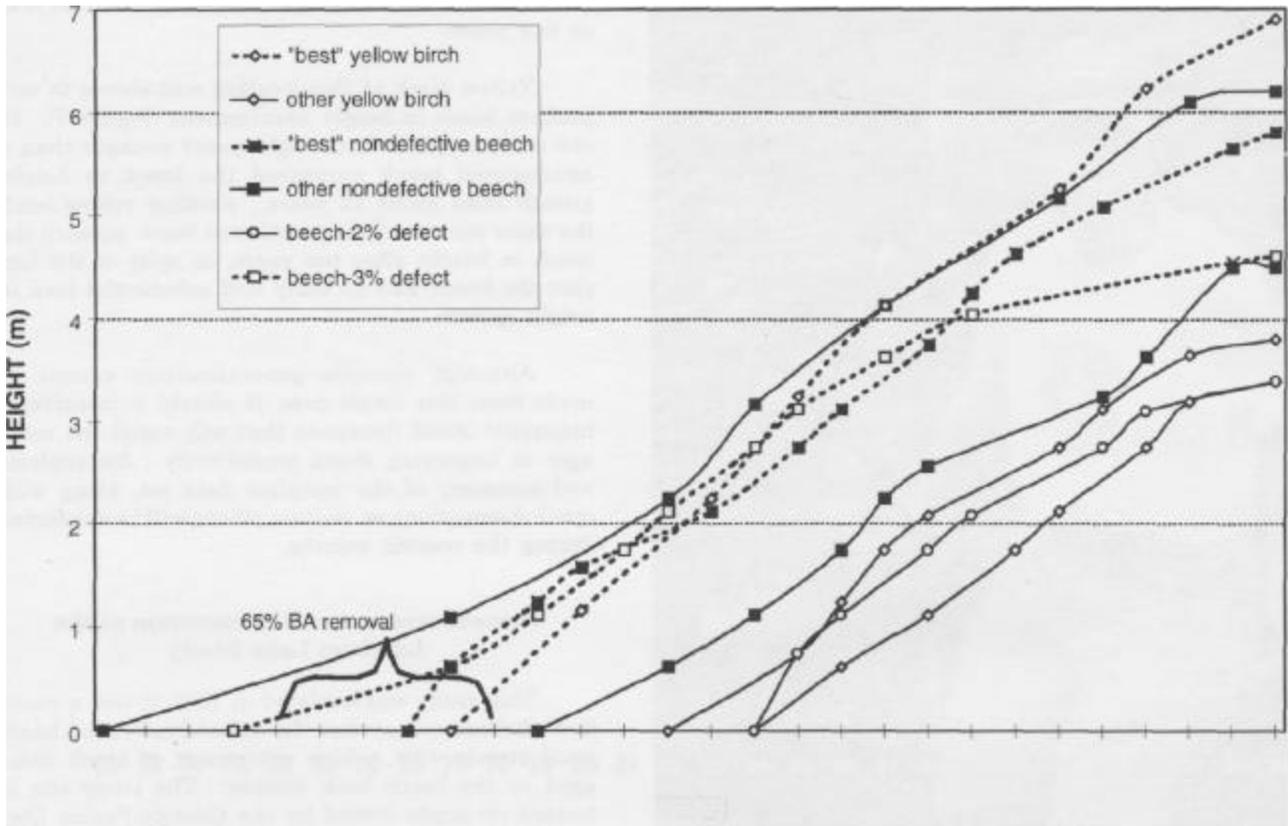
The initial stand had a basal area of approximately 85 ft<sup>2</sup>/A, with about half the basal area as defective beech. The understory consisted of a patchy distribution of dense beech thickets, especially where some earlier harvesting has occurred. Only 3% of the overstory basal area was in conifer species. A silvicultural prescription was developed that included treating the understory advance regeneration (mostly beech) with a back pack mist blower application of one of two herbicides (triclopyr or glyphosate). This was followed by treatment of the larger defective beech stems with a frill application of the same chemical, as the plots required.

Beech resistant to the beech scale and all other hardwood species were left as the residual overstory. The residual beech were found to be resistant by challenging the stems via a bark test using the beech scale insect. The defective beech were harvested in October of 1983. Details of the early regeneration response and herbicide efficacy have been published (Ostrofsky and McCormack 1986).

In late January and early February 1991, the final shelterwood harvest was conducted. All remaining merchantable trees were harvested, including

YEAR

Figure 7. The height-age relationship for yellow birch and American beech regenerating after a heavy partial cut, Dyer Township,



Maine.

beech known to be resistant to the beech scale. Stumps and regenerating sprouts of the resistant beech were located and measured for several years following the harvest by Dr. David Houston, USDA Forest Service. These resistant beech have also been an important source of plant material for several other studies conducted by the USDA Forest Service.

Regeneration on the site was again assessed in 1996, and a dramatic change in species composition has resulted from the herbicide treatments and from other natural factors of stand development (Figure 8). High numbers of yellow and paper birch and of red maple now form the principal hardwood component in the herbicide-treated blocks. In addition, advance conifer regeneration makes up a significant portion of the developing stand (Figure 9). This latter development will result in what is sure to become a highly productive mixedwood stand. Disease-susceptible beech regeneration still dominates the control (no herbicide) blocks.

The majority of beech in the herbicide-treated blocks are expected to be resistant to infestation by the beech scale. These sprouts developed primarily

from the resistant trees harvested in the final cut of the shelterwood (Figure 10). Exact estimates of the percentage of resistant beech in the herbicide-treated blocks will be difficult to obtain until a 100% tally is made, and associated stumps from resistant trees can be relocated.

To date, the shelterwood method used in conjunction with herbicides has greatly improved the developing stand. Part of the success at this site is also due to the unexpected but welcome development of the softwood component. The treatments have led to an increase in productivity by greatly reducing the defective beech component, increased the numbers of resistant beech stems in the new stand, and improved tree species composition and diversity on a local scale.

Future monitoring of this resistant stock is highly desirable. This study site has some of the oldest known resistant beech to have developed from a management treatment specifically designed for that purpose. In addition to monitoring the development of resistant beech, there is a good opportunity for studying beech scale and beech bark disease interactions as the treatment and control blocks develop into

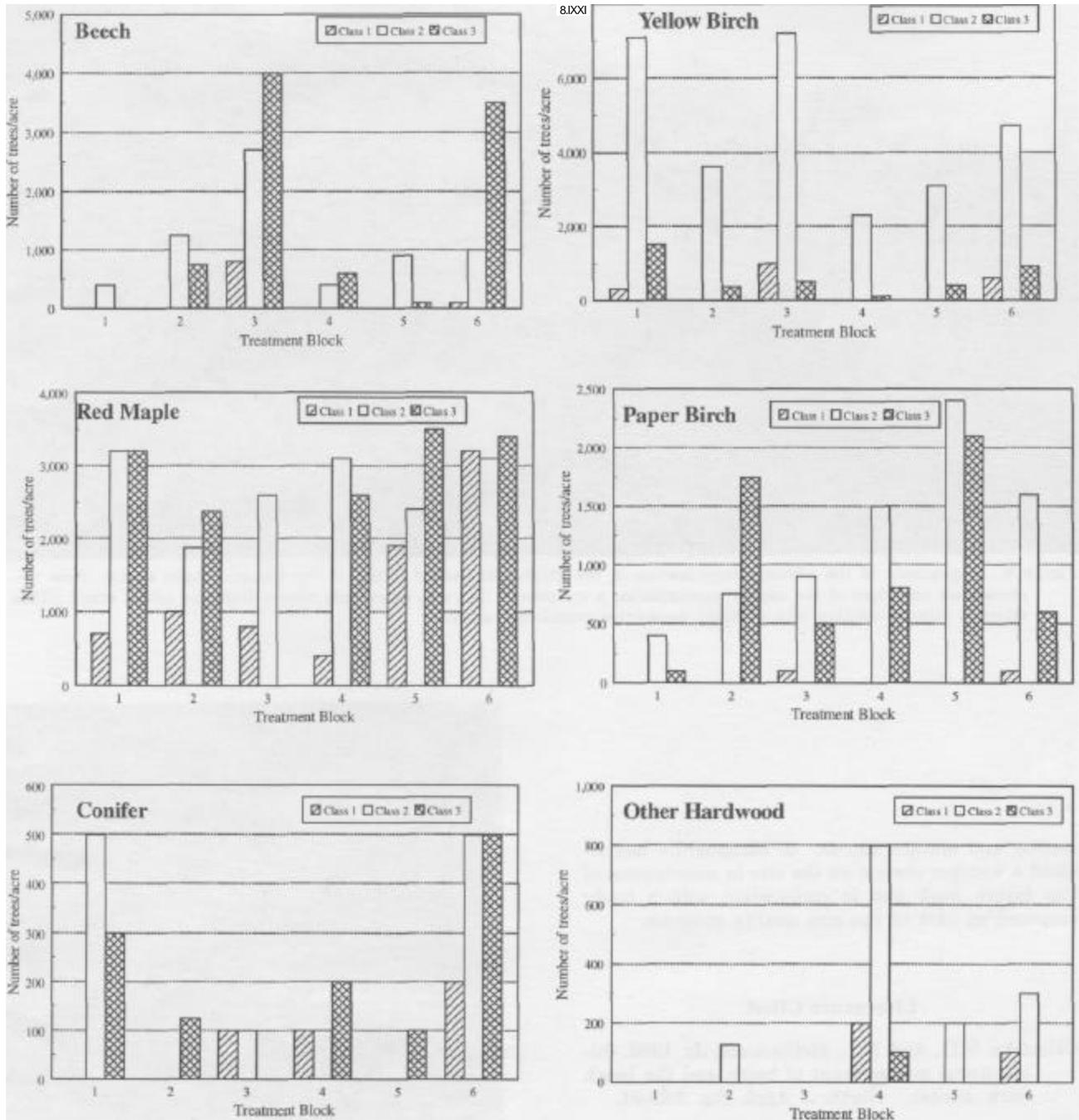


Figure 8. Regeneration at the Lambert Lake study site five years after a final shelterwood harvest and 13 years after the initial shelterwood cut and herbicide treatment for beech management. Note that the large majority of beech present in the herbicide-treated blocks are expected to be resistant to infestation by the beech scale, while most beech in the control blocks are susceptible to the scale and to the beech bark disease. Blocks 1 and 2 = triclopyr treatment; blocks 4 and 5 = glyphosate treatment; blocks 3 and 6 = control (no herbicide) treatment. Size class 1 includes regeneration up to 10 cm in height; size class 2 includes regeneration between 10 cm and 1 m in height; size class 3 includes regeneration above 1 m in height.





Figure 9. Appearance of the advance regeneration in the glyphosate-treated blocks of the Lambert Lake study. Note the abundance and vigor of the conifer regeneration, a component that was essentially absent from the initial stand. This stand is sure to develop into a highly productive mixedwood stand.

sapling and mature stands. J. McLaughlin has located a weather station on the site in anticipation of this future work and in conjunction with a study proposed as part of the site quality program.

#### Literature Cited

- Ostrofsky, W.D., and M.L. McCormack, Jr. 1986. Silvicultural management of beech and the beech bark disease. *North. J. Appl. For.* 3:89-91.
- Ostrofsky, W.D., and D.R. Houston. 1989. Harvesting alternatives for stands damaged by the beech bark disease, p. 173-177 in *Proceedings, 1988 Society of American Foresters National Convention*, SAF Publ. 88-01.



Figure 10. Beech sprouts developing from the resistant trees harvested in the final cut of the shelterwood. Maintenance of a healthy beech component in the new stand was an important objective of the silvicultural prescription.

## SITE QUALITY

Dr. James W. McLaughlin

### Overview

I began my employment with the Cooperative Forestry Research Unit on March 1, 1996. I am pleased and honored to have the opportunity to be a member of such an outstanding and well-respected organization as the CFRU, and I'm looking forward to meeting the challenging issues that the forest industry in Maine is facing today and in the future. We also hired Stephanie Arnold as an Assistant Scientist in June 1996 to work on the Soil-Site Quality Program as well as aid other CFRU scientists and cooperating scientists in the data analyses for their respective programs.

Mark Leathers, former graduate student on the hardwood site classification project successfully defended his M.S. thesis entitled "Site Index Curves and Growth Efficiency of Sugar Maple (*Acer saccharum*, Marsh.) by Habitat Type in Western Maine." Mark's work was initially started under the guidance of Dr. Russell Briggs, formerly of CFRU, and completed under the guidance of Dr. Robert Seymour. Mark presented some of his findings in the 1995 CFRU Annual Report.

The main focus of the past six months for the Soil-Site Quality Program has been the hardwood classification project. We spent the majority of the 1996 field season establishing and sampling plots in Washington County. We also made contacts with scientists in the United States and New Brunswick who have been doing similar work, and we are looking forward to lengthy collaborative efforts. A study on evaluating climatic and site factor effects on beech-bark disease has also been initiated in collaboration with Dr. William Ostrofsky of CFRU. We are also working up a research initiative for the Weymouth Point Watersheds study in collaboration with Dr. Maxwell McCormack of CFRU and Dr. Kate Frego of the Department of Biology at UNB, Saint John. Dr. Frego's interests lie in the area of forest management and plant biodiversity, and she is heavily involved in work at the Fundy Model Forest. We plan to look at various aspects of soil chemical and microbial responses to forest-harvesting practices as part of the collaboration. We will be attending various meetings during November 1996, December 1996, and January 1997 in New Brunswick concerning where our Soil-Site Quality Program will fit with the objectives of the Fundy Model Forest. The remainder of the 1996 Annual Report will focus on the site classification project.

### Introduction to the Site Classification Project

Forest managers are continually confronted with a multitude of questions regarding the use of forest lands and greater restrictions on management practices. Therefore, as foresters we need to identify research initiatives and develop operational methods

that will not only suit our management objectives of improving tree growth, but also minimize the impacts of timber harvesting on environmental degradation. In present day terms, this has been coined as forest sustainability. To achieve forest sustainability in physically diverse environments (variable climate, topography, geology, and soils) requires that this physical diversity be recognized, along with biological and ecological diversity that is produced. This is achieved by ecological site classification. Site classification systems should be designed with a holistic forest ecosystem health approach in mind. A key element to manage for healthy forest ecosystems is the integration of fundamental ecological knowledge into forest management decision making. This will allow the development of strategies that are silviculturally and environmentally sound.

The emphasis of forest management is becoming more integrated at the ecosystem level, rather than just the stand level. Consequently, attention focuses on trends over time throughout the entire landscape from a multitude of combined natural perturbations (spruce budworm, beech bark disease, hurricanes, etc.) and timber harvesting which involves smaller land units and land types. These smaller land units and land types reflect characteristic combinations of climate, landform, and vegetative communities. However, few examples exist in New England of long-term ecosystem-level changes where both small-scale disturbances and environmental factors have been described (Leak and Smith 1996).

Long-term ecosystem information is of great importance to better predict what forest types are associated with certain environmental variables. For instance, Leak (1987) reported on species compositional changes over a 50-year period at the Bartlett Forest in New Hampshire and found that fine till soils (loams) are proceeding to beech-sugar maple, with some indications that perpetuation of sugar maple depends upon canopy disturbance on granitic soils. Sandy tills are moving towards beech, with some representation of tolerant softwoods. Shallow basal till (well and poorly drained), shallow to bedrock, or ice-contacted gravel are moving toward eastern hemlock and/or red spruce, with hemlock generally dominant at low elevations and red spruce dominant at high elevations. Leak and Smith (1996) reported on 60 years of forest management and natural disturbances in a New Hampshire forested landscape at the Bartlett Experimental Forest. This study included a number of management practices, including selection cutting, thinnings, group selection cutting, shelterwood cutting, and commercial clearcutting. Their major finding was that forests at the Bartlett Experimental Forest were fairly resistant to management influences on species composition and that natural succession was the dominant factor affecting long-term changes in the forested landscape.

Applying the knowledge of long-term ecosystem changes and potential causal environmental agents to forest management can provide greater returns on financial investments in forest management decisions because we will have a thorough understanding of which tree species will do best given certain soil-site characteristics. We can also use the information to design management plans that can achieve forest sustainability.

The Soil-Site Quality Program within the Cooperative Forestry Research Unit is incorporating the physical, biological, and ecological dynamics of forested ecosystems to address the question: how can we better manage and, ultimately sustain our forest resources? The Soil-Site Quality Program will provide critical information on ways to devise management plans that will determine the optimum balance between economic investments of capital and maintenance of environmental integrity based upon soil-site characteristics.

### Objectives

The primary objective of our classification system is to develop a practical forest ecosystem classification which, when integrated into a field guide, will furnish a framework for foresters and other land managers working in a specific region in the state of Maine.

In our approach, successional information will be used to structure the presentation of forest cover types within site types. Information about successional dynamics may be useful to forest managers in choosing the best cutting methods (e.g., clearcutting to promote intolerant stage forests, open-shelterwood cutting to produce intermediary-stage secondary forests, or dense-shelterwood or selection cutting to promote tolerant-stage forests) given certain soil-site characteristics.

We are using data from research sites established by the Soil-Site Quality Program and/or CFI plots located on landholdings of Baskahegan, Champion, and Georgia-Pacific. The CFI plot data will serve to define potential interactions of harvesting types and natural succession. The data will also be used in conjunction with plots we have established as reference points to put a comprehensive package together that is easily interpreted and defines the roles of soil-site characteristics, harvesting, successional trends, and their interactions on specific management questions, such as

1. How do forest management practices interact with natural succession?
2. What is the optimum approach to determine good quality sites? Can we use specific ecological groups of ground vegetation (seedlings, herbs, and shrubs) to indicate site quality? This information, along with basic soil data can result

in more efficient use of time and resources when evaluating potential site quality.

3. When should dollars be invested in managing our desirable species by precommercial thinning, commercial thinning, or stand conversion?
4. What is the most economically feasible way to manage for desirable species? For instance, based upon site classification data, is it economically feasible to remove undesirable species from a site and maintain desired species, such as sugar maple, white ash, yellow birch, paper birch, and possibly aspen? If it is economically feasible to remove undesirable species, what is the best management system to be invoked on a given site? Can the desired management systems for desirable hardwood species be used to discriminate against undesirables without using herbicides?
5. What is the optimum residual basal area and diameter distribution to maintain adequate regeneration to ensure that multiple-age forest structure and desirable species composition are maintained?
6. What types of sites will promote the optimum economic and environmental balance to support a clearcutting management scheme?
7. What types of sites will promote the optimum economic and environmental balance to prescribe a multiple-species management scheme?
8. What types of sites should be put into old growth?
9. When is the optimum season to harvest a stand?

In addition to silvicultural attributes, we will provide crucial information concerning potential environmental impacts of particular management strategies on given sites. Information provided here will include

1. What are the potentials on a given site for soil productivity degradation? What types of management strategies can be used to minimize potential soil productivity degradation?
2. How does harvesting impact the microbiology of forest soils? What are the consequences of potentially altering the composition and activity of the microbiota in terms of soil nutrient cycling?
3. What are the potentials on a given site for water quality degradation, both nutrient and sediment loading into draining waters? What management strategies can be used to minimize water quality degradation?

4. What is the optimum buffer zone required to minimize nutrient and sediment runoff into draining waters?

Our classification system for hardwoods in Maine, therefore, goes beyond providing basic soil-site quality data for optimizing forest productivity potential. The present and future research initiatives we will be developing will be state-of-the-art that address both silviculturally and environmentally important questions faced by forest landowners and managers in Maine.

### **Terminology Used in the Site Classification Program**

Any developed site classification system requires the use of certain terms that may be unfamiliar to many foresters. After an extensive review of the literature, we have chosen to follow the classification system used for the Amos Lowlands Region of Quebec (Cartier et al. 1996; Harvey et al. 1996). This system appears to be the most appropriate by allowing for fairly easy interpretations of forest productivity, successional trends, and management plans that can be understood without extensive deviations from "field reality." The terms used are

1. Ecological Region — - The highest level of classification, defined as an area of land with a distinctive climate expressed by vegetation.
2. Successional Series — An encompassing of the chronosequences, and their respective vegetation types, that lead to a common steady-state forest.
3. Ecological Phase — The finest level of classification, defined as a land unit which is relatively homogenous in terms of its soil as characterized by surficial deposit and soil moisture regime and present vegetation.
4. Site Type — The physical substrate of a forest station, characterized by surface deposit, soil moisture regime, and other soil and site parameters. The site type presumes specific successional series and known or assumed productivity range, as well as management constraints and capabilities.
5. Forest Station — A relatively homogenous land unit in terms of site conditions and forest composition for which a similar outcome and productivity (within an acceptable range) may be expected from a given silvicultural regime. Also understood in this definition is the similarity of operational constraints and potential for various silvicultural interventions. The forest station is, thus, a larger, more general unit than the ecological type, but with both an ecological and silvicultural or operational sense.

Grouping fine-scale ecological or vegetation units into larger, more general units is central to forest ecosystem classification (Barnes 1986; Rastetter et al. 1992; Lee and McDonald 1993). For our classification system, we will first partition the data into three sets by broad cover type: hardwood, mixedwood, and softwood with their respective ecological phases. From each set of ecological phases, a similarity index will be created and hierarchical cluster analysis performed. Cluster analysis will be used to produce broader units which will be used to identify significant site types and possible forest stations.

### **Classification of Ecological Phases and Successional Series**

Data from two sites, Talmadge and Waite Townships, Washington County, Maine, which we sampled during the 1996 field season are used as an example of how our classification system will work for ecological phases and forest cover types. We have not completed the forest station classification at this time. We emphasize that the results at this time are preliminary and modifications of the various ecological phases and forest cover types will likely occur as the database increases. The majority of the stands at the two sites are even-aged hardwood which have regenerated from clearcutting approximately 20 years ago. Also included are mixed hardwood/softwood and softwood stands that were sampled. An example of the hardwood regenerated stands is shown in Figure 11.

Ecological phases are determined as the vegetation currently present at a given sampling location and an example of the ecological phases along with selected soil characteristics are shown for Talmadge and Waite Townships, Maine, in Table 3. Surficial deposit at all sampling locations in the two townships was glacial till. There were 30 ecological phases delineated for the two townships. The preliminary projected climax forests (successional series) were determined from the current overstory and the seedling and sapling stages for each sampled stand. For these young stands, it is projected that about 50% of the successional series are northern hardwoods, 30% hardwood/softwood, and 20% softwood/hardwood mixed stands.

At this time the database is not yet large enough to make accurate projections and relationships between soil-site variables and successional series. However, preliminary data show certain relationships are already being picked up from the limited database (Tables 4 and 5). These include (a) negative relationships between yellow birch and beech densities and basal areas, red maple density, and beech density; (b) negative relationships between yellow birch basal area and mottling depth; and (c) positive relationships between both beech density and basal area with mottling depth. The indication is that as



Figure 11. Twenty-year-old even-aged hardwood stand regenerated from clearcutting located in Talmadge Township, Washington County, Maine.

depth to mottling becomes closer to the soil surface (within a certain range), yellow birch basal area increases, with a subsequent decrease in beech basal area and density.

Also of interest is that the Talmadge site has a higher total density (6,324 stems/acre) than Waite (5,058 stems/acre). In addition, yellow birch, hemlock, and black spruce have higher densities and basal area at Talmadge, whereas beech, sugar maple, and red maple have higher densities at Waite (Figure 12). Total basal area at the two sites is somewhat similar (84 ft<sup>2</sup>/acre at Talmadge and 92 ft<sup>2</sup>/acre at Waite), while species basal areas reflect those for densities (Figure 12). Soils at the two sites are fairly similar, and range from loamy sands to silt loams.

As the database grows over the next two years, we anticipate that the relationships between soil-site variables and ecological phases, successional series, and forest productivity will be made with fairly high confidence. We also have not yet incorporated the CFI data for the ecological region. That will be conducted over the winter, 1996-1997. We expect that the use of the CFI plots will further improve our interpretations among site type, ecological phases successional series, harvesting types, and productivity. We have also begun soil mineralogical analysis

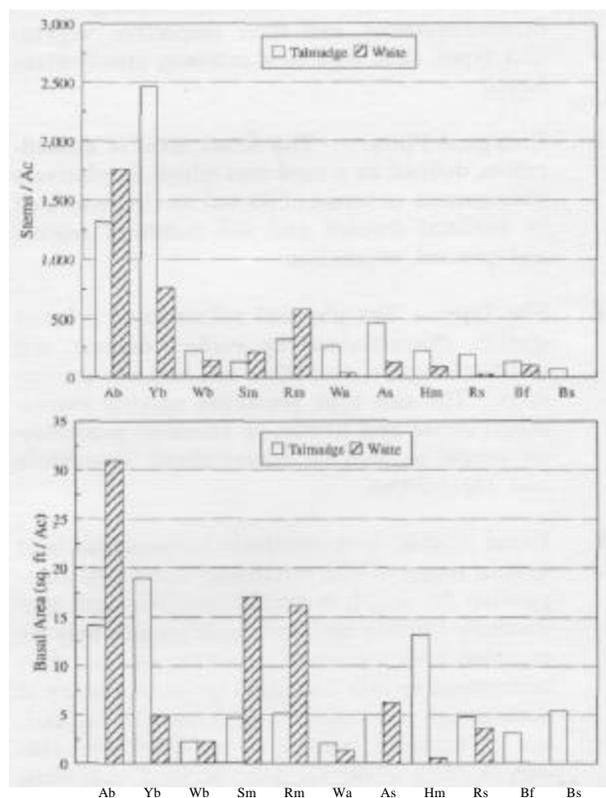


Figure 12. Densities and basal area of dominant overstory trees (>2 in. dbh) for stands located at Talmadge and Waite Townships, Washington County, Maine.



Table 3. Ecological phases inventoried for Talmadge and Waite Townships, Washington County, Maine.

Ecological phase <sup>a</sup>	Dominant seedlings <sup>b</sup> *	Successional series	Soil depth (cm)	Texture <sup>c</sup>	Humus depth (cm)	Mottling depth (cm)
Ab-Yb	Ab,Yb,Sm,Bf	Northern hardwoods	45-65	SiL,L, SaL	2-9	25-100
Ab-Rm	Ab,Yb,Sm, Wa,Hm	Northern hardwoods	16	L	2	4
Ab-Yb-Sm	Ab,Yb,Sm,Wa	Northern hardwoods	75-80	SiL,L, SaL	2-9	>80
Ab-Wb-Yb	Ab,Yb,Sm	Northern hardwoods	48	SaL	2	>48
Ab-Yb-Wb-As	Yb,Wa,Ab,Sm	Northern hardwoods	100	L	5	>100
Ab-Yb-Sm-As	Yb,Ab,Wa,Sm	Northern hardwoods	60	SaL	5	>60
Ab-Yb-Rm-As	Yb,Sm,Wa,Ab	Northern hardwoods	63	LSa	5	48
Ab-Yb-Sm-Wa	Ab,Wa,Sm,Yb	Northern hardwoods	100	L	5	>100
Yb	Yb,Ab,Sm,Wa	Northern hardwoods	50	SiL,SaL	1-4	45-50
Yb-Rm	Yb,Wa,Sm,Ab	Northern hardwoods	61	L	4	>61
Yb-Rm-As	Yb,Sm,Wa,Ab	Northern hardwoods	62	SaL	5	43
Sm-Rm	Ab,Wa,Yb, Sm,Rs	Northern hardwoods	33	SaL	6	>33
Rm-Sm-Wa	Sm,Yb,Wa,Rm	Northern hardwoods	55	L	2	>55
Rm-Ab-Sm	Ab,Wa,Yb,Sm	Northern hardwoods	65	SaL	3	45
Ab-Sm-Rs	Ab,Wa	Northern hardwoods	67	SaL	4	>67
Ab-Yb-Rs	Ab,Yb,Sm,Wa	Northern hardwoods	68	SaL	4	37
Ab-Yb-Rm-Bf	Ab,Yb,Bf,Hm	Hardwood/softwood	70	LSa	3	45
Ab-Wb-Yb-Hm	Yb,Ab,Hm,Bf, Rs	Hardwood/softwood	56	SaL	6	>56
Ab-Yb-Wa-Hm	Ab,Wa,Hm,Rs, Bf	Hardwood/softwood	50	LSa	10	32
Yb-Rm-As-Jp	Yb,Ab,Sm, Wa,Rs,Bf,Hm	Hardwood/softwood	80	L	6	27
Yb-Sm-Wa-Hm-Rs-Bf	Ab,Bf,Yb,Wa	Hardwood/softwood	72	L	14	11
Rm-Ab-Yb-Bf	Yb,Ab,Bf	Hardwood/softwood	60	SaL	5	>60
Sm-Ab-Yb-Hm	Ab,Sm,Yb, Wa,Hm,Bf	Hardwood/softwood	56	L	10	0
Sm-Ab-As-Yb-Rs	Sm,Ab,Yb, Bf,Hm	Hardwood/softwood	12	SaL	25	6
Hm-Rs-Bf-Ab-Yb-Wb	Yb,Wa,Sm,	Softwood/hardwood	53	SaL	11	>53
Hm-Rs-Bf-Ab-Yb-Wa	Yb,Wa,Sm,	Softwood/hardwood	50	LSa	10	32
Hm-Bf-Sm-Wa-Yb	Hm,Yb,Wa,	Softwood/hardwood	72	LSa	2	11
Hm-Bf-Ab-Yb-Wb-Rm-As	Yb,Rs,Bf, Ab,Hm	Softwood/hardwood	42	SaL	14	7
Hm-Ab-Wb	Hm,Yb,Rs,Wa	Softwood/hardwood	54	LSa	10	15
Bs-Hm	Hm,Bf,Bs	Softwood	60	L	13	26

<sup>a</sup> Ab=American beech, As=aspen (quaking and bigtooth), Yb=yellow birch, Wb=white birch, Sm=sugar maple, Rm=red maple, Rs=red spruce, Bf=balsam fir, Hm=hemlock, Jp=jack pine, Wa=white ash

<sup>b</sup> Species for seedlings are in order of most to least dominant

<sup>c</sup> LSa=loamy sand, SaL=sandy loam, L=loam, SiL=silt loam

Table 4. Correlation matrix for density of selected tree species and environmental variables for Talmadge and Waite Townships, Washington County, Maine.<sup>3</sup>

	AB	YB	RM	O horizon depth	Total depth	Rooting depth	Mottling depth
AB	-	-0.46 (0.03)	-0.41 (0.05)	0.13 (0.56)	0.30 (0.17)	0.26 (0.22)	0.35 (0.10)
YB	-0.46 (0.03)	-	0.13 (0.55)	-0.28 (0.18)	-0.05 (0.83)	-0.08 (0.72)	-0.27 (0.21)
RM	-0.41 (0.05)	0.13 (0.55)	-	0.12 (0.58)	-0.03 (0.88)	-0.12 (0.58)	-0.30 (0.16)
O horizon depth	-0.13 (0.56)	-0.28 (0.19)	-0.11 (0.58)	-	0.10 (0.65)	-0.18 (0.42)	-0.20 (0.36)
Total depth	0.30 (0.17)	-0.05 (0.83)	-0.03 (0.88)	0.10 (0.65)	-	0.22 (0.32)	0.26 (0.22)
Rooting depth	0.26 (0.23)	-0.08 (0.72)	-0.12 (0.58)	-0.17 (0.42)	0.22 (0.32)	-	0.37 (0.08)
Mottling depth	0.35 (0.10)	-0.27 (0.21)	-0.30 (0.16)	-0.20 (0.36)	0.26 (0.23)	0.37 (0.08)	-

<sup>a</sup> AB = American beech, YB = Yellow birch, RM = Red maple.

Table 5. Correlation matrix for basal area of selected tree species and environmental variables for Talmadge and Waite Townships, Washington County, Maine."

	AB	YB	RM	O horizon depth	Total depth	Rooting depth	Mottling depth
AB	-	-0.30 (0.16)	0.10 (0.64)	-0.28 (0.20)	0.20 (0.37)	0.10 (0.64)	0.29 (0.17)
YB	-0.30 (0.16)	-	-0.17 (0.60)	0.13 (0.53)	0.26 (0.22)	-0.09 (0.67)	-0.38 (0.06)
RM	0.10 (0.64)	-0.17 (0.60)	-	-0.23 (0.28)	-0.36 (0.09)	-0.24 (0.26)	-0.28 (0.19)
O horizon depth	-0.28 (0.20)	0.13 (0.53)	-0.23 (0.28)	-	0.10 (0.65)	-0.18 (0.42)	-0.20 (0.36)
Total depth	0.20 (0.37)	0.26 (0.22)	-0.36 (0.09)	0.10 (0.65)	-	0.22 (0.32)	0.26 (.22)
Rooting depth	0.10 (0.64)	-0.09 (0.67)	-0.24 (0.26)	-0.17 (0.42)	0.22 (0.32)	-	0.37 (0.08)
Mottling depth	0.29 (0.18)	-0.38 (0.06)	-0.28 (0.19)	-0.20 (0.36)	0.26 (0.23)	0.37 (0.08)	-

<sup>a</sup> AB = American beech, YB = Yellow birch, RM = Red maple.

and believe that this will also significantly contribute to understanding site type, successional series, harvesting types, and productivity relationships. We will also be incorporating data from western Maine into the database over the winter to expand the ecological regions.

**Development of Interpretations**

Interpretation development will consist of applying basic ecological knowledge to primary ecological units (ecological phases) based on these units' attributes. Greatest importance is to be placed on soil-site variables in the development of interpretations (Table 6) as opposed to vegetation because often forest association data are available without mensuration data. Forest association information alone limits the capacity to develop real silvicultural interpretations based on vegetation. Also, all the soil-site variables are, in fact, important in determining forest potential and a number of silvicultural constraints.

The interpretive limitations of the ecological phase attributes and the fact that spatial considerations will be abstracted in the classification exercise explain the simplicity of many interpretations, such as those based uniquely on soil texture and drainage class.

Interpretation	Variables used
Windthrow risk	soil depth, texture, drainage,
Table 6. Interpretations developed for classification of ecological phases.	
	forest composition
Compaction risk	texture, drainage
Erosion risk Frost	texture, % slope
heave risk	texture, drainage
Competition risk (raspberry, grasses, str. maple)	surface deposit, texture, drainage, vegetation
Potential productivity	surface deposit type & depth, texture, drainage
Planting suitability	surface deposit type & depth, humus depth, drainage, texture
Strip cutting suitability	forest type, surface deposit type & depth

**Classification of Forest Stations**

The classification of forest stations will be hierarchical in nature and developed using a hybrid approach involving two phases. The first phase is examining information obtained at the ecological (climatic) regional scale as delineated by Briggs and Lemin (1992). For the ecological region of Washington County, we have established plots and collected mensuration data on mature hardwood, mixed hardwood/softwood, and softwood stands on Baskahegan landholding in Danforth Township in Washington County. We will also sample a number of stands that have been subjected to selection cutting and beech removal during the 1997 field season. Soil-site characterizations also will be conducted during the 1997 field season. These data will then be combined with that from Talmadge and Waite Townships to aid in our harvesting-succession-forest productivity characterizations.

The second phase will incorporate mensurational and biophysical data from either CFI plots or uncut stands for which we have established plots on landholding of the cooperators. The same soil-site and vegetation measurements will be made on both CFI and selected uncut plots. We have conducted soil characterizations and begun to analyze 20 hardwood CFI plots on Georgia-Pacific landholding. We will expand the CFI database this winter to include mixed hardwood/softwood and softwood stands. The CFI data will allow us to improve our evaluation of the interactions among harvesting types, succession, and productivity.

The classification of forest stations will be done using hierarchical cluster analysis. This classification produces units whose site characteristics are relatively homogenous, but whose forest composition may be more variable than site characteristics. Each site type will be characterized by surface deposits and a broad soil moisture class. Other environmental attributes will also associate site types, including soil depth, depth to till, humus type and depth, soil texture, and drainage class. The site type classification forms the abiotic underpinning for the second phase of the forest station classification.

The database (both the Soil-Site Program and CFI plots) will be reviewed and forest cover types will be associated empirically with the different site types. All forest cover types associated with a given site type will then associate with a successional stage: pioneer, intolerant, intermediate, sub-climax, and climax as shown in Table 7. The successional classes will not be explicitly linked to stand age, but rather to stand composition and probable successional pathways, and as such are meant to provide an indication of forest dynamics on a given site type.

Partitioning of ecological phases by cover type followed by cluster analyses will provide the basis for a classification of forest stations. Number of classes should increase as does within-class homogeneity as

Table 7. Distribution of forest cover types across site types for Talmadge and Waite Townships, Washington County, Maine.

Forest cover type	Successional stage'	Site type''			Total
		Shallow to bedrock	Shallow till — number of plots -----	Deep till	
<b>Hardwood</b>					
Yellow birch <sup>c</sup>	3	0	2 2 0	0 3 1	2 5 2 4 1
Beech-birch-maple	3-4	0	1 1	3	1
Beech-maple	4	1	1	0 0	
Beech-birch	3	0			
Maple	3-4	0			3 3 2 2 1
Maple-ash	3-4	0	3	0 2 0 1 1	
<b>Mixedwood dominated by hardwoods</b>			1 2 1 0		
Mixed hardwood-	3-4				
hemlock	0				
Mixed hardwood-	3-4				
balsam fir	0				
Mixed hardwood-	3				
red spruce	0				
Mixed hardwood-	2-3				
jack pine	0				
Mixed hardwood-	4				
mixed softwood	0				
<b>Mixedwood dominated by softwood</b>					
Hemlock-birch	3	0	1	0	1 4
Mixed softwood-	3-4	0	3	1	
mixed hardwood					
<b>Soft wood</b>					
Black spruce-	4				
hemlock					
Total			18	13	32

<sup>a</sup> 1 = Intolerant, 2 = Intermediary, 3 = Sub-climax, 4 = Climax

<sup>b</sup> All surface deposit type is glacial till

<sup>c</sup> Ecological phase birch includes both yellow and white birch; maple includes both red and sugar maple

the calculated similarity index increases. No particular similarity threshold will be employed, and the initial classification will be a combination of flexible interpretation of cluster analysis dendrograms and knowledge of regional forest ecosystems. Spatial proximity of sites — for example, shallow tills and very shallow tills or two site types of common surface deposit type and adjacent moisture regime classes — will be taken into consideration during interpretation of cluster analyses.

surface deposit followed by cover type (Table 7). This approach provides some indication of early and later

Given that site and land characteristics are relatively permanent, the forest station classification will be presented with an *a priori* stratification by

successional forest types to be found on common site types. Some site types are anticipated to have very specific composition, whereas others will likely contain a broader composition.

The preliminary work at Talmadge and Waite Townships indicate that there is approximately a 50-50 split between both shallow and deep till for hard-

wood forest cover types, mixedwood dominated by hardwoods occur on shallow tills at about a 65% frequency, and mixedwood dominated by softwoods occur on shallow tills 80% of the time. The lone pure softwood (black spruce-hemlock) plot sampled occurred on deep till, but that plot occurred on the toe slope position and depth to mottling was 10 inches.

### Classification Units and Field Keys

The final classification will be composed of a number of forest cover types grouped into general cover types situated on the various site types (Table 7). The system simplifies the classification to suit the users' perception of the forest landscape rather than force foresters to refine their perception of actual field conditions.

Maine is a state that is not characterized by vast expanses of old undisturbed forests. Much of the state has been cut, burned, cultivated, abandoned, or infested by insects over the last half century. The abundance of recently disturbed and second growth forests and our soil-site forest classification underline the importance of site type recognition in the classification system. A simple key based on soil characteristics, coupled with a schematic toposquence will be developed to permit the user to rapidly identify the site type and associated site type with local physiography. Soil characteristics used in the key will include texture, organic matter, till depth, mottling depth, rooting depth, and drainage class. We will also include indicator species groups for understorey vegetation in the field keys.

Broad silvicultural scenarios will be developed with input from regional foresters using the forest site and station classification system presented here. The scenarios will provide a framework for silvicultural prescriptions, but are not intended to be directive in nature.

### Conclusions

The hybrid approach to classification, which combines information from ecological studies and regional inventories, provides a greater representation of forest ecosystems than either source taken alone. For example, it is possible that a forest type may be absent on a regional inventory, whereas it may be present on sub-regional studies. Also, balsam fir may be extensively represented in the ecological studies undertaken between 1960 and 1980, but may be less frequently sampled from the 1980s to today because of spruce budworm outbreaks in the 1970s and extensive salvage harvesting that occurred from the late 1970s to the mid-1980s. This underlies the influence of major disturbances of regional inventory and the utility of CFI inventories in understanding changes in forest composition and structure.

The rationale for using a classification approach based on interpretations rather than solely on the ecological phase attributes themselves is simple: because forest stations are meant to be silviculturally significant as well as biophysical entities, by developing silvicultural and environmental interpretations for ecological phases prior to classification, the basis for grouping ecological phases is more apparent and, to a certain extent, logical in a practical sense. Moreover, the approach allows us to

return to the finer ecological phase units if the forest station is considered too broad for a particular interpretation.

The primary objective of this classification system is to develop a practical forest ecosystem classification which, when integrated into a field guide, will furnish a framework for foresters and other land managers working in a specific region.

### Literature Cited

- Barnes, B.V. 1986 Varieties of experience in classification and mapping ibrestiand ecosystems, p.5-23 in G.M. Wickware and W.C. Stevens (co-chairs) Site Classification in Relation to Forest Management. COJFRC Symp. Proc. No. 0P-14, Canadian Forest Service, Sault Ste. Marie, Ontario.
- Briggs, R.D., and R.C. Lemin. 1992. Delineation of climatic zones in Maine. *Can. J. For. Res.* 22:801-811.
- Cartier, P., B.D. Harvey, and Y. Bergeron. 1996. A forest classification guide for the Amos Lowlands Ecological Region, northwestern Quebec: A forest management approach. *Environ. Mon. and Assess.* 39:249-263.
- Harvey, B.D., P. Cartier, Y. Bergeron, and P. Nolet. 1996. Development of a practical forest ecosystem classification from existing biophysical studies: An approach used in northwestern Quebec. *Environ. Mon. and Assess.* 39:231-247.
- Lee, B., and C. McDonald. 1993. Comparing three classification strategies for use in ecology. *J. Veg. Sci.* 4:341-348.
- Leak, W.B., 1987. Fifty years of compositional change in deciduous and coniferous types in New Hampshire. *Can. J. For. Res.* 17:388-393.
- Leak, W.B., and M.L. Smith. 1996. Sixty years of management and natural disturbance in a New England forested landscape. *For. Ecol. and Manage.* 81:63-73.
- Rastetter, E.B., A.W. King, B.J. Crosby, G.M. Hornberger, R.V. O'Neill, and J.E. Hobbie. 1992. Aggregating fine-scale ecological knowledge to model coarse attributes of ecosystems. *Ecol. Appl.* 2:55-70.

## TREE IMPROVEMENT

Brian Baltunis, Kyle Peer, and Dr. Michael S. Greenwood

### Introduction

Over the last year, considerable progress towards the mass production of plantation stock from select hybrid larch families has been made thanks to the efforts of Brian Baltunis and Kyle Peer. Our approach is to produce seed by controlled crossing in S.D. Warren's hybrid larch orchard at Unity, and to create cutting hedges from this seed. We are evaluating a new rooting bench for the production of rooted cuttings from the hedges which will allow us to produce any number of plants from particularly good families. We are continuing to monitor the growth of hybrid larch families in the test at Johnson Mountain. Reports on some of these activities follow.

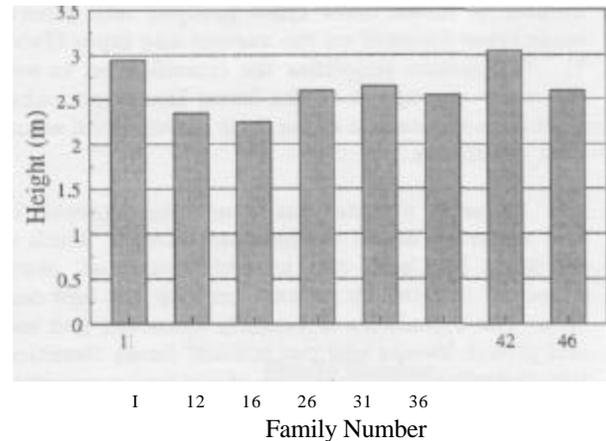


Figure 13. Variation in height among families of European x Japanese hybrid.

### Evaluation of a Hybrid Larch Progeny Test at Johnson Mountain

Measurements in 1995 were analyzed in order to assess overall growth of the families in the test after four growing seasons. The average percent survival for the test ranged from 73% for Japanese larch to a high of 92% for tamarack (Table 8). Japanese larch is vulnerable to cold temperatures in the spring, and tamarack would be expected to have a relatively high percent survival since it is a native species. Total height for hybrid groups ranged from 206 cm for Japanese larch to 272 cm for tamarack x Japanese hybrid. The von Lochow check (XLD789) had the lowest height in the test.

Variation in height among hybrid groups is clearly evident. Tamarack, European and Japanese larches had heights below the test mean of 246 cm. Hybrid vigor is demonstrated by height values in Table 8. All of the interspecific hybrids had greater heights than their parent species. Variation in height among families within a hybrid group is also evident (Figure 13). For example, within the European x Japanese larch hybrid group, average family heights

ranged from 230 cm to just over 300 cm. The best family in the test in 1993, 1994, and 1995 was EJ42. However, there is great within-family variation. Heights of individual trees in this family ranged from 180 cm to more than 400 cm in 1995. The variations among hybrid groups, within hybrid groups, and within families demonstrates the potential for large improvement in tree height by selecting the tallest families in the best hybrid groups.

An analysis of variance revealed significant differences in tree heights by block, family, and block by family interaction (Table 9). The significant block effect is largely due to variable competition control among the blocks. A comparison of mean heights by block revealed that heights of trees in blocks 9 and 10 were significantly less than heights of trees in blocks 1-8 ( $\alpha = 0.05$ ). Blocks 9 and 10 were accidentally missed during an aerial herbicide application.

There have been some interesting trends in height between 1993 and 1995 (Figures 14 and 15). In 1995, 17 out of the top 20 families were interspecific hybrids, while 15 out of the worst 20 families were either tamarack, European or Japanese larch.

Table 8. Average survival, total height age 4 (HT), and 1995 height increment (HI) for hybrid groups.

Cross	n <sub>i</sub>	Percent Survival	HT, cm	HK1995) cm
JJ	210	72.9	205.5	82.1
TT	300	92.0	244.2	85.6
EE	210	88.5	239.9	99.3
EJ	240	83.8	62.9	101.8
JE	262	80.5	259.2	102.6
TE	180	83.9	260.6	94.8
ET	30	80.0	258.2	98.9
TJ	55	83.6	271.7	104.4
XLD489	30	80.0	244.3	85.0
XLD789	30	83.3	174.7	63.4

Table 9. Analysis of variance (Height = Bl + Fam + Bl x Fam).

Source	DF	Mean Sq	Pr > F
Block	9	109932	0.0001
Family Bl	51	17039	0.0001
x Fam	448	4097	0.0001
Error	790	2827	0.0001
Bl x Fam as error term			
Source	DF	Mean Sq	Pr > F
Family	51	17039	0.0001



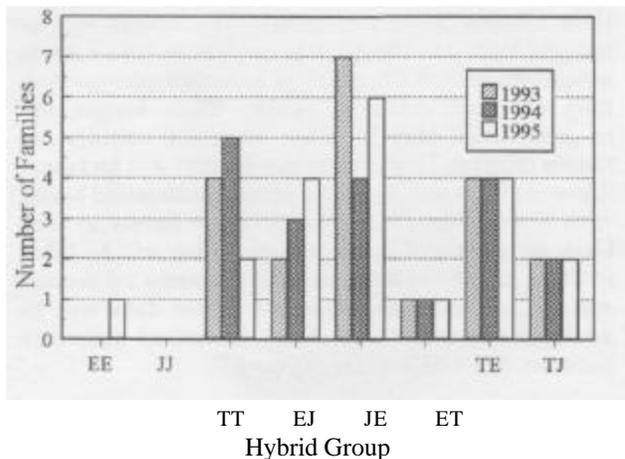


Figure 14. Number of families ranked in the top 20 for height, 1993-1995.

Tamarack families started out with good height growth, but dropped in rank by 1995. The European x Japanese hybrids have been increasing in rank. We expect these trends to continue in the future. Height, dbh, and ground-line diameter are currently being measured for 1996.

**Optimizing Hybrid Larch Hedging and Rooted Cutting Performance**

Over the last 15 years, there has been continued interest in the use of exotic Larch sp. (*Larix decidua*, *L. laricina*, and *L. leptolepis*) and their hybrids. Larch wood has a higher specific gravity than spruces while having comparable fiber length. The growth rates are as high as 1.5 m a year and larch species can adapt to a variety of sites. Integration of larch plantations into current forest management practices will result in an increase in fiber production with a decrease in rotation length to about 20-30 years.

We are currently evaluating methods for optimizing rooted cutting production of larch species and their hybrids. Rooted cuttings allow for the mass production of hybrids, which are difficult and costly to produce through controlled crosses. Two of our objectives are to optimize conditions for rooting and to optimize production of cuttings with desirable growth traits.

Objective one is to compare rooting success using three different factors: the amount of mist applied to the cuttings, the age of the donor plant from which the cuttings are taken, and the family from which the cuttings are taken. Donor stock representatives of six families, including three hybrids, were planted on December 12, 1995. While the donor material was being grown in a greenhouse, two 3- by 20-ft mist benches were constructed. Each contained five mist nozzles and were surrounded up to a height of 30 in. by fiberglass walls. A Gemini 6® mist controller was installed, which allowed mist bench one to have a mist quantity of ten seconds every ten minutes and mist bench two a quantity of six seconds every 16 minutes.

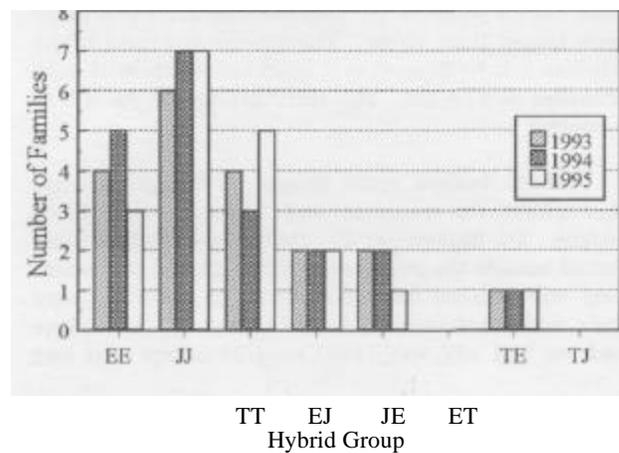


Figure 15. Number of families ranked in the bottom 20 for height, 1993-1995.

Cuttings were taken from each of the seven families growing in the greenhouse on August 13, 1996. Cuttings were also taken from the identical seven families from larch trees that had been growing for five years at a plantation on Johnson Mt. in Maine. Two hundred cuttings per family were taken from the greenhouse growing trees and the older plantation trees.

These cuttings were arranged in a complete randomized block design with each block having ten individuals per family from the one- and five-year-old trees. This came to a total of 140 individuals per block. Each of the mist benches contained ten of these blocks. These cuttings will be lifted from the rooting media on October 12, 1996, and be scored from 1-5 with a higher score being given for better rooting success. Anova will be used to see if there is a significant difference in rooting between the two mist treatments, the two age classes and the seven families.

Objective two will compare hedging of the donor plant at different heights on the rooting and growing performance of the cutting material. Hedges are made from growing seedlings that are severely pruned in order to eliminate apical dominance, which produces short multibranching hedges. These hedges produce more side branches from which cuttings can be taken and help to produce cuttings that exhibit juvenile characteristics. Juvenile characteristics are important for cuttings since juvenile cuttings grow orthotropically (like a normal tree) while cuttings with mature characteristics grow plagiotropically (like a branch). Cuttings exhibiting mature characteristics cannot be used in commercial field plantings.

This study began with the germination of four families on February 19, 1996, of which one was a hybrid. These families were grown in 118 cm<sup>3</sup> Ray Leach "super stubby cells"® until July 1, 1996, when they were transferred to one-gallon plastic pots. Each of the families were randomly divided into three separate treatments. The trees in treatment one will be hedged once they reach a height of 20 cm. These trees will be continually hedged so that they never



grow higher than 20 cm and the side branches never grow longer than 10 cm. The second one-third of the families will be hedged to a height of 35 cm with side branches of 17.5 cm. The third group will be left as a control.

These hedges were grown in the greenhouse throughout the summer and formed well-defined hedges. On September 23, 1996, these hedges were moved outside the greenhouse onto a gravel pad where they will remain for two months in order to meet their cold requirement. As of October 28, the hedges had set bud and were beginning to yellow and lose

their needles. After two months the hedges will be brought back into the greenhouse where, under warm temperatures and 16 hours of extended photoperiod, they will flush and grow again. These hedges will be grown until May 10, 1997, when 600 cuttings per family (200 per height class per family) will be taken. These cuttings will be placed in ten randomized blocks with 20 cuttings per height class per family in each block for a total of 240 per block. They will be lifted in three months and scored with the same 1-5 scoring system as previously described. This data will be analyzed to see if there is any statistical difference between the hedging treatments.

## TREE IMPROVEMENT

Dr. Katherine K. Carter

Larches (*Larix* spp.) are recognized as a fast-growing group of tree species with good potential for productivity in Maine. As part of an extensive network of larch plantation trials established to determine the suitability of different larch seed sources for planting in Maine, the survival and growth of a research planting of larch species and provenances growing in Talmadge, Maine, was evaluated. Trees in this plantation represent 68 different seed sources from five larch species and Japanese-European hybrids. Table 10 summarizes the number of seed sources tested at Talmadge for each species, and their origins.

The plantation is on an old-field site and had a moderately thick grass cover at time of planting. Seedlings for this plantation were raised in the University of Maine greenhouse and outplanted in June 1984 as 4-month-old containerized seedlings. Trees were planted on an 8-ft x 10-ft spacing, with each seed source represented by three-tree plots in each of four replications. Survival and height growth were evaluated after six growing seasons, and tree diameter was measured in September 1996, when the trees had completed 13 growing seasons.

Survival of most provenances has been excellent, with many seed sources having 100% survival

at age six. The exception was several provenances of Dahurian larch, which had poor initial survival. Survival of all provenances declined only very slightly after age six. Age-six mean height for seed sources varied from a high of 14.2 ft for one hybrid seed source, to a low of 2.1 ft for one Dahurian provenance (Table 11). Hybrids, as a group, outgrew all other species. At age 13, hybrids still maintained their growth advantage over the other groups, with an average DBH of 5 in. Non-hybrid European and Japanese larch included some individual seed sources which were nearly as large as the hybrid average (Figure 16). The single seed source of tamarack had smaller average DBH than the European, Japanese, and hybrid larches. Siberian and Dahurian larches were much smaller than the other groups.

These 13-year results indicate that hybrid larch seed sources are growing well at this site in eastern Maine. Some individual provenances of European and Japanese larch also have excellent survival and growth to date, but on the average these species are less productive than the hybrids. Most seed sources of European, Japanese, and hybrid larch surpass the native tamarack in height and DBH. Siberian and Dahurian larches appear to be poorly adapted to growing conditions in eastern Maine and have demonstrated inferior survival and height growth.

Table 10. Species, hybrids, and seed sources included in the Talmadge larch trial.

Larch Species	Number of seed sources	Additional comments
Tamarack ( <i>L. laricina</i> )	1	Seed collected in Old Town, Maine.
European ( <i>L. decidua</i> )	16	Seed from West Germany, Austria, Poland, and the Sudetan region. Some sources are seed orchard collections from West Germany, Poland, and Romania.
Japanese ( <i>L. leptolepis</i> )	34	Most seedlots are original collections from various locations in Japan. Also some collections from seed orchards in Japan, Korea, the U. S., and Europe.
Siberian ( <i>L. sibirica</i> )	1	Seed collected within the range of <i>L. sibirica</i> in the USSR.
Dahurian ( <i>L. gmelinii</i> )	5	Most sources originate from the range of <i>L. gmelinii</i> in the USSR.
Hybrids (various crosses of European and Japanese)	5	Includes both Japanese and European seed parents.



Table 11. Mean height (age 6) and DBH (age 13) for the six larch species and hybrids planted at Talmadge, Maine.

Species	Height (feet) at Age 6		DBH (inches) at age 13	
	Average	Range	Average	Range
Tamarack	10.9	—	3.8	—
Hybrids	11.9	9.7-14.2	5.4	3.8-6.1
European	10.7	8.5-13.4	5.0	4.1-5.8
Japanese	10.3	8.8-12.8	4.8	3.4-6.0
Siberian	3.1	2.4-3.5	0.8	0.6-1.0
Dahurian	4.3	2.1-7.4	1.2	0.1-3.4

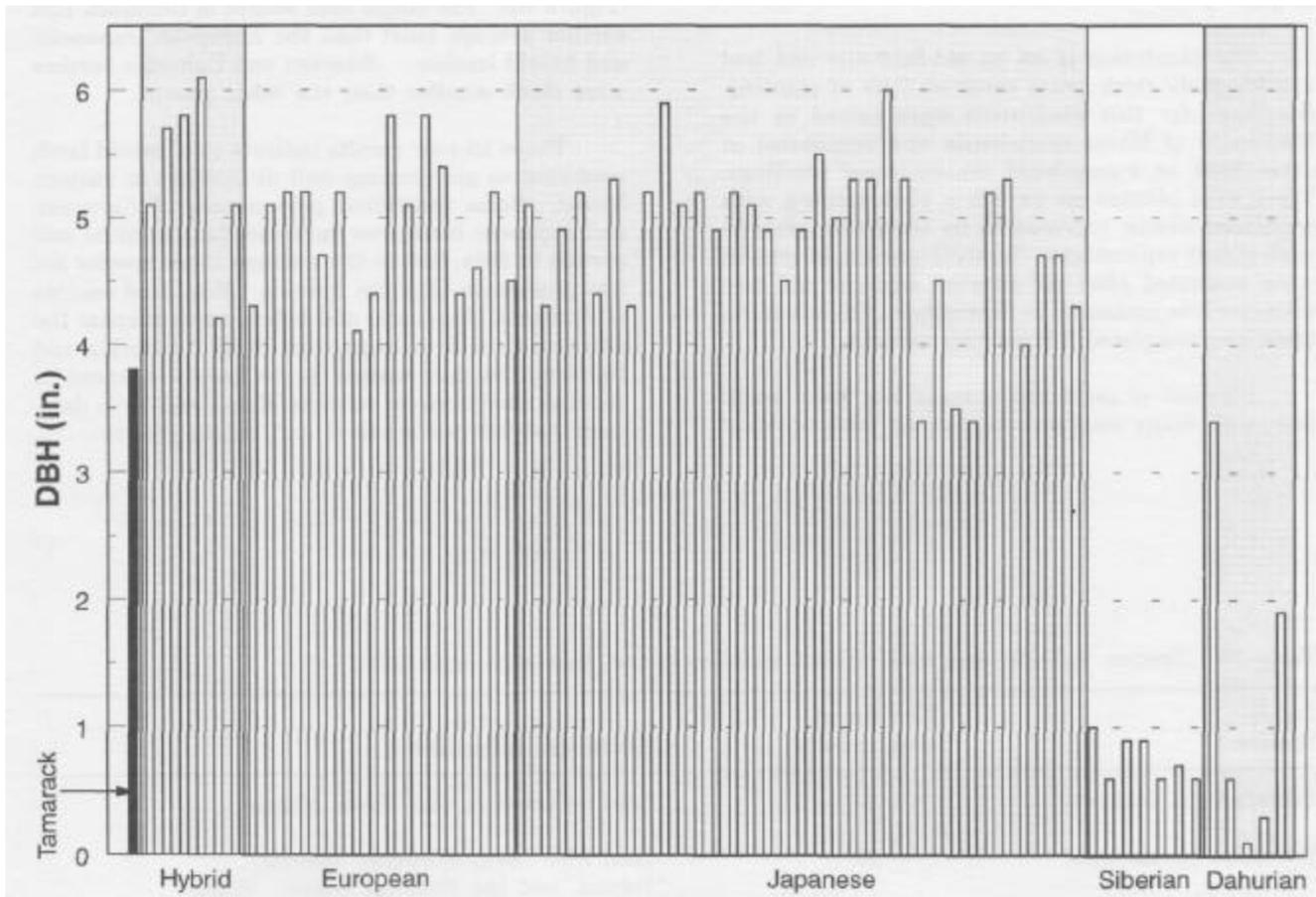


Figure 16. Average DBH at age 13 for each seed source of the larch species and hybrids at Talmadge, Maine.



## GROWTH AND YIELD

Dr. Robert S. Seymour

### Density Management Diagram for Spruce-Fir

Duncan Wilson completed his M.S. in May, and is now employed as Research Associate by the University of Florida Forest Productivity Cooperative. Using an archived data set compiled by Dr. Ralph Griffin and several of his graduate students, Wilson constructed a density management diagram for eastern spruce-fir forests. Such diagrams are commonly used in the western and southern United States, but have not previously been formulated for northeastern species. The diagram can be used for many different purposes related to density management, including plantation spacing, precommercial and commercial thinnings. Figure 17 shows an example of how stand development of two precommercial thinning strategies can be compared with that of an unmanaged stand.

A manuscript documenting the construction of the diagram and illustrating its use is presently under revision. In the interim, a limited number of copies of Wilson's thesis are available to CFRU cooperators by request.

### Stemwood Growth — Canopy Leaf Area Studies

Field work continued to expand Dr. Daniel Gilmore's work on balsam fir (completed in 1995) to several other species. Laura Kenefic, Ph.D. student working under a Cooperative Education agreement with the USDA Forest Service, sampled 20 eastern hemlock trees from a variety of canopy positions within the five-year selection treatments at the Penobscot Experimental Forest. Audrey Barker, M.S. candidate, sampled 16 eastern white pines from a similar range of competitive positions. The range of crown classes, crown sizes, and total heights is summarized in Figure 18. In both studies three branches per tree were sampled for foliar biomass and leaf area; lab work is ongoing. The goals in both studies are (1) to develop accurate prediction models for individual-tree leaf area as a function of sapwood area and/or crown dimensions and (2) to develop models to predict stemwood growth (per tree, per unit of leaf area, and per acre) from tree and stand-level leaf areas.

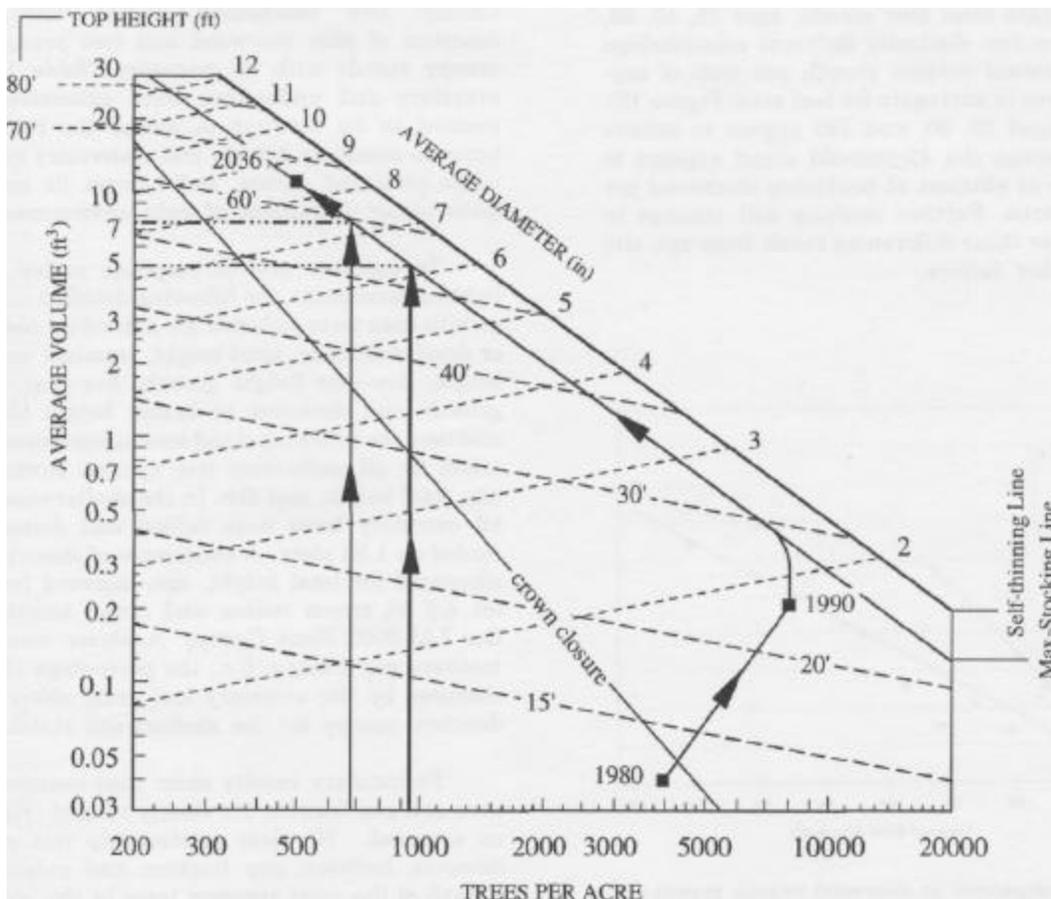


Figure 17. Natural development of a young stand regenerated with the shelterwood method, projected to a top height of 65 ft in the year 2036, at which time the unthinned stand is expected to have an average stem volume of 10.9 cubic ft, an average dbh of 8.5 in., and a density of 497 trees per acre. Stands precommercially thinned to either 677 or 945 trees per acre would reach the self-thinning line at average volumes of 7.5 and 5.0 cubic ft, respectively.

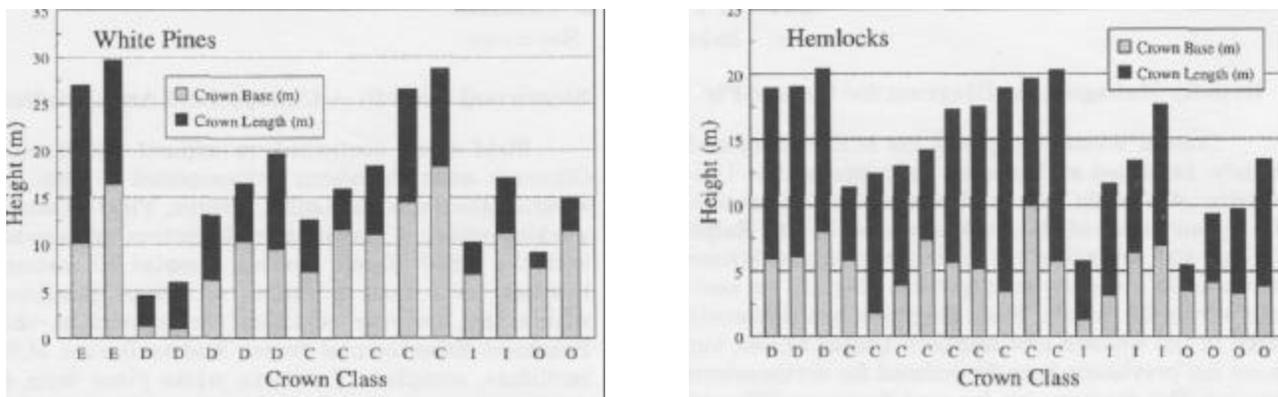
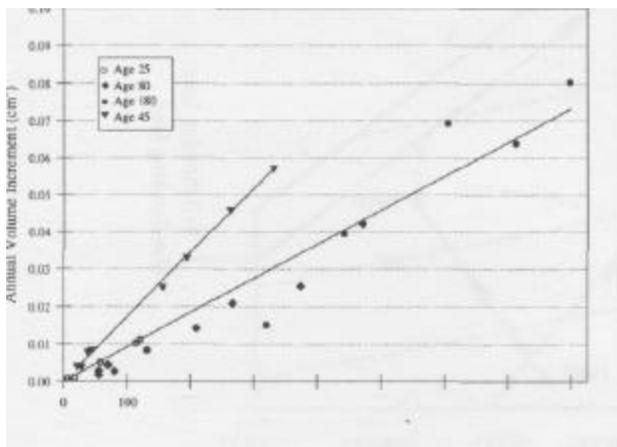


Figure 18. Distribution of white pine and eastern hemlock trees sampled in 1996, by crown class, crown size, and height. E = Emergent, D = Dominant, C = Codominant, I = Intermediate, O = Overtopped.

Ms. Barker will use the white pine equations to test whether age, canopy position, and possibly site index, influence the relationship between leaf area and stemwood growth. A total of 380 pines, growing in 13 separate stands on the University Forest, were cored to estimate sapwood area and radial growth. Sites range from an 18-year-old, recently spaced stand to 120- and 180-year-old mixed pine-hemlock stands where the pines are growing as large-dbh emergents. Preliminary data from four stands, ages 25, 45, 80, and 180, show two distinctly different relationships between stemwood volume growth per unit of sapwood basal area (a surrogate for leaf area; Figure 19). The stands aged 25, 80, and 180 appear to behave similarly, whereas the 45-year-old stand appears to be over twice as efficient at producing stemwood per unit of leaf area. Further analysis will attempt to isolate whether these differences result from age, site quality, or other factors.

Sapwood Basal Area (cm<sup>2</sup>)

Figure 19. Comparison in stemwood volume growth per



unit of sapwood basal area, in a pilot study of four separate eastern white pine stands of widely differing ages. The 45-year-old stand appears to be more than twice as efficient as the others combined, which do not appear to differ from one another.

### Effect of Pine Shelterwood Overstories on Growth and Development of Spruce-Fir Understories

Daniel McConville completed field work on a project investigating what effect, if any, residual pine overstories have on developing spruce-fir saplings in the understory. McConville sampled seven sites on Champion International lands in northern Hancock County: five two-storied stands with various densities of pine overwood and two young, single-canopy stands with no overstory (Table 12). Both overstory and understory were extensively documented in an attempt to model the relationship between overstory density and understory growth for white pine, red spruce, and balsam fir understory trees under a gradient of light environments.

To estimate growth response under different light environments, the following detailed understory growth data were collected for individual codominant or dominant trees: total height, terminal and lateral length, five-year height growth, five-year diameter growth, and diameter at breast height (dbh). In addition, the following stand-level measurements were taken for all understory tree species: stocking, density, total height, and dbh. In the shelterwood stands, all overstory trees were tallied and diameters recorded on 1 ha plots. A subsample of these trees was measured for total height, age, sapwood basal area (at 4.5 ft), crown radius, and crown length. A Li-Cor LAI-2000 Plant Canopy Analyzer was used to measure gap fraction (i.e., the percentage of sky not obscured by the overstory leaf area) above the understory canopy for the shelterwood stands.

Preliminary results show that overstory basal area and gap fraction are closely related (Figure 20), as expected. No clear relationship was observed, however, between gap fraction and recent height growth of the most vigorous trees in the understory. Spruce and fir saplings appear to be growing as well under a canopy that intercepts more than 50% of available light (overstory pine basal areas of 65%-82%) as they are in stands with no overstory (100% gap fraction; Figure 21).



Table 12. Summary of overstory and understory stand components in the study of variable overstory pine densities.

Overstory:

Site	Location	Basal Area (ft <sup>2</sup> /ac)	Percent pine	White Pine			Percent gap fraction
				Trees/acre	Avg. dbh (in.)	Age	
1	T39MD	116	92	97	14.2	80	18.8
2	T39MD	65	78	65	12.0	63	44.6
3	T32MD-3	82	97	59	15.7	78	43.4
4	T32MD-2	33	94	32	13.4	69	53.1
5	Univ Forest	35	94	11	23.2	120	64.9
6	T32MD	0		0			100.0
7	T32MD	0		0			100.0

Young age class:

Site	Time since last harvest	Percent stocking (milacre)			Average height (m)		
		fir	spruce	pine	fir	spruce	pine
1	11	83	0	0	3.35		.
2	10	67	83	64	1.63	1.87	1.62
3	9	78	58	53	3.45	3.15	2.66
4	9	53	22	94	1.99	1.41	1.77
5	9	39	0	92	3.38	3.03	2.52
6	10	92	56	19	2.11	1.68	2.47
7	10	61	28	11	2.45	2.18	1.95



mA



Figure 20. Relationship between overstory basal area and canopy gap fraction (the percentage of the sky not obstructed by overstory leaf area) for five eastern white pine shelterwood overstories.

Figure 21. Relationship between height growth of the five most rapidly growing understory saplings (balsam fir, white pine, and red spruce) to canopy gap fraction. There were no spruces or pines beneath the densest overstory (19% gap fraction).

## SLUDGE AND ASH

Dr. Robert K. Shepard

### Introduction

Growth measurements were made in three stands and foliage samples were collected from the same stands prior to the beginning of the 1996 growing season. Soil samples were taken from two areas after the 1995 growing season. Much of 1996 was spent on various aspects of the research on wood quality. This report presents important results from this past year's work on sludge and ash and describes early results from one of the wood quality studies.

### Sludge and Ash

#### Area 1

A combination of papermill sludge and wood ash was applied at rates of 0 and approximately 2.4, 4.8, and 9.6 dry tons/A; at one of three times - late May, late July, or late September; and for 1, 2, or 3 years in succession to plots in a clearcut planted to black spruce. Thus, an individual plot was treated with one rate, at one spreading time, and received up to three applications. The first treatments were in May 1988, and the last were in September 1990.

Measurements of dbh made after the 1995 growing season and analyses of foliage samples collected at the same time indicate that treatment effects were still evident. The trend of reduced dbh with increased application rate continued (Figure 22). Trees in control plots had the largest dbh and trees in the maximum rate plots had the smallest dbh. This trend first appeared in root collar diameter measurements made after the 1989 growing season and is attributed primarily to more intense vegetative competition in treated plots. A comparison of 1995 dbh and 1994 dbh (Figure 23) indicated that this negative effect did

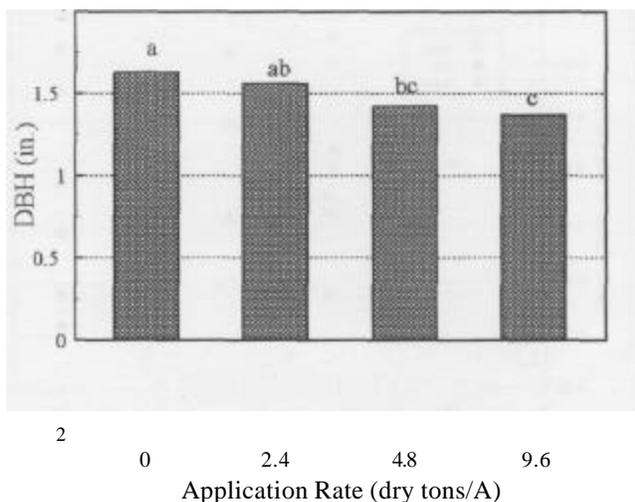


Figure 22. 1995 dbh of planted black spruce treated with a mixture of papermill sludge and wood ash at four rates. The treatments were applied 1, 2, or 3 times, with the first in 1988 and the third in 1990. The seedlings were planted in 1986. Means having the same lower case letter are not significantly different (P=0.05).

not increase significantly during the 1995 growing season. During 1995 diameter growth of control trees was 0.35 in., whereas trees that received the maximum rate grew 0.32 in.

Foliar concentrations of potassium, phosphorus, boron, aluminum, and manganese were all significantly affected by application rate, with the first three increasing as rate increased and the last two decreasing. In addition, both aluminum and manganese decreased significantly as number of applications increased, presumably due primarily to a higher forest floor and mineral soil pH in plots treated either two or three times. Aluminum and manganese become less available to be taken up by plants as soil pH increases.

#### Area 2

The area was treated with a mixture of primary and secondary papermill sludge at a rate of 40 dry tons/A in the fall of 1989. Portions were left untreated. The area had been planted to red pine about six years before the sludge application. Stem diameter measurements made after the 1995 growing season revealed that the positive effect on diameter growth that existed through 1994 had ceased, and that trees from the control plots outgrew trees from the treated plots, although the difference was not significant (Figure 24). The difference was due primarily to much reduced growth of treated trees.

There was still an effect of the treatment on foliar calcium and phosphorus concentrations, with both being significantly higher in foliage from treated plots. In addition, boron and manganese concentrations were still lower in foliage from treated plots. This is in keeping with trends first observed in 1991;

14

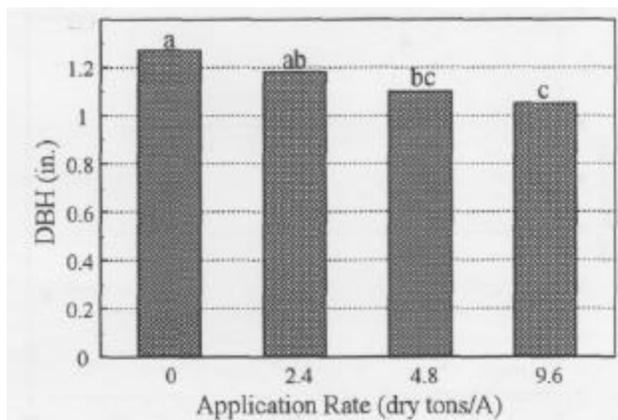


Figure 23. 1994 dbh of planted black spruce treated with a mixture of papermill sludge and wood ash at four rates. The treatments were applied 1, 2, or 3 times, with the first in 1988 and the third in 1990. The seedlings were planted in 1986. Means having the same lower case letter are not significantly different (P=0.05).



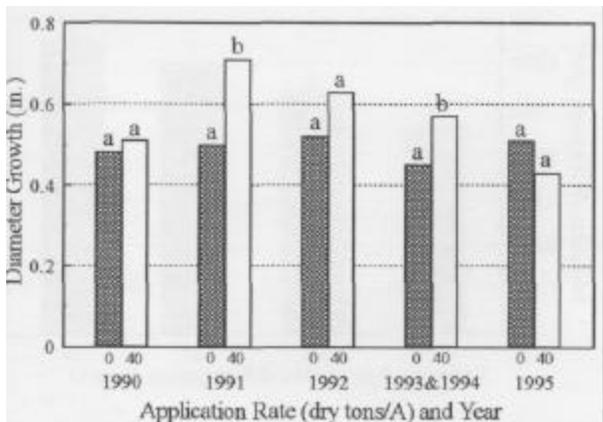


Figure 24. Yearly diameter growth of planted red pine treated with a mixture of primary and secondary papermill sludge at two rates in early October 1989. Trees were approximately six years old when treated. Measurements were made at a stem height of 3 ft. Growth for 1993 and 1994 is the average for the two years. Means having the same lower case letter are not significantly different (P=0.05).

however, in contrast to previous years, the differences in boron and manganese were not significant in 1995.

**Area 3**

The area was treated with a mixture of primary and secondary papermill sludge at rates ranging from 0 to more than 50 dry tons/A in the fall of 1989. Red pine had been planted about 4 years previously. Immediately after the sludge was applied, groups of seedlings were selected to represent the following application rates: 0, and approximately 5 to 15, 15 to 30, and 30+ dry tons/A.

Measurements made after the 1995 growing season showed a highly significant treatment effect on dbh (Figure 25). Trees that received the maximum rate had a dbh 0.51 in. less than the controls. Trees that received the other non-zero treatments also had a smaller dbh than the controls, but the differences were not significant. The same growth trend existed after the 1994 growing season (Figure 26). During the 1995 growing season, trees that received no sludge grew 0.57 in., whereas those that received the maximum rate grew 0.49 in. The trend of reduced diameter with increasing application rate was first detected after the 1990 growing season in measurements made at a stem height of 1 ft.

Foliage samples from this stand were taken in early May 1996, but element analyses have not yet been completed.

**Wood Quality Research**

Four wood quality projects are currently in progress, each having a different set of objectives. One of the projects has as its overall objective the

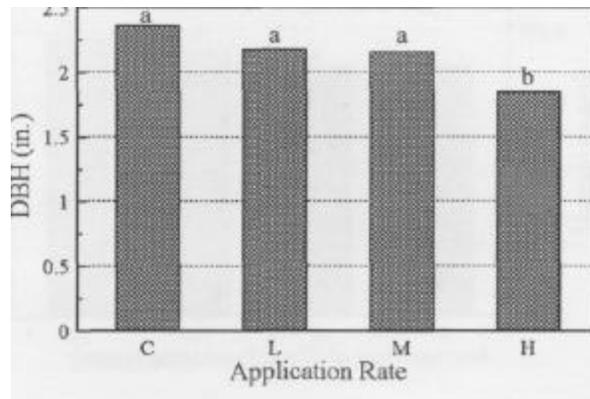


Figure 25. 1995 dbh of planted red pine treated with a mixture of primary and secondary papermill sludge in late September 1989. Trees were approximately four years old when treated. C=0 dry tons/ac, L=5 to 15 dry tons/A, M=15 to 30 dry tons/A, H=30+ dry tons/A. Means having the same lower case letter are not significantly different (P=0.05).

characterization of important wood properties of red spruce, including how they vary with age. Some early results from this study are presented here.

Five dominant trees were selected from each of seven 65-to 70-year-old red spruce stands growing on moderately well to well drained sites north of Moosehead Lake. The trees were felled and a bolt, extending from about 4 ft to approximately 9 ft, was taken from each tree. A 2-in.-wide flitch, centered on the pith, was cut from each bolt. Specimens for examining the relationship of specific gravity, modulus of rupture (MOR), and modulus of elasticity (MOE) to age were cut from two opposite radii on the flitch, as close to breast height as possible. The test specimens were 0.57 in. wide x 0.57 in. deep x 10 in. long.

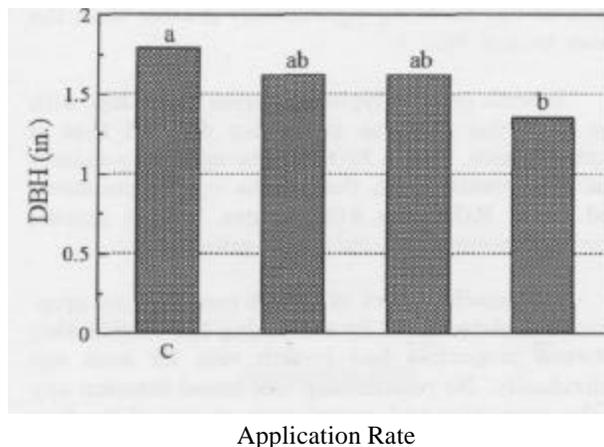


Figure 26. 1994 dbh of planted red pine treated with a mixture of primary and secondary papermill sludge in late September, 1989. Trees were approximately 4 years old when treated. C=0 dry tons/ac, L=5 to 15 dry tons/ac, M=15 to 30 dry tons/ac, H=30+ dry tons/ac. Means having the same lower case letter are not significantly different (P=0.05).



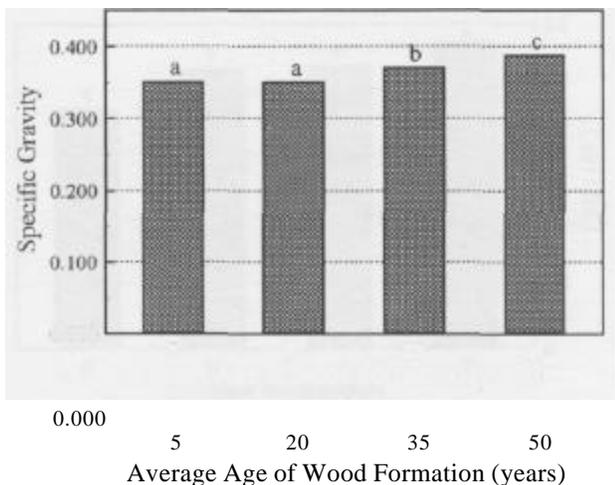


Figure 27. Specific gravity at approximately breast height of dominant red spruce at four ages of wood formation. Means having the same lower case letter are not significantly different (P=0.05).

Individual specimens were centered on growth rings 5, 20, 35, and 50 from the pith (subsequently referred to as ages 5, 20, 35, and 50 years). The number of annual rings in the specimens increased as distance from the pith increased, with specimens centered on the fifth growth ring averaging about five rings and those centered on growth ring 50 about 15 rings. The specimens were tested following criteria set forth by the American Society of Testing and Materials. The general relationship between each of the three properties and age is presented here.

Figures 27 through 29 clearly show a pronounced relationship between each property and age, and the figures also reveal a difference between the relationship for specific gravity (Figure 27) and those for MOR (Figure 28) and MOE (Figure 29). Both MOR and MOE increased significantly with each successive increase in age, although at a decreasing rate. In contrast, specific gravity did not begin to increase until after age 20, with the mean at age 35 being significantly greater than that at age 20 and the mean at age 50 being significantly greater than the mean at age 35.

Specific gravity typically varies much less with age than the strength properties do, and that is apparent here. Mean MOE of the age 50 specimens was 45% greater than that of the age 5 specimens, and mean MOR was 41% greater. Mean specific gravity, however, was only 11% greater.

The possible effect of growth rate on wood properties was determined by examining the relationship between properties and growth rate for each age individually. No relationship was found between any of the properties and growth rate at any of the four ages.

It is apparent from the wood property-age relationships that red spruce stands grown on a rotation of less than 50 years will be harvested before the

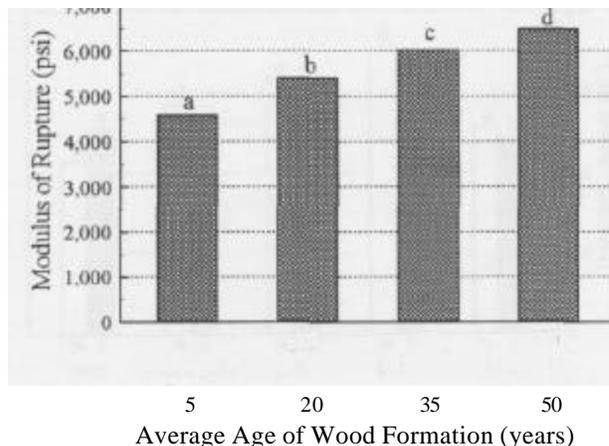


Figure 28. Modulus of rupture at approximately breast height of dominant red spruce at four ages of wood formation. Means having the same lower case letter are not significantly different (P=0.05).

trees begin to produce wood of maximum density and strength for the species. This has implications for both pulp yields and the characteristics of structural lumber from such stands.

None of the properties will continue to increase with age indefinitely. A detailed examination of the relationship between specific gravity and age for all seven stands of this study, based on seven trees per stand and about 2500 total observations, indicates that specific gravity levels off (juvenile period ends and mature period begins) at about age 62. Examination of trends in individual stands revealed that this age varied from about 59 years to 72 years. MOR and MOE probably level off at about the same age as, or somewhat sooner than, specific gravity.

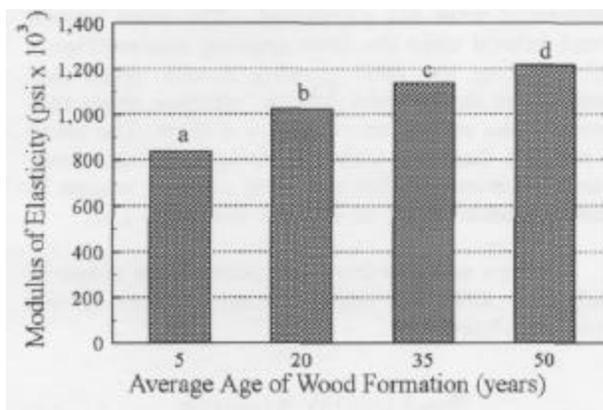


Figure 29. Modulus of elasticity at approximately breast height of dominant red spruce at four ages of wood formation. Means having the same lower case letter

are not significantly different ( $P=0.05$ ).

## EFFECTS OF TIMBER HARVESTING AND TRAPPING ON AMERICAN MARTENS IN NORTHERN MAINE

Dr. Daniel J. Harrison

### Introduction

Field work on the CFRU-funded portion of our project began in May 1994 within the Baxter Park site. This site represents the baseline without trapping or timber harvesting and is designed to compare the relative effects of trapping and timber harvesting (T4 RII) and timber harvesting without trapping (T5 RII) on marten population characteristics and habitat selection. Additional funding to support this work is provided by the Maine Forest Service (MFS) and the Maine Department of Inland Fisheries and Wildlife (MDIFW). Companion studies in the adjacent industrial landscape (T4 RII, T5 RII) are being funded by MDIFW, the Maine Agricultural and Forest Experiment Station (MAFES), and the Department of Wildlife Ecology (DWE), University of Maine. Associated projects are also being supported by the National Council of the Paper Industry for Air and Stream Improvement (NCASI). Project personnel during 1995-96 included David Payer (Ph.D. student), Theodore Chapin (Research Associate), Thomas Hodgman (Research Associate), H. Joseph Lachowski (M.S. student), Duggins Wroe (technician), Scott McLellan (undergraduate technician), and Rodney Kelshaw, Michael Estabrook, and Anthony McCue (undergraduate summer technicians). Payer's dissertation will address a comparison of marten population characteristics and habitat selection among the three treatments. Field work will be completed during spring 1998 and will represent the basis of a single final report to be submitted to all project sponsors in 1999.

### Objectives

The specific objectives of the CFRU funded portion of our project are to

1. Document and compare seasonal habitat selection by martens in an untrapped forest preserve, an untrapped industrial forest, and a trapped industrial forest.
2. Document and compare population characteristics (i.e., home range size, inter- and intra-sexual home range overlap, density, age and sex structure, survival and percent females lactating) of martens in an untrapped forest preserve, an untrapped industrial forest, and a trapped industrial forest.

### Funding

As proposed, CFRU funding covers 50% of the direct costs to operate the Baxter Park study area. Scheduled CFRU funding, additional to \$15,564 provided by Maine Forest Service and \$5,700 "in kind" support (flying time, contract labor, vehicles) provided

by MDIFW was sufficient to cover field operations during FY 1995-96. All funding was provided as scheduled, which allowed us to proceed with all objectives as proposed. Further, companion studies of marten on adjacent industrial forest continue to be fully funded via MDIFW, MAFES, and DWE.

The National Council of the Paper Industry for Air and Stream Improvement is providing additional support during 1 April 1995 to 31 March 1997. This funding is targeted to evaluate and compare microhabitat characteristics in areas receiving different intensities of use (high use, low use, no use) by martens. The specific objective of this work is to document and compare microhabitat characteristics between forests (> 20 ft in height) with different intensities of use by resident, nonjuvenile martens. This work is occurring within the industrial forest treatment area (trapping closure) and within Baxter Park. The goal is to integrate the landscape-level findings from the extensive study with site-specific recommendations on ways to maximize habitat suitability for martens in harvested stands. Field work for this portion of the project occurred simultaneously with ongoing radio telemetry studies of marten during summers 1995-96 in T5 RII WELS and in Baxter Park.

### Progress During October 1995 to September 1996

We trapped martens from 22 May to 30 June 1996 in T5 RII WELS, T4 RII WELS and Baxter State Park. We captured and radiocollared 76 (28 females, 48 males) marten during 1996, which was a 38% and 58% increase in number of captures over 1995 and 1994, respectively. Each captured marten was sexed, weighed, measured, examined for reproductive status, aged, ear-tagged, and radiocollared. The number of adult male marten resident on the Baxter Park study site ranged from eight to 17 individuals during 1991 to 1995 whereas the number of adult female residents ranged from four to ten (Figure 30).

We monitored radiocollared martens from the air on a weekly basis from 1 October 1995 to 20 May 1996. From 21 May to 30 September 1996, resident marten were monitored approximately two to four times weekly from the ground and weekly from aircraft. As of 30 September 1996, approximately 9,000 locations of collared martens had been obtained. We have sufficient data from all residents to specify individual home ranges and to examine habitat use patterns (placement of the home range on the landscape, habitat selection within the home range, and use of microhabitat characteristics). Home ranges of males have remained relatively stable across years, whereas home ranges of females were smaller in summer 1995 relative to the four previous summers (Figure 31).

**Associated Projects**

**Marten Use and Microhabitat**

Background and Scope: Stand-scale habitat selection by marten is thought to reflect a choice for stands with microhabitat characteristics that provide an abundance of horizontal and vertical structure. However, the relationships of marten use of forests with structural attributes has not been quantified, except for den and rest sites, which do not appear to be limiting in the forests of Maine. A verified relationship of the use intensity of forested habitats with structural attributes may enable managers to shed the paradigm that martens require mature, conifer-dominated forests, and may provide opportunities to manage for the structural characteristics of forests required by martens in a wider variety of forest age classes and species types than has previously been considered compatible with marten conservation.

Hence, our specific objectives are (1) to document and compare microhabitat characteristics between forested areas (> 20 ft in height) receiving different intensities of use (number of locations/area) by successful martens (i.e., based on survival and reproductive history) in an industrial forest and a forest preserve and (2) to develop stand-level recommendations regarding silvicultural techniques, harvesting methods, and slash management strategies to maximize habitat quality for martens.

The areas defined by the minimum convex polygon encompassing marten locations on each study site were partitioned into 16-ha grid cells, and intensity of use was quantified for each cell. We sampled overstory, understory, and microhabitat habitat variables at eight sampling sites randomly distributed within each cell. Sampling intensity was stratified by relative cell use to reduce variance. Each cell had a minimum of one sampling station per every 2.5 ha.

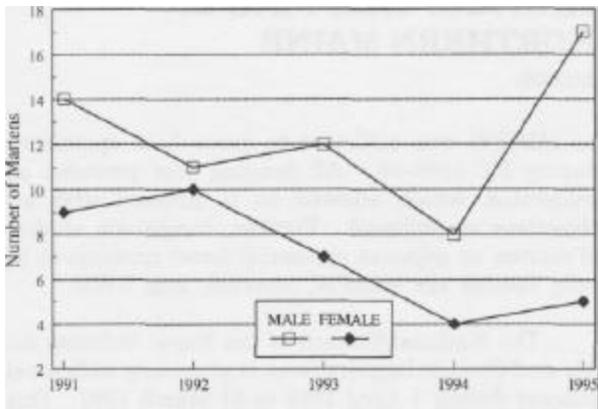


Figure 30. Number of resident martens captured on the Baxter State Park study area, 1991-95.

We continue to monitor population density, individual survival, and reproductive success of captured martens across sites. These data will be used to help us evaluate differences in habitat quality and population performance of martens exposed to the three forest harvest/trapping treatments.

Three townships (T5 R11, T6 R11, and T6 R10) were closed to commercial furbearer (except beaver and bear) trapping by the Maine Department of Inland Fisheries and Wildlife (MDIFW) during 1994 and 1995 to facilitate our study of effects of trapping on marten populations. During 1996 a rule-making to extend this closure was extended for the 1996 trapping season. We are working with MDIFW to enforce this closure, and project personnel have posted signs in strategic areas throughout the three townships to inform trappers of the duration of the closure and the objectives of our study. Additionally, a mailing was sent by MDIFW to all licensed trappers in Maine to inform them of the rule-making.

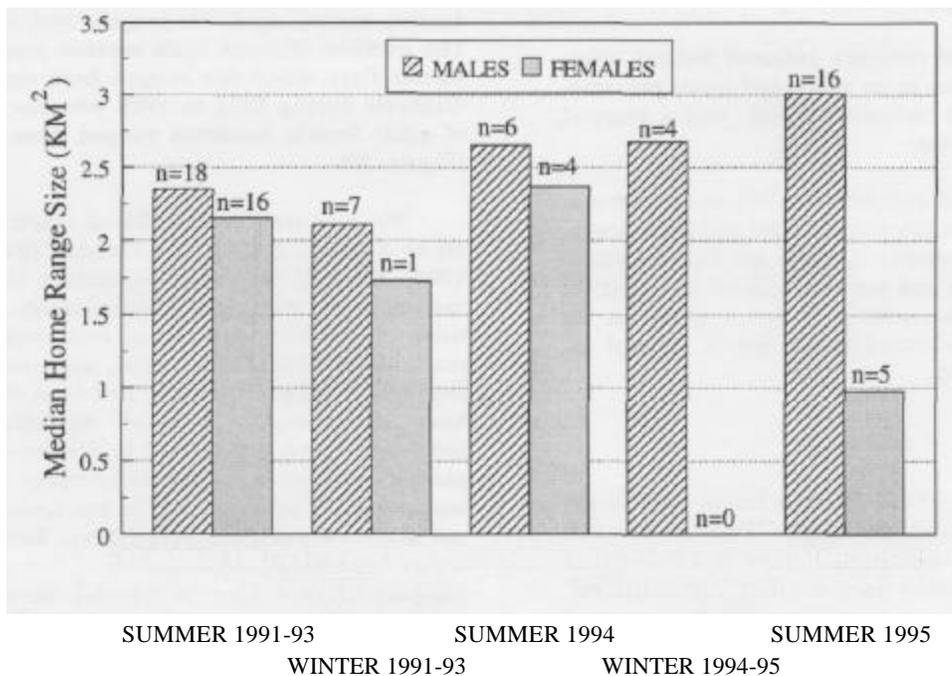


Figure 31. Seasonal home range sizes (median) of radiocollared martens on the Baxter State Park study area, 1991-95.



Use of microhabitat characteristics is being analyzed separately for the industrial forest site and the forest preserve. Following univariate testing and subsequent variable reduction approaches, we will use discriminant function analysis to describe and predict differences in structural characteristics between areas receiving different intensities of use by marten on the Baxter Park and industrial forest sites. Highly correlated variables will be collapsed as necessary. Further, comparisons of microhabitat features between regenerating clearcuts (generally receive little use by marten) and regenerating budworm kills (receive much use by marten) will be conducted to identify microhabitat features that might be managed for in the future to maximize use of stands by marten following forest harvesting.

**Results:** In 1995 and 1996 we surveyed 360 randomly placed plots within the industrial forest and 288 plots in Baxter State Park within areas receiving high, low, or no use by martens. Twenty-two microhabitat variables were measured at each site.

Preliminary univariate analyses for data collected on the industrial forest site suggest that coarse woody debris may not be a limiting factor influencing use of forests by marten in Maine; volumes of snags, stumps, root masses, and logs do not vary appreciably among sites receiving different intensities of marten use (Figure 32). However, basal area averaged  $> 110 \text{ ft}^2/\text{A}$  in low and high use areas, and  $< 65 \text{ ft}^2/\text{A}$  in areas where no use by resident marten was observed (Figure 33). Further, basal areas of hardwood and softwood trees were nearly equal on high use areas, whereas softwood basal area greatly exceeded hardwood basal area on low use areas (Figure 33). This data is contrary to the paradigm that marten prefer conifer-dominated stands and is consistent with stand- and landscape scale analyses that suggest that, in Maine, marten prefer mixed conifer-deciduous stands over conifer stands. Finally, the microhabitat data confirm results from our previous work that suggests

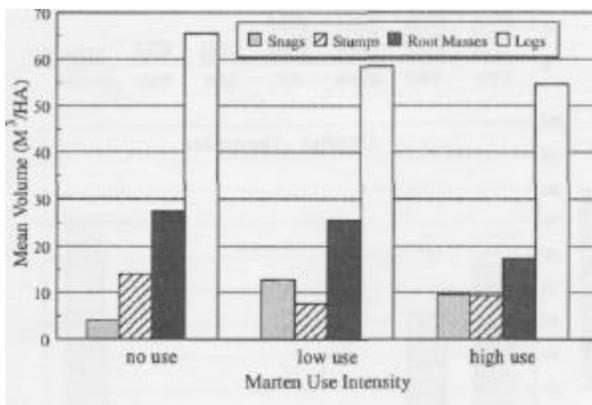


Figure 32. Median volumes of four coarse woody debris classes in areas of high, low, and no observed use by resident martens on the industrial forest site, T5 RII WELS, Maine.

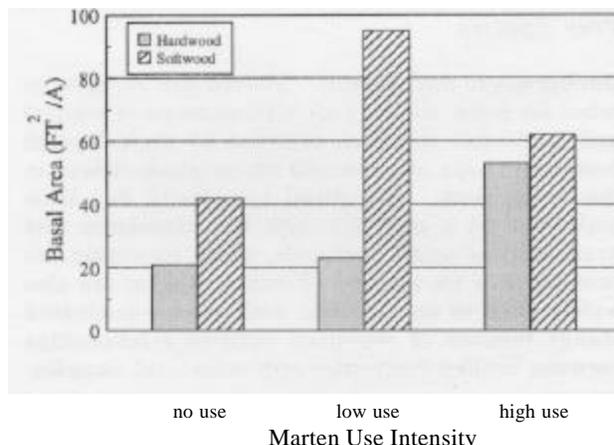


Figure 33. Median basal area of softwood and hardwood trees in areas of high, low, and no observed use by resident martens on the industrial forest site, T5 RII WELS, Maine.

that height of dominant canopy trees must exceed a threshold of 30 ft for an area to receive substantial use by marten (Figure 34). Although canopy closure of stands receiving use by marten inhabiting the industrial forest exceeded 90% (Figure 34), previous work by us in Baxter Park indicated that structurally complex budworm-killed stands with  $< 50\%$  canopy closure receive substantial use by marten. Thus, on the industrial forest site where clearcutting has been the predominant management practice, and where budworm-infected stands were sprayed and salvaged, canopy closure may be merely a correlate of stand age and may not be the ultimate factor influencing use intensity by martens. Multivariate modelling will help to account for multi-collinearity among variables.

FUNDING SOURCES: NCASI, MDIFW, MAFES, CFRU, MFS, DWE

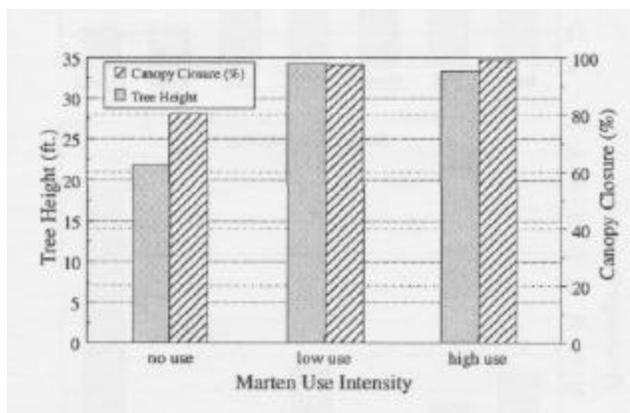


Figure 34. Median tree height and canopy closure in areas of high, low, and no observed use by resident martens on the industrial forest site, T5 RII WELS, Maine.



**Forest Type and Microhabitat Associations of Prey Species**

**Background and Scope:** Marten are thought to select for forest stands with high amounts of vertical and horizontal structure provided by multi-layered overstory, snags, stumps, and coarse woody debris on the forest floor. Structural complexity has been postulated as a correlate with the abundance and availability of small mammals, which constitute the primary prey for marten. Further, marten are also widely cited as an associate with conifer-dominated stands because of perceived positive relationships between conifer dominance and structural complexity.

Hence, we are investigating the relationship between overstory forest characteristics, microhabitat characteristics, and densities of prey species used by martens (primarily lagomorphs and small rodents). Specific objectives are (1) to document seasonal food habits of marten on our industrial forest site (T4 RII, T5 RII WELS) in northern Maine; (2) to estimate and compare small mammal densities in different forest types (mature mixedwood, mature hardwood, mature softwood, regenerating forest, and stands with severe spruce-budworm damage) classified based on overstory species, tree height, canopy closure, and stocking density; (3) to quantify differences in structural complexity in different stand types; and (4) to evaluate which stand, microhabitat, and structural characteristics are the best predictors of small mammal densities.

Food habits of marten have been quantified from marten scats collected during other field activities. Small mammals were live-trapped in five habitat types (mature mixed deciduous-coniferous, mature deciduous, mature coniferous, regenerating forest, and stands with severe spruce-budworm damage). Also, snowshoe hare densities are being indexed on each grid by counting pellets on transects distributed throughout the trap grids. Microhabitat characteristics were measured on the trapping grids and then analyzed to determine if small mammals demonstrate habitat selection at the stand level (based on overstory type) or at the microhabitat level. Multivariate linear regression models are being used to evaluate the relationship between the response variable (small mammal densities) and the explanatory variables (microhabitat variables), and to predict the precision by which a foraging marten may be able to predict available food resources from overstory and microhabitat characteristics. We hope to identify which structural features could be managed for in harvested forest stands to maintain use by marten and their principal prey species.

**Results:** Marten scats (n = 219) collected during 1991 through 1995 were analyzed for percentage occurrence of food items. Weighted equally among seasons, red-backed vole was the most common prey species (45.5%), followed by deer mice (32.3%), red squirrels (23.1%), snowshoe hare (12.6%), and shrews (13.3%) (Fig. 35). Individually, a snowshoe hare greatly exceeds the volume of other prey species;

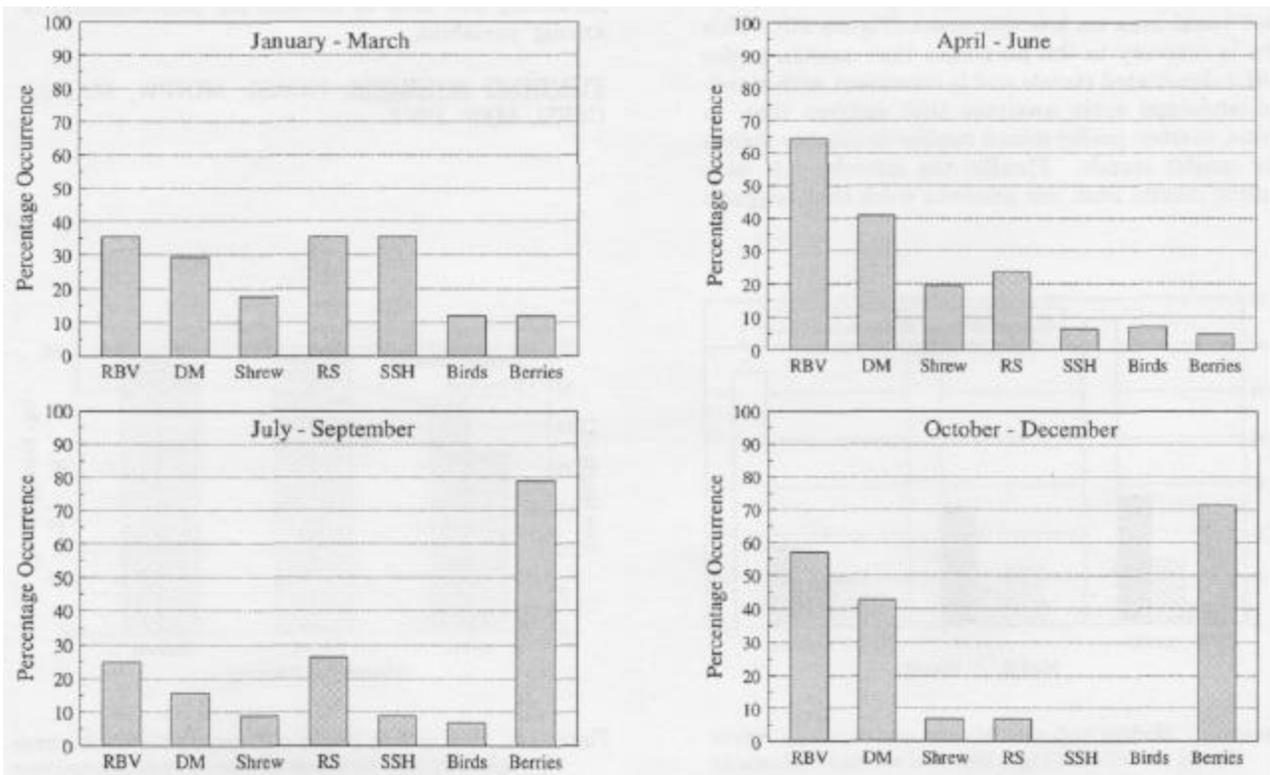


Figure 35. Percentage occurrence, by season, of food items in 219 marten scats collected during 1991 through 1995 in T4 RII WELS, T5 RII WELS, T5 RIO WELS, northern Maine. RBV = red-backed vole, DM = deer mouse, RS = red squirrel, SSH = snowshoe hare.

therefore, hares may be more important to marten than indicated by percent occurrence in scats. Further, occurrence of hare ranked first (tied with red-backed voles) as the most commonly occurring prey species during winter, suggesting that hares may be more important than previously thought in the ecology of marten during the most energetically stressful season (winter). Interestingly, pellet densities and rates of incidental captures of hares were higher in regenerating clearcuts than in all other forest types. Incidental capture rates of red squirrels did not differ significantly among forest overstory types.

Small mammal densities were estimated based on 1849 captures of 865 individuals during summer 1995 and 700 captures of 287 individuals in 1996. Mixed deciduous-coniferous forest had the highest vole densities, deciduous and mixed forests had highest densities of deer mice, and deciduous habitats had the highest densities of shrews. Given marten food preferences, mixed stands probably provide the greatest prey availability, followed by deciduous and then coniferous stands. As a group, mice and voles were more abundant in hardwood and mixed stands than in regenerating, budworm-killed, or coniferous stands. Notably, the rank order in mice and vole densities

consistently parallels the rank order in overstory type selection that we observed by radiocollared marten during 1989 and 1990 on the industrial forest site.

Small mammal abundance was higher in mature stands than in regenerating or budworm-killed stands, and was associated with microhabitat variables that are influenced by stand age. Significant variables in multivariate regressions such as canopy closure, dbh, litter depth, percent live ground cover, and volume of stumps, are all influenced greatly by stand age, past forestry practices, and history of insect defoliation. Remarkably, small mammal densities were not significantly associated with variables associated with structure, or with volumes of coarse woody debris. Apparently, sufficient structure to satisfy the habitat requirements of small mammals and martens occurs within the variety of forest types and age classes that we surveyed. Thus, several lines of evidence now indicate that availability of coarse woody structure does not generally limit marten use of mature and regenerating forests in Maine.

## 1996 PUBLICATIONS RESULTING FROM RESEARCH SUPPORTED BY THE CFRU

- Bnggs, R.D., A.J. Kimball, and J. Cormier. 1996. Assessing compliance with BMPs on harvested sites in Maine: Final Report. Maine Agric. For. Expt. Sta. Misc. Rept. 400. 35 pp.
- Chapin, T.G., D.J. Harrison, D.D. Katnik, D.M. Phillips, and E.G. York. 1995. Influence of landscape pattern, forest type, and forest structure on use of habitat by marten in Maine. Final contract report submitted to National Council of the Paper Industry for Air and Stream Improvement. 87 pp.
- Gilmore, D.W., and R.D. Briggs. 1996. Empirical yield prediction equations for plantation-grown European larch in Maine. *North. J. Appl. For.* 3:1:37-40.
- Gilmore D.W., and R.S. Seymour. 1996. Alternative measures of stem growth efficiency applied to *Abies balsamea* from four canopy positions in central Maine, USA. *For. Ecol. and Mgt.* 84:209-218.
- Gilmore, D.W., and R. S. Seymour. Crown architecture of *Abies balsamea* from four canopy positions. *Tree Physiol.* *in press*.
- Gilmore, D.W., R.S. Seymour, and D.A. Maguire. Foliage—sapwood area relationships for *Abies balsamea* in central Maine, USA. *Can. J. For. Res.* *in press*.
- Greenwood, M.S. 1995. Juvenility and maturation in conifers: Current concepts. *Tree Physiol.* 15:433-38.
- Lautenschlager, R.A. 1995. Competition between forest brush and planted white spruce in north-central Maine. *North. J. Appl. For.* 12(4): 163-167.
- McLaughlin, J.W., G. Liu, M.F. Jurgensen, and M.R. Gale. 1996. Organic carbon characteristics in a spruce swamp five years after harvesting. *Soil Sci. Soc. Am. J.* 60:1228-1236.
- Ostrofsky, W.D. 1996. Harvesting practices, tree injuries, and the management of forest health in the Northeastern United States, pp. 36-47 *in* S.P. Raychaudhuri and K. Maramorosch (eds.) *Forest Trees and Palms, Diseases and Control.* Oxford & IBH Publishing Co., Pvt. Ltd., New Delhi, India.
- Stafford, C., M. Leathers, and R.D. Briggs. 1996. Forestry-related nonpoint source pollution in Maine: A literature review. Maine Agric. For. Expt. Sta. Misc. Rept. 399. 18 pp.
- Trettin, C.C., M.F. Jurgensen, J.W. McLaughlin, and M.R. Gale. 1996. Functional responses to harvesting and site preparation in a coniferous swamp, *in* C.C. Trettin, M.R. Jurgensen, D.F. Grigal, M.R. Gale, and J. Jeglum (eds.), *Northern Forested Wetlands: Ecology and Management.* CRC Lewis Publishers. Boca Raton, FL. *in press*.

## AFFILIATED PUBLICATIONS

- Carter, K.K. 1996. Provenance tests as indicators of growth response to climate change in 10 north temperate tree species. *Can. J. For. Res.* 26:1089-1095.
- Cormier, J. 1996. Review and discussion of forestry BMPs. Internal Misc. Rept. 29 pp.
- Dai, K'o H., M.B. David, G.F. Vance, J.W. McLaughlin, and I.J. Fernandez. 1996. Acidity characteristics of soluble organic substances in spruce-fir forest floor leachates. *Soil Sci.* 161:694-704.
- Fernandez, I.J., L.E. Rustad, J.A. Simmons, and J.W. McLaughlin. 1995. The Howland Integrated Forest Study (HIFS) - Ecosystem Research Report No. 20. Ecosystem Manipulation Experiments: Scientific Approaches, Experimental Design, and Relevant Results. Luxembourg, Belgium: Office for Official Publ. of the European Communities. ISBN 92-827-4854-5. p. 298-306.
- McLaughlin, J.W, I. Fernandez, and K. Richards. 1996. Atmospheric deposition to a low-elevation spruce-fir forest, Maine, USA. *J. of Environ. Qual.* 25:248-59.
- McLaughlin, J.W, D. Reed, M. Jurgensen, G. Mroz, and S. Bagley. 1996. Relationships between soluble sugar concentrations in roots and ecosystem stress for first-year sugar maple seedlings. *Water, Air, and Soil Poll.* 88:1-19.
- Trettin, C.C., M.F. Jurgensen, M.R. Gale, and J.W. McLaughlin. 1995. Soil carbon in northern forested wetlands: Impacts of silvicultural practices, p. 437-461. *in* W.W. McFee and J.M. Kelly (eds) *Carbon Form and Function in Forest Soils.* Chapter 20. Soil Science Society of America, Madison, WI.

## ADDITIONAL TECHNOLOGY TRANSFER ACTIVITIES BY CFRU PERSONNEL

- Briggs, R.D. Best Management Practices: Operational practices to attain sustainability. Session moderator, SAF National Convention, Portland, ME. October 28-29, 1995.
- Briggs, R.D. The functioning terrestrial system, presentation to SAF National Convention, Portland, ME. October 28-29, 1995.
- Carter, K.K. Tree improvement in Maine and the Lake States. Tour for the SAF National Convention, Portland, ME. October 28-29, 1995.
- Carter, K.K. Maine's forests. Interview for TV program "Quest." Program aired January 9, 1996.
- Chapin, T.G., and D.J. Harrison. Seasonal selection of habitats by resting marten in Maine. 52nd Northeast Fish and Wildlife Conference, Farmington, CT. April 2, 1996.
- Chapin, T.G., and D.J. Harrison. Seasonal habitat selection by marten in an untrapped forest preserve. Ecol. Soc. of America 1996 Annual Combined Meeting. Providence, RI. August 14, 1996.
- Christ, M., M.D. David, P.J. McHale, J.W. McLaughlin, L.E. Rustad, M.J. Mitchell, and I.J. Fernandez. Controls on microbial biomass C, N, and P in spruce and northern hardwood forest soils. Poster presentation, Soil Sci. Soc. of America Annual Meeting, St. Louis, MO. October 29 - November 3, 1995.
- Gilmore, D.W., and R.S. Seymour. Crown structure, stem form development, and foliage-sapwood area relationships for balsam fir in central Maine. Poster presentation, SAF National Convention, Portland, ME. October 28-29, 1995.
- Greenwood, M.S. Modeling ecosystem processes: Are measurements of physiological parameters relevant? SAF National Convention, Portland, ME. October 28-29, 1995.
- Greenwood, M.S. Environmental after-effects: Temperature stress and genetic change. SAF National Convention, Portland, ME. October 28-29, 1995.
- Greenwood, M.S. Maine's forests. Interview for TV program "Quest". Program aired January 9, 1996.
- Greenwood, M.S. Literature review of genetics and propagation of paper birch. Hardwood Silviculture Workshop, Bangor, ME. May 29, 1996.
- Greenwood, M.S. Differential gene expression during maturation-caused decline in adventitious rooting ability in loblolly pine. Meeting chair, Second International Symposium on the Biology of Root Formation and Development, Jerusalem, Israel. June 23-28, 1996.
- Greenwood, M.S. Exploiting variation and hybrid vigor in a *Larix* sp. breeding program. NC State Tree Improvement Contact Meeting, Fredericton, NB. August 19-22, 1996.
- Greenwood, M.S. Loss of adventitious rooting ability during maturation in loblolly pine. Invited paper, Joint Meeting of IUFRO Working groups on somatic cell genetics and molecular genetics of trees. Gent, Belgium. October 23, 1995.
- Greenwood, M.S. Site visitation. J.D. Irving Black Brook. Fredericton, NB. August 19-22, 1996.
- Harrison, D.J. Influence of forest harvesting on marten populations in northern Maine. SAF National Convention, Portland, ME. October 28-29, 1995.
- Harrison, D.J. Habitat requirements of American marten: Reassessing paradigms. Seminar presented to Department of Wildlife Ecology, Orono, ME. November 28, 1995.
- Harrison, D.J. Marten, forests, and biodiversity: a model for conservation. Maine Forest Biodiversity Conference, Ellsworth, ME. March 12, 1996.
- Harrison, D. J. Funding, infrastructure, and partnerships for wildlife conservation in the U.S. Seminar presented to Department of Ecosystem Planning, Tokyo Noko University, Japan. March 20, 1996.
- Harrison, D. J. Habitat relationships of American marten: specialist or generalist. Seminar presented to U. S. Forest Service Redwood Sciences Laboratory and College of Natural Resources, Humboldt University, Arcata, CA. March 28, 1996.
- Harrison, D. J. Influence of spatial and body scaling on habitat selection by mammalian carnivores. Presentation to Utah Cooperative Fish and Wildlife Research Unit and Dept. of Fisheries and Wildlife, Univ. of Utah, Logan. April 5, 1996.
- Harrison, D. J. Influence of spatial and body scaling on habitat selection by mammalian carnivores. Seminar presented to Dept. of Zoology and Physiology, Univ. of Wyoming, Laramie. April 11, 1996.

- Harrison, D. J. Marten as a barometer of forest health in Maine. Annual Meeting, Maine Chapter of The Wildlife Society, Brewer, ME. April 25, 1996.
- Harrison, D.J., D. Payer, and H.J. Lachowski. Influence of forest harvesting and forest structure on habitat selection by American marten. Presentation and field tour to NCASI and other forestry industry representatives. Millinocket, ME. August 22, 1996.
- Houtman, N.R. Weymouth Point Study. White Paper Series "Forestry in the spotlight," College of Natural Resources, Forestry and Agriculture, Orono, ME. September 16, 1996.
- Leathers, M.A., and R.D. Briggs. Height development of sugar maple on four habitat types in western Maine. Poster presentation, SAF National Convention, Portland, ME. October 28-29, 1995
- McCormack, M.L., Jr. General chair, SAF National Convention, Portland, ME. October 28-29, 1995.
- McCormack, M.L., Jr. Maine's forests. Interview for TV program "Quest." Program aired January 9, 1996.
- McLaughlin, J.W., I.J. Fernandez, S.M. Goltz, L.E. Rustad, and L. Zibilski. Biogeochemical cycles of carbon, nitrogen, and sulfur at the Howland integrated forest study sites, Howland, ME. Poster Presentation, SAF National Convention, Portland, ME. October 28-29, 1995
- McLaughlin, J.W. Cooperative Forestry Research Unit's Soil-Site Quality Program: current and future research initiatives. Informational session for Cooperative Extension Faculty, Orono, ME. September 18, 1996.
- Ostrofsky, W.D., and P.T. Caron. Quantity and condition of advance regeneration following hardwood overstory removal using a single-grip processor. Poster presentation to CFRU Advisory Committee, Millinocket, ME. September 20, 1995.
- Ostrofsky, W.D. Understanding tree biology and improving forest health. Workshop and field tour, Orono, ME. October 19, 1995.
- Ostrofsky, W.D. Innovative funding alternatives. The CFRU: An industrial cooperative. Presentation at the National Extension Forester's Conference, Portsmouth, N.H. October 27, 1995.
- Ostrofsky, W.D. Changes in tree health following low thinning of a paper birch stand. Poster presentation, SAF National Convention, Portland, ME. October 28-29, 1995.
- Ostrofsky, W.D. The Cooperative Forestry Research Unit: Twenty years of accomplishments. Poster presentation, SAF National Convention, Portland, ME. October 28-29, 1995.
- Ostrofsky, W.D. The Cooperative Forestry Research Unit. Presentation to the National Research Council of Canada, Quebec, P.Q. November 1, 1995.
- Ostrofsky, W.D. Tracing log defects from living trees to the product. Presentation to the Maine Hardwood Association, Waterville, ME. December 6, 1995.
- Ostrofsky, W. D. Vice-Chair (Program Chair) for the Northeastern Forest Pest Council, Albany. New York, March 11-13, 1996.
- Ostrofsky, W.D. Understanding tree biology and improving forest health. Workshop and field tour, Orono, ME. September 5, 1996.
- Ostrofsky, W.D. The importance of past logging history on stand hazard assessment. Presentation in Forest Logging Safety Workshop, Orono, ME. September 18, 1996.
- Seymour, R.S. Maine's forests. Interview for TV program "Quest." Program aired January 9, 1996.
- Seymour, R.S. NESAF, Lowell, MA, March 19-21, 1996. Panelist on Green Certification Program.
- Seymour, R.S. Silvicultural impacts of the Ban Clear-Cutting referendum. Presentation to the Maine Legislature. Augusta, ME. March 25, 1996.
- Seymour, R.S. The Maine Council on Sustainable Forest Management: Current Forest Politics in Maine, Forestry Noontime Seminar Series, University of Maine, Orono, ME. April 12, 1996.
- Shepard, R.K. Wood ash and sludge treatments on forest sites in Maine. Presentation to National Bioash Utilization Conference, Portland, ME. April 29-30, 1996.
- Simmons, J.A., I.J. Fernandez, R.D. Briggs. Soil respiration and net N mineralization among a climate gradient in Maine. Poster presentation, SAF National Convention, Portland, ME. October 28-29, 1995.
- Wilson, D. and R.S. Seymour. Density management diagram for spruce-fir in Maine. Poster presentation, SAF National Convention, Portland, ME. October 28-29, 1995.

**COOPERATIVE FORESTRY RESEARCH UNIT  
ADVISORY COMMITTEE  
1996 Membership**

The CFRU Advisory Committee sets priorities and reviews proposals for the Cooperative Forestry Research Unit. Members active during all, or part, of 1996 were

Anthony Filauro, Great Northern Paper (Chair)  
Peter Triandafillou, James River Timber Corporation (Vice Chair)  
Si Balch, Boise Cascade Corporation (Financial Officer)  
Brian Higgs, Baskahegan Company (Member at Large)  
G. Bruce Wiersma, Dean, College of Natural Resources, Forestry and Agriculture  
John Cashwell, Seven Islands Land Company  
Douglas Denico and Carl Haag, S.D. Warren Company  
Robert Frank, USDA Forest Service  
Dennis Gingles, International Paper Company  
Peter Ludwig, Champion International Corporation  
Thomas A. Morrison, Maine Bureau of Parks and Lands  
John D. Stowell, Timberlands, Inc.  
Phil Sullivan, J.D. Irving, Limited  
Kevin Topolniski, Fraser, Inc.  
John Trobaugh and Bob Barr, Georgia-Pacific Corporation  
Henry Whittemore, Hancock Timber Resource Group

**CFRU STAFF  
(September 30, 1996)**

**Program Leaders**

William D. Ostrofsky, Associate Research Professor of Forest Resources (CFRU Leader)  
Maxwell L. McCormack, Jr., Research Professor of Forest Resources James W.  
McLaughlin, Assistant Research Professor of Forest Resources

**Professional Staff**

Stephanie S. Arnold, Assistant Scientist  
Peter Caron, Research Associate Richard J.  
Dionne, Research Associate Eleanor G.  
Heinz, Administrative Assistant

**Cooperating Professors**

Michael S. Greenwood, Professor of Forest Resources Robert S.  
Seymour, Professor of Forest Resources Robert K. Shepard,  
Professor of Forest Resources Katherine K. Carter, Associate  
Professor of Forest Resources Daniel J. Harrison, Associate  
Professor of Wildlife

## CFRU COOPERATORS 1996

Baskahegan Company  
Bethel Furniture Stock, Inc.  
Boise Cascade Corporation  
Bouchard, H.O., Inc.  
Champion International Corporation  
Field Timberlands  
Finestkind Tree Farms  
Fraser, Inc.  
Georgia-Pacific Corporation  
Great Northern Paper, Inc.-Bowater  
Hancock Timber Resource Group  
Haynes, H.C., Inc.  
Huber, J.M. Corporation  
International Paper Company  
Irving, J.D., Ltd.  
Isaacson Lumber Company  
James River Timber Corporation  
Knight Tree Farm  
LandVest

Madden, Inc., F.A.,  
Maine Bureau of Public Lands  
Maine Christmas Tree Association  
Maine Power Services  
Moosehead Manufacturing Company  
Penley Corporation  
Prentiss & Carlisle  
Pride Manufacturing Company  
Robbins Lumber Company  
Ste. Aurelie Timberlands Co., Ltd.  
Saunders Brothers  
Seven Islands Land Company  
Sewall Company, James W.  
Timberlands Corporation  
Totman, General Clayton O.  
Wales & Son, Rodney H.  
Warren, S.D. Company  
Western Maine Nurseries

## OTHER ORGANIZATIONS PROVIDING SUPPORT FOR CFRU PROJECTS

Cooperative States Research Service  
Maine Agricultural & Forest Experiment Station  
Maine Forest Products Council  
Maine Forest Service  
McIntire-Stennis

Monsanto Agricultural Products Company  
Timberland Enterprises, Inc. USDA  
Northeastern Forest Experiment Station USDA  
State & Private Forestry

## APPENDIX A

### Terminology

SCIENTIFIC NAME	COMMON NAME
<i>Abies balsamea</i> (L.) Mill.	Balsam fir
<i>Abies</i> spp.	Fir
<i>Acer pensylvanicum</i> L.	Striped maple
<i>Acer rubrum</i> L.	Red maple
<i>Acer saccharum</i> Marsh.	Sugar maple
<i>Betula alleghaniensis</i> Britton	Yellow birch
<i>Betula papyrifera</i> Marsh.	Paper birch
<i>Castanea dentata</i> (Marsh.) Borkh.	American chestnut
<i>Fagus grandifolia</i> Ehrh.	American beech
<i>Fraxinus americana</i> L.	White ash
<i>Larix decidua</i> Mill.	European larch
<i>Larix gmelinii</i> (Rupri) Litvin	Dahurian larch
<i>Larix laricina</i> (Du Roi) K. Koch	Tamarack
<i>Larix leptolepis</i> (Sieb. & Zucc.) Gord.	Japanese larch
<i>Larix sibirica</i> Ledeb.	Siberian larch
<i>Larix</i> spp.	Larch
<i>Picea abies</i> (L.) Karst.	Norway spruce
<i>Picea glauca</i> (Moench) Voss	White spruce
<i>Picea mariana</i> (Mill.) B.S.P.	Black spruce
<i>Picea rubens</i> Sarg.	Red spruce
<i>Picea</i> spp.	Spruce
<i>Pinus banksiana</i> Lamb.	Jack pine
<i>Pinus resinosa</i> Ait.	Red pine
<i>Pinus strobus</i> L.	White pine
<i>Populus</i> spp.	Aspen
<i>Rubus</i> spp.	Raspberry
<i>Tsuga canadensis</i> (L.) Carr.	Eastern hemlock
<i>Alces alces</i> L. <i>Blarina</i>	Moose
<i>(brevicauda)</i> Say <i>Castor</i>	(Shorttail) shrew
<i>canadensis</i> Kuhl <i>Clethrionomys</i>	Beaver
<i>gapperi</i> Vigors <i>Lepus americanus</i>	Red-backed vole
Erxleben <i>Maries americana</i>	Snowshoe hare
Turton <i>Peromyscus maniculatus</i>	American marten
Wagner <i>Sorex (cinereus)</i> Kerr	Deer mouse
<i>Tamiasciurus hudsonicus</i> Erxleben	(Masked) shrew
<i>Ursus americanus</i> Pallas	Red squirrel
	Black bear
<i>Choristoneura fumiferana</i> Clemens	Spruce budworm
<i>Cryptococcus fagisuga</i> Lind.	Beech scale

