

# CFRU Information Report 41

1997 ANNUAL REPORT AND  
RESEARCH SUMMARY OF THE  
COOPERATIVE FORESTRY RESEARCH UNIT

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



All best wishes to Dr. Maxwell L. McCormack on the occasion of his retirement as Research Professor, College of Natural Resources, Forestry, and Agriculture, University of Maine, June 30, 1997.

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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.

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## ADVISORY COMMITTEE CHAIR'S REPORT

### Membership Committee

The Membership Committee solicits new members to join the CFRU and routinely meets with current member companies to discuss research programs and other priorities. In July, the Membership Committee met with a representative of Champion International Corporation. In August, a meeting was held with Seven Islands Land Co.

### Ad Hoc Committee

At the September meeting of the Advisory Committee, discussion focused on

1. the research objectives adopted for the current five-year cycle,
2. the funding mechanism used for support of research projects undertaken by the CFRU, and
3. opportunities that may be available to better coordinate research efforts within the university and between academic institutions.

In response to the issues raised, an ad hoc committee was formed to examine options for improving the operation and structure of the CFRU. The committee will focus on the issues raised at the September meeting and will report their findings and recommendations to the Advisory Committee in 1998.

### Personnel Changes

On July 1, Dr. Maxwell McCormack retired from the CFRU after 21 years of service. Dr. McCormack's silvicultural research work significantly improved how forest management is practiced in the state of Maine. His legacy is evident on many forest lands managed in Maine.

In honor of Dr. McCormack's accomplishments in forest research and his service to the CFRU, on September 23, the Advisory Committee voted Dr. McCormack to be an honorary lifetime member of the organization. Congratulations! Dr. McCormack joins Dr. Fred Knight, Professor Emeritus, as the only other individual to receive this honor.

In October, Dr. Robert Wagner, a senior scientist and program leader at the Ontario Forest Research Institute, accepted the silviculture position vacated due to Dr. McCormack's retirement. Dr. Wagner is a welcomed addition to the CFRU and fills an important role in the organization. Dr. Wagner will assume his duties at the CFRU in early 1998.

On June 30th, Eleanor Heinz retired as secretary of the Cooperative Forestry Research Unit. For the past ten years she assisted in carrying out the day-to-day activities of the CFRU. Eleanor did a good job and will be missed.

On August 11th, Margaret Colman assumed the secretarial responsibilities of the CFRU. She has made a smooth transition into the position, picking up where Eleanor left off.

In closing, it has been a challenge and a privilege to serve as chairman of the CFRU during the past two years. I thank the scientists, the staff, and the CFRU membership for the cooperative effort made in achieving our goals. The past few years have been difficult due to several personnel changes. Now with that behind us and a full staff on board for 1998, I look forward to the accomplishments we will achieve in the coming year.

Anthony Filauro, Chair  
CFRU Advisory Committee

## DEAN'S REPORT

The Cooperative Forestry Research Unit has undergone some substantial changes over the past two years, and continues to be an important factor in shaping the direction of forestry in Maine. These changes have been detailed in the following CFRU Leader's report. The College, too, has undergone some significant change during this period of time. On July 1, 1997, the College of Natural Resources, Forestry, and Agriculture became the College of Natural Sciences, Forestry, and Agriculture. The College now contains fourteen Departments or Units, including the CFRU. I am very confident that the new College structure will allow for even more interdisciplinary efforts, and see the change as one of great opportunity.

With respect to CFRU, this opportunity has been underscored this past year by two events. The first is that there is now a legislative initiative to develop substantial funding for "advanced technologies for forestry and agriculture." The potential for strengthening and improving the research mission of the College is tremendous. The second is that now, with several new scientists in place, the CFRU Advisory Committee has asked for a reevaluation of

priorities and structuring. This evaluation is currently underway by an ad-hoc committee of CFRU cooperators. Each of these efforts will strengthen the overall mission and accomplishments of the greater forestry community in the state. Now more than ever, the College, and the CFRU in its role, is poised to play a significant part in developing the path to sound forest resource use and protection. This is a most exciting challenge!

Over the past year, I have visited with many cooperators, and I continue to be impressed with your enthusiasm, sincerity, and focus toward providing the best management possible for the forest resources. I thank everyone with whom I have had contact for your frank discussions. They have been very helpful to me professionally, and have also been very personally rewarding. The challenges lay before us. The Cooperative Forestry Research Unit is newly charged. Lets go!

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



CFRU cooperators examining a white pine stand during the September CFRU Advisory Committee field tour, Township 39MD.

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**BALANCE SHEET**

1996-1997 Period  
10/1/96-9/30/97

ASSETS:

BALANCE FORWARD SEPTEMBER 30, 1996	\$589,608.03	
INVESTMENTS 10/01/96-09/30/97	38,031.56	
CONTRIBUTIONS RECEIVED FY96	52,506.50	
CONTRIBUTIONS RECEIVED FY97 LESS	430,979.00	
FY98 BUDGET TOTAL ASSETS:	<u>(523,134.00)</u>	587,991.09

EXPENSES:

VEHICLE REPLACEMENT - MCLAUGHLIN	0.00	
ADMINISTRATION - OSTROFSKY	63,430.61	
SILVICULTURE - MCCORMACK SOIL-SITE	131,884.69	
- MCLAUGHLIN HARDWOOD/ASH -	114,249.56	
OSTROFSKY SLUDGE/ASH - SHEPARD	91,955.58	
TREE IMPROVEMENT - GREENWOOD	4,636.71	
TREE IMPROVEMENT - CARTER	4,126.59	
GROWTH/YIELD - SEYMOUR PINE	26,226.97	
MARTEN - HARRISON	19,574.47	
	17,077.29	
TOTAL EXPENSES: 10/01/96-09/30/97		473,162.47
LESS VEHICLE ACCOUNT BALANCE		21,275.00
AS OF 09/30/97		<b>93,553.62</b>

## CFRU LEADER'S REPORT

The Cooperative Forestry Research Unit was marked by another year of significant change in personnel. As indicated in our annual report of last year, Dr. McCormack retired from the CFRU as of June 30, 1997. Dr. McCormack will always be recognized as the leading force in establishing the CFRU as a premier forestry research organization from its inception, and it is hoped that he will continue his interaction with CFRU activities as much as his time now allows.

Filling the all-important Silviculture position left by Dr. McCormack was, at the outset, a daunting task. However, the search effort was very successful in finding a research silviculturist of the highest caliber, Dr. Robert Wagner, to carry on the work. Dr. Wagner brings to CFRU a substantial record of experience and accomplishments in silviculture, vegetation management, and industrially oriented research. We are very pleased he will be joining us, and look forward to his continuing his energetic efforts with the Silviculture program. Dr. Wagner will be officially starting with the University of Maine on April 1, 1997.

As of June 30, 1997, CFRU Administrative Assistant Eleanor Heinz also retired. Eleanor worked for the CFRU for over ten years, and did an excellent, professional job. We wish her all the best for her retirement years. Her position was filled in August by Margaret Colman, who has adapted to her new job quickly and competently. We extend a warm welcome to Margaret.

As this Annual Report indicates, research has continued energetically. Dr. McCormack, in cooperation with Champion International Corporation, Dr. R. Briggs of the State University of New York, and the CFRU, has established some new trials of various fertilizer applications in precommercially thinned softwood stands. Although not reported in detail here, it is anticipated that Dr. Wagner will be coordinating closely with this effort during the coming year. A significant summary report is being prepared for presentation at the Ninth North American Forest Soils Conference. The report "Long-term effects of forest management on nutrients in spruce-fir forests,"

authored by R.D. Briggs, J.W. Hornbeck, C.T. Smith, R. Lemin, J. McLaughlin, and M.L. McCormack, will include much recently summarized data from the Weymouth Point Watersheds study.

Significant progress is being made by Dr. McLaughlin on the hardwood site classification system, in addition to other hardwood management studies he has recently established. Additional new information was described by graduate student Tracy Patton and myself on development of beech regeneration in hardwood stands damaged by beech bark disease.

The cooperating scientists have also continued enthusiastically with their projects. Dr. Seymour will be on sabbatical leave during the 1998 fiscal year, which has allowed for reallocation of some operating funding to other projects. Dr. Harrison has completed year four of a six-year portion of the pine marten study. Dr. Carter continues to evaluate well-established provenance plantings, and Dr. Greenwood continues work with accelerated breeding and propagation techniques for larch species. The work of Dr. Shepard has now shifted from examining effects of sludge and ash residuals on soil properties and tree growth to researching effects of various management strategies on wood quality properties. Much of this laboratory work is being done by CFRU Research Associate Richard Dionne, in addition to his duties in the Silviculture program.

Finally, some much-needed maintenance was accomplished at the CFRU building, located on the University forest property in Old Town. In addition to some restaining and cleaning, major drainage work was installed for the driveway and yard areas. This will ensure that the foundation will be preserved, and the building will remain functional for years to come.

I thank all our cooperators for allowing the completion of another successful year, and the CFRU staff for the continued support and efforts in bringing the CFRU back up to our full complement of personnel. I look forward to meeting the forestry challenges in the coming years with you.

William D. Ostrofsky, Leader  
Cooperative Forestry Research Unit

## SILVICULTURAL TECHNIQUES FOR THE IMPROVEMENT OF TIMBER QUALITY

Dr. William D. Ostrofsky

### Overview

The research effort over the past year has focused on the completion of a major study involving beech regeneration development in stands harvested to various residual densities. This project, conducted by M.S. graduate student T. Zschau, was completed in late June. The description and results of this project that appear below are taken from her thesis "Effects of Overstory Density and Beech Bark Disease Severity on Height Growth Patterns of American Beech and Associated Species." To date, two poster presentations were prepared from this work. The first described tree competition effects on beech sapling development and was exhibited at the New England Society of American Foresters meeting, held in Portland, Maine, in March. The second was an examination of the effects of the beech bark disease on height development of sapling beech and was exhibited at the Society of American Foresters National Convention in Memphis, Tennessee.

Continuing work included the remeasurement of trees in two studies designed to monitor the effects of papermill residual ashes on conifer growth. One study has provided six-year post-treatment results of sludge ash application to a black spruce plantation; the other provides four-year post-treatment results of sludge ash and wood ash applications in a red pine plantation. It is planned that monitoring of both studies will continue at two- or three-year intervals for several more years.

Invited presentations were made at two forest workshops. A seminar entitled "Tree injuries, harvesting practices, and the management of forest health" was delivered at the sixteenth annual insect and disease briefing held in Dubois, Pennsylvania, in March. The meeting was sponsored by Pennsylvania State Cooperative Extension and the Forest Pest Management Division of the Pennsylvania Bureau of Forestry. In May, the presentation "Basics for minimizing damage to residual trees" was delivered at the workshop "Exploring Opportunities for Low Impact Forestry in Hancock County" in Ellsworth, Maine.

With the completion of the beech regeneration project and with the ash amendment studies in a monitoring mode, this program is now in a position to consider new research efforts. With that in mind, during the summer a new graduate student was recruited, with the expectation of starting a new Ph.D. program in January of 1998. The specific project is yet to be determined, but will likely involve some aspect of the management of precommercially thinned softwood stands, a research effort discussed at the

CFRU Advisory Committee meeting in September. A research work plan is currently being developed, and will be proposed before the start of the 1998 field season.

### Harvesting Intensity, Beech Development, and the Beech Bark Disease

Considerable information has been developed over the past 20 years regarding the biology and management of beech and the beech bark disease (Ostrofsky and Houston 1989). Maintaining a favorable species composition and reducing the amount and development of susceptible beech is key to improving productivity in disease-affected stands. However, empirical data quantifying the interrelationships between harvesting intensity, the disease, and beech growth and development in forest stands is still very limited. Understanding the effects of overstory density and beech bark disease severity on early height growth development will provide a foundation for developing more accurate predictions of the dynamics of disease-affected stands. This study has two major objectives. The first objective is to evaluate differences in height growth patterns of sapling stage beech, paper birch, and yellow birch growing under different overstory residual densities. The second objective is to develop and evaluate an index for beech bark disease defects on sapling sized beech, for the purpose of determining the effect of the disease on early height growth.

This study by M.S. graduate student T. Zschau was done in cooperation with the Georgia-Pacific Corporation, which allowed the use of its Continuous Forest Inventory (CFI) data and provided access to its lands. Appreciation is extended to R. Sirken, Georgia-Pacific, for data assistance, and also to P. Caron, J. McLaughlin, and S. Arnold, CFRU, for providing help with various aspects of the field work.

The study design, methods, and plot locations were detailed in the 1996 CFRU Annual Report. Briefly, five CFI plots were located in each of four harvest treatments representing harvest intensities of uncut, light partial cut ( $>60 \text{ ft}^2 \text{ BA/A}$ ), heavy partial cut ( $21\text{-}59 \text{ ft}^2 \text{ BA/A}$ ), and clearcut. Only one harvest treatment was performed on these plots (with the exception of the uncut, where no harvesting was recorded) over the past 40 years. From each of three subplots at each location, three saplings were selected for stem analysis: one non-defective beech, one defective beech, and one associated competitor (yellow birch in the uncut and partial cut, paper birch in the clearcuts).

Table 1. Post-harvest over story conditions in each treatment

Treatment	Diameter (cm)	% Beech <sup>a</sup>	Beech Volume (mVha)
Uncut	21.5"	30	3293
	(20-23.4)	(10-54)	(21.72-60.58)
Light Partial	22.1	224	2889
	(20.3-25.7)	(12-38)	(13.86-49.72)
Heavy Partial	19.0	332	1459
	(18.3-19.8)	d-73)	(3.22-27.07)
Clearcut	20.8	218	439
	(16.5-29.7)	(0-95)	(0-18.88)

<sup>a</sup> mean (range)

<sup>b</sup> percentage beech in terms of m<sup>3</sup>/ha

### Characterization of Stands

The overstory and understory was characterized in each of the 20 selected plots. The overstory conditions immediately following the last harvest operation is shown in Table 1, while the current (1996) overstory conditions are summarized in Table 2.

Understory conditions immediately following the harvest operations were not noted in the CFI data, however the current understory conditions are shown in Table 3. The current understory conditions in the four treatments do vary in terms of basal area and density, but are similar in mean diameter and height.

Table 2. Current (1996) overstory conditions in each treatment.

Treatment	Diameter (cm)	% Beech <sup>b</sup>
Uncut	27.4"	12.7
	(22.9-32.2)	(6-26)
Light Partial	24	2.4
	(22.6-25)	(0-8)
Heavy Partial	23.6	37.7
	(23.1-25.4)	(0-85)
Clearcut	20.4	13.8
	(14.9-23.8)	(0-69)

<sup>a</sup>mean (range)

<sup>b</sup>percentage beech in terms of stems/ha

### Patterns of Sapling Beech and Birches

A comparison of beech height growth with that of yellow birch (partial cuts) and white birch (clearcuts) provided partial cuts and in the clearcuts (Table 4). Height documentation and quantified a generally accepted idea that growth rates of beech were below that of the birches the birches can out-compete beech if provided with enough light for all four treatments for the current (1991-1996) five-year period. Harvesting which improves (increases) light conditions will also improve the competitive advantage of the birches, but adequate birch regeneration must first be established or already present.

Table 3. Current (1996) understory conditions in each treatment.

Treatment	Basal Area (m <sup>2</sup> /ha)	Density (stems/ha)	Beech Total Height	All Species Total Height	% Beech <sup>a</sup>
Uncut	1.1"	1600	2.5	3.4	258
	(0.3-1.7)	(333-3417)	(1.7-3.4)	(2.7-4.8)	(0-93)
Light Partial	2.8	3383	3.2	3.5	210
	(0.8-4.6)	(1917-7250)	(2.9-3.5)	(2.6-5.6)	(0-61)
Heavy Partial	7.2	8633	3.4	4.0	294
	(4.7-13)	(5583-9667)	(2.5-4.4)	(3.6-4.7)	(9-53)
Clearcut	149	17717	3.3	4.3	219
	(8.6-18.5)	(10083-27333)	(1.8-4.3)	(3.2-5.1)	(16-31)

<sup>a</sup>percentage beech in terms of stems/ha

<sup>b</sup>mean (range)

Table 4. Mean five-year annual height growth rates (cm/year) for each species for the two time periods by treatment.

Species	Treatment	Height Growth Rate (cm/yr.)	
		Post-harvest	1996
American beech	Uncut	14(1) <sup>a</sup>	18(1)
	Light Partial	18(2)	19(4)
	Heavy Partial	22(2)	19(2)
	Clearcut	29(2)	24(2)
Yellow birch	Uncut	12(2)	27(3)
	Light Partial	39(6)	33(4)
	Heavy Partial	41(9)	32(5)
Paper birch	Clearcut	67(31)	35(4)

<sup>a</sup>10-30 years after the harvest  
<sup>b</sup>mean (standard error)

### Effects of Harvest Intensity on Beech Bark Disease Incidence

The percentage of understory beech affected with beech bark disease differs significantly between harvest treatments (Figure 1). The uncut and heavy partial cut treatments had the greatest percentage of defective beech, while the clearcut treatment had the lowest. The light partial harvest was intermediate in percentage of defective beech. Increasing harvest intensity resulted in a decrease in the proportion of young beech with the disease. This relationship likely occurs because the uncut and lightly harvested stands had a higher percentage and volume of residual, defective overstory beech. These overstory stems probably served as reservoirs for the beech scale insects and the *Nectria* fungus. Heavy cutting would result in a sanitation effect by reducing the population levels of both agents, and increasing the time required for reinfestation and reinfection of the developing stand.

### Effects of Harvest Intensity on Beech Bark Disease Severity

Defect levels of diseased beech were found to be significantly different ( $p = 0.018$ ) between harvest treatments. Mean defect level was highest on individual stems in the clearcut and heavy partial harvest treatments, and lower in the light partial harvest and unharvested treatments (Figure 2). Reasons for this relationship are not known for certain, but may relate to the nutritional quality of the stems for the insects. Beech saplings growing in an environment with a high light intensity have previously been shown to be growing faster in height. It may be possible that these rapidly growing high-vigor trees are also higher in nutritional quality as well, which could allow more favorable development of scale populations.

Interestingly, the percentage of beech in the overstory was found to have no significant effect on the severity of the defect supported by individual stems. This further suggests that individual tree variation in disease susceptibility is likely more of a factor than other stand conditions.

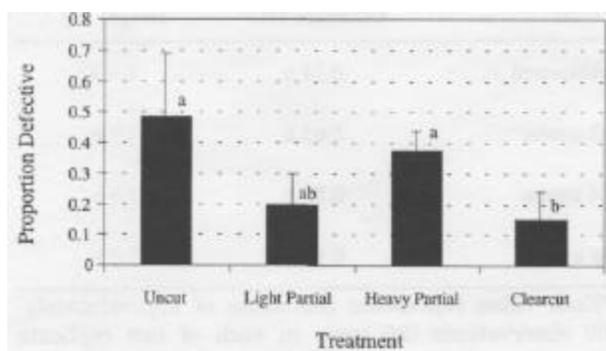


Figure 1. Percentage of understory beech damaged by beech bark disease, by harvest treatment. Bars with the same letters are not statistically different ( $P=0.05$ ).

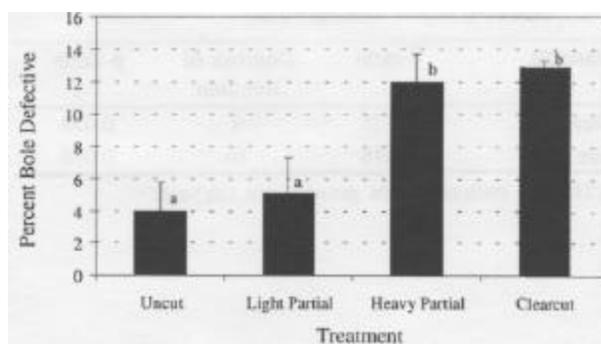


Figure 2. Defect levels of diseased beech, by harvest treatment. Bars with the same letters are not statistically different ( $P=0.05$ ).

**Effects of Beech Bark Disease Defect on Sapling Height Growth**

The effect of beech bark disease severity on sapling height development, a relationship quantified for the first time by this study, was assessed using a defect index developed specifically for this project. A significant relationship between current (1991-1996) beech height growth rates and current defect levels was described (Figure 3). As severity of external defect increases, height growth rates of affected saplings are reduced. Also, the addition of the defect factor to the regression of growth rate by site slightly improved the model of that relationship. (Table 5)

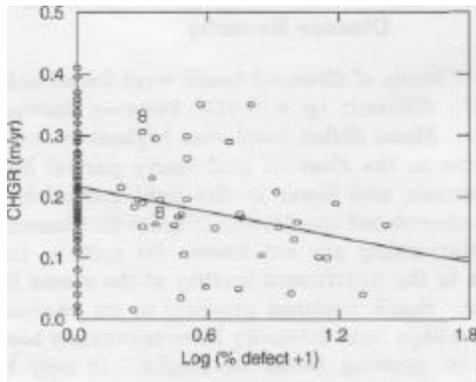


Figure 3. Periodic annual height growth rates for the most recent five years (1991-1996) of beech regeneration with different levels of beech bark disease defect. (CHGR = current height growth rates)

Table 5. Linear regression results for analysis of site and BED defect effects on current beech height growth. Equation is:  $CHGR^a = Constant + Log(\% \text{ defect} + 1) + \text{Site (categorical)}$

Variable	F ratio	Degrees of freedom	p-value
Defect	5.375	1 19	0.023
Site	1.618		0.070

<sup>a</sup>CHGR = current height growth rate (m/year)

**Remeasurements—Papermill Sludge Ash and Wood Ash Studies**

**Black Spruce**

In 1991 a study was established in King and Bartlett Township on International Paper Company lands, to assess effects of papermill sludge ash on growth of planted black spruce. Four treatments of the residual ash material were applied based on CaCO<sub>3</sub> equivalent rates of 0, 2, 4, and 6 tons/A. Details of the plot layout and study design are outlined in the 1992 CFRU Annual Report.

In 1994, three years (growing seasons) post-treatment, no significant differences in black spruce height growth were evident between treatments (1994 CFRU Annual Report). However, a significant difference in root collar basal area was found. Crop trees in the control plots (0 tons/A CaCO<sub>3</sub> equiv.) had larger root collar diameters than did those in treated plots. At that time, observations from this and other studies indicated that the herbaceous vegetation was stimulated by the ash amendments. This increased competition was suggested as the cause for the retarded growth of the crop trees in the ash-amended plots.

In August of 1997, height and diameter of the spruce (six growing seasons post-treatment) were measured again. Although the crop trees are well above the herbaceous competition now (the site was treated twice with an herbicide aerially applied), the growth differences between the treatments are still apparent. (Table 6). Not only is the mean diameter (taken at 2 ft above ground) of the trees in the control plots greater than the diameter of those in the treated plots, but height of trees is also significantly different between treatments. Trees in the control plots are 0.5 to 1 ft greater in height, with the height difference increasing with increasing ash application. That

Table 6. Black spruce height and diameter by treatment six years (growing seasons) after ash application.<sup>3</sup>

Treatment Rate <sup>a</sup>	Diameter (in.) <sup>c</sup>	Height (ft)
Untreated	0.74a	8.6a
2 tons/ac	0.63b	7.9b
4 tons/ac	0.57b	7.5b
6 tons/ac	0.54b	7.5b

<sup>a</sup>Each value represents the mean of approximately 80 observations (20 trees in each of two replicate plots, in each of two blocks) per treatment. Values followed by the same letter, within columns, are not significantly different. <sup>b</sup>CaCO<sub>3</sub> equivalent. <sup>c</sup>Diameter measured at 2.0 ft above ground.

Table 7. Red pine height and diameter by treatment, four years (growing seasons) after ash application.<sup>3</sup>

Residual	Treatment Rate <sup>a</sup>	Diameter (in.) <sup>b</sup>	Height (ft)
Sludge Ash	Untreated	1.23	5.3
	3 tons/ac	1.40	5.8
	6 tons/ac	1.30	5.7
	9 tons/ac	1.41	5.9
Wood Ash	Untreated	1.27	5.6*
	3 tons/ac	1.29	5.5
	6 tons/ac	1.39	5.9
	9 tons/ac	1.45	6.1*

<sup>a</sup>Each value represents the mean of 54 observations (nine trees in each of six replicate plots) per treatment.

<sup>b</sup>CaCO<sub>3</sub> equivalent.

<sup>c</sup>Diameter measured at 2.0 ft above ground.

\*Values followed by an asterisk are significantly different at P=0.05 using Tukeys studentized range test.

these differences have continued for so long a period of time in spite of vegetation control indicates that serious consideration be given to timing of the ash residual application and the timing of subsequent vegetation management efforts. How long these growth differences will persist is unknown, but continued monitoring of the plantation is planned.

### Red Pine

This study was established in 1992 to assess effects of papermill sludge ash and wood ash residuals on the growth of planted red pine. The study site is located in Caratunk Township on S.D. Warren Co. lands and consists of 48 plots each containing nine planted red pine and nine sugar maple seedlings (or sprouts) of natural origin. Details of the study are outlined in the 1993 and 1994 CFRU Annual Reports. Half the plots were treated with papermill sludge ash, and half with wood ash at rates of 0, 3, 6, or 9 tons CaCO<sub>3</sub> equivalent per acre. The development of sugar maple, although being monitored in conjunction with that of the red pine, has not yet been fully analyzed and will be reported at another time. Sugar maple growth continues to be affected by a moderate level of browsing damage, which has been shown to be unrelated to ash application rate or type.

In spring of 1997, four growing seasons after ash application, plot maintenance in the form of competition control with brush saws was completed, and the crop trees were remeasured. Competition

control with brush saws has been regularly applied to these plots since the start of the study in an attempt to minimize competition effects and residual ash interactions. The 1997 growth data revealed no significant effects of sludge ash application on diameter growth or height growth of the planted red pine (Table 7). For the wood ash treatments, a significant difference in height growth, but not diameter growth, was found only between the untreated plots and the 9 ton/A treatment.

### Additional Work and Future Directions

Two topics are being explored as potential study areas for this program. One line of studies will propose additional work on beech management problems, and a second effort will be to address various management aspects of precommercially thinned softwood stands.

There is a continued need to pursue management options of American beech, especially in light of the recognized value that beech has as a supplier of hard mast for a variety of wildlife species. The beech bark disease likely has had a significant impact on beech nut production, both by decimating large-diameter trees capable of producing large amounts of seeds and by the action of the disease on reducing tree energy reserves. Neither of these aspects have been intensively studied or quantified in Maine. A more thorough understanding is needed of the flowering and fruit production aspects of beech. Use of resistant beech stock is also of interest for producing disease-resistant material for both timber and wildlife. To this end, a few days were spent this past summer assessing flowering phenology and nut production on several trees known to be resistant to the beech scale (Figure 4). Mature nut production was nearly non-existent in the Bangor and Franklin areas, the two areas closely examined. Initial setup of beech scale insect traps was also carried out at the Penobscot Experimental Forest and at a site near Lambert Lake, to develop a source of insects for tree resistance testing (Figure 5)

At the September CFRU Advisory Committee meeting, a new research focus was proposed to examine various aspects of intensively managed spruce-fir forests now at, or rapidly approaching, commercial thinning size. While the principal interest is to better understand the growth and yield dynamics of these precommercially thinned stands, many other questions also need to be answered if these stands are to be appropriately managed. Harvesting/stand damage interactions, windthrow susceptibility, and root disease, soil, and spacing/thinning relationships are three areas that will be explored for future studies. This effort is expected to begin in January, with the arrival of a new graduate student who will be assigned to this program.



Figure 4. Male flowers of American beech.

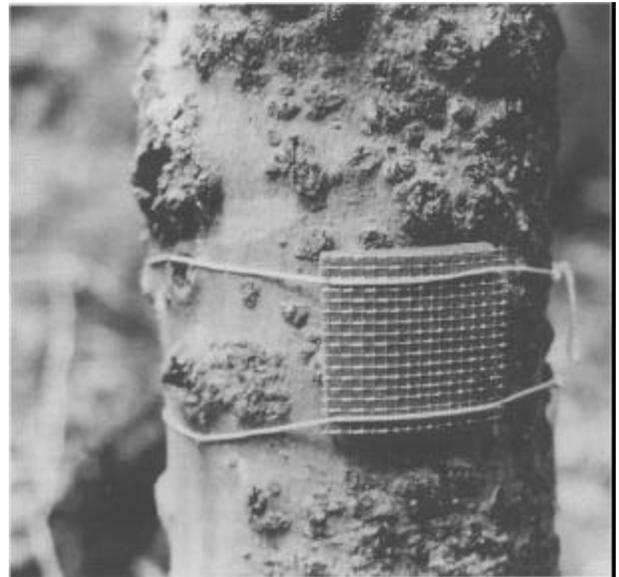


Figure 5. Method used to propagate dense colonies of the beech scale insect to assess resistance of study trees.

### Literature Cited

- Cooperative Forestry Research Unit. 1994. 1994 Annual Report and Research Summary of the Cooperative Forestry Research Unit. Maine Agric. Expt. Sta. Misc. Rept. 389. 57 p.
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## SITE QUALITY

Dr. James W. McLaughlin

### Introduction

Program emphases over the past year have included both the hardwood classification project and the Weymouth Point Watersheds study. We have made tremendous progress with the classification project that the cooperators will find very useful in devising their management plans. We have also initiated a crop tree release study focusing on yellow birch in conjunction with Georgia-Pacific Corporation, as part of our management recommendations for the classification project. For the Weymouth Point initiative, we have brought on Richard Cobb as a master of science degree student from Northern Arizona University. Richard worked with the Forest Soils Group at Northern Arizona for two years. He also spent this past summer working in Alaska at the Toolik Long-Term Ecology Research Site. Richard's project will focus on precommercial thinning effects on soil carbon, nitrogen, and phosphorus cycling. We plan to couple Richard's work with the past work at Weymouth Point, conducted by Drs. Maxwell McCormack, Jr., and Russell Briggs, the projected commercial thinning study, and other regional studies on softwood silviculture and soil nutrient cycling. Taken together, these studies will allow us to develop a comprehensive conceptual model concerning forest management of the spruce-fir forest type and soil nutrient cycling in Maine.

The remainder of this report is devoted to the studies undertaken to date. Potential research that deals with both softwood and hardwood silviculture relationships to site quality that will improve our ability to manage the forest resource on a sustainable basis is also suggested throughout the report.

### Site Classification

We completed our sampling on Georgia-Pacific Corporation and Baskahegan Company lands this past field season. We have now located stands in conjunction with Champion International Corporation. We will focus our efforts there for the first part of the 1998 field season. After that is completed, we will move our sampling efforts to northern Maine, where we plan to establish sites in conjunction with Fraser Paper, Ltd., J.D. Irving, Ltd., and Seven Islands Land Company. We have also begun to incorporate the work conducted by Dr. Russell Briggs and his coworkers for western Maine into the grand scheme of the classification project.

An introduction to the classification project, including terminology and methodology was previously reported by McLaughlin (1996) in the 1996 Annual Report and Research Summary. The reader is referred to that report for the introduction and methodology of the classification system. The focus of this year's report is an interpretation of the results to date and to introduce a preliminary field guide.

This report emphasizes eastern Maine. Also, we have begun to re-analyze the data for western Maine that were collected by Dr. Russell Briggs and his coworkers. The western Maine data will be thoroughly worked up this winter and presented in more depth in the 1998 report. However, we will be very happy to share the information with any of the cooperators during the interim. We would also emphasize that, although the focus of the classification system is hardwoods, we continue to also sample mixed wood and softwood stands. We strongly believe that all forest types must be included in a common classification system. We will not be repeating the previous efforts of Dr. Russell Briggs, but will build upon his exceptional work. The remainder of the Site Classification portion of the report will be devoted to a discussion of the results to date and the field guide.

### Relationships of Species Basal Areas with Soil Variables

Canonical correspondence analysis (CCA) was used to describe species basal area distribution along soil gradients in eastern Maine. However, before the results are discussed, a brief description of CCA is warranted. Species points represent the dominant patterns in community composition insofar as they can be explained by the environmental variables. In addition, the species points and the arrows of the environmental variables jointly reflect the species distributions along each of the environmental gradients (Ter Braak 1986). In a CCA diagram, only the directions and relative lengths of the environmental arrows convey information. Each arrow determines a direction or canonical axis in the diagram, obtained by extending the arrow in both directions. From each species point, a perpendicular line is dropped to the axis to determine the species position along a particular axis.

The eigenvalues in Table 8 show that canonical axis 1 explains most of the variation in the data of the three major canonical axes. The ratio of the eigenvalue to total variance indicates the proportion of variance explained by a given ordination axis. Those values are given in the variance in species data rows in Table 8. The correlation coefficients also indicate that axis 1 is most strongly related to species-soil variables (Table 8). However, the measured soil variables only explained 4.6% of the total variability in the species data.

Inclusion of the data we collect from Champion International Corporation lands may help improve the explained variation based on the soil variables we are measuring. This would be through increasing the spread in soil drainage classes and texture, as well as providing a better contrast with the landscape measurements. Other possible data that may help improve the explained variability are soil nutrient

Table 8. Axis summary statistics for canonical correspondence analysis of species basal areas for eastern Maine forests (total variance in the species data=4.566).

	Axis 1	Axis 2	Axis 3
Eigenvalue	.312	.149	.111
Variance in species data			
% of variation explained	6.800	3.300	2.400
Cumulative % of variation explained	6.800	10.100	12.500
Pearson Correlation, species-soil	.702	.464	.478
Kendall (Rank) Correlation, species- soil	.566	.209	.356

Table 9. Correlations of canonical axes with soil variables for eastern Maine.

Soil variable	Axis 1	Axis 2	Axis 3
Forest floor depth	.827	.201	.483
Total solum depth	-.730	.282	.383
Depth to mottling	-.820	-.158	.273
Texture	.460	.892	-.402

measurements. This would likely not be economically feasible for a large-scale study because of the high analytical costs associated with soil nutrient analyses.

In interpreting percentages of variance explained, it must be kept in mind that the goal is not 100% because part of the total variance is due to noise in the data. Even an ordination that explains only a low percentage is often quite informative (Ter Braak 1986). However, it would be beneficial to make attempts to improve the amount of explained variation. Including the landscape variables, such as slope position, percent slope, slope shape, elevation, and aspect failed to improve the explained variation for the eastern Maine data set. However, the preliminary CCA analysis for western Maine has shown that the landscape variables were more strongly related to species basal areas than were soil variables. The total explained variability for western Maine, by the landscape variables, was, however, only 2.7%.

An explanation of the CCA diagram for eastern Maine, shown in Figure 6, is that the first canonical axis is related to forest floor depth, solum depth, and depth to mottling (see Table 9, also). The interpretation is that as forest floor depth increases, there is a decrease in both depth to mottling and total solum depth, as represented by the first canonical axis. The second axis represents soil texture, while the third axis (not shown) represents a forest floor, total solum depth, and soil texture gradient.

The first observation in Figure 6 is that softwoods and hardwoods separate along the first axis, although mountain maple is associated with softwoods.

The softwood species occupy areas of thick forest floor, shallow mottling depth, and shallow total solum depth. This implies that softwoods are most common on very poorly drained soils. The various softwood species separated out quite well along axis 2 (soil texture). Northern white cedar occupies the most poorly drained sites and balsam fir and black spruce the other end of the drainage class gradient for softwoods. In terms of soil texture, white pine occupies one end of the gradient sandy soils (outwash) and black spruce occupies the other end (silt loams).

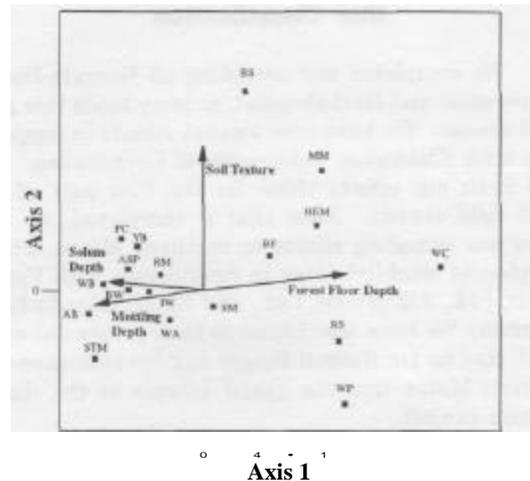


Figure 6. Canonical Correspondence diagram of the distribution of basal area for major species in hardwood forests of eastern Maine with soil variables (AB=American beech, ASP=aspen, BW=basswood, BF=balsam fir, BS=black spruce, HEM=hemlock, IW=ironwood, MM=mountain maple, PC=pin cherry, SM=sugar maple, STM=striped maple, RM=red maple, RS=red spruce, WA=white ash, WB=white birch, WC=white cedar, WP=white pine, YB=yellow birch).

The hardwood species did not separate out as well as the softwoods (Figure 6). But, some safe inferences are possible. Beech and white birch occupy areas that have relatively thin forest floors, and deep soils with fairly deep mottling depths (Figure 6). This indicates that those species are associated with better drained sites. Yellow birch, basswood, white ash, and ironwood appear to associate with more poorly drained soils than beech or white birch (Figure 6). Yellow birch, white ash, and ironwood are separated from one another based on soil texture, with white ash more dominant on loamy sands, ironwood on sandy loams, and yellow birch on loams. Sugar maple appears to be most common on the more poorly drained soils with loamy sand and sandy loam textures. However, sugar maple is not found on the very poorly drained soils that are occupied by softwoods.

The results obtained from CCA for drainage class are consistent with those from the actual data. For instance, sugar maple occurs throughout soil drainage classes, but is most pronounced on the poorly drained soils (see Tables 15 and 17 in this report). Inclusion of the data that we will be collecting from Champion International Corporation landholdings will likely make the separation even more convincing because some of the sites we have located are on both sandier and heavier textured soils than we have sampled to date.

**Field Guide**

The field guide is presented by the Ecological Land Classification (ELC) system of the USDA Forest Service (Smith and Carpenter 1996). The ELC for eastern Maine is the following:

*Ecoregion:* Warm Continental Division  
Laurentian Mixed Forest Province

*Section:* Maine-New Brunswick Foothills and Lowlands

*Subsection:* Maine Foothills

*Land Type Associations,*  
*Land Types,*  
*and Land Type Phases:* have not yet been delineated for Maine.

We have identified five site types, defined by surficial deposits, thus far: deep glacial till, shallow glacial till, marine clays, shallow-to-bedrock, and outwash plains. For the purposes of this presentation, the focus is deep glacial till site type. We have identified the sugar maple-American beech forest station, based on cluster analysis (see 1996 Annual Report and Research Summary for description of methods) as the climax stage within the deep glacial till site type. Within this forest station, maple-beech and mixedwood forest cover types occur. For intermediate stage stands within the deep till site type, the beech-birch-maple forest station has been iden-

<b>Site Type: Deep Till</b>	
<b>Climax Stage:</b>	Forest Station: Sugar Maple - American Beech
	Forest Cover Types: Maple-Beech; Mixedwood
	Shrubs: Striped Maple, Elderberry
	Herbs: Wild Lily, Starflower
<b>Intermediate Stage:</b>	Forest Station: Beech - Birch - Maple
	Forest Cover Types: Beech-Birch, Beech-Maple, Maple-Ash; Mixedwood

**Shrubs:** Elderberry (*Sambucus pubens* Michx.)

**Herbs:** Wild Lily (*Mnitinliertnim cantidense*), Starflower (*Trientalis borealis*), Solomon Seal (*Polygonatum spp.*); Sweet cicely (*Oshmorhiza claytoni*); Lady Fern (*Adiantum filix-femina*), Spinulose Shield Fern (*Dryopteris spinulosa*); Sedge (*Carex spp.*)

<b>Site Type: Deep Till</b>		Geomorphological Type: Deep Basal Till
0	O	Texture: Loamy Sands to Silt Loams
2	BW	
4	Bs	Drainage: Moderately Well Drained to Poorly
6		
8		
10		
12		
14	Bh: Trace	
16		
18		
20	BC	Mottling Depth: 22 h
22		
24	C	Rooting Depth: 13 in
26		
28		

Figure 7. Forest stations and soil variables for deep till site type for eastern Maine.

tified. The forest cover types within this forest station are beech-birch, beech-maple, maple-ash, and mixed wood (Figure 7). A list of common shrub and herbaceous vegetation is also included in Figure 7. We have preliminarily identified Solomon seal (*Polygonatum spp.*) and sweet cicely (*Oshmorhiza claytoni*) as indicators of high quality sites. The indicator species data will be more thoroughly analyzed over the course of the next field season.

Soil texture within the deep till site type ranges from loamy sands to silt loams, and drainage classes range from moderately well to poorly drained (Figure 7). Figure 7 also presents information concerning soil horizons, average depth to mottling, average rooting depth, and total solum depth.

Table 10. Period of optimum operability for skid trails for the sugar maple-beech and sugar maple-birch-beech forest stations of eastern Maine.

**Drainage Period of Optimum Operability**

Excessively Well	January through December
Moderately Well	May through February
Somewhat Poorly	June through February
Poorly Very Poorly	July through September
Poorly	July through September On frozen soil

**Operational Constraints**

A development of operational constraints is also included in the field guide. Table 10 shows optimum operability for skid trails based upon soil drainage class. This will be modified to include soil texture and landscape position for the final draft of the field guide. Table 11 shows potential consequences for harvesting during the inappropriate season, stratified by soil drainage class. We strongly recommend only harvesting on very poorly drained soils on frozen ground to minimize soil productivity and water quality degradation. Another strong recommendation is only harvesting during dry periods on soils that are somewhat poorly and poorly drained. However, we realize that actual management plans will be dependent upon the soil map units within a given forest station, but every possible effort to coordinate harvesting plans with seasonality based upon soil drainage class should be made.

**Silvicultural and Ecological Information for Primary Species**

Silvicultural and ecological information will include a general description of species that are common to the different soil series/associations and drainage classes as shown in Table 12. Table 13

shows the potential forest productivity and reforestation recommendations that are being developed for eastern Maine. Table 14 shows an example of how the site index values will be presented in the field guide. Tables 13 and 14 are currently shown by soil drainage class. However, these will further be stratified by soil textural classes, as well as drainage class in the final field guide.

Tables 15 through 18 give information on overstory basal area and density for each species, by soil drainage class for each of the forest stations identified. The basal area values for each species generally follow the pattern that was shown for the CCA.

Sugar maple occurs throughout all drainage classes delineated thus far. Dubis (1994) found a similar result for sugar maple in western Maine. However, Leathers (1996) reported that the growth efficiency for sugar maple was best on moderately well and somewhat poorly drained soils. We would expect similar relationships in eastern Maine based upon our knowledge of sugar maple ecological and biological requirements (i.e., sugar maple is a nutrient demanding species and will perform best on nutrient rich soils). The site index values we are presently working on will help confirm or refute that assumption. Sugar maple basal area in eastern Maine is also related more to soil texture than to drainage class (Figure 6). Highest basal area occurs on loam soils. In mature stands (100 years old), sugar maple basal area is 84.7 ft<sup>2</sup> ac<sup>-1</sup> vs. 57.8 ft<sup>2</sup> ac<sup>-1</sup> on loam and sandy loam textural classes, respectively. In the young stands (20 to 30 years old), sugar maple basal area is 18.8 ft<sup>2</sup> ac<sup>-1</sup> on loam textures and 7.6 ft<sup>2</sup> ac<sup>-1</sup> on loamy sand texture. Loam textural classes have higher cation exchange capacity (CEC) and greater water holding capacity than the coarser soil textures (MacDonald et al. 1991). This is important in the nutritional requirements of sugar maple (McLaughlin et al. 1994b, 1996a). Although sugar maple occurs on all soil drainage classes, there is a relationship between sugar maple basal area and soil drainage

Table 11. Potential risks for operations conducted during the inappropriate season for the sugar maple-beech and beech-birch-maple forest stations of eastern Maine.

Soil Drainage Class	Compaction and Rutting	Erosion		Competing Vegetation				
		Slope 15%	Slope 16-30%	Grasses and sedges	Raspberry	Striped maple	Hobble bush	Mt. maple
Well	Low	Low to Mod.	Low to Mod.	Low to Mod.	Mod. to High	Mod. to high	Low to Mod.	Low
Moderately Well, Somewhat Poorly	Mod. to	Low to Mod.	Mod. to high	Mod. to high	Mod. to high	Mod. to high	Mod. to high	Mod. to high
Poorly, Very Poorly	High	Low to Mod.	High	High	Low to Mod.	Low to Mod.	Low	Low to Mod.

Table 12. Common forest vegetation by soil series/association and drainage class.

Soil Series/Association	Drainage Class	Common Forest Vegetation
Elliotts ville/Danforth/Marlow	Well	Beech, yellow birch, sugar maple, red spruce, white spruce, balsam fir
Chesuncook	Moderately Well	Sugar maple, white pine, balsam fir, red spruce, white spruce, white ash, yellow birch, white birch
Tetas	Somewhat Poorly	Red maple, sugar maple, beech, white birch, yellow birch, red spruce, white spruce, balsam fir
Monarda	Poorly	Red spruce, white spruce, balsam fir, yellow birch, paper birch, red maple
BumhanVPeacham	Very Poorly	Black spruce, red spruce, cedar, red maple, hemlock, cedar

Table 13. Forest potential for the sugar maple-beech and beech-birch-maple forest stations of eastern Maine.

Productivity			Reforestation	
Yellow birch	Sugar maple	White ash	Recommended	Acceptable
High	Mod. to high sugar maple	High	Yellow birch, white ash, sugar maple	Black spruce, red spruce, balsam fir, white pine,

Table 14. Species site index by soil drainage class for the sugar maple-beech and beech-birch-maple forest station in eastern Maine.

Drainage Class	Site Index									
	American beech	Yellow birch	White birch	Sugar maple	White ash	Aspen	Red spruce	White spruce	Black spruce	Hemlock

Well

Moderately Well Somewhat Poorly Poorly Very Poorly

Example Tally Sheet

Table 15. Overstory characteristics for 20 to 30-year old hardwood stands in eastern Maine (beech-birch-maple forest station).

Drainage Class	Species									
	Beech		Yellow birch		White birch		Sugar maple		Red maple	
	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)
MWD	24.5	306	14.6	259	14.2	275	5.7	100	1.4	6.5
SPD	9.6	147	30.0	573	1.6	9	0.3	18	11.6	13.5
PD	3.7	85	16.7	445	3.5	28	7.8	365	5.1	
	Ironwood		White ash		Aspen		Basswood		Striped maple	
	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)
MWD	2.1	36.0	1.7	6	0	0	0.7	12	1.9	48
SPD	0.1	0.21	1.6	54	11.4	18.0	0.2	5	0.2	18
PD			2.7	31	0		0.8	15	1.0	36
	Pin cherry		Red spruce		Balsam fir		Hemlock		Black spruce	
	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)
MWD	0	0.19	0.1	30	0.2	3	10.3	24	0	0.0
SPD		38.08	4.9	42	2.7	57	4.9	36	0.145	33
PD		15	2.7	23	8.6	18	22.5	51		

Table 16. Advanced regeneration by soil drainage class for 20- to 30-year-old hardwood stands in eastern Maine (beech-birch-maple forest station).

Drainage Class	Species										
	Beech birch	Yellow birch	White ash	Striped maple	Ironwood	Red maple	Sugar maple	Red maple	Red spruce	Balsam fir	Hemlock
	Stems/ac										
MWD	1182	174	96	456	90	72	54	0	0	24	
SPD	999	996	380	162	27	2053	18	24	45	0	
PD	453	405	720	224	441	459	63	9	1224	457	

Table 17. Overstory characteristics by soil drainage class for mature (100-year old) hardwood stands in eastern Maine (sugar maple-beech forest station).

Drainage Class	Species									
	Beech		Yellow birch		White birch		Sugar maple		Red maple	
	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)
MWD	14.8	132	1.4	5	0	0 0	63.9	180	0	0 0
SPD PD	26.2	114	2.4	6	0 0	0	55.5	252	0 5.8	48
	0.4	18	6.1	18			94.5	186		
	Ironwood		White ash		Aspen		Basswood		Striped maple	
	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)
MWD	1.4	36	11.3	12	0	0 0	0	0 0	2.5	63 0
SPD PD	10.0	81	19.8	18	0 0	0	0 7.7	12	0 0	0
	0.2	6	1.7	36						
	Pin cherry		Red spruce		Balsam fir		Hemlock Basal		Black spruce	
	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	area (no./ac)	Density (ft <sup>2</sup> /ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)
MWD	0	0 0	3.1	9 0	0	0 0	0	0 0	0	0 0
SPD PD	0 0	0	0 6.0	72	0 11.3	114	0 46.1	138	0 0	0

Table 18. Advanced regeneration by soil drainage class for mature (100-year-old) northern hardwood stands in eastern Maine (sugar maple-beech forest station).

Drainage Class	Species										
	Beech birch	Yellow	White	White ash maple	Striped maple	Ironwood	Sugar maple	Red maple	Red spruce	Balsam fir	Hemlock
	Stems/ac										
MWD	981	28	1265	517	848	1049	0	32	0		
SPD	1759	14	634	114	446	1166	0	0	0		0
PD	348	42	604	96	1146	756	0	162	144		276

class as indicated by the CCA (Figure 6). Sugar maple basal area is 27% and 93% lower on moderately well and somewhat poorly drained soils, respectively, than on poorly drained soils for young hardwood forests (Table 15). Sugar maple basal area is also 32% and 41% lower on moderately well and somewhat poorly drainage classes than on poorly drained soils in mature stands (Table 17).

Advance regeneration (defined as seedlings greater than one foot tall) for sugar maple is greatest on somewhat poorly drained soils than either moderately well or poorly drained soils in young stands (Table 16). Sugar maple advance regeneration in mature stands, however, is fairly evenly distributed between moderately well and somewhat poorly drainage class, and lowest on poorly drained soils (Table 18). This may be a result of competition between sugar maple seedlings with those of balsam fir and white ash on the poorly drained soils, and beech on moderately well drained soils in young stands. In the mature stands, sugar maple advance regeneration on the poorly drained classes may be inhibited somewhat by competition with ironwood seedlings (Table 18). In any event, in the mature hardwood forest, there appears to be adequate advance regeneration of all preferred species (i.e., sugar maple and white ash) to provide adequate competition against defective understory beech, after a partial harvest. However, this may not always be the case. In the event of high densities of defective beech in the understory (but with some level of preferred species stocking in the understory), more elaborate harvesting regimes, such as group selection or open shelterwood cuts may need to be invoked. In the event of very high potentially defective beech advanced regeneration (i.e., >60%), either an understory herbicide application or possibly a stand conversion may have to be considered. This is an area that should be seriously considered for future hardwood research.

Yellow birch basal area, density, and seedling numbers are all highest on somewhat poorly drained soils in the young regenerating stands (Tables 15 and 16). Yellow birch regeneration is generally best on moist soils (Roberge 1988). Basal area and density of yellow birch for somewhat poorly drained soils are at least three times those for the other soil drainage classes in the young stands (Table 15). However, seedlings greater than one foot tall for yellow birch on the somewhat poorly drained soils is equal to beech and about one-half that of sugar maple. However, yellow birch seedling stocking is still fairly high (Table 16).

Beech basal area and number of seedlings in the young stands were greatest on moderately well drained sites, but was also represented on the other soil drainage classes (Tables 15 and 16). We anticipate the sampling next field season to include the well and excessively drained sites will show even more dominance of beech in eastern Maine hardwood forests. In the mature stand, beech basal area and

advanced regeneration is most dominant on somewhat poorly drained soils, although beech was well represented on all drainage classes (Tables 17 and 18). The prevalence of advanced regenerating beech (much of which is defective) needs more serious consideration in devising management plans, particularly if one wishes to decrease herbicide applications. If a cooperater chooses an herbicide application in the understory, they are referred to the manuscript of Ostrofsky and McCormack (1986). Also the scientists within the CFRU will be very willing to discuss this management issue.

White ash is a minor component of the young hardwood stands (Tables 15 and 16), but has a more dominant position in the mature forest (Tables 17 and 18). White ash basal area and seedling numbers are greatest on the poorly drained classes in the young forests (Table 15). Poorly drained soils have the least basal area, but greatest density of white ash in the mature forests (Table 17).

Ironwood is also a minor component of the young forests (Table 15). However, it is a significant component of the seedling class, particularly on poorly drained soils (Table 16). In the mature forests, ironwood is best represented on somewhat poorly drained soils (Table 17). As with the younger forest, ironwood seedlings are most common on poorly drained soils. They are fairly well represented on the other drainage classes, as well (Table 18).

It must be emphasized that the majority of poorly drained sites we sampled were also enriched, and had fairly high nutrient contents (e.g., see Table 21). This is the reason for the high occurrences of sugar maple, yellow birch, white ash, and basswood on that drainage class. Different soil textural classes would likely produce very different species occurrences. For example, a domination of softwoods is likely to occur on both coarse and heavier texture soils (see Figure 6).

### Management Possibilities for Hardwoods

We are also developing management possibilities for the hardwood forests of eastern Maine based upon stand age and ecological requirements of the dominant species. We still need to incorporate soil textural classes into the scheme shown in Table 19. For simplicity, stand ages of 10 to 20 years may be managed under a crop tree release to favor preferred species, such as yellow birch, white ash, white birch, and other species, depending upon the objectives of the landowners. The onset of canopy closure of northern hardwood stands following clearcut harvesting has been suggested as an appropriate time to project future stand composition of even-aged northern hardwood stands (Wang and Nyland 1996). At that time cultural treatments can be devised. The cultural treatment employed in young stands in eastern Maine, however, will be dependent upon the amount of defective beech in the stand. For instance, if a stand

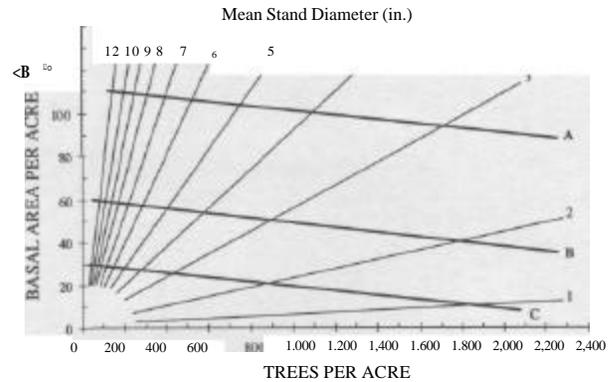
Table 19. Management possibilities based on stand age.

Stand Age (years)	Management Scheme
10 to 20	<u>Crop tree release</u> Species to favor Yellow birch White birch White ash Red maple Aspen
40 to 60	Crop tree release Species to favor Sugar maple Yellow birch
100 to 150	Selection harvest Species to favor Sugar maple Yellow birch White ash

is a site class 1 or 2 (Briggs 1994) and the composition is primarily defective beech, then a stand conversion to softwoods may be warranted. This type of information needs to be evaluated more fully, but we will use what information is available and our knowledge of silvics and ecology to develop interpretations to incorporate into the final draft of the field guide.

At stand ages between 40 and 60 years, we recommend a crop tree release (commercial thinning) to favor sugar maple and yellow birch. The crop tree release at this time may also benefit beech. We would only recommend release of beech if it were not defective and fit into the overall management picture of the landowner. For mature hardwood stands, 100 to 150 years old, we recommend selection harvesting. The type of harvest needs to be investigated in greater depth. This is particularly true in the case of significant beech regeneration (i.e., greater than 20%). Under this type of situation, if there is good stocking of advance regeneration of preferred species, a group selection or open shelterwood cut may be warranted. These are only speculations at this time, and we need hard data from experimentation to make objective and correct interpretations.

The stocking guides for white birch, developed by Safford (1983) and mature northern hardwoods developed by Leak et al. (1987) (Figure 8) will also be presented in the field guide. These stocking guides will provide information for land managers to determine when harvesting operations should be conducted to improve stand development. We are using the stocking guides developed for white birch (Safford 1983) as shown in Figure 8 for management interpretations for 10- to 20-year-old hardwood stands. We have chosen the white birch stocking guides for three reasons. First, there are no stocking guides developed for young northern hardwood stands of the northeastern United States, other than the white birch



58 25

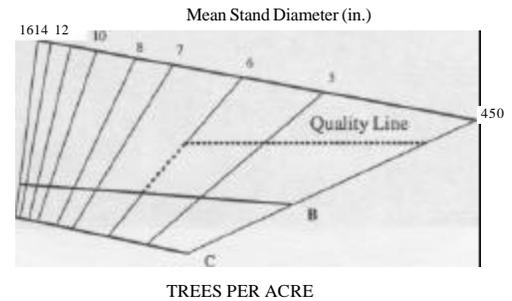


Figure 8. (A) Stocking guide for white birch in the northeastern United States (from Safford 1983) used for initial estimate of 10- to 20-year-old northern hardwood stands regenerated after clearcut harvesting. (B) Stocking guide for mature northern hardwood stands in the northeastern United States (from Leak et al. 1987).

guidelines. Secondly, based upon the stocking guide for northern hardwoods (Leak et al. 1987) as shown in Figure 8, stocking for the 4 in. diameter class is similar to that developed by Safford (1983) for white birch. Thirdly, a significant stocking of the young stands in eastern Maine are composed of intolerant to midtolerant hardwoods (white birch, aspen, white ash, yellow birch, red maple), although there may a significant component of tolerant beech and sugar maple. The white birch stocking guide, however, should suffice as a first approximation to stocking of young hardwood stands.

### Crop Tree Release of Yellow Birch and White Ash

We have initiated a crop tree release for yellow birch and white ash on a 20-year-old northern hardwood stand on Georgia-Pacific Corporation landholdings in Talmadge Township, eastern Maine. The stand has regenerated naturally after clearcut harvesting (Figure 9). Dominant species include yellow birch and beech, with sugar maple, white ash, red maple, white birch, and aspen also present (Figure 10). The



Figure 9. (A) Unthinned 20-year-old northern hardwood

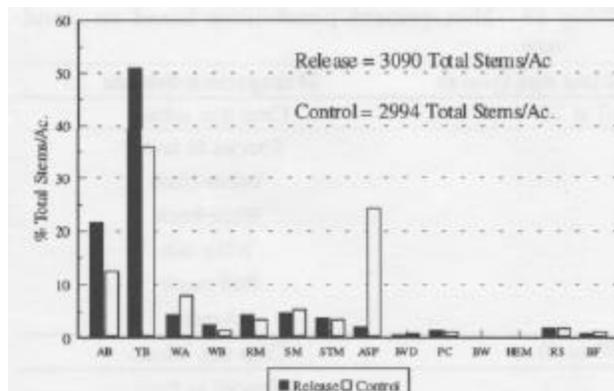


Figure 10. Species composition for a 20-year-old hardwood stand in the beech-birch-maple forest station of eastern Maine (AB=American beech, ASP=aspen, BW=basswood, BF=balsam fir, HEM=hemlock, IWD=ironwood, PC=pin cherry, SM=sugar maple, STM=striped maple, RM=red maple, RS=red spruce, WA=white ash, WB=white birch, YB=yellow birch).

crop tree release is a management scheme we have developed in consultation with Georgia-Pacific Corporation personnel. This type of release is shown in Figure 9.

The objective of the crop tree study is to reduce the rotation length for veneer and number 1 grade yellow birch logs. Projections from previous work have suggested a reduction in the rotation length of one-half to one-third compared to non-culturally treated stands (Erdmann et al. 1981; Wood et al. 1996). However, Leak and Solomon (1997) reported that 30 years following crop tree release for yellow birch, released trees averaged only 2 in. greater dbh than that of control trees. There may, therefore, be a requirement for at least one more entry into a stand. This likely would occur within 10 to 15 years of the original release.

Based upon the assumptions previously discussed for the stocking guide of young hardwood stands, this particular stand is in need of a thinning. This is based upon the following stand characteristics: the stand basal area is 84 ft<sup>2</sup> ac<sup>-1</sup>, has a mean stand diameter of 3.9 in., and consists of 1,602 trees ac<sup>-1</sup> for those trees 2 inches and greater in DBH (~3,000 stems ac<sup>-1</sup> for all stems greater than 4V& ft high). Looking at the stocking guide for both white birch and northern hardwoods, the stand is above the A line and, therefore, overstocked. There is fairly good stocking of yellow birch and white ash that will allow for the thinning operation to be justified.

The release method chosen was the crown-touching technique (Lamson and Smith 1987) and we used a 6- to 9-ft spacing around the crown of each designated crop tree. This spacing was chosen because it has been shown to be the best balance between growth stimulation and wood quality degradation (i.e., epicormic branching) (Erdmann et al. 1981; Lamson and Smith 1987; Lees 1995). We released 30 to 35



stand regenerated after clearcut harvesting. (B) Thinned yellow birch crop tree.

Table 20. Mean diameter and height for designated yellow birch and white ash crop trees at Talmadge Township, Maine.

Treatment	Species					
	Yellow Birch			White Ash		
	Dbh (in.)	Ht (ft)	Number of trees	Dbh (in.)	Ht (ft)	Number of trees
Release	2.85	33.1	79	2.35	31.5	16
Control	2.77	33.2	62	2.62	33.2	22

trees  $ac^{-1}$  on three, 1-acre treatment plots and marked 30 trees  $ac^{-1}$  as crop trees in each of three, 1-acre control plots. If the release was conducted in a 10-year-old stand, we could have conceivably increased the number of trees released to about 75 to 100. That is the recommendation for 10-year-old stands. For 20- to 25-year-old stands, the recommendation is to release 25 to 35 trees  $ac^{-1}$  (Erdmann et al. 1981). The average dbh and heights of selected crop trees are given in Table 20. We also sampled soils and determined soil nutrient pools for the site (Table 21). The nutrient pools are within the range of those reported for hardwood forests that occur on similar soil texture classes in the northern part of the United States (MacDonald et al. 1991).

The experimental design is a fixed-effect design consisting of three release plots and three control plots. Analysis of covariance will be used to test the hypothesis of no treatment effects. Initial tree dbh and height measurements will be used as covariates in the statistical analyses.

### Weymouth Point

We have initiated a number of new studies at the Weymouth Point Watersheds and have maintained certain ongoing studies, as well. The following is a summary of the studies currently ongoing. A more

comprehensive evaluation of the data and presentation of the results will be provided in the 1998 Annual Report and Research Summary.

### 1. Long-Term Trends in Soil Nutrient Cycling After Whole-Tree Harvesting

Project objectives are (1) to understand the time it takes forest soil nutrient cycling to recover to pre-harvest levels and (2) to use these data in conjunction with other regional studies and current and prior Weymouth Point research to build a conceptual model of forest practices effects on soil nutrient cycling. The original control watershed plots established in 1980 by Tat Smith and Dr. Maxwell McCormack, Jr., were re-established this past field season. An inventory of the overstory species was completed and a brief description is presented in Table 22. Average diameter of balsam fir is 6.9 in. and average height is 60.6 ft. Average diameter of red spruce is 8.7 in. and average height is 57.9 ft. We are presently conducting inventories for the plots in the harvested watershed.

Soil sampling was also completed for both the harvested and control watersheds, and nutrients are currently being analyzed. Lysimeters were also installed early in the field season and the first sampling for soil solution chemistry was completed in the

Table 21. Forest floor and mineral soil nutrient pools for a 20-year-old hardwood stand regenerated after clear cut harvesting in Talmadge Township, Maine.

Constituent	Horizon				Total Solum
	Oe+Oa	Bs	BC		
	$kg^{-1} ha^{-1}$				
Exchangeable Ca	4,096	3,034	1,056		8,186
Exchangeable K	796	1,450	884		3,130
Exchangeable Mg	604	393	164		1,161
Exchangeable Al	13	5,395	1,196		6,605
Exchangeable Fe	10	218	56		284
Available P	59	205	144		408
Total Organic Carbon	35,218	118,610	27,144		180,972
Total Nitrogen	1,365	3,500	96		4,961

Table 22. Overstory species characteristics by soil drainage class for the unharvested watershed at the Weymouth Point Watersheds, Maine.

Drainage Class	Species							
	Spruce		Balsam Fir		Other Conifers		Hardwoods	
	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)
MWD SPD PD	203	1742	0	0	36	41	0	0
VPD	173	2147	7.1	932	0	0	0	0
Watershed Average	113	851	189	264	7.2	61	22	163
	38	1235	1.2	82	2.8	61	0	0
	132	1344	6.8	270	11.5	48	5.6	55

fall, 1997. Lysimeter sampling in the harvested watershed has been ongoing since 1980.

## 2. Precommercial Thinning Effects on Soil Carbon, Nitrogen, and Phosphorus Cycling

Project objectives are (1) to understand the effects of precommercial thinning of spruce-fir stands naturally regenerated after whole-tree harvesting on soil carbon, nitrogen, and phosphorus cycling and (2) to use these data in conjunction with other regional studies and current and prior Weymouth Point research to build a conceptual model of forest practices effects on soil nutrient cycling. Our new graduate student, Richard Cobb, will be working on this study. The work will complement that previously conducted by Dr. Russell Briggs and not duplicate his past efforts. This study will emphasize gaseous losses of carbon and nitrogen and organic constituents of carbon, nitrogen, and phosphorus. Mineralization rates of those elements will also be measured. The justification for this work is that often organic forms of nitrogen and phosphorus (bound to carbon) play a much greater role in nutrient movement through the soil profile after forest harvesting than does inorganic compounds, such as NO<sub>3</sub><sup>-</sup>, NH<sub>4</sub><sup>+</sup>, and PO<sub>4</sub><sup>3-</sup> (McLaughlin et al. 1996a, 1996b; Trettin et al. 1997). Also a significant component of carbon and nitrogen losses from soils in response to cultural practices may occur as CO<sub>2</sub>, CH<sub>4</sub>, and NO<sub>2</sub> (Trettin et al. 1995).

Plots have been established, inventoried, and lysimeters installed on site classes 2 and 5 (Briggs 1994) (3 plots for PCT, 3 control plots in the harvested watershed, and 3 plots in the unharvested watershed for each site class). Sampling will begin spring 1998.

## 3. Soil Chemical Comparisons Among Hardwood and Softwood Regenerated Areas and the Uncut Control Watershed.

Project objectives are (1) to understand soil nutrient cycling responses to both hardwood and softwood regeneration after whole-tree harvesting in the same watershed and (2) to use these data in conjunction with other regional studies and current and prior Weymouth Point research to build a conceptual model of forest practices effects on soil nutrient cycling. We have established four plots in an area of the harvested watershed that received no herbicide applications after the initial harvest of the watershed. We will be using four of the long-term recovery plots, and the plots established in the control watershed for experimental comparisons. Soil sampling on all plots was completed this field season and nutrient analyses are currently being conducted. Lysimeters have also been installed on each plot and sampling will begin in spring 1998. We have also inventoried all the vegetation in each plot and will be determining biomass estimates during this winter. Preliminary data are shown in Table 23.

Table 23. Overstory species characteristics by soil drainage class for the hardwood regenerated plots at the Weymouth Point Watersheds, Maine.

Drainage Class	Species									
	White birch		Red maple		Aspen		Pin cherry		Balsam fir	
	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)	Basal area (ft <sup>2</sup> /ac)	Density (no./ac)
MWD	13.7	273	5.0	152	8.1	91	7.1	182	5.2	111
SPD	13.0	294	0.5	20	8.9	91	6.2	192	1.8	41
PD	2.4	71	3.3	111	32.3	344	4.0	101	11.2	294
VPD	-	-	-	-	-	-	-	-	-	-
Watershed average	9.7	213	2.9	95	16.4	175	5.7	158	6.1	148

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MASS PRODUCTION OF HYBRID LARCH FAMILIES

Brian Baltunis, Kyle Peer, and Michael Greenwood

**A. Optimizing Hybrid Larch Rooted Cutting Performance: The Effects of Mist Quantity, Maturation, and State of Shoot Development on Rooting**

Larch sp. (*Larix decidua* Mill., *L. laricina* (Du Roi) K. Koch, and *L. leptolepis* Gord.) and their hybrids represent the fastest growing conifers in the Acadian forest with height growth rates as high as 1.5 m a year. Larch wood has a higher specific gravity than spruces while having comparable fiber length, and the species can adapt to a variety of sites. Larch plantations will result in an increase in fiber production with a decrease in rotation length to 20-30 years from the present rotation length of 50-70 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. Our objectives are to compare the effects of mist quantity, maturation of the donor stock, and state of shoot development on rooting.

The effect of mist on rooting was evaluated by varying the amount of mist applied (Mist 1 = 10 seconds every 10 minutes, Mist 2 = 6 seconds every 16 minutes), the addition of supplemental water, and the family from which the cuttings were taken. The results are shown in Figure 11. The main effects of mist, supplemental watering, family and block were all highly significant ( $P < .001$ ). The treatment of mist 1 without supplemental watering provided the highest rooting percentage with a mean of 70% compared to Mist 2 with a mean of 35%. JE25 was the best overall rooting family in mist 1, rooting at 91

Maturation effects were evaluated by comparing rooting success of cuttings taken from seven age cohorts (planted 1990-1996) of half-sib open-grown hybrid larch (Figure 12). Age of donor plants significantly affects both percentage rooting and root quality score in trial 3 with scoring and rooting percentage ( $P < .001$ ); block effects were non-significant. Rooting percentage exhibited a significant linear relationship with age.

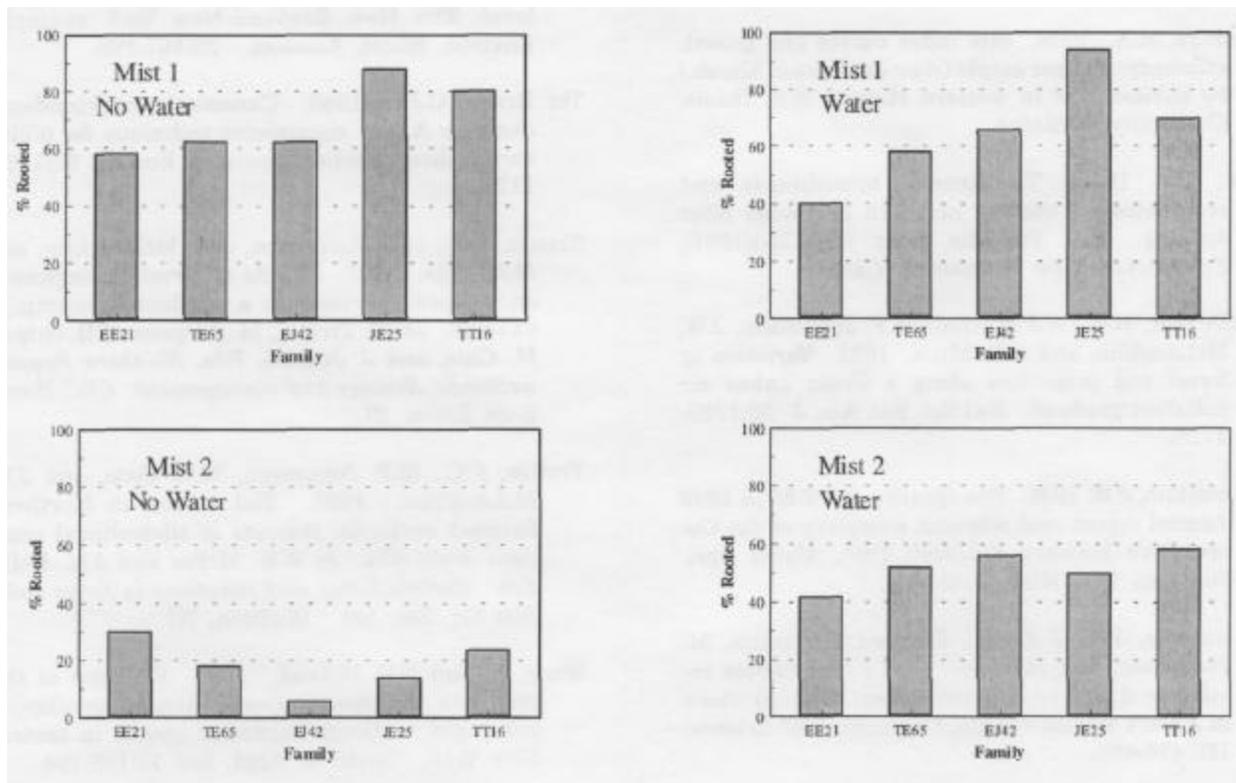


Figure 11: Rooting percentages by mist treatment.

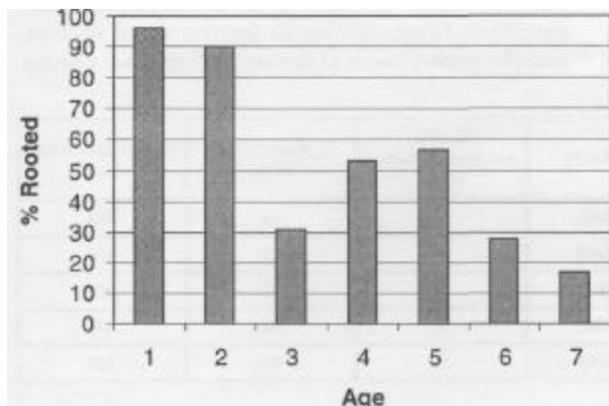


Figure 12: Percentage rooting by age.

The effect of the state of shoot development on rooting was evaluated by comparing rooting percentage of cuttings of five families stuck on July 14, 1997, (softwood) to those stuck on September 3, 1997, (hardwood). State of shoot development was highly significant ( $P < .001$ ) with the softwood cuttings rooting better in all families (Figure 13). Family variation was not significant in the September 3 cuttings, but was significant for the combined data.

EE21 TE65 EJ42 JE25 TT16

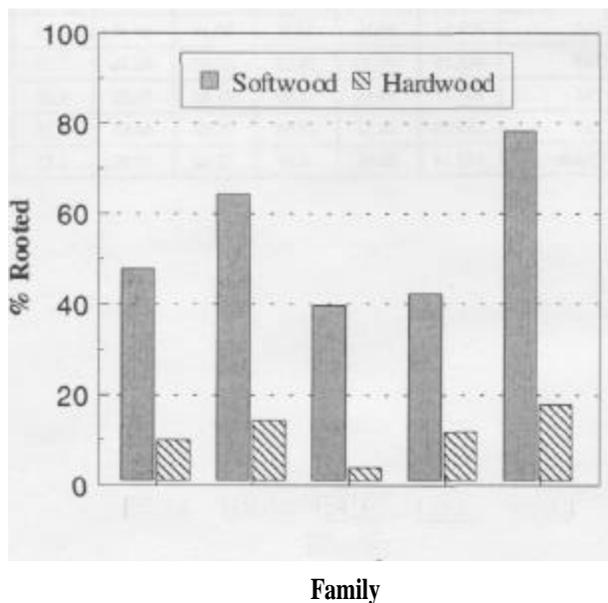


Figure 13: Comparisons of rooting percentage between cuttings taken on July 13 (softwood) to cuttings taken on September 3 (hardwood).

**B. Evaluation of a Five-year Old Hybrid Larch Progeny Test in Johnson Mountain Township, Maine**

Tree breeding programs across North America, Europe, and Asia have included *Larix* for nearly a hundred years. In some cases, tree breeding programs have been established to develop intraspecific crosses and interspecific hybrids using *Larix decidua*

Mill, *L. leptolepis* (Sieb and Zucc) Gord., and *L. laricina* (Du Roi) K. Koch. Fifth-year growth measurements were compared for intraspecific crosses of *Larix decidua* (ExE), *L. laricina* (TxT), *L. leptolepis* (JxJ), and interspecific hybrids between *L. decidua* and *L. leptolepis* (ExJ), *L. decidua* and *L. laricina* (ExT), *L. leptolepis* and *L. decidua* (JxE), *L. laricina* and *L. decidua* (TxE), and *L. laricina* and *L. leptolepis* (TxJ) at a progeny test in Johnson Mountain Township, Maine. In addition patterns in lateral shoot elongation of ExE, TxT, ExJ, JxE, and TxE were explored in order to explain variations in total height.

Highly significant differences in height and DBH were detected for hybrid group and family. The progeny test mean height in 1996 was 3.44 m and ranged from 2.9 m for *L. leptolepis* to approximately 3.65 m for the interspecific hybrids. Mean DBH for hybrid groups ranged from 2.63 cm for *L. leptolepis* to 3.92 cm for ExT while averaging 3.44 cm. All interspecific hybrid groups had a mean height and DBH greater than any of the parent species (Table 24). Estimates of volume based on GLD and height ranged from 2,493 cm<sup>3</sup> for *L. leptolepis* to 5,232 cm<sup>3</sup> for the *L. decidua* x *laricina* hybrid. Hybrid vigor was demonstrated for all interspecific hybrids, and superior families have been identified based on fast growth (Figures 11 and 12). Family selection within interspecific hybrids can increase the gain in height and volume for tree improvement programs. The five tallest families in the test had height advantages between 7-12% over the mean height of all interspecific hybrids (Table 25). These five families were between 20-26% and 30-36% taller than the combined mean height of intraspecific crosses and the mean height of the two commercial checks, respectively. Gains in volume of up to 128% over the commercial check lots can be achieved by selecting the best families in the test (Table 26).

Table 24. Total number of seedlings planted (n.), percentage survival, mean DBH, mean GLD, mean height, height increment (HI), and mean volume by hybrid group for 1996. Commercial check means are listed for comparison.

Hybrid Group	n.	Percent Survival	HT, m	DBH, cm	OLD, cm	HI cm	Volume, cm <sup>3</sup>
ET	30	87	3.69	3.92	7.36	1.11	5232
TJ	55	80	3.68	3.56	6.87	1.03	4547
TE	180	78	3.66	3.82	7.02	1.06	4722
JE	262	77	3.65	3.88	7.35	1.06	5162
EJ	240	83	3.62	3.90	7.16	1.00	4859
TT	300	91	3.37	3.06	6.04	93	3219
EE	210	85	3.35	3.38	6.74	95	3984
JJ	210	67	2.90	2.63	5.73	84	2493
XLD-4-89	30	77	3.30	3.05	6.72	86	3913
XLD-LI-7-89	30	77	2.67	2.35	5.67	92	2247



Table 25. Percentage gain in height from selecting the five tallest families over the mean of interspecific hybrids, the mean for the three species, and the pooled mean of the two commercial checks.

Family	% over interspecific hybrid mean	% over species mean	% over commercial checks
EJ11	12	26	36
EJ42	10	24	34
TE43	8	22	32
JE65	8	22	31
JE61	7	20	30

Differences among hybrid groups were observed for all lateral shoot elongation traits (Table 27). These differences in shoot growth components suggest that *Larix laricina*, *L. decidua*, and interspecific hybrids of larch all exhibited different growth patterns. *Larix laricina* families had both the earliest initiation and cessation of shoot growth and the shortest duration of elongation. In fact *L. laricina* families had ceased elongation by August 9, while TxJ hybrids did not stop elongating until August 22. *Larix laricina* and *L. decidua* families had lower total heights than interspecific hybrids. This may be a result of the two species ceasing growth earlier and having a shorter elongation period than hybrids. Growth cessation and duration of elongation in this study were strongly correlated with 1996 total height. The implication of these significant correlations means that one may identify superior families of hybrid larch by selecting for late cessation or long duration of elongation.

Table 26. Percentage gain in volume from selecting the five tallest families over the mean of interspecific hybrids, the mean for the three species, and the pooled mean of the two commercial checks.

Family	% over interspecific hybrid mean	% over species mean	% over commercial checks
EJ11	30	88	101
EJ42	48	114	128
TE43	19	71	83
JE65	37	98	111
JE61	34	94	107

Table 27. Hybrid means for 1996 height, growth initiation (GI), start of linear growth (GS), growth cessation (GC), growth duration (GD), rate of elongation (mm/day).

Hybrid	1996 HT (cm)	GI (days)	GS (days)	GC (days)	GD (days)	RE (mm/day)
ExE	357.50	19.10	34.85	81.05	61.95	5.07
ExJ	417.30	19.76	35.97	86.14	66.38	5.04
JxE	408.84	19.20	34.91	85.11	65.91	5.19
TxE	408.75	16.50	29.72	82.66	66.16	7.16
TxJ	407.77	18.18	32.89	89.90	71.72	6.09
TxT	369.73	16.32	29.63	76.99	60.67	6.15
Check	322.14	20.52	38.09	78.42	57.90	4.53

## TREE IMPROVEMENT

Dr. Katherine K. Carter

During 1997, two plantations of plus-tree progeny were evaluated to determine the effectiveness of the selection process. One plantation consisted of 10-year-old select families of Japanese larch, while the other was a 24-year-old plantation of selected white spruce families. Each of these test plantations also included "check" seedlots of unselected stock of the same species for comparison purposes.

### Japanese Larch

This plantation consists of 31 Japanese larch families (seedlots beginning with "L") grown from open-pollinated seed collected from plus-trees in the Oji Paper Company's seed orchard in Japan. Seed was donated to the International Paper Company and grown by the University of Maine. The plantation also includes five provenance collections (seedlots beginning with "f") of unselected Japanese larch to serve as "check" seedlots. Containerized seedlings were planted in 1988 on an old-field site near Fairfield, Maine, using a randomized complete block design with four-tree rows and five replications.

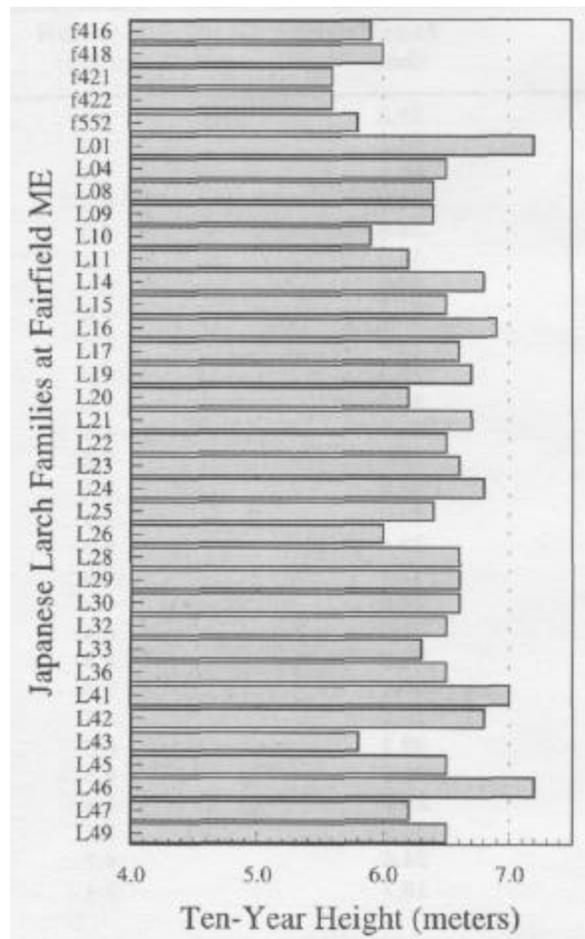


Figure 14. Mean 10-year-old height for 31 Japanese larch selected seed sources and five unselected seedlots.

At age ten, mean overall height for these trees is 6.4 meters, with individual seed source means (Figure 14) ranging from 7.2 m (seedlot LOI) to 5.6 m (seedlot 422). Survival averaged 84%, with individual seedlots ranging from 64% to 100%; the 17 fastest-growing seedlots all had survival rates above 80%. Mean heights for all but two of the plus-tree families exceeded those of the five check seedlots; overall "check" mean height was 5.8 m while the mean of all plus-tree families was 6.5 m, an average height gain of 12%. Seed source mean height at age three and age ten was highly correlated ( $r=0.67$ ), indicating that superior families could be identified as early as age three.

### White Spruce

During the 1960s and early 1970s, white spruce plus-trees for seed collection were selected by the "Spruce-Fir Committee" coordinated by Clyde Hunt of the USDA Forest Service. Plus trees were selected in Maine and New Hampshire (Figure 15) on the basis of growth rate in comparison to other nearby white spruce. Open-pollinated seed was collected and grown to produce planting stock. Bareroot 3-0 seedlings were planted in 1974 on an old-field site near Moscow, Maine.

Ordinary nursery-run white spruce seedling stock from the Maine and New Hampshire state nurseries was included to serve as a "commercial check" for comparison to the plus-tree progeny. Norway and red spruce seedlots were also included for comparison. Eleven years after planting, progeny of all plus trees were taller than the Maine checklot at Moscow. At that time, plus-tree progeny height averaged 22% taller than the New Hampshire checklot and 36% taller than the Maine checklot. After this measurement, the plantation was thinned by removing the poorer trees in each plot, to maintain good growth rates.

When remeasured in 1997, 24 growing seasons after planting, all but two of the plus-tree seedlots still maintained their superior height compared to the Maine and New Hampshire check lots (Table 28). Average height of the plus-tree progeny was 32.4 feet, compared to 29.0 feet for the Maine checklot (a 12% gain). Average DBH was 6.7 inches for all progeny, a 21% gain over the Maine checklot.

Height at ages 11 and 24 was correlated ( $r=0.69$ ), indicating that faster-growing families could be reliably identified at the earlier age.

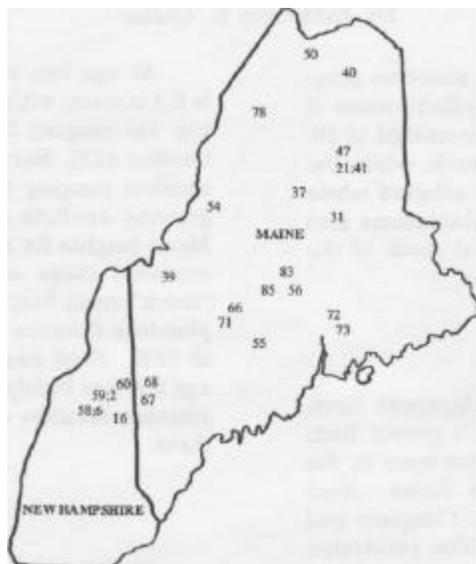


Figure 15. Location of white spruce plus-trees selected by the Spruce-Fir Committee.

Table 28. Height and diameter of white spruce plus-tree progeny from Spruce-Fir Committee select trees (AC#s) and comparison ("check") seedlots from Maine and New Hampshire, growing in a test plantation near Moscow, Maine.

Family	11-yr. Height Superiority*	24-yr. Height Superiority*	24-yr. Height (feet)	24-yr. DBH (inches)
AC02	27%	28%	37.3	8.5
AC06	37%	25%	36.3	7.8
AC58	36%	22%	35.3	7.5
AC47	35%	20%	34.9	6.9
AC72	16%	20%	34.8	7.3
AC55	39%	19%	34.7	7.1
AC83	34%	19%	34.5	6.9
AC71	45%	18%	34.4	7.6
AC73	27%	16%	33.6	6.6
AC59	22%	15%	33.3	6.9
AC85	33%	14%	33.1	7.6
AC68	16%	14%	33.0	6.4
AC66	23%	14%	33.0	7.2
AC41	25%	13%	32.9	6.4
AC16	29%	13%	32.9	7.4
AC40	7%	12%	32.4	6.8
AC67	19%	10%	32.1	6.0
AC50	17%	8%	31.6	6.3
AC21	20%	8%	31.4	6.4
AC78	6%	4%	30.2	5.8
AC54	8%	3%	30.0	6.8
AC31	16%	0%	29.2	6.4
AC39	8%	0%	29.1	5.8
ME-WS check	—	—	29.0	5.5
NH-WS check	—	—	29.5	4.8
Norway spruce	2%	-36%	24.9	5.7
red spruce			24.5	4.7
AC60			18.7	2.4

\*Superiority is calculated relative to the mean height of New Hampshire and Maine check seedlots, which were ordinary, unselected seedlings obtained from each state nursery.

## GROWTH AND YIELD

Dr. Robert S. Seymour

### Growth and Yield Program

During the past year, two additional papers from former Ph.D. student Daniel Gilmore's studies of balsam fir canopy structure were published, bringing the total from his work to four. In addition, work was completed on two major projects designed to advance understanding of forest productivity based on forest canopy structure and individual tree leaf area. The first study, undertaken by Graduate Research Assistant Daniel McConville, involves the relationship between variable-density pine overstories and growth of understory fir and spruce saplings. This research was reviewed on the annual CFRU field tour on Sept. 24. The second study, undertaken by Graduate Research Assistant Audrey Barker with funding from University sources, is a comprehensive assessment of leaf area and growth efficiency relationships for eastern white pine. Barker presented a poster on this work at the national convention of the Society of American Foresters held in Memphis. Both students plan to complete their theses by January 1998.

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

This study includes five stands that were harvested during the mid-1980s, leaving different densities of white pine reserve trees. Two stands without overstories of the same age were also selected as controls (Table 29). At each site, a relatively uniform area of about 2.5 acres was designated for study, within which an intensive 6x6-plot grid was established on a 5.5-m spacing. At each grid location, heights and height growth rates of the most dominant spruce, fir and white pine (if present) were measured. Regeneration plots were also taken to quantify overall stand stocking and density (Table 30). Canopy gap fraction (the percentage of the sky unobstructed by overstory

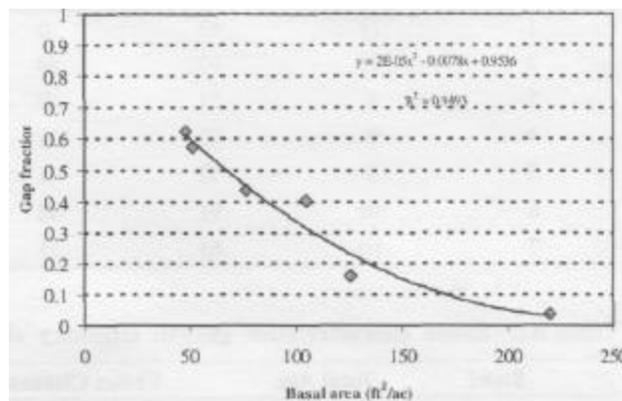


Figure 16. Mean gap fraction over basal area (ftVac) for each of the six overstory study sites

canopy) was measured at each location using the Licor 2000 plant canopy analyzer. All overstory pines were measured for dbh and height, and stem-mapped with a Criterion laser instrument relative to the grid locations.

Preliminary results indicate that overstory basal area is strongly related to gap fraction (Figure 16), which suggests that foresters can use conventional stand density parameters as a surrogate for direct light measurements. Interestingly, five-year height growth of both firs and spruces (those trees greater than one meter tall at the beginning of the growth period) does not appear to be reduced by pine overstories with gap fractions down to 30% (70% canopy cover). Indeed, the data actually suggest an optimum height growth under a canopy of about 50-70% (30-50% gap fraction; Figure 17). Thus, it appears that during the first 10 years of the regeneration period, substantial pine overwoods can be retained without sacrificing sapling development.

Table 29. Summary of overstory characteristics, pine overstory study.

Site	Location	Basal area (ft²/ac)	Trees/acre	Avg. dbh (in.)	Age	Mean gap fraction	Gap fract. Range
1	T39MD	125	97	142	80	0.16	0.04-0.25
2	T39MD	76	65	120	63	0.44	0.28-0.66
3	T32MD-3	105	59	157	78	0.40	0.31-0.53
4	T32MD-2	48	32	134	69	0.62	0.41-0.83
5	Univ. For.	51	11	232	120	0.58	0.38-0.89
6	T32MD	0	0			1.00	
7	T32MD	0	0			1.00	

Table 30. Summary of understory characteristics, pine overstory study.

	Time since last harvest	% fir stocking	% spruce stocking	% pine stocking	Average height fir (ft)	Average height spruce (ft)	Average height pine (ft)
1	11	83	0	0	10.98		
2	10	67	83	64	5.35	6.13	5.31
3	9	78	58	53	11.32	10.33	8.72
4	9	53	22	94	6.53	4.62	5.81
5	9	39	0	92	11.09	9.94	8.27
6	10	92	56	19	6.92	5.51	8.10
7	10	61	28	11	8.04	7.15	6.40

Table 31. Stand characteristics, growth efficiency study.

Stand	Total Age	Crown Classes	Site Index	Soil Drainage
1	25	D*	50	Poorly - somewhat poorly
2	39	D,C,I,S*	52	Somewhat excessively
3	50	D,C,I,S	59	Moderately well
4	52	D,C,I,S	54	Somewhat poorly
5	52	Lower stratum	54	Moderately well - somewhat poorly
6	74	D,C,I,S	56	Well - somewhat excessively
7	98	D,C,I,S	52	Somewhat poorly
8	104	D,C,I,S	45	Somewhat poorly
9	132	D,C,I,S	56	Somewhat poorly
10	139	Emergent, S	50	Somewhat poorly
11	126;42	Isolated; Lower stratum	58	Well
12	198	Emergent	52	Somewhat poorly - moderately well

D = dominant; C = codominant; I = intermediate; S = suppressed

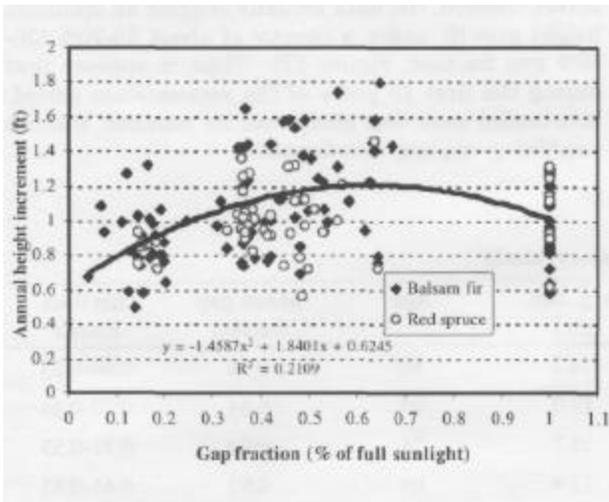


Figure 17. The relationship between average annual height increment (feet) and gap fraction for spruce and fir saplings.

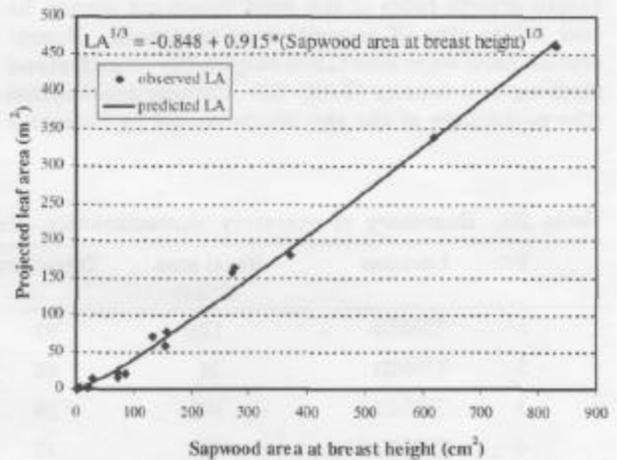


Figure 18. Leaf area predicted from sapwood area at breast height.

**Leaf area-Sapwood Relationships and Growth Efficiency of Eastern White Pine**

Lab analysis of leaf area samples collected from 16 white pines ranging from 3.4 to 61.3 cm dbh (ages 12-128 at bh) in 1996 was completed. An accurate regression model that predicts tree leaf area from the cross-sectional sapwood area at bh was formulated (Figure 18), and used to predict tree leaf areas in a much larger sample of 380 trees from 12 stands chosen to span a range in age and canopy architecture (Table 31). Growth efficiency was calculated as the annual volume growth (avg. last five years) divided by the predicted leaf area of each tree.

Preliminary analyses suggest little differences among crown classes in growth efficiency. In some cases, lower crown classes may be slightly less efficient depending on assumptions made to correct for missing rings and slower height growth. The major pattern appears to be age-related. Trees in 50-year-old stands appear to have higher growth efficiencies than either younger or older trees (Figure 19), although the pattern is somewhat complicated by small differences in site quality among the various age classes.

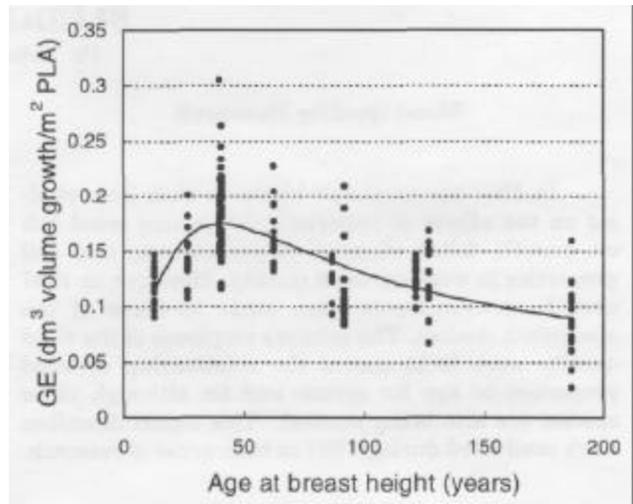


Figure 19. Growth efficiency (GE) as a function of age ( $GE=0.0292+(AGE/139.306+0.0853*AGE^2)$ ,  $r^2=0.50$ ) for upper crown class trees (dominants, codominants, and emergents).

## SLUDGE AND ASH

Dr. Robert K. Shepard

### Wood Quality Research

In 1997 the emphasis began to shift from studies on the effects of papermill sludge and wood ash on growth, foliar element concentrations, and soil properties to work on wood quality. However, in 1997 growth measurements were made in three of the sludge/ash studies. The primary emphasis of the wood quality work is to assess the relationship of wood properties to age for spruce and fir, although other species are also being studied. This report describes work conducted during 1997 in both areas of research.

### Sludge and Wood Ash

#### Area 1 (Great Northern Paper Co.)

A combination of papermill sludge and wood ash was hand applied to plots at rates of 0 and 2.4, 4.8, and 9.6 dry tons/ac; at one of three times—late May, late July, or late September; and for one, two, or three years in succession in a clearcut planted to black spruce in 1986. 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 1996 growing season showed that a trend between dbh and application rate still existed, although the effect of application rate on dbh was not statistically significant. Trees in the control plots had the largest dbh,

and dbh decreased successively with each increase in application rate. The difference in dbh between the control and the 9.6-tons/ac plots was 0.21 in. The decrease in dbh with increasing application rate that existed after the 1996 growing season is a carryover from the effect that the treatments had in stimulating the growth of competing vegetation during the early years of the study and the effect that that vegetation had on growth of the black spruce seedlings. During the 1996 growing season, the overall mean diameter growth was 0.39 in. and was virtually identical at all application rates. It is anticipated that one more set of measurements will be made in these plots.

#### Area 2 (International Paper Co.)

A mixture of primary and secondary papermill sludge was applied to plots at rates of 0 and 40 dry tons/ac in October 1989. The plots had been established in a clearcut planted to red pine about five years prior to the sludge application. The sludge was applied to the plots by machine in conjunction with an operational spreading of the area.

Diameter measurements clearly indicated a growth response beginning in 1991 and lasting until 1994 (Figure 20). In 1995 growth in control plots slightly exceeded that in treated plots. Measurements made after the 1996 growing season indicated that there was little difference in growth between control plots and treated plots. It is anticipated that one more set of measurements will be made in these plots.

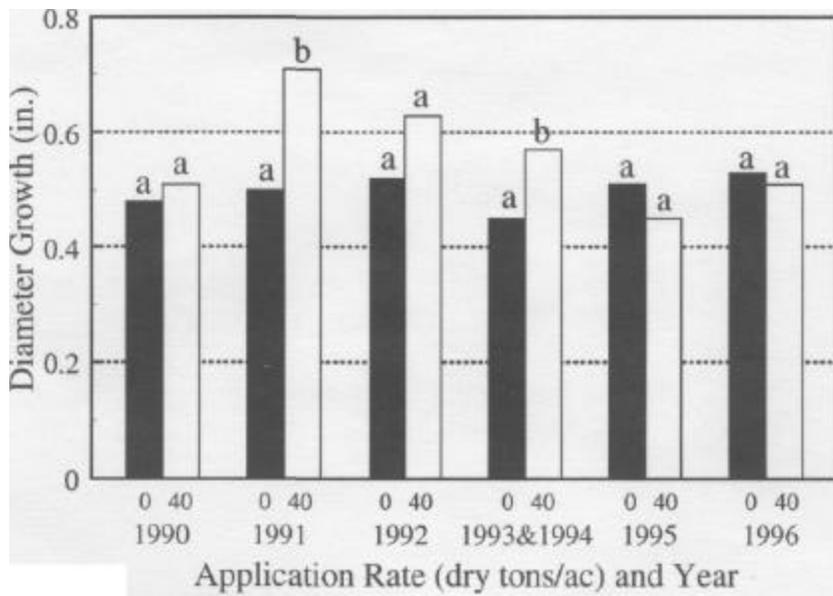


Figure 20. Diameter growth (stem height 3 ft) of planted red pine treated with a mixture of primary and secondary papermill sludge at rates of 0 and 40 dry tons/ac. The sludge was applied in October 1989. Means having the same lower case letter are not significantly different (P=0.05).

**Area 3 (International Paper Co.)**

A mixture of primary and secondary papermill sludge was applied to a clearcut planted to red pine about five years prior to the application. The sludge was applied by machine at a highly variable rate, ranging from 0 to more than 60 dry tons/ac. After the sludge was applied, seedlings were selected to represent application rates of 0 and approximately 5 to 15, 15+ to 30, and 30+ dry tons/ac.

Measurements of dbh made after the 1996 growing season (Figure 21) show a progressive decrease in dbh with increasing application rate. The mean dbh of trees that received the highest application rate was significantly less than the mean dbh of trees that received each of the other rates. This trend was clearly evident in diameter growth for the five-year period 1990 through 1994 (Figure 22). These measurements were made at a stem height of 1 ft because the seedlings averaged only 2 ft tall when the study was initiated. The effect of application rate reached a maximum after the 1994 growing season. This is the first year that measurements were made at breast height. Since then there has been no significant difference in diameter growth at breast height between treatments, but the difference in dbh has been maintained.

**Wood Quality Research**

The effort during 1997 was spent primarily on three studies. *Study 1*—This study is directed at assessing the effects of drainage class and age on wood properties of red spruce. *Study 2*—This study involves the possible effects of precommercial thinning, as well as commercial thinning in mature stands, on wood properties. Both balsam fir and red spruce are included in the precommercial thinning portion of the study. The commercial thinning portion of the study

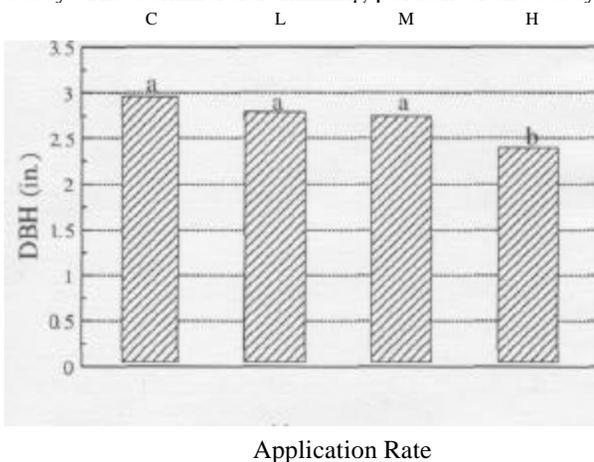


Figure 21. 1996 diameter at breast height of planted red pine treated with a mixture of primary and secondary papermill sludge at four rates. The sludge was applied in September 1989. Means having the same lower case letter are not significantly different (P=0.05). (C = 0 dry tons/ac, L = 5 to 15 dry tons/ac, M = 15+ to 30 dry tons/ac, H = 30+ dry tons/ac).

focuses on red spruce. *Study J*—This study looks at the possible effects of age and growth rate on wood properties of red pine, with an emphasis on young, rapidly growing stands of merchantable size trees.

**Study 1**

Seven mature red spruce stands were selected on somewhat poorly drained soils and seven on poorly drained soils in the spruce-fir region of northcentral Maine. Five trees were selected from among the dominant and codominant crown classes in each stand. Tree age was generally about 70 to 75 years at breast height. All trees were felled and a bolt was taken from each tree near breast height. The bolts were sealed on both ends to prevent moisture loss and brought to Orono, where a 3-in.-wide flitch, centered on the pith, was sawn from each. Specimens to be used in determining specific gravity, modulus of rupture, and modulus of elasticity will be cut from the flitches. The specimens will be centered on growth rings 5, 20, 35, and 50 from the pith. Preparation and testing of specimens from trees in stands on the poorly drained soils is approximately one-half complete. Preparation and testing of specimens from trees from stands on the somewhat poorly drained soils has not yet started.

Work on trees from seven stands on moderately well drained soils has been completed. The results of this work were presented in the 1996 CFRU Annual Report. The results clearly indicate a pronounced effect of age and that all properties continued to increase through age 50. Specific gravity was about 10% higher at age 50 than at age 5, and modulus of rupture and modulus of elasticity were about 50% higher. There was very little difference in wood properties among stands.

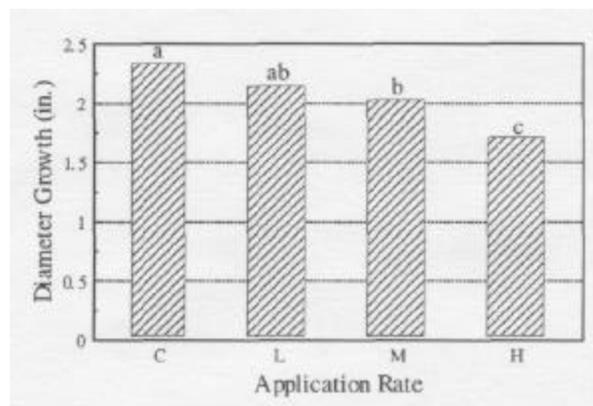


Figure 22. Diameter growth (stem height 1 ft) from 1990 through 1994 of planted red pine treated with a mixture of primary secondary papermill sludge at four rates. The sludge was applied in September 1989. Means having the same lower case letter are not significantly different. (C = 0 dry tons/ac, L = 5 to 15 dry tons/ac, M = 15+ to 30 dry tons/ac, H = 30+ dry tons/ac).

## Study 2

Sample material was taken from mature trees in thinned and unthinned plots in a stand of 75-year-old red spruce following the same procedure as in Study 1. The plots had been thinned in 1983. Three precommercially thinned stands, each having an unthinned area to serve as a control, were located. All precommercially thinned stands are predominantly balsam fir, but one stand appears to have sufficient red spruce to be able to examine the effect of precommercial thinning on that species also. Trees in all stands are 27-28 years old at breast height, with 13-14 years of pre-thinning growth and 14 years of post thinning growth. It is anticipated that trees from at least one of these stands will be obtained in 1998.

## Study 3

Work on the relationship of wood properties to age and growth rate in red pine is nearing completion. Wood properties being studied are specific gravity, modulus of rupture, modulus of elasticity, longitudinal shrinkage, and microfibril angle. Analyses of the data have not been completed, but it appears that the values of the first three properties increase until about age 40 (40th growth ring from the pith). An increase in the value of those properties means that wood becomes more suitable for uses in which those properties are important. Longitudinal shrinkage and microfibril angle decrease until about age 25. A decrease in the value of these properties means that wood becomes more suitable for uses in which these properties are important. It is clear that wood quality improves as trees become older and that shorter rotations will result in an overall reduction in wood quality.

**EFFECTS OF TIMBER HARVESTING AND TRAPPING ON POPULATION CHARACTERISTICS,  
HABITAT SELECTION, AND AREA OCCUPANCY BY AMERICAN MARTEN IN NORTHERN MAINE**

**Dr. Daniel J. Harrison**

Field work on the CFRU-funded portion of our project began in May 1994 within the Baxter Park site. This site is within a forest reserve without recent (> 35 years) trapping or timber harvesting, and serves as the baseline for evaluating the relative effects of trapping and timber harvesting (T4 RII WELS) and timber harvesting without trapping (T5 RII WELS) 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 WELS, T5 RII WELS) are being funded by MDIFW, the Maine Agricultural and Forest Experiment Station (MAFES), and the Department of Wildlife Ecology (OWE), 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 1996-97 included David Payer (Ph.D. student), Angela Fuller (M.S. student), H. Joseph Lachowski (M.S. student), Duggins Wroe (technician), Angela Matz (technician), Gerrard Thomas (technician), and Rodney Kelshaw, Anthony McCue, Jesse Berube, and Meredith Loud (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. A. Fuller's thesis research is evaluating the influence of partial harvesting on marten and their primary prey species; her project is supported by CFRU (1998-99) and by MAFES and OWE (1997 pilot study). Lachowski's thesis, which was completed in December 1996, was funded by MAFES and DWE, and evaluated relationships among prey abundance, habitat, and martens on industrial forestlands in T4 RII WELS and T5 RII WELS.

### **Objectives**

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

- 1) to document and compare seasonal habitat selection by martens in an untrapped forest reserve, an untrapped industrial forest, and a trapped industrial forest; and
- 2) to document and compare population characteristics (i.e., home range size, inter- and intra-sexual home range overlap, density, age and sex structure, survival

and percentage females lactating) of martens in an untrapped forest reserve, an untrapped industrial forest, and a trapped industrial forest.

### **Finding**

As proposed, CFRU funding covers 50% of the direct costs to operate the Baxter Park study area. Scheduled CFRU funding, additional to annual support provided by Maine Forest Service (\$15,564) and \$5,700 "in kind" support (flying time, contract labor) provided by MDIFW was sufficient to cover field operations in Baxter State Park during FY 1996-97. 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 continued to be fully funded via MDIFW, MAFES, and DWE.

Although partial harvesting approaches are the dominant silvicultural practices currently being used to manage forests in Maine, nearly all previous work on the effects of timber harvesting on wildlife in Maine have evaluated influences of clearcut logging. Thus, CFRU approved an expansion of the marten project during 1997 to include an evaluation of the influence of partial harvesting activities on marten and their primary prey species. Funding for that project will be provided by CFRU during 1998 and 1999. Additionally, MAFES and DWE provided limited support to initiate the process of radiocollaring, monitoring, and snow tracking of martens in partially harvested stands during January through September 1997.

The National Council of the Paper Industry for Air and Stream Improvement provided additional support during 1 April 1995 to 31 March 1997. This funding was used to evaluate and compare microhabitat characteristics in areas receiving different intensities of use (high use, low use, no use) by martens. The specific objectives of this work were to document and compare microhabitat characteristics between forests (> 20 ft. in height) with different intensities of use by resident, nonjuvenile martens, and to compare microhabitat characteristics between stands subjected to natural disturbance (spruce-budworm mortality) and logging disturbance. 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 and 1996 in T5 RII WELS, and in Baxter State Park. The final report for this project will be completed by December 1997 and will be made available to CFRU cooperators.

**Progress During October 1996 to September 1997**

We trapped martens from 2 June to 5 July in T5 RII WELS, T4 RII WELS, and Baxter State Park (BSP). 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 8 to 17 individuals during 1991-97, whereas the number of adult female residents ranged from 2 to 10 (Figure 23). The total number of marten captured and radiocollared on the three study sites during 1997 was 51 (18 females, 33 males), which compared with 48 (21 F, 27 M), 55 (22 F, 33 M), and 76 (28 F, 48 M) marten captured on the three study sites during 1994, 1995, and 1996, respectively. Percentage changes in numbers of marten captured in 1997 compared to 1996 was +5% in the forest reserve (BSP), -31% in the industrial site without recreational trapping, and -47% in the industrial site with recreational trapping (Figure 24). Densities of deer mice and red-backed voles declined 67% between 1995 and 1996, which appears to have caused a reduction in survival and recruitment of marten into the resident population. Small mammal populations rebounded in summer of 1996, which could result in better recruitment into the populations inhabiting industrial forest sites during winter 1997. Thus, we will be proposing to project cooperators a plan to capture and radiocollar marten for an additional summer (1998) in T5 RII WELS. This one year extension on our site with

timber harvesting and without trapping would allow us to better evaluate whether the expansion of marten populations in managed, untrapped forests can be maintained over time. This extension would cost ca. \$7,000 for 1998, compared with an annual cost of ca. \$20,000 for the previous work in that township. The differences in costs would result from efficiencies related to the operation of ongoing companion studies (e.g., investigations of marten, small mammals, and snowshoe hare in partially harvested stands), which would provide shared field personnel, vehicles, equipment, and housing. If approved by project sponsors, this extension would delay the final date of project completion by six to nine months.

We monitored radiocollared martens from the air on a weekly basis from 1 October 1996 to 31 May 1997. From 1 June to 30 September 1997, resident marten were monitored approximately 2-4 times weekly from the ground, and weekly from aircraft. As of 30 September 1997, approximately 11,000 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 related to microhabitat characteristics).

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

Three townships (T5 RII WELS, T6 RII WELS, and T6 RIO WELS) were closed to commercial fur-

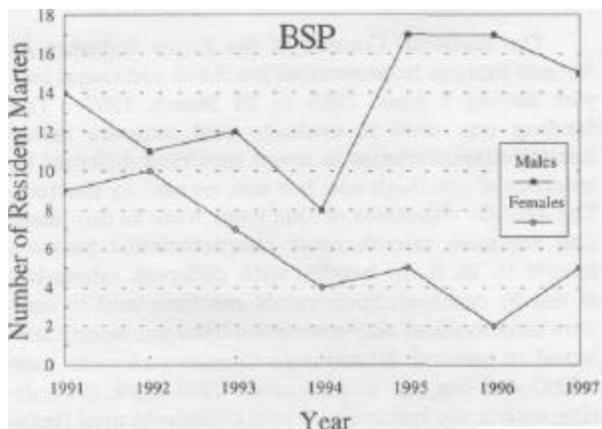


Figure 23. Numbers of resident male and female marten captured on the forest reserve site in Baxter State Park during 1991-97. Fifty percent of dedicated funding for studies on the BSP site are funded by CFRU and 50% are provided by Maine Forest Service. Significant "in kind" support for aircraft time and seasonal labor is provided by Maine Department of Inland Fisheries and Wildlife.

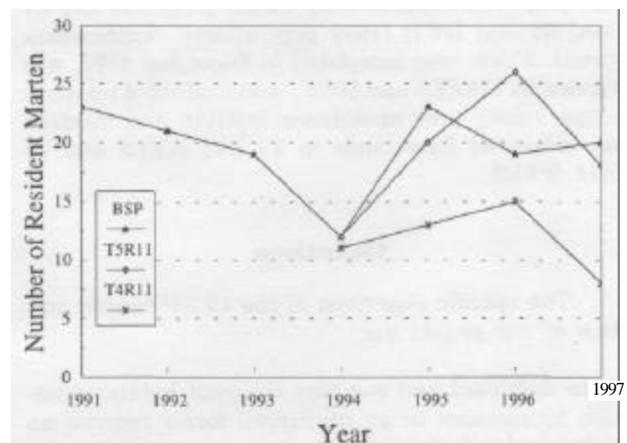


Figure 24. Number of resident marten captured on the forest reserve in Baxter State Park (BSP), the treatment area with timber harvesting and trapping closure (T5R11), and the treatment area with both timber harvesting and recreational fur trapping (T4R11) during 1991-97.

bearer (except beaver and bear) trapping by the MDIFW during 1994, 1995, and 1996 to facilitate our study of effects of trapping on marten populations. Recently, a rule-making decision to extend this closure in T5 RII WELS, to expand the closure to T4 RII WELS, and to eliminate the closure in T6 RII WELS and T6 RIO WELS was enacted for the 1997 trapping season. These closures will simultaneously allow us to continue to monitor populations of marten in the treatment area with timber harvesting and without trapping (T5 RII WELS), and will provide the protection necessary to maintain sufficient numbers of surviving marten for our studies of the influence of partial harvesting on winter selection within home ranges comprised of partially harvested and residual stands. We continue to work with MDIFW to enforce the closures, 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 to all licensed trappers in Maine to inform them of changes resulting from recent rule-making

### Associated Projects

#### Influence of Partial Harvesting on Marten and Their Primary Prey Species

*Scope and Objectives*. Habitat loss has been cited as a major cause of extinction of American marten from its original range. Research conducted on the effects of forest harvesting on populations of American marten have focused largely on clearcutting. Forest practices in Maine are currently shifting from a reliance on clearcutting to partial harvesting (97% of all Maine timber harvesting in 1996 was partial harvesting); however, few studies have determined the relative differences in habitat quality of partially harvested areas relative to residual forest stands for marten and their associated prey species. Thus, we conducted pilot studies during winter and summer field seasons in 1997. We evaluated the feasibility of evaluating landscape and stand scale habitat selection by attempting to capture and radio collar marten that inhabit home ranges that contain substantial (> 20% of home range) areas that have been partially harvested since 1993. We will compare use patterns of marten pre- and post-harvesting to evaluate landscape-scale selection. Stand-scale selection will be evaluated by assessing the relative preference of partially harvested areas within home ranges of resident marten. Two-year funding for this project was approved by CFRU cooperators for 1998 and 1999.

Choice of forest stands by marten is associated with food abundance, and it has been suggested that marten populations are proximally food regulated. We

will compare small mammal densities in partially harvested stands to other forest types and relate densities to microhabitat features, including coarse woody debris. Small mammals will be live-trapped on 20 trapping grids in six forest types (n=three mixed partial harvest, four deciduous partial harvest, seven uncut mature-mixed, two uncut mature-hardwood, two uncut mature-softwood, and two regenerating clearcut). Microhabitat features will be measured at the trapping grids and will be used to evaluate the influence of stand and microsite variables on the abundance of small mammals. During a companion study in 1995, microhabitat features were measured on the trap grids for small mammals located in mature (n=11) and regenerating (n=2) forest stands.

Specific objectives of the partial harvesting study are

- 1) to compare changes in use of the landscape by marten before and after partial harvesting;
- 2) to document stand-scale patterns of habitat selection by marten whose home ranges have been influenced by partial harvesting and compare to patterns of habitat selection of marten in areas without partial harvesting;
- 3) to estimate small mammal and snowshoe hare densities in partially harvested stands and compare with other forest types; and
- 4) to document and compare overstory, understory, and coarse woody debris characteristics among partially harvested stands and uncut, mature forest stands.

*Status*: As of 30 September 1997, we have radiocollared 11 (3 F, 8 M) marten whose home ranges comprise >20% partially harvested stands. Approximately 575 telemetry locations have been obtained from ground and aircraft. Small mammal trapping was conducted in partially harvested and mature stands and resulted in 1,326 captures of 601 individuals (63% red-backed voles, 24% deer mice, 13% shrews during 7,680 trap-nights. Microsite characteristics were sampled at 112 locations distributed across seven grids used to census small mammals. Grids were located in forest stands that were partially harvested during 1991-1995.

*Future Plans*: We will attempt to capture and radiocollar all resident martens with home ranges that comprise partially harvested stands on our 165 km<sup>2</sup> study site during spring 1998. Locations of radiocollared animals will be obtained during winter 1998, summer 1998, and winter 1999. Small mammal trapping will be repeated during summer 1998. At the end of the leaf-off season (spring 1998), counts

of snowshoe hare pellets will be conducted on 5 m x 30 cm transects on the innermost 12 trapping stations within each grid used to census small mammals. Project completion is scheduled for December 1999.

*Funding Sources:* MAFES and DWE (1997), CFRU (1998, 1999).

### **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 feet in height) receiving different intensities of use (# 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. Further, comparisons of microhabitat features between regenerating clearcuts (generally receive little use by martens) and regenerating budworm kills (receive much use by martens) will be conducted to identify microhabitat features that might be managed for in the future to maximize use of stands by martens following forest harvesting.

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. Fifteen grid cells per use category were sampled in areas defined as receiving high use, low use, and no use in the industrial forest, and 18 grid cells were sampled in areas of both high use and low use in Baxter State Park. Each cell had a minimum of one sampling station per every 2.5 ha.

*Results:* In 1995-1996 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 results from multivariate analysis suggest that, within the industrial forest, areas used by martens were distinguished from unused areas primarily by characteristics related to stand maturity, i.e., used areas had greater snag volume and tree height. In contrast, unused areas had a more open overstory canopy and denser growth in the shrub layer. Relatively high hardwood basal areas and deep litter characterized areas that received high marten use. These relationships were consistent with habitat associations of preferred small mammal prey species, as described in a companion study. Thus, martens appeared to be selecting habitat to maximize access to prey. We further conclude that forestry practices that preserve characteristics of stand maturity in harvested stands (e.g., partial harvesting and snag retention) will likely benefit martens and urge additional research into the effects of partial harvesting of forests on habitat quality for martens.

In contrast to the industrial forest, we detected few differences between areas receiving high vs. low use by martens in the forest reserve. Factors other than the habitat characteristics we studied (e.g., intraspecific competition, access to mates, prey abundance) may influence choice of microsites by martens in areas where nearly all of the forested stands include mature trees, and where human harvesting has little influence on marten demographics.

*Funding Sources:* NCASI, MDIFW, MAFES, CFRU, MFS, DWE

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

*Background and Scope:* Martens 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 martens. Further, martens are also widely cited as an associate with conifer-dominated stands because of perceived positive relationships between conifer dominance and structural complexity.

Hence, we investigated 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 martens on our industrial forest site (T4 R11, T5 R11 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 were 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 were 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 were used to evaluate the relationship between the response variable (small mammal densities) and the explanatory variables (microhabitat variables), and to evaluate whether foraging marten select for the same overstory and microhabitat characteristics that are selected by their primary prey species. We have used this information to identify which structural features could be managed for in harvested forest stands to maintain use by marten and their principal prey species.

*Status:* This project was completed during 1997 and the final report, in the form of H. J. Lachowski's M.S. thesis (May 1997), is available upon request.

*Results:* We examined food habits of marten, overstory habitat selection by small mammals, and microhabitat characteristics associated with small mammals captures. Percentage occurrence of food items was quantified for 219 individual marten scats. Red-backed voles occurred in 45.5% of scats and deer mice in 32.3%. Snowshoe hare and red squirrel were more frequently consumed in winter and occurred in 35.3% of winter scats. Berries were the principle component of the marten diet (> 71% occurrence in scats) during summer and fall. Marten seemed to select mice and voles in proportion to their relative abundance. Proportionately, red-backed voles and deer mice, re-

spectively, accounted for 62.7% and 37.3% of mice and vole occurrences in scats and constitute 66.8% and 32.1% of mice and vole captures.

Small mammal populations experienced a 67% decline between 1995 and 1996. During both years, deciduous and mixed coniferous-deciduous stands had greater small mammal abundance than coniferous and regenerating stands. Abundance in budworm-killed stands declined only 27%, whereas regenerating habitat seems to be a poor habitat for mice and voles (88% decline). Snowshoe hare density was greater in regenerating and budworm-killed stands than either deciduous or mixed stands. Red squirrels were ubiquitous in distribution across the five forest cover types. Budworm-killed stands may be important to marten because of their prey base and abundance of potential resting sites (i.e., snags for summer thermoregulation and ground structure for winter subnivean access).

Small mammal abundance was higher in mature stands than in regenerating or budworm-killed stands and was correlated with several variables that reflected stand maturity (canopy cover, average dbh, volume of stumps). In this study, small mammals did not seem to select habitat based on structure or volume of coarse woody debris, perhaps because in northern Maine sufficient structure was available in all mature stands to satisfy small mammal habitat requirements.

Studies in northern Maine suggest that marten may select complex horizontal and vertical structure found in mature and insect defoliated stands. Marten also use mixed and deciduous stands, possibly because of higher prey abundances compared to regenerating stands. Small mammals may also be associated with structure associated with mature forest stands. Further research needs to address thresholds of structure required by small mammals. Increasing structural diversity in regenerating stands may increase small mammal abundances, which in turn may encourage greater marten use.

*Funding Sources:* MAFES, DWE

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## ADDITIONAL TECHNOLOGY TRANSFER

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- Barker, A.A. and R.S. Seymour. Growth efficiency of eastern white pine (*Pinus strobus* L.): Influences of age and canopy position. Poster presented at National Convention of the Society of American Foresters, October 5-9, 1997. Memphis, TN.
- Dubis, J.J., and R.D. Briggs. Site Classification in western Maine. I. Habitat types and species composition. American Society of Agronomy Annual Meeting. Indianapolis, IN. November 3-8, 1996.
- Greenwood, M. Interviews for Channel 2, WABI and FM88 on foliage change. Week of October 3, 1996.
- Greenwood, M. Clearcutting referendum discussion at Orono Methodist Church. October 8, 1996.
- Greenwood, M. Selective harvesting and genetic degradation—lessons from tree improvement programs. Presentation in Robert Seymour's industrial forestry graduate seminar. November 7, 1996.
- Greenwood, M. Selective harvest and genetic degradation. Presented at Forestry Noontime Seminar Series at the University of Maine. February 7, 1997.
- Greenwood, M. Auxin-induced callus formation in epicotyls and hypocotyls in relation to rooting competence. Presented at Raleigh, NC at NCSU Lob and Slash Pine Rooted Cutting Project. Annual meeting. April 8, 1997.
- Harrison, D.J. Microhabitat-, stand-, and landscape scale habitat selection by marten in Maine. Workshop on Lynx and Marten Management in Eastern Boreal Forests, White Mountain National Forest, Gilead, MS. August 25-27, 1997.
- Harrison, D.J., and W.B. Krohn. What do, and don't we know about lynx and marten in Maine? Workshop on Lynx and Marten Management in Eastern Boreal Forests, White Mountain National Forest, Gilead, MS. August 25-27, 1997.
- Harrison, D.J. Habitat selection by American marten at multiple spatial scales. Invited seminar presented to Wildlife Division, Department of Natural Resources, St. Johns, Newfoundland. March 3, 1997.
- Harrison, D.J. Influence of forest harvesting and trapping on populations of American marten. Invited seminar presented to Forest Industry personnel, Corner Brook, Newfoundland. March 4, 1997.
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- Leathers, M.A., R.S. Seymour, R.D. Briggs, D.A. Maguire, and J.W. McLaughlin. Site classification in western Maine. II. Habitat types and sugar maple growth. American Society of Agronomy Annual Meeting. Indianapolis, IN. November 3-8, 1996.
- McLaughlin, J.W. Assessing compliance with BMPs on harvested sites in Maine: Final report. Maine Foresters Workshop for Annual Credits: Professional Development Series. Orono, ME. December 10-11, 1996.
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- Ostrofsky, W.D. Northeastern Forest Pest Council, Meeting Chair, and Session Moderator, Biology and management of exotic weed pests in the U.S. Portland, ME. March 11-13, 1997.
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- Payer, D. Marten research in Maine: Results of recent work, and future directions. Slide presentation and discussion, presented to the Central Maine Chapter of the Maine Trappers Association, Palmyra, Maine. 30 attendees. April 3, 1997.
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**COOPERATIVE FORESTRY RESEARCH UNIT  
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Maine Agricultural & Forest Experiment Station  
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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>Acer spicatum</i> Lam.	Mountain maple
<i>Betula alleghaniensis</i> Britton	Yellow birch
<i>Betula papyrifera</i> Marsh.	Paper birch
<i>Fagus grandifolia</i> Ehrh.	American beech
<i>Fraxinus americana</i> L.	White ash
<i>Larix decidua</i> Mill.	European larch
<i>Larix laricina</i> (Du Roi) K. Koch	Tamarack
<i>Larix leptolepis</i> (Sieb. & Zucc.) Gord.	Japanese larch
<i>Larix</i> spp.	Larch
<i>Osmorhiza clay ton</i> (Michx.) Clarke	Sweet cicely
<i>Ostrya virginiana</i> (Mill.) K. Koch	Ironwood
<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 resinosa</i> Ait.	Red pine
<i>Pinus strobus</i> L.	White pine
<i>Polygonatum</i> spp.	Solomon seal
<i>Populus</i> spp.	Aspen
<i>Prunus pensylvanica</i> L.	Pin cherry
<i>Rubus</i> spp.	Raspberry
<i>Thuja occidentalis</i> L.	Northern white-cedar
<i>Tilia americana</i> L.	Basswood
<i>Tsuga canadensis</i> L. Carr.	Hemlock
<i>Viburnum</i> spp.	Hobble bush
<i>Blarina (breuicauda)</i> Say	(Shorttail) shrew
<i>Clethrionomys gapperi</i> Vigors	Red-backed vole
<i>Lepus americanus</i> Erxleben	Snowshoe hare
<i>Maries americana</i> Turton	American marten
<i>Peromyscus maniculatus</i> Wagner	Deer mouse
<i>Sorex (cinereus)</i> Keer	(Masked) shrew
<i>Tamiasciurus hudsonicus</i> Erxleben	Red squirrel
<i>Choristoneura fumiferana</i> Clemens	Spruce budworm