

# CFRU Information Report 37

1995 ANNUAL REPORT AND  
RESEARCH SUMMARY OF THE  
COOPERATIVE FORESTRY RESEARCH UNIT

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

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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

This has been another successful and interesting year for CFRU. We have been involved with research, priority setting, membership recruitment, funding discussions, technical information transfer, and personnel changes.

CFRU is funding eight research projects: silviculture, timber quality improvement, ash/sludge, tree improvement, site classification, growth and yield modeling, and pine marten. In addition, Dr. McCormack holds the Henry W. Saunders Professor of Hardwood Silviculture Chair.

During the year we polled members to confirm our priorities for 1996-2000. After analysis we found there was strong support for most of the areas we currently cover plus an interest in harvesting. Specifics on these appear elsewhere in the report (see Appendix B).

The subject of funding and membership comes up constantly. Two specific membership visits were made to Prentiss & Carlisle and J. M. Huber Corporation. A funding formula proposal was discussed at the September meeting and then shelved. A funding committee is now reviewing numerous possibilities.

Technology transfer, training, and publications continued to be an area of focus. We have continued with two specific efforts aimed directly at cooperators: the monthly technical articles and the September field meeting. The September meeting this year

was held in Millinocket and included senior management from several cooperators. The purpose was to showcase past major work at Weymouth Point, solidify both priorities and funding commitments for 1996-2000, and review CFRU's and forest industry's role in research in a larger world context.

Of particular note this year was the National SAF meeting held in Portland, Maine. The scientists were all deeply involved in its organization as well as presenting numerous posters and papers. Dr. McCormack was the General Chair and deserves great credit for its success. CFRU scientists are an active and credible source of forestry information for Maine and beyond.

We have a couple of personnel changes occurring. Dr. Briggs left us in June and his replacement is being sought. Dr. McCormack is exploring a further reduction in time commitment during 1996. This leaves us with some interesting options for accomplishing our goals.

CFRU is a fine organization, which lives up to its name and potential. I am grateful for the help and support of everyone connected with it and look forward to helping CFRU reach its goals in the changing world.

Si Balch, Chair  
CFRU Advisory Committee

## DEAN'S REPORT

The Cooperative Forestry Research Unit has completed another successful research year. The CFRU continues to be an indispensable part of the College of Natural Resources, Forestry and Agriculture by providing the important link between the College and Maine forest industries. The CFRU is recognized nationwide, as their involvement in the recent and highly successful SAF National Convention in Portland attests.

Several changes have had a direct affect on the CFRU this past year. An important change in CFRU staffing occurred when Dr. Russ Briggs accepted a faculty position at the College of Environmental Science and Forestry, SUNY, Syracuse, New York. We will all miss his energy and enthusiasm, and we wish him the best. A search committee is now assessing applications to refill this important position.

As of the first of July, I assumed responsibility as acting Vice President for Research and Public Service at the University of Maine. I maintain my office in Winslow Hall, and expect to be back in my capacity as Dean of the College of Natural Resources, Forestry, and Agriculture in a few months. In the meantime, Don Stimpson has served as Acting Dean, and has done a first-class job of handling College affairs.

It has again been my pleasure to be associated with the Cooperative Forestry Research Unit. There is no better example of the positive results that can be obtained through working cooperatively with responsible and dedicated industry leaders.

G. Bruce Wiersma, Director,  
Maine Agricultural and Forest Experiment Station  
Interim Vice President for  
Research and Public Service

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**BALANCE SHEET**

1994-1995 Period  
10/1/94-9/30/95

ASSETS:

BALANCE FORWARDED SEPTEMBER 30, 1995	\$ 645,619.49	
FUNDS RETURNED TO CONTROL AFTER adjustments on 09/30/95	36,971.42	
INVESTMENTS 10/01/94-09/30/95	42,729.31	
CONTRIBUTIONS 10/01/94-09/30/95	420,154.00	
TOTAL ASSETS:		\$1,145,474.22

EXPENSES: 10/01/94-9/30/95

ADMINISTRATION - OSTROFSKY	61,886.20
SILVICULTURE - McCORMACK SOIL	138,220.16
SITE ~ BRIGGS HARDWOOD/ASH -	126,871.20
OSTROFSKY TREE IMPROVEMENT -	97,108.30
CARTER GROWTH/YIELD -	29,597.70
SEYMOUR PINE MARTEN -	17,769.00
HARRISON SLUDGE & ASH -	16,881.90
SHEPARD TREE IMPROVEMENT ~	5,703.62
GREENWOOD	4,515.50

TOTAL EXPENSES:		\$ 498,553.58
ENCUMBRANCES: Vehicle		17,060.00
BALANCE WITH ENCUMBRANCES 09/30/95		629,860.64
LESS DEDICATED FUNDS:		400,000.00
BALANCE ENDING 09/30/95		229,860.64

## CFRU LEADER'S REPORT

The Cooperative Forestry Research Unit has completed another productive year performing an unusually wide variety of forestry activities. Research projects have vigorously continued. Several long-established studies are providing new and important information on forest management topics including precommercial thinning of spruce-fir using herbicides, wood product losses associated with logging injuries, and effects of papermill sludge residuals to forest sites. In addition, several studies were initiated including a critical examination of Best Management Practices, a major effort on herbicide surfactant efficacy, and examination and assessment of hardwood overstory removal using a single-grip processor. Many other ongoing studies, in addition to those highlighted here, are detailed in this report.

Scientists and staff of the CFRU were also busy with numerous meetings throughout the year, starting with active participation in the New England SAP meeting in Burlington, Vermont, in March. Eclipsing efforts towards all other meetings, however, was preparation and accomplishment of the National SAP meeting in Portland, Maine, during October 1995. Dr. Maxwell McCormack, who served as General Chair of the National SAP meeting, is deserving of high acclaim for the overwhelming success of that meeting!

In late July, Dr. Russ Briggs left the CFRU to assume his duties *at* SUNY, Syracuse. He was extremely active up to the day of his departure, and made sure that the completion of several of his research efforts would be effectively accomplished. M.S. graduate student Mark Leathers has provided the program summary for this report. The CFRU search committee is now actively reviewing applications for the position vacated by Dr. Briggs.

Finalization of research priorities for the fifth five-year research period (October 1996 - September 2001) was completed at the September 1995 CFRU Advisory Committee meeting. A summary of the evaluation process and the priorities is listed as an appendix to this report.

The many changes with which the CFRU had to deal this past year and additional, anticipated changes for the coming year provides *a*. challenging work environment for all. The changes, however, also reflect an organization that is vibrant and deeply concerned about the forest resources of Maine. I look forward to meeting the challenges that the new year will bring.

William D. Ostrofsky, Leader  
Cooperative Forestry Research Unit

## SILVICULTURE

Dr. Maxwell L. McCormack, Jr.

### Overview

During 1995 an effort was devoted to administering the programs of the National Convention of the Society of American Foresters. I organized a two-day operational forestry workshop in conjunction with the Annual Meeting of the Northeastern Weed Science Society in Boston during early January. The CFRU refunding field tour in September was organized and appropriate preparations were made at the Weymouth Point Study Site. Stem analysis and plot measurement data from the 1994 field season were processed. This provides a large pool of data from the Austin Pond Study and the long-term spruce-fir thinning study to serve as a basis for manuscript preparation which is now under way. Field work was devoted to measurements on the 1989 aerial strip thinning site and establishment of two new field studies, one to evaluate surfactant combinations with glyphosate and a second to address improvement of a partially harvested hardwood stand.

The 1995 National Convention of the Society of American Foresters, the largest forestry technology transfer event ever to take place in the state of Maine, was hosted by the New England SAF in Portland, Maine, 28 October through 1 November. I served as the General Chair, Russell Briggs and William Ostrofsky chaired the subcommittee for technical posters, and Ron Lemin and Rick Dionne chaired the signs and reproduction subcommittee. The preconvention tour originating in Bangor and the tour of silviculture instructors organized by Robert Seymour visited CFRU study sites.

There were more than 1800 registrants, including more than 250 forestry students from throughout North America. Three days of activities took place in the Cumberland County Civic Center where 110 technical posters, an SAF Convention record, were displayed in the hallways of the upper level. A Critical Issues Forum, held in the Civic Center, addressed private property rights using the Northern Forest Lands Council as a case study. A delegate's choice day featured two workshops and 13 field tours through forests and mills of the region.

The final two days of the Convention were composed of technical programs carried out by the 27 Working Groups of SAF. Eight concurrent general sessions included presentations by 45 speakers. Twenty-four individual technical sessions were based on presentations of 109 speakers. One lunchtime period provided brown bag lunch sessions for informal discussions of ten topics of interest.

### Hardwood Silviculture

In mid-March more than 200 participants attended a workshop, "Hardwood Resource: Chal-

lenges and Opportunities," convened at the Hugh John Flemming Forestry Centre in Fredericton, New Brunswick. The two-day forum focused on the current status of hardwood supply, management, and silviculture. Speakers discussed research on hardwoods and identified areas for improvement. I was an invited contributor, and shared hardwood management strategies based on experiences in the U.S.

Table 1 was developed for the workshop to serve as a basis for discussion of silvicultural and harvesting activities. The table summarizes the complex array of silvical characteristics that provides challenges and unique opportunities in manipulating hardwood stands of high value over relatively long periods of time. It includes two common conifer species which can provide high-value, long-lived mixed stand components.

During the latter part of the field season an operational harvesting study was initiated in a hardwood stand to evaluate possible silvicultural treatments for reduction of diseased beech stems and improvement of species composition in the developing stand. This is being conducted in Lakeview Plantation on land managed by Wagner Forest Management for the Hancock Timber Resource Group. The stand is being partially harvested with special effort to retain healthy beech and species other than beech. Diseased beech stumps and saplings will be suppressed. Additional treatments will be carried out to introduce sugar maple regeneration as a component of the next stand.

### Precommercial Thinning of Spruce-Fir

Since the establishment of CFRU a high priority has been the need for cost-effective silvicultural treatments to reduce tree densities in the overstocked regeneration typical of post-harvesting stand development. Because of difficult working conditions and the unpredictability of available labor, a desirable characteristic of effective treatments is for them not to be labor intensive. From 1982 through 1989 several field trials were conducted by aerially applying precisely targeted herbicide bands to remove mechanically spaced corridors within dense stands of conifer regeneration. During the trial period, promising treatment bands and precise delivery systems were developed. Applications of picloram + 2,4-D in treated bands 7 to 9 ft wide, with approximately 3 ft residual strips of potential crop trees, result in an acceptable physical condition on the ground. Recent improvements in electronic guidance systems for application aircraft satisfy the remaining need in perfecting the aerial technique.

The 1989 trials were the most advanced level of the aerial treatments. In order to gain insight into treatment effects, those sites were revisited during

Table 1. Silvical characteristics of selected northern hardwood species.<sup>1</sup>

SPECIES	Shade Tolerance	Relative Site Required	Early Relative Ht Growth	Sprouting Vigor	Freq of Seed Crops (yrs)	Relative Life Span (yrs)
Sugar MAPLE	TOL	①	③②	②	3-7	200-300
American BEECH	TOL	②	③	③①	(2-5)	300-400
Red SPRUCE	TOL	③	④	-	3-8	300-400
White ASH	INTER	①	②	②①	2-5	200-250
Red OAK	INTER	②	②	①	3-5	300+
Red MAPLE	INTER	③	②	①	1	150
White PINE	INTER	③	③②	-	3-10	400+
Yellow BIRCH	INTER	②①	②	③	1-3	300+
Paper BIRCH	Intolerant	②	①	②	2	100-200
ASPEN	Intolerant	③	①+	①	4-5	30-100

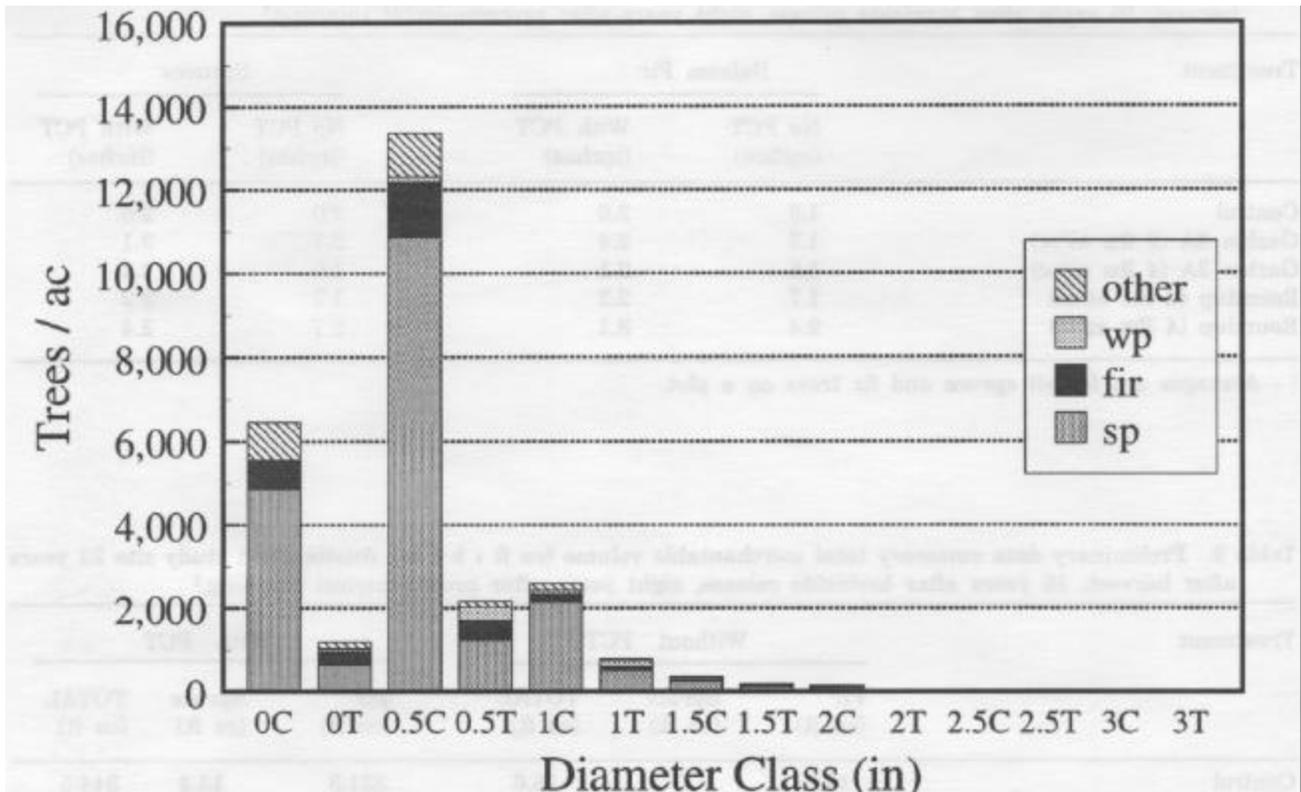
NOTES: Two conifer species included that can provide high-value, long-lived stand components. White ash tends to be more tolerant as seedlings. Beech sprouting is infrequent from stumps, common from root suckers. Beech seed crops are inconsistent depending on incidence of beech bark disease. Circled numbers: @ = high/fast; @ = medium/moderate; @ = low/slow.

<sup>1</sup>This table compiled for the conference, "The New Brunswick Hardwood Resource, Challenges and Opportunities," Hugh John Flemming Forestry Centre, Fredericton, NB, 14 March 1995. Table adapted from Table 1 in Hornbeck, J. W. and W. B. Leak. 1992. Ecology and Management of Northern Hardwood Forests in New England. USDA Forest Service, Gen. Tech. Rept. NE-159. 44 p.

the 1995 field season. A retrospective appraisal of the young stand conditions was made. Representative plots were measured in a variety of band conditions to provide data on potential crop tree numbers, species, sizes, and growth rates. Comparisons with untreated portions of the same stands were attempted by identifying a limited number of locations in the same stands where the herbicide bands had not been applied. The untreated plot data are informative, but do not serve as truly valid controls. However, the treated area plots should characterize

the trees growing in the band treatments.

Trees were measured in half-inch diameter classes. A preliminary indication of reductions in stem numbers is illustrated in Figure 1. Data evaluations are underway to document the numbers of potential crop trees, by species, and their growth rates within thinned areas of different widths of treated strips. Stem analyses of selected crop trees will be reviewed as examples of growth rates of residual crop trees.



**Austin Pond Study Site Data**

Much time was devoted to measuring and evaluating the stem cross-sections collected for stem analyses during the 1994 field season. Tree volumes and growth rates are being computed. Since the original study was established only for herbicide efficacy evaluations, there are some difficulties with the data. Some preliminary data are shown in the following tables. Table 2 contains values of average quadratic mean diameters for four selected treatments. Table 3 shows total merchantable volumes for the same four treatments.

The application of operational precommercial thinning treatments eight years prior to collecting these data causes some confounding because of the guidelines followed during the thinning. Benefits from the herbicide release are evident, but the effects of the precommercial thinning often dominate the tree conditions. The entire data package, coordinated with past reports on this study site, are now a high priority for manuscript completion.

**Study of Surfactant Combinations with Glyphosate**

On 31 August 1995, a helicopter-applied field trial was established to evaluate nine selected

surfactants for use with glyphosate. This trial was initiated in response to recent changes and needs relative to the surfactant component of glyphosate-based forest vegetation management treatments.

1. All field experiences, to date, have verified the need for an effective surfactant, in sufficient quantity, in order to achieve silvicultural effectiveness from glyphosate applications.
2. Glyphosate is no longer formulated with an included surfactant in a product labeled for forestry use. Thus, it is necessary for the applicator, or landowner, to add an appropriate surfactant in sufficient quantity.
3. Recent developments in surfactant chemistry have made available a number of new products. These new surfactants raise possibilities for improving efficacy of glyphosate on difficult-to-control undesirables such as red maple.
4. Experiences in other regions with different surfactants have shown promise for improving rainfastness of glyphosate-based treatments. This improvement could add time to the limited spray window in our region.

Table 2. Preliminary data summary average quadratic mean diameter; Austin Pond study site 23 years after harvest, 16 years after herbicide release, eight years after precommercial thinning.<sup>1</sup>

Treatment	Balsam Fir		Spruces	
	No PCT (inches)	With PCT (inches)	No PCT (inches)	With PCT (inches)
Control	1.3	2.6	2.0	2.6
Garlon 3A (2 Ibs ai/ac)	1.7	2.4	2.1	3.1
Garlon 3A (4 Ibs ai/ac)	1.5	2.1	1.6	2.1
Roundup (2 Ibs ai/ac)	1.7	2.2	1.7	2.2
Roundup (4 Ibs ai/ac)	2.4	3.1	2.7	2.4

<sup>1</sup> - Averages are for all spruce and fir trees on a plot.

Table 3. Preliminary data summary total merchantable volume (cu ft i b / ac); Austin Pond study site 23 years after harvest, 16 years after herbicide release, eight years after precommercial thinning.<sup>1</sup>

Treatment	Without PCT			With PCT		
	Fir (cu ft)	Spruce (cu ft)	TOTAL (cu ft)	Fir (cu ft)	Spruce (cu ft)	TOTAL (cu ft)
Control	16.6	0	16.6	331.3	13.2	344.5
Garlon 3A (2 Ibs ai/ac)	455.0	30.5	485.5	293.3	82.5	375.8
Garlon 3A (4 Ibs ai/ac)	389.2	39.5	428.7	335.5	27.0	362.5
Roundup (2 Ibs ai/ac)	72.2	18.4	90.6	289.1	21.0	310.1
Roundup (4 Ibs ai/ac)	354.9	47.7	402.6	558.1	21.5	579.6

<sup>1</sup> - Volumes are for all trees 4.0", or more, in dbh on a plot.

This study is located in Great Pond Township on parcels within the 1995 herbicide spray program of Champion International; their support and cooperation is hereby gratefully acknowledged. The applications were applied by Maine Helicopter of Augusta with Wayne Clark as pilot. Additional financial support was provided by Dr. Domingo C. Riego, The Agricultural Group, Monsanto. The assistance and counsel of Dr. Peter J. G. Stevens, OSi Specialties, Inc., is acknowledged with appreciation. The following cooperators provided the materials used in the treatments:

Brewer International, Vero Beach, FL  
 Helena Chemical Company, Memphis, TN  
 Exacto Incorporated, Richmond, IL  
 Monsanto, The Agricultural Group, Carmel, IN  
 OSi Specialties, Inc., Tarrytown, NY  
 Loveland Industries, Inc., Tully, NY

A review of surfactant candidates resulted in the choices and levels listed in Table 4. Treatment No. 2, Accord + Entry II was used as a standard since it represents the basic Roundup® treatment with which we have had many years of experience.

All treatments were "hot mixed" as needed to load the helicopter in the desired sequence of applications with eight rinses inserted between surfactant treatments or groups of treatments. Batching used premeasured quantities of chemicals and procedures developed to assure cleanliness and accurate mixing for each treatment. All treatments were applied in a single morning spray session.

Prior to treatment, extensive field work was carried out to locate 30 plot center lines which were marked with large garbage bags of varying bright colors. Each plot was a single helicopter swath marked with 90 ft between centers to allow for buffer space between plots.

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Table 4. Surfactant treatments included in 1995 operational field trial with glyphosate. The base for each treatment was 2 lbs a.i. glyphosate (i.e., 2 qt Accord) in water to apply 5 gal total volume per acre.

	Treatment	Surfactant Level <sup>1</sup>
1	Control	.
2	Accord + Entry II (Standard)	20 oz
3	MON 77225 (dry glyphosate + MON58131)	0.25%
4	Accord + Arsenal 4WS <sup>2</sup> + Entry II	20 oz
5	Accord + MON 58131 (OSi Y-12800)	0.125 %
6	Accord + MON 58131 (OSi Y-12800)	0.25 %
7	Accord + MON 58131 (OSi Y-12800)	0.50 %
8	Accord + OSi SILWET L-77	0.125 %
9	Accord + SilEnergy (Brewer)	1.6 oz
10	Accord + SilEnergy (Brewer)	3.2 oz
11	Accord + LI 700 (Loveland)	10 oz
12	Accord + Flame (Loveland)	10 oz
13	Accord + Optima (Helena)	0.50 %
14	Accord + Kinetic (Helena)	0.125 %
15	Accord + Surfex TO 2025 (Exacto)	1 oz

<sup>1</sup>Percentages are v/v for total volume of batch; fluid volumes are amounts per acre.

<sup>2</sup>Arsenal 4WS rate was 1.5 oz per acre.

Actual swaths ranged in width from 75 to 85 ft. Because of irregular boundaries on the parcel, plot sizes were 4 to 9 acres. One live flagger worked each swath to assist in identifying the appropriate line of garbage bags. In addition, CFRU Research Technician Rick Dionne flew as spotter in the helicopter.

Conditions at the time of application were extremely dry. Target vegetation was under stress, and for some species, there had been noticeable leaf loss. This condition could compromise the results. However, relative differences between treatments, if any, should be informative. Data definitely will be indicative of likely results for the treatments when ap-

plied to target vegetation under drought stress. Throughout development of operational treatments, it is important to consider an ever present need in our region: expanding the operational spray window.

Preliminary observations will be made into autumn and through spring to early summer 1996. A detailed review of efficacy will be carried out in late August to early September 1996. At that time plans will be made for further review. Generally, a minimum of three years of observations is necessary to gain full understanding of effects in this type of study, but preliminary guidelines could be available by late summer 1996.

# SILVICULTURAL TECHNIQUES FOR THE IMPROVEMENT OF TIMBER QUALITY

Dr. William D. Ostrofsky

## Introduction

The research effort over the past year focussed on two projects. The first project involved completion of a ten-year study of thinning in paper birch, and examined the use of a single-grip processor for hardwood overstory removal. The second study was the continued monitoring of crop tree development and vegetation response from the application of papermill sludge ash and wood ash. A portion of this latter study formed the basis for a M.F. project, completed by C. Malitz in August. In September, T. Patton joined the program, and will be developing her plans for an M.S. thesis program over the coming winter.

Two major reports were published. Results are reported from a study of fine root chemistry of red spruce (Smith, Shortle, and Ostrofsky 1995). This study was initiated in 1989, and was partially funded by a cooperative agreement with the USDA Forest Service. In addition, a bibliography of all known CFRU publications, from the initiation of CFRU in 1976 through June of 1995, was edited and published. The bibliography lists more than 480 publications and should serve cooperators well as a quick reference guide to research results.

Assistance with all field work was again provided by CFRU Research Associate P. Caron. Also helping with data collection and field work was graduate student C. Malitz. M. Munoz, S. Alvarez, and M. Alvarez, three undergraduate forest engineering students from the University of Madrid, Spain, also spent several weeks at the birch thinning site. They assisted with plot layout and assessments of advance regeneration before and after overstory harvesting.

## Overstory Removal of Paper Birch - Effects on Advance Regeneration

Harvesting prescriptions that require the removal of an overstory from young advance regeneration are often the most difficult to accomplish. Advance regeneration is highly susceptible to damage from the felling of larger stems and especially from the skidding activities of whole-tree harvesting operations now in widespread use.

The use of in-woods processing and forwarding equipment, along with appropriate harvesting methods, have been developed in Scandinavian and European countries over the past two decades. The use of single- and double-grip processors and forwarders have been adopted by some companies in eastern Canada and, most recently, the northeastern United States primarily as an alternative method of thinning

in small-diameter softwood or mixedwood stands. Although production costs appear to be higher than with traditional equipment, savings in reduced damage to residual trees, reduced impact to the soil and site, and ability to enter stands earlier are often cited as advantages. The use of processor and forwarder harvesting methods may also be appropriate for other difficult silvicultural applications, but to date few of these applications have been critically evaluated.

The objective of the present study is to assess the effectiveness of a single-grip processor used for hardwood overstory removal on softwood and hardwood advance regeneration. Actual losses to regeneration as well as condition of remaining vegetation are being evaluated.

A sixty-acre stand of paper birch was thinned in 1984 in a CFRU experiment to assess logging damage to residual trees following whole-tree harvesting methods (Ostrofsky, Seymour, and Lemin 1986). The stand, located in Grafton Township on Boise Cascade land, was identified for final harvest in 1995. Due to the documented stand history and the established treatment layout, the opportunity was available to conduct an assessment of overstory removal effects on advance softwood and hardwood regeneration.

The overstory was approximately 75% paper birch and 25% yellow birch, with 35 ft<sup>2</sup>/A of basal area. Trees averaged 7.5 inches in diameter at breast height. Advance regeneration included balsam fir, paper and yellow birch, red maple, aspen, and red spruce. Balsam fir and the birches were predominant.

Three overstory removal treatments were evaluated: manual felling followed by forwarding and processor felling followed by forwarding (Figures 2 and 3), and feller-buncher felling followed by grapple skidding. Harvesting was conducted in July and August of 1995.

Five plots 10 m by 24 m were established in each treatment area (Figure 4). Plots for the two forwarder treatments were centered on and perpendicular to main skid trails established from the previous thinning. The stand area harvested by the feller-buncher had no previous skid trail designation established.

Each plot was divided into eight sections, to assess effect of distance from trails on damage to advance regeneration. Two mil-acre regeneration plots were measured before and after overstory removal for



Figure 2. The Rottne 2000 single-grip processor harvesting a paper birch overstory.

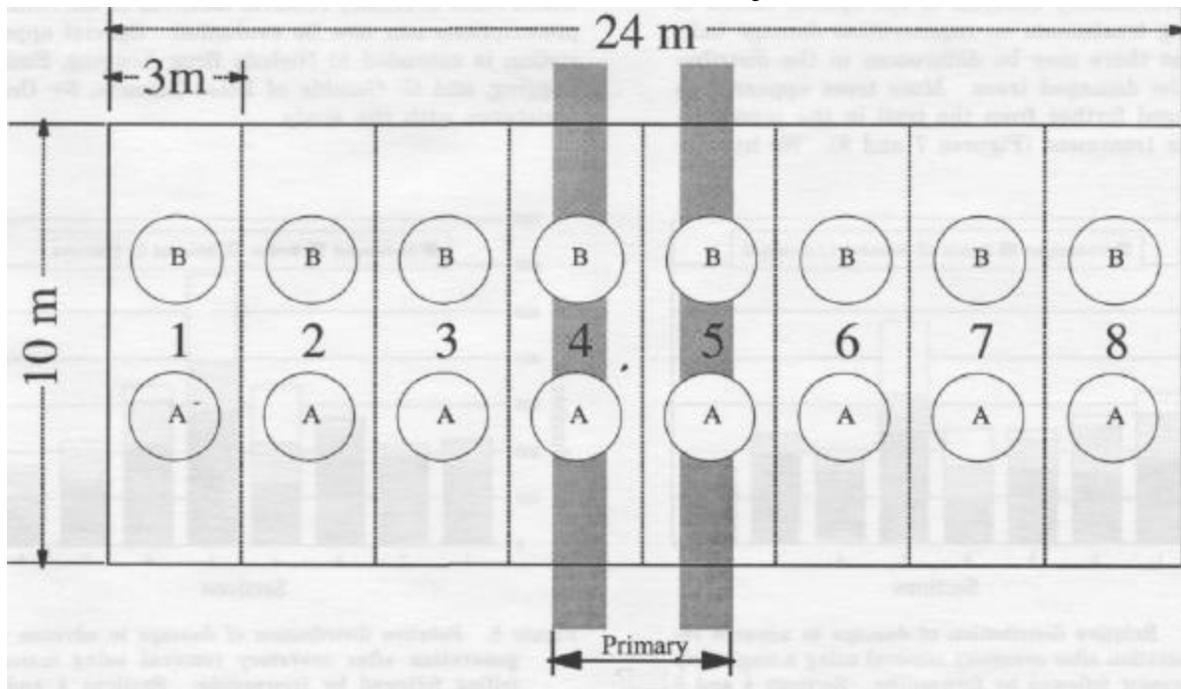


Figure 3. Moving birch logs to the landing with the forwarder.

comparison. Plots in the feller-buncher treatment have not yet been assessed for post-harvest damage.

Data indicate that percentages of advance regeneration affected by overstory removal using either manual felling or felling with a single-grip processor, followed by forwarding are comparable (Figures 5 and 6). Regeneration damaged or lost in the manual

felling treatment included 55% of the fir, 54% of the yellow birch, and 57% of the paper birch. Regeneration damaged or lost in the processor felling treatment included 44% of fir, 66% of yellow birch, and 57% of paper birch. Not all damaged trees will die. Of the percentages reported above, 44% of the fir and between 21% and 26% of both paper and yellow birch were expected to survive and contribute to stand development for both treatments.



Trail

Figure 4. Plot layout for measurement of advance regeneration.



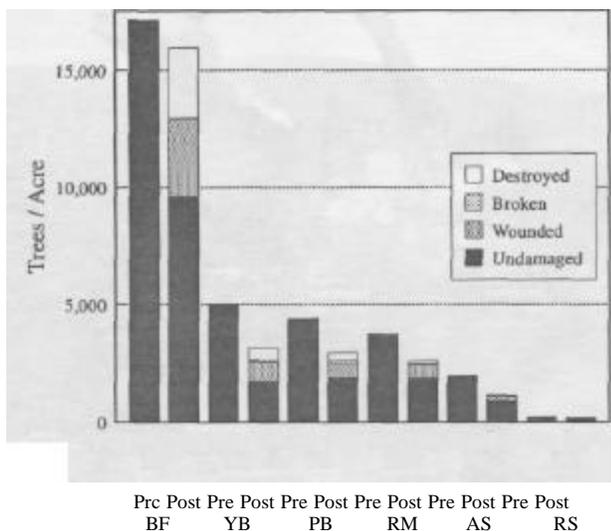


Figure 5. Condition and amount of advance regeneration before and after overstory removal using a single-grip processor followed by forwarding.

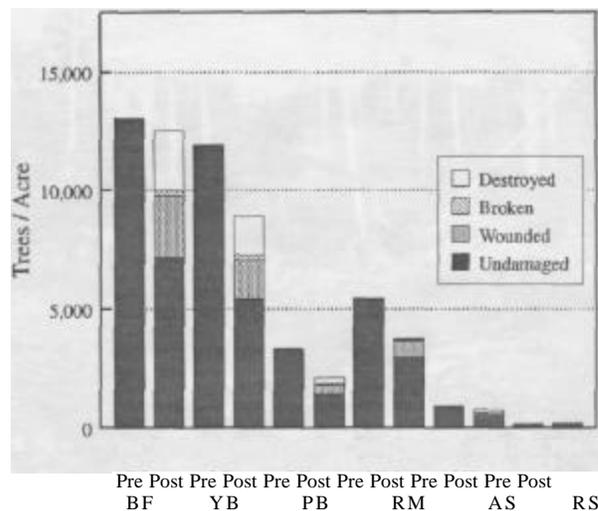


Figure 6. Condition and amount of advance regeneration before and after overstory removal using manual felling followed by forwarding.

In neither treatment was damage or loss of regeneration considered serious enough to affect future productivity of the stand. Regeneration statistics resulting from traditional feller-buncher overstory removal followed by grapple skidding are not yet available.

A preliminary analysis of the spatial effects of the felling treatments on regeneration damage indicates that there may be differences in the distribution of the damaged trees. More trees appeared to be damaged farther from the trail in the processor-forwarder treatment (Figures 7 and 8). We hypoth-

esize that this was likely an effect of the more concentrated limbing and topping done by the processor, as compared with that from manual felling.

In any case, total damage appears to be similar and of relatively minor consequence to stand productivity. This study provides regeneration data against which other overstory removal methods or harvesting prescriptions can now be evaluated. Special appreciation is extended to Nichols Bros. Logging, Smith Logging, and G. Gamble of Boise-Cascade, for their assistance with the study.

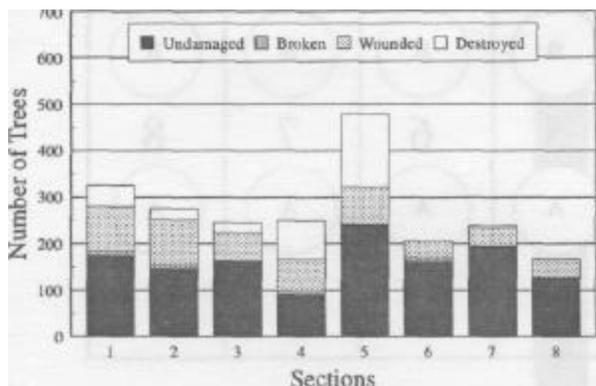


Figure 7. Relative distribution of damage to advance regeneration after overstory removal using a single-grip processor followed by forwarding. Sections 4 and 5 represent the location of the primary trail of the processor and forwarder.

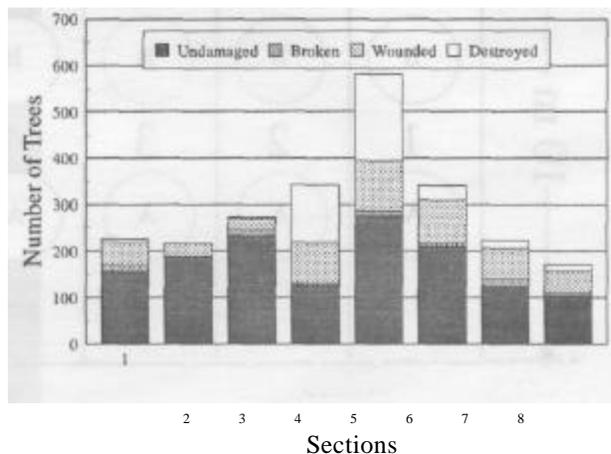


Figure 8. Relative distribution of damage to advance regeneration after overstory removal using manual felling followed by forwarding. Sections 4 and 5

represent the location of the primary trail of the

forwarder.

**Lumber Recovery from Thinned Paper Birch**

Another part of the ten-year paper birch thinning study included assessing the importance of various logging injuries in relation to the actual volume and value lost to final wood products. During the summer of 1995, the residual birch stand was harvested as described in the previous section of this report. Prior to the operational harvest, a total of 32 surviving plot trees were dissected and measured for stain, decay, and other defects related to specific wounds inflicted during the thinning. Results of individual tree dissections are now being compiled and analyzed.

Also during 1995, ten paper birch crop trees were selected from each of four damage categories: undamaged, slightly, moderately, and severely damaged for mill processing. The damage categories were those defined by the initial 1984 study. The first 8-ft log of each selected tree was sawn into 4x6-inch thick flitches, standard processing before kiln drying for the manufacture of dowels. The study trees were processed by Pride Manufacturing of Burnham, Maine.

Lumber was then graded based on 1x1x16-inch cutting units. Numbers of cutting units affected by defects associated with the logging injuries were tallied, and degrade was calculated (Table 5). Variation was high among the ten trees processed. Losses included those from decay, heavy stain, insect damage, and shake (Figure 9). Shake was commonly associated with barrier zone formation around the wound area.

Overall, volume losses to surviving trees were small compared with losses due to mortality. This result is probably because the trees remaining ten years after the thinning were the most vigorous, and likely were individuals able to compartmentalize wounds most effectively. Additional analyses and comparisons with results from the 32 dissected plot trees will be conducted this winter.

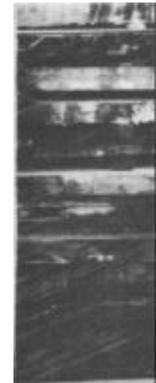


Figure 9. Stem decay resulting from a severe injury inflicted 11 years earlier. This represents the largest volume of decay observed in surviving, harvested trees.

Table 5. Loss due to defects associated with logging wounds, by wound damage class.

Number of Cutting Units"

Damage Class	Total	Sound	Defective	Mean Loss (%)	Range
None	1572	1572	0	0.0	—
Slight	1696	1642	54	3.3	0 - 16.9
Moderate	1825	1806	19	1.0	0 - 3.6
Severe	2582	2256	326	12.6	0. - 57.4

"Cutting Unit = 1x1x16-inches.

**Forest Land Application of Paper-mill Sludge Ash and Wood Ash**

Assessment of the effects of papermill sludge ash and wood ash to forest growth continued, with the completion of a M.F. project conducted by C. Malitz. The study was initiated in 1992 to determine the biological effects of papermill sludge ash and wood ash application to forest land. Four rates each of papermill sludge ash and wood ash were applied to plots in a newly established red pine plantation. The rates of ash applied were 0, 3, 6, and 9 tons/acre CaCO<sub>3</sub> equivalent. Ash was applied in late summer of 1992, and competition was mechanically controlled in the plots in 1992 and 1993.

Red pine were measured for total tree height and root collar diameter at the time of ash application, and one and two years after application. By the summer of 1994, a relatively uniform canopy of raspberry also had developed in all plots. The amount of competing vegetation (primarily raspberry) was measured, and element concentration status of raspberry foliage was obtained.

Statistical analysis revealed no significant (P<0.05) growth differences of red pine in plots treated with wood ash from those treated with sludge ash. Trees in plots treated with the highest rate (9 tons/acre CaCO<sub>3</sub> equivalent) of sludge ash were significantly (P<0.05) taller and had greater basal area

growth than did those in the control (no ash) plots. Trees in plots treated with the highest rate of wood ash were also significantly taller than those from control plots, but did not have a greater basal area.

Above-ground raspberry biomass in plots treated with sludge ash was not significantly higher (P<0.05) than biomass from control plots. Plots amended with wood ash, however, had significantly greater amounts of above-ground raspberry biomass than control plots at all levels of application. Analysis of raspberry foliage revealed no significant change in elemental status at any sludge ash application rate. Raspberry from plots to which wood ash had been applied showed significantly lower (P<0.05) levels of Mn and Al, and significantly greater levels, at higher application rates, of B, K, and P than raspberry from control plots (Table 6).

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Table 6. Elemental analysis of *Rubus* spp. foliage two years following papermill sludge ash and wood ash application at Heald Pond study site, Caratunk Township, Maine<sup>3</sup>.

Residual	Treatment	N	Ca	K	Mg	Al	B	Cu	Fe	Mn	Zn	
Sludge Ash	Untreated	1.80	6615	12550	3582	1385	21	31	5.5	49	882	37
	3 tons/ac	1.64	6770	13483	3430	1842	30	31	5.4	52	676	27
	6 tons/ac	1.62	6790	14450	3353	2008	22	32	5.4	45	670	35
	9 tons/ac	1.58	7010.	14683	3043	1647	29	33	6.4	48	805	27
Wood Ash	Untreated	1.80	6835	12583 <sup>b</sup>	3477 <sup>a</sup>	1370 <sup>b</sup>	31 <sup>b</sup>	31 <sup>b</sup>	5.3	47	772 <sup>b</sup>	34
	3 tons/ac	1.67	7440	14267	4067	2220	20	34	5.7	43	382	29
	6 tons/ac	1.61	8272	14983	4323	2340	22	36	5.3	44	333	27
	9 tons/ac	1.61	7923	14833	4505	2460	26	39	5.4	45	323	23

<sup>a</sup>Values (% for N, mg/kg for all others) represent means for six replicate plots.

<sup>b</sup>Significant difference (P<0.05) between treatment amounts within ash type.

## SITE QUALITY

Mark Leathers

### Introduction

Examination of productivity of northern hardwood systems has intensified during the past year. The focus is on sugar maple since it occurs throughout the northern hardwood types in Maine and has a high commercial value. Forty trees were sampled from 40 separate sites across western Maine. Sample trees were chosen from four of the ten habitat types (Dubis 1994) that are dominated by northern hardwood species. The habitat types of interest are WCT (wet compact till), ENR (enriched), DCT (dry compact till), and STB (shallow to bedrock). Stem analysis was performed (Figure 10) on each tree along with foliage samples and crown architecture measurements to estimate total leaf area. Rigorous lab analysis of the samples has been completed. S. Duigan, undergraduate in forestry, and L. Snow, undergraduate in education supported by a Department of Energy grant, continued to assist with sample analysis and data entry throughout the year.

### Site-Index Curves For Sugar Maple

Until now there have been no site-index curves developed for sugar maple in Maine. A rigorous screening of the stem analysis data to remove trees that showed any effects of suppression resulted in 20 trees suitable for developing site-index curves (Table 7). These curves (Figure 11) are an improvement over those published by Curtis and Post (1962) and Solomon (1968) for the Green Mountains of Vermont. These new site-index curves were presented as a poster at the 1995 Society of American Forester's National Convention in Portland, Maine.

### Relationship of Growth to Habitat Type

When height growth of sugar maple was partitioned by habitat type (Figure 12), the only significant difference in growth pattern seems to be in the shallow to bedrock (bedrock within 24" of the soil surface) habitat type. This finding reinforces that of Dubis (1994) who rejected the idea that sugar maple growth is dependent on soil drainage class. It appears more likely that growth is dependent on slope position. The best example is with the moderately well to well drained dry compact till habitat type, which appears to exhibit no difference in height growth from poorly drained wet compact till or enriched habitat types, but is different from shallow to bedrock habitat which has similar drainage. I will attempt to verify this with further analysis this fall. The analysis of the crown architecture and foliage data is currently underway. The results will provide valuable information on sugar maple growth efficiency on the different habitat types.

Figure 10. Mature sugar maple tree being felled for stem



analysis.

Table 7. Characteristics of trees used to construct height development curves.

Habitat " Type	N	DBH (cm)	Age (@bh)	Height (meters)
DCT	4	33.2 (26.5-40.5)	66.5 (57.0-85.0)	21.2 (19.3-23.3)
ENR	5	34.4 (29.5-45.5)	69.0 (62.0-79.0)	22.0 (19.0-23.5)
STB	5	29.0 (23.1-32.5)	74.0 (55.0-85.0)	19.7 (19.2-21.1)
WCT	6	26.3 (18.9-31.2)	58.2 (48.0-66.0)	20.0 (19.2-21.1)

"DCT=dry compact till; ENR=enriched; STB=shallow to bedrock; WCT=wet compact till.

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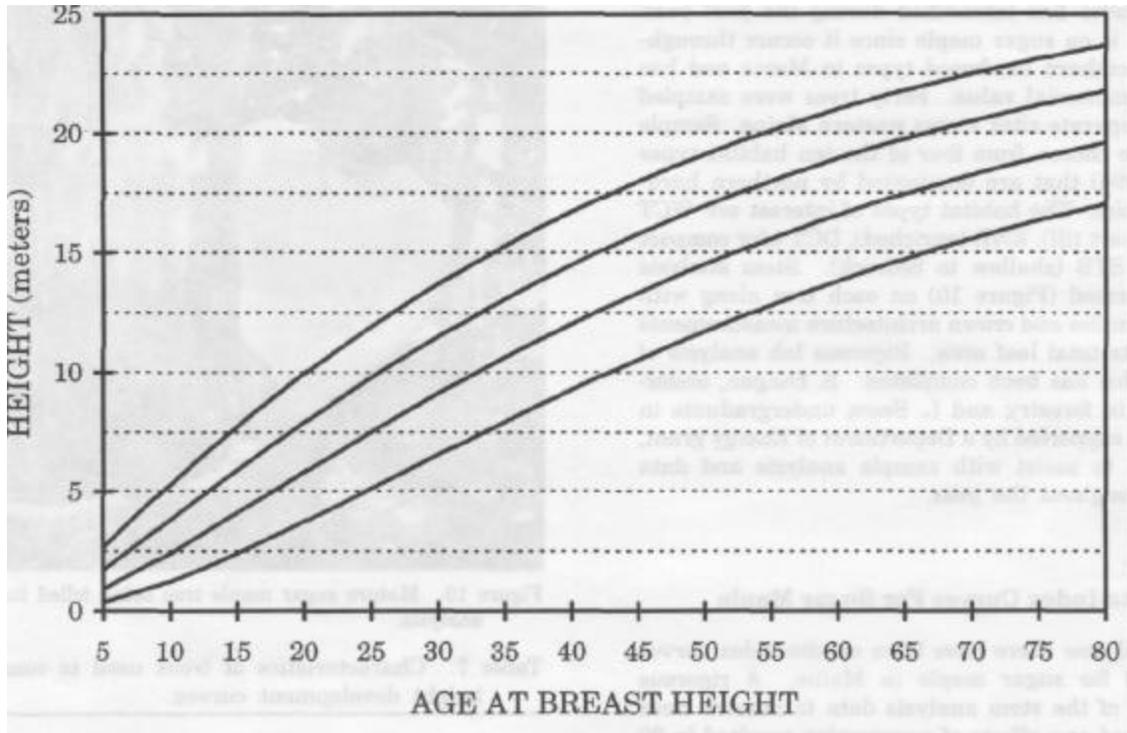
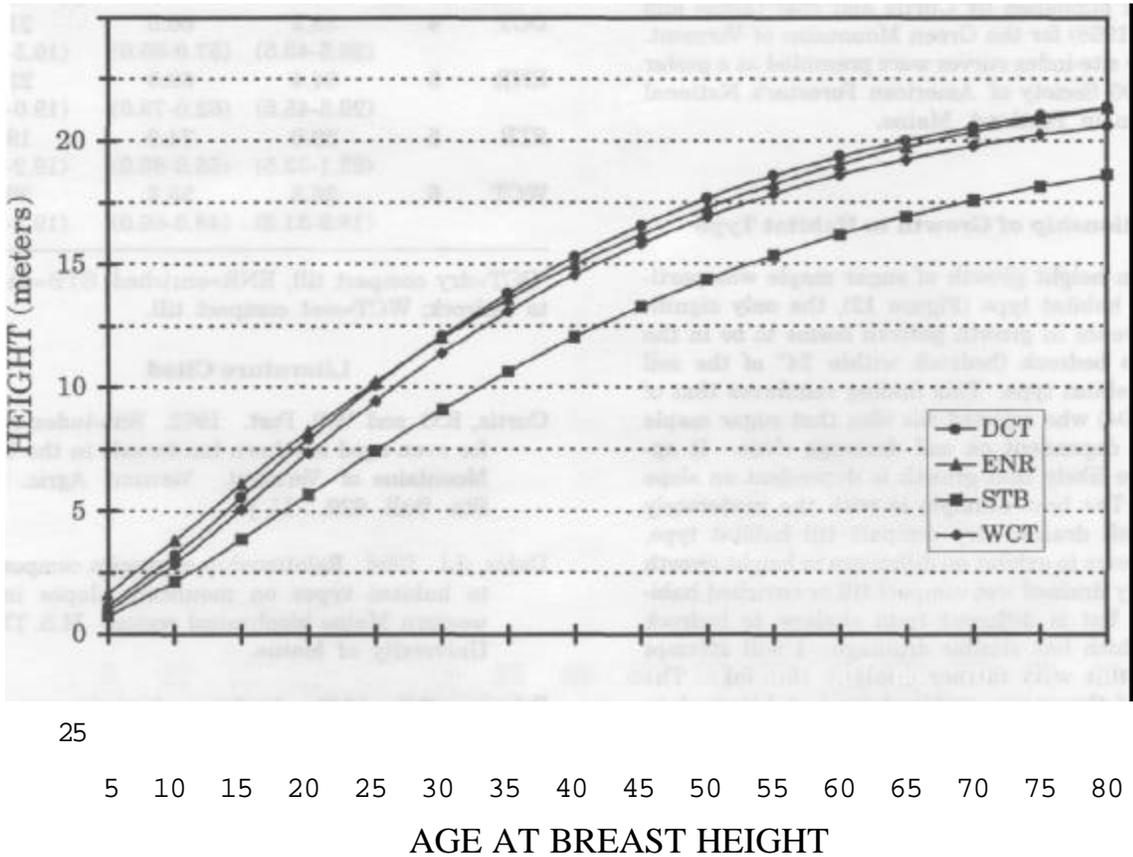


Figure 11: Site-index curves for sugar maple based on 20 trees from 20 plots in western Maine.



25

5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80  
 AGE AT BREAST HEIGHT

Figure 12: Height development curves for sugar maple in western Maine, by habitat type.

## TREE IMPROVEMENT

Dr. Michael S. Greenwood

### **Vegetative Propagation of Hybrid Larch for Plantations**

Forest managers in Maine must deal with intensifying and seemingly conflicting public concerns about wood supply shortfalls and demands that large amounts of land be set aside to preserve some forest land from timber harvest. Recently, a strategy that can potentially reconcile these apparently contradictory concerns has been proposed, which stresses identification of forest land appropriate for either preservation, intensive management, or so-called New Forestry practices (Seymour and Hunter 1992). The authors hoped that consideration of their triad strategy would help to form a consensus among such diverse groups as Green Party members and industrial land managers, but both groups have greeted the proposal with skepticism. Some environmentalists object to even a limited amount of clearcutting and plantation establishment, while large industrial landholders are reluctant to give up autonomous management of their lands, and question the economics of plantation establishment.

While few question that plantations on appropriate sites following clearcutting can increase yields, there is little information on how plantations should be deployed on a landscape scale so as to minimize the deleterious effects of fragmentation of the surrounding naturally regenerated forest. Also, even the best plantations are not truly monocultures since competing vegetation is never completely removed, even when herbicides are used. Indeed, Hunter (1990) has proposed that well-planned clearcuts and plantations can actually contribute to biodiversity in a positive way. In addition, few question the need for preservation of some forest land for ecological and aesthetic reasons. How do we sensibly address the simultaneous needs to sustain both production of wood as a commodity and preserve a biodiverse, healthy, productive forest? One approach is to try to demonstrate the triad approach to management at various landscape scales and to assess its biological, economic and social impacts.

Although plantation establishment in Maine has occurred on a small scale (less than 3% of total land harvested, [Maass 1988]), existing plantations demonstrate that species such as larch, Norway spruce or red pine may increase yields 2.5 to 6 times the yields of unmanaged natural stands (Seymour 1993). Furthermore, plantations may produce wood more cost effectively than well-managed natural stands. There are a number of species, both native and exotic, that can be considered for plantation establishment. Over the past 20 years, larch has been planted on former Scott lands, and about 500 acres of hybrid larch are being planted annually on S.D. Warren land, to provide a future strategic reserve of spruce budworm-resistant softwood (Haag and Hatch 1991, and pers.

comm.). These hybrid plantations consist of seedlings all originating from the Von Lochow seed orchard in Germany, one of the few sources of large quantities of hybrid seed between Japanese and European larch. The hybrids have achieved heights in excess of 15 feet in five years, and have outperformed both parental species as well as native tamarack. The seed from the Von Lochow orchard is the result of supplemental pollination of a single European female parent with pollen collected from nearby Japanese larch located in provenance tests, resulting in a mixture of hybrid families.

We have used a prototype indoor larch breeding orchard to produce more than 50 crosses between and among Eastern, European, and Japanese larch (Eysteinnsson et al. 1993). We have recently evaluated height growth of these crosses after three years on a test site adjacent to operational hybrid larch plantations on S.D. Warren land near Johnson Mountain, Maine. Heights among 17 European x Japanese crosses ranged from 4.3 to 6.7 ft, and all the families were taller than the Von Lochow hybrid check, which was included in the test (Greenwood 1994). The hybrid families were also compared to pure crosses of both Japanese and European larch, and hybrid vigor was clearly demonstrated, in that all hybrids exhibited greater height growth than within family crosses. The wide variation in height growth among the hybrid families demonstrates the potential for further gains in height growth by mass production of seed or rooted cuttings of selected hybrid families. However, seed production by larch is notoriously poor, with seed viability ranging from 10% to 40% (Eysteinnsson et al. 1993).

In recent years vegetative propagation by rooted cuttings has proven more cost effective than tissue culture for a number of woody species, and a number of industrial pilot programs have been established for black and Norway spruce, Douglas-fir and loblolly pine (Greenwood et al. 1991). In all cases, cuttings must be made from seedling hedges since cuttings from trees that are only a few years old not only root less well but exhibit undesirable mature characteristics such as plagiotropism and reduced growth. Hybrid larch exhibits these mature characteristics after less than two years (Luke Paques pers. comm.). The adverse effects of maturation can be avoided by decapitation (hedging) to encourage the development of axillary buds below the terminal, which retain juvenile characteristics. These axillary shoots are harvested as cuttings, and this operation can be repeated several times without losing juvenile characteristics. At present we do not know the optimum age for starting hybrid larch hedges, nor do we know how long hedges can continue to produce juvenile cuttings.

**Planned Research**

We propose to evaluate the feasibility of mass propagation of hybrid larch families using rooted cuttings from hedged plants and to establish the resulting cuttings at the Penobscot Experimental Forest and on industrial sites as well, if possible. Our goals are to develop cutting hedges that remain juvenile in order to produce rooted cuttings that grow like seedlings, and to compare the yield of larch plantations established from these rooted cuttings with those of other species that are currently being planted as part of the Forest Ecosystem Research Program. In particular we will test the hypothesis that hedging before one year will maintain the production of fast-growing, orthotropic cuttings that will perform as well as seedlings. In addition, we will determine whether or not, as expected, hybrid larch will grow faster than other plantation species.

We will also conduct a preliminary study on woody and herbaceous species diversity in existing larch plantations on S.D. Warren land in comparison to adjacent stands, which are managed for natural regeneration.

The work will be carried out by two new graduate students, B. Baltunis and K. Peer, who have already begun work on the projects. K. Peer is partially supported by CFRU.

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## TREE IMPROVEMENT

Dr. Katherine K. Carter

Black spruce is one of the commonly planted tree species in Maine, and it has good potential for plantation growth and productivity. In 1979, research was begun through the Cooperative Forestry Research Unit at the University of Maine to determine whether growth of black spruce could be improved through genetic selection. In particular, we wanted to discover the degree to which height growth was under genetic control and the best selection method for capturing this genetic variability.

To answer these questions, many individual trees in 16 black spruce stands from northern, central, and western Maine were measured, and seed was collected from three classes of trees in each stand: (1) "average" trees, those most closely approximating the stand average in growth rate; (2) "plus" trees, those with the greatest height growth rate; and (3) "extra" trees, additional trees within the stand that had large cone crops. In all, seed was collected from 70 parent trees and used to grow seedlings for the establishment of three test plantations, which were planted in 1981 in Howland, T5R14, and Brassua Township (Figure 13).

Graduate student D. Iriantono analyzed growth data for these family test plantations after 13 years in the field (age 15 from seed) (Table 8). Average survival in the three plantations is 79%, and average height is 15.8 ft, with a current average height growth per year of 17.6 inches. The tallest individual trees are more than 23 ft in height. In each of the three plantations, there are significant differences in height among the families. The tallest and shortest families are typically about 15% above or below the plantation mean height. These family differences have a genetic basis, with a calculated heritability value of 0.21 for the three plantations. Thus, there is a good potential to improve growth of black spruce planting stock through genetic selection of parents.

What is the most effective method for genetic selection in this species? We can compare two alternatives: the original method of identifying plus-trees through measurement of trees in natural stands, or the alternative of selecting the best-performing fami-

lies in the field tests. Offspring of the "plus" trees average 16.75 ft tall at age 13, as compared to 15.98 ft for offspring of "comparison" trees and 16.03 ft for offspring of "extra" trees. This is a gain of 0.75 ft for the plus-tree offspring, or about 5% above the average (comparison) trees. Alternatively, we could select the families that have proven to have the best average growth in the test plantations. Selecting the top 20% of the families in each plantation results in a 10% average increase in height (about 1.5 ft) as compared to the overall plantation mean. Thus, either the plus-tree selection method or the family selection method can be used to improve growth rate of black spruce planting stock. The choice between the two methods may depend upon the resources and time available and the amount of gain desired.

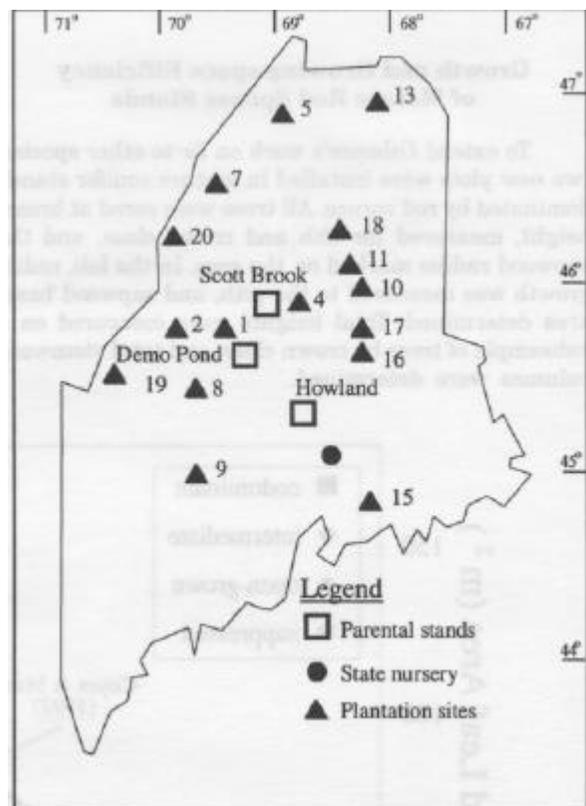


Figure 13. Parental stands, nursery and plantation sites.

Table 8. Survival and height for 13-year-old black spruce family test, summarized for single sites and combined sites.

	Howland	Brassua	T5R14	Combined
Survival	86%	83%	67%	78%
Average height (ft)	16.2	15.0	16.1	15.8
Range of family means(ft)	13.5-18.2	12.1-17.1	13.6-19.3	13.9-17.9
Range of individual means (ft)	6.7-23.1	6.7-22.3	7.3-23.1	6.7-23.1

## GROWTH AND YIELD

Dr. Robert S. Seymour

### Crown-Stemwood Growth Relationships for Balsam Fir

Ph.D. candidate D. Gilmore completed his investigation of the relationship of crown parameters to growth and growing space efficiency in balsam fir. One paper has been published, and several others are in review or preparation. A key to this comprehensive study was the ability to accurately predict the leaf area and foliar biomass of individual trees using sapwood basal area and crown length (Figure 14). Once leaf areas are known, stemwood growth can be accurately predicted by crown class (Figure 15). These and other relationships provide the basis for modifying the TASS model to develop managed-stand yield tables for intensively managed, fir-dominated stands.

### Growth and Growing-space Efficiency of Mature Red Spruce Stands

To extend Gilmore's work on fir to other species, two new plots were installed in mature conifer stands dominated by red spruce. All trees were cored at breast height, measured for dbh and crown class, and the sapwood radius marked on the core. In the lab, radial growth was measured to the pith, and sapwood basal area determined. Total heights were measured on a subsample of trees by crown class, and total stemwood volumes were determined.

Preliminary results for one plot (visited at the Weymouth Point control watershed on the September 1995 CFRU tour) show that this stand has a two-aged structure. The younger age class, about 70 years old at breast height (Figure 16), dominates the stand in terms of trees per acre (500), but has produced less volume since 1920 than 180 older trees that survived the ca. 1920 disturbance. Interestingly, the recent gross periodic annual increment (1990-94) of both cohorts exceeds 100 cubic feet per acre per year, while the mean annual increment is only 70, suggesting the stand is not yet biologically mature (Table 9). The relationship between volume growth and sapwood basal area is quite strong (Figure 17). Many dominant trees from the older cohort were nearly as efficient as the younger codominants (Figure 18), which tends to contradict previous studies that have shown much lower efficiency in older dominant trees.

### Development of a Density Management Diagram for Even-aged Spruce-Fir

A density management diagram is being constructed for even-aged spruce-fir stands to aid foresters in decisions concerning density management. The data sets used represent the broad range of density, age, and site quality typically found in even-aged spruce-fir stands throughout the region. A maximum

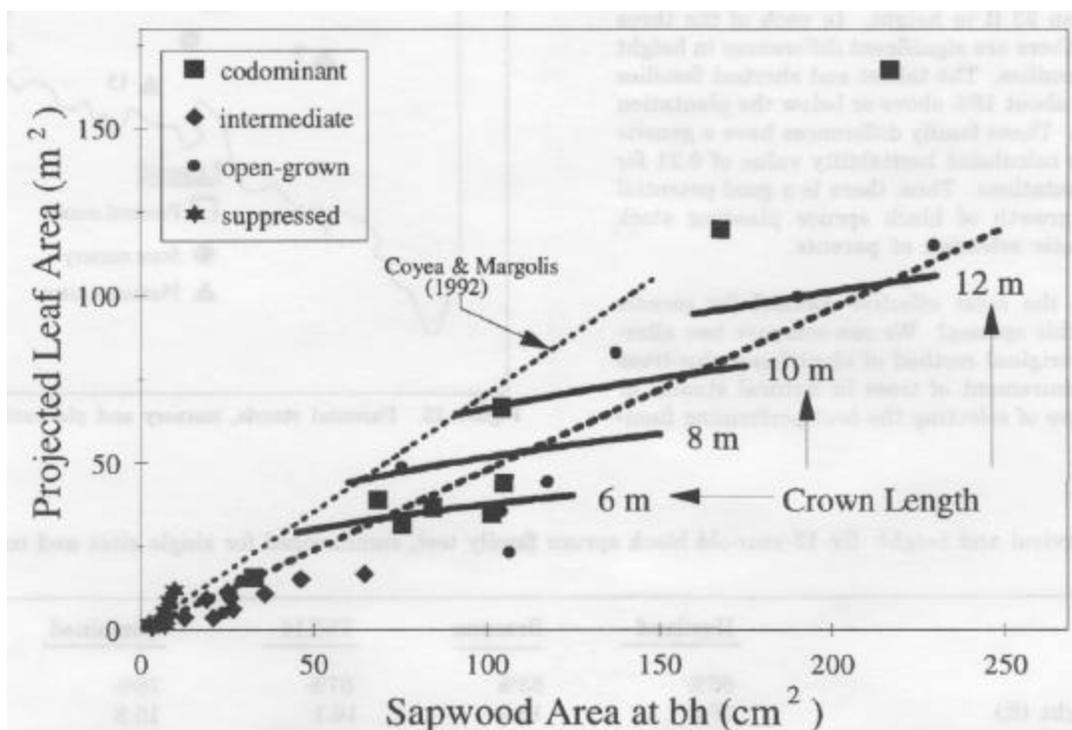


Figure 14. Relationship between sapwood area (sa) at breast height and projected leaf area (pla) for balsam fir by crown class, with and without including crown length (cl) as a predictor. The published equation of Coyea and Margolis (1992) is shown for comparison.

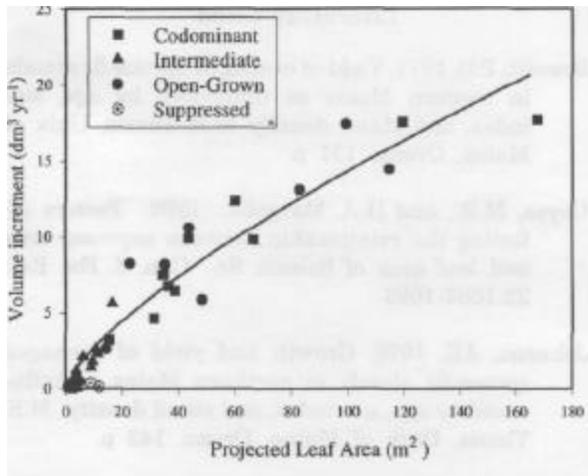


Figure 15. Relationship between projected leaf area and stemwood volume increment for balsam fir, by crown class.

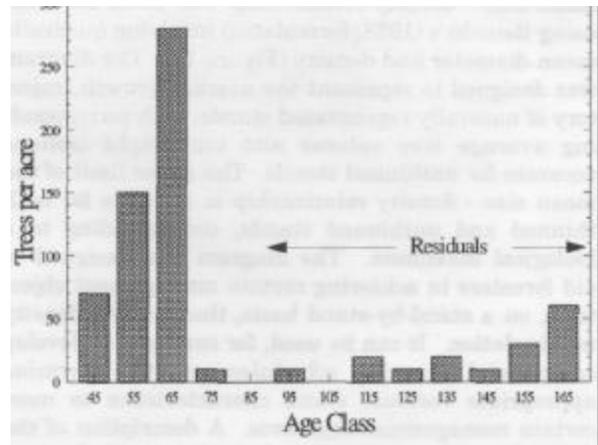


Figure 16. Age distribution of mature red spruce stand described in Table 9.

Table 9. Stocking and growth of a fully stocked, two-aged red spruce stand on the Weymouth Point Control Watershed, T4R12, Maine. Volumes are total stemwood; site index = 40".

1995 Volume (ftVacre)	1920 Growth Cohort	1990-94 Trees per Acre	Basal Area (ft <sup>2</sup> /acre)	Volume (ftVacre)	Mean Annual Increment since 1920
1920-Origin	500	108	2,615	52.8	34.9
Pre-1920 Residuals	180	121	3,368	735	35.1
50.5					
Total Stand	680	229	5,983	103.3	70.0

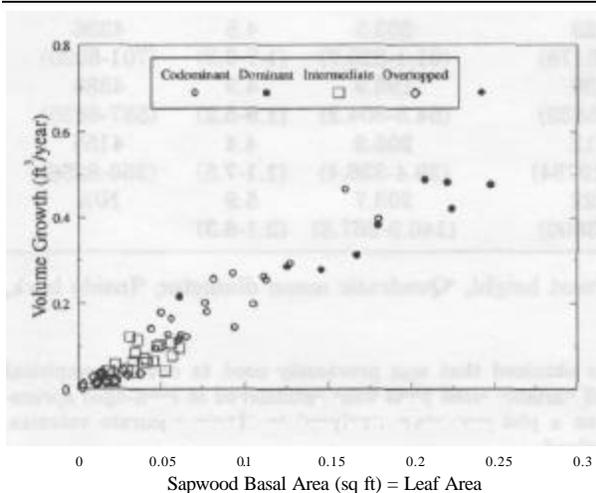


Figure 17. Relationship between stemwood volume growth and sapwood basal area for mature red spruce trees, by crown class.

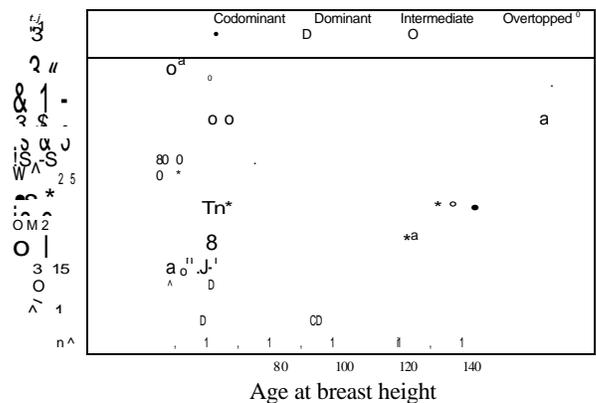


Figure 18. Relationship between stemwood volume growth efficiency and breast height age of mature red spruce trees, by crown class.

mean size - density relationship was fit to the data using Reineke's (1933) formulation involving quadratic mean diameter and density (Figure 19). The diagram was designed to represent the average growth trajectory of naturally regenerated stands, with corresponding average tree volume and top height isolines accurate for unthinned stands. The upper limit of the mean size - density relationship is accurate for both thinned and unthinned stands, corresponding to a biological maximum. The diagram was designed to aid foresters in achieving certain management objectives, on a stand-by-stand basis, that involve density manipulation. It can be used, for example, to develop commercial thinning schedules and to determine appropriate residual stand characteristics to meet certain management objectives. A description of the data sets, with mensurational characteristics is given in Table 10.

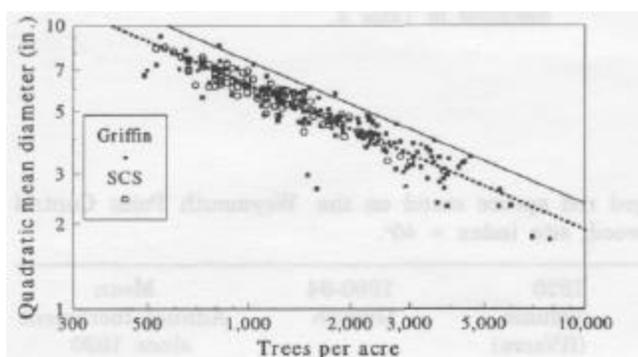


Figure 19: Relationship between density and the quadratic mean diameter was fit with principal components analysis (PCA). The upper line represents a biological maximum mean size - density relationship. The lower line was fit through the center of the data, excluding plots without mortality, and represents average stand development.

Table 10. Mensurational characteristics of the plot data.<sup>3</sup>

Source	Region in Maine	n	Age (yrs)	Site index <sup>1</sup> (ft)	Density (per acre)	Basal area (ft <sup>2</sup> )	Mean dbh <sup>2</sup> (in)	Total volume <sup>d</sup> (ft <sup>3</sup> )
Griffin	East	40	50.4 (8.7-86.0)	43.7 (30-65)	2223 (547-5178)	203.5 (61.1-320.7)	4.5 (1.7-9.2)	4336 (701-8920)
Griffin	North	54	49.1 (16.2-76.9)	47.7 (23-69)	1839 (469-5539)	195.9 (54.5-304.2)	4.9 (1.9-8.2)	4385 (537-6625)
Griffin	West	76	40.3 (6.2-67.9)	52.6 (41-77)	2912 (501-19784)	205.9 (39.4-326.4)	4.4 (1.1-7.5)	4155 (350-8356)
SCS	West	99	52.7 (33.0-73.4)	53.1 (40-67)	1222 (533-3800)	203.7 (140.9-267.8)	5.9 (3.1-8.3)	N/A

<sup>1</sup>Means with ranges in parentheses, <sup>2</sup>Base age 50 years at breast height, <sup>3</sup>Quadratic mean diameter, <sup>4</sup>Inside bark, including top and stump

*Griffin Data Set:* A comprehensive growth and yield data set was obtained that was previously used to develop empirical yield tables (Brewitt 1971; Johnson 1976; Schiltz 1978). A total of 205 variably sized plots were established in even-aged spruce-fir stands throughout the northern portion of Maine. Every tree on a plot was stem analyzed to obtain accurate volumes. Species, diameter, height, and the age of each disk were also obtained.

*SCS Data Set:* The second data set was collected for a SCS study by Schiltz and Grisi (1980). A total of 105 0.03-ac plots were established in even-aged spruce-fir stands in western Maine. Accurate site index and soil drainage class were obtained for each plot. Species and diameter were also obtained for each tree on a plot.

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## SLUDGE AND ASH

Dr. Robert K. Shepard

### Introduction

The 1995 growing season was the eighth since CFRU research on sludge and ash was initiated. Efforts during 1995 were concentrated on three of the study sites where treatment effects were still evident. The study sites are located in T1 R9 WELS in northcentral Maine, and in Coplin Plantation and Letter E Township in western Maine. Work during 1995 included growth measurements and sampling of the soil and foliage. Results are presented and discussed for each location individually.

### Procedures

#### T1 R9 WELS

A mixture of wood ash and secondary papermill sludge was applied to plots at rates of 0, 2.4, 4.8, and 9.6 dry tons per acre, at three different times during the allowed spreading period, and for one, two, or three years in succession. The first application was in late May 1988 and the last in late September 1990. Growth measurements were made and soil and foliage samples taken at various intervals following initiation of the study. Laboratory analyses of soil and foliage samples taken in 1995 have not yet been completed.

#### Coplin Plantation

A mixture of primary and secondary papermill sludge was applied in early October 1989 to plots in a clearcut planted to red pine. Rates were 0 and approximately 40 dry tons per acre. Diameter growth measurements were made after the 1989, 1990, 1991, 1992, and 1994 growing seasons. Height growth measurements for all years were made in the spring of 1995, before the beginning of the 1995 growing season. Measurements for the 1995 growing season will be made in the spring of 1996, before growth begins. Foliage samples were collected at the same times as diameter measurements were made, as well as after the 1995 growing season, and soil samples were taken after the 1990, 1991, and 1995 growing seasons.

#### Letter E Township

A mixture of primary and secondary papermill sludge was applied in late September 1989 to a clearcut planted to red pine. Rates were highly variable and ranged from 0 in areas that were missed entirely to more than 60 dry tons/ac. Red pine seedlings were selected to represent the following general application rates: 0, 5 to 15, 15 to 30, and greater than 30 dry tons per acre. Stem diameter measurements at a height of 1 ft and growth measurements were made after the 1989, 1990, 1991, 1992, and 1994 growing seasons. Dbh measurements were made in the spring of 1995, before growth began. Foliage

samples were taken after the 1990, 1991, 1992, and 1994 growing seasons.

### Results and Discussion

#### T1 R9 WELS

**Growth Response:** Dbh measurements were made prior to the beginning of the 1995 growing season and after the 1995 growing season. The analysis of these measurements clearly indicates that the significant ( $P < 0.05$ ) treatment effect on stem cross-section growth observed at the root collar through 1991 and at the 1 ft stem height from 1992 through 1994 also occurred at breast height (Figure 20). As in the lower portion of the stem, where growth decreased successively with increasing application rate, dbh also decreased successively with increasing application rate. The decreased growth is attributed primarily to the stimulation of competing herbaceous vegetation in treated plots. After the 1994 growing season, dbh at the maximum rate was 0.22 in. less than for the control. The same trend existed after the 1995 growing season (Figure 21), but the difference in dbh from one rate to the next was about the same as after 1994. There is no indication that the treatment effect increased during the 1995 growing season.

**Foliar Nutrient Concentrations:** Laboratory analysis of foliage samples taken after the 1994 growing season showed that concentrations of six nutrients — phosphorus, potassium, magnesium (Figure 22), boron, manganese (Figure 23) and aluminum — were still significantly influenced by application rate. The first four increased and the last two decreased as application rate increased. Increases probably occurred because the nutrients were added in the sludge and because their availability in-

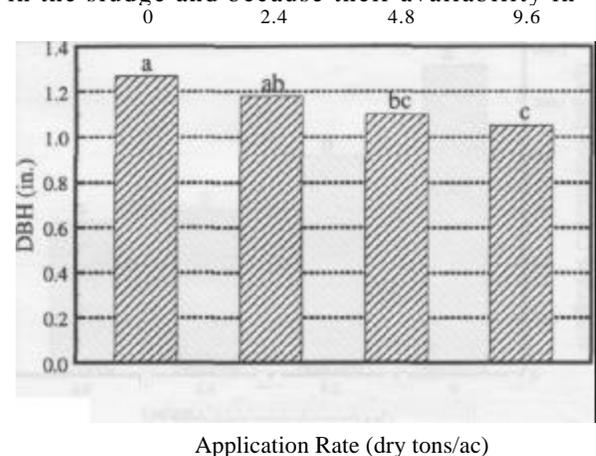


Figure 20. Dbh of black spruce after the 1994 growing season treated with a mixture of wood ash and secondary papermill sludge at four rates. The mixture was applied in 1988, 1989, and 1990. Means having the same lower case letter are not significantly ( $P = 0.05$ ) different.



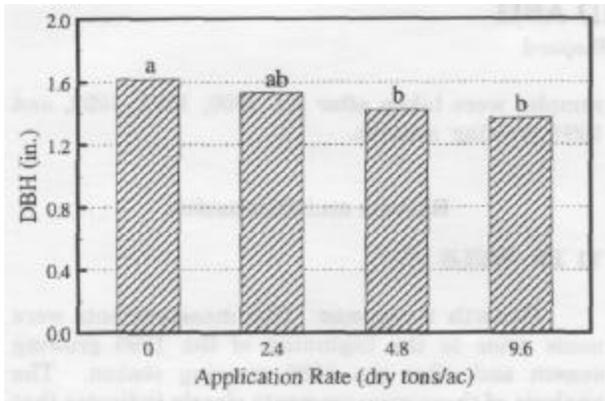


Figure 21. Dbh of black spruce after the 1995 growing season treated with a mixture of wood ash and secondary papermill sludge at four rates. The mixture was applied in 1988, 1989, and 1990. Means having the same lower case letter are not significantly ( $P = 0.05$ ) different.

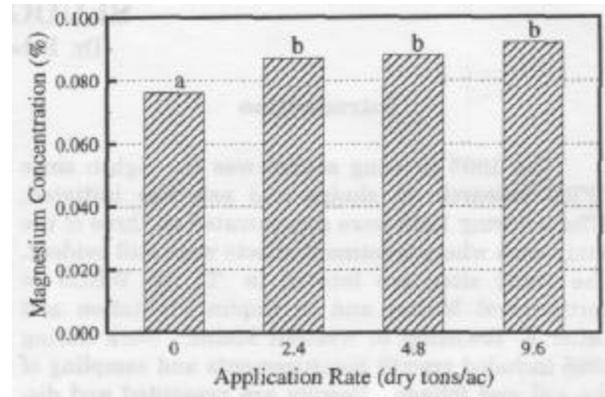


Figure 22. Magnesium concentrations in the 1994 foliage of black spruce treated with a mixture of wood ash and secondary papermill sludge at four rates. The mixture was applied in 1988, 1989, and 1990. Means having the same lower case letter are not significantly ( $P = 0.05$ ) different.

creases as soil pH increases. Decreases of manganese and aluminum probably occurred because of an increase in soil and forest floor pH, which reduced their availability for uptake, and because of possible interference with their uptake due to the higher concentrations of calcium and magnesium in the soil. It should be emphasized that the 1994 growing season was the fourth since the last treatments were applied.

Concentrations of four elements — potassium, boron, manganese and aluminum — were significantly affected by the number of applications. Concentrations of potassium and boron increased, and concentrations of manganese and aluminum decreased as number of applications increased. The reason for the two distinct trends is probably the same as that for the trends associated with application rate.

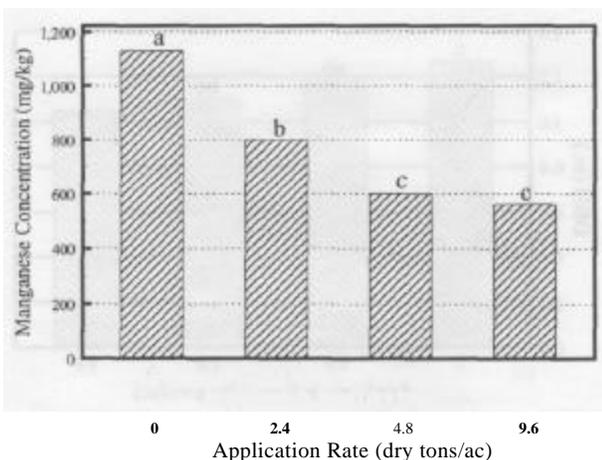


Figure 23. Manganese concentrations in the 1994 foliage of black spruce treated with a mixture of wood ash and secondary papermill sludge at four rates. The mixture was applied in 1988, 1989, and 1990. Means having the same lower case letter are not significantly ( $P = 0.05$ ) different.

### Coplin Plantation

**Growth Response:** Stem diameter growth, measured at a height of 3 ft, was improved by the application of sludge (Figure 24). There was no effect in 1990, and the maximum effect was in 1991. The difference between the treatment and the control was not significant in 1992, but was significant for the 1993 and 1994 seasons combined. Over the five-year post-treatment period, mean diameter growth of treated trees exceeded that of control trees by slightly more than 0.5 in.

Height growth measurements provided an unexpected result — a significant increase in growth during both the 1992 and 1993 growing seasons (Figure 25). During the period 1990 through 1994, height growth of the treated trees was 12 in. greater than height growth of the control trees.

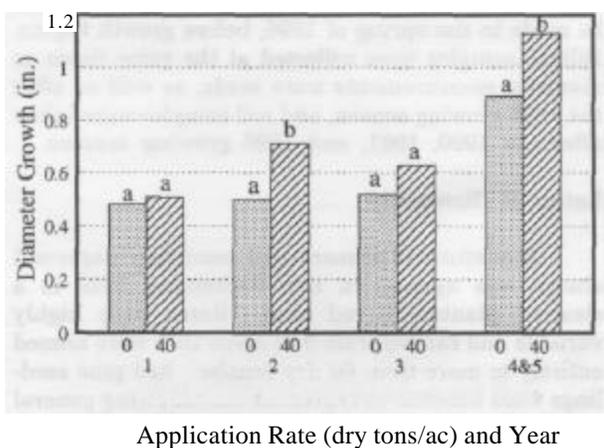


Figure 24. Stem diameter growth of red pine treated with a mixture of primary and secondary papermill sludge in October 1989. Means having the same lower case letter are not significantly ( $P = 0.05$ ) different.



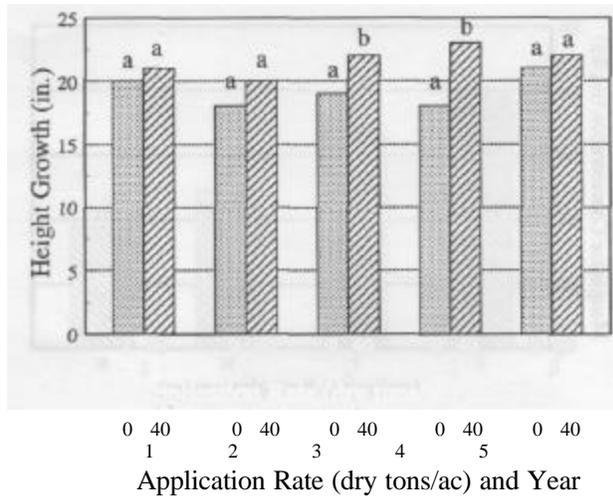


Figure 25. Height growth of red pine treated with a mixture of primary and secondary papermill sludge in October 1989. Means having the same lower case letter are not significantly ( $P = 0.05$ ) different.

**Foliar Nutrient Concentrations:** Laboratory analyses of 1994 foliage samples revealed significant differences in five foliar nutrient concentrations — phosphorus, boron, copper, iron and manganese between trees from treated and control plots. Only phosphorus concentrations were higher in treated trees; concentrations of the other nutrients were lower. After the 1992 growing season there were significant differences between treated and control trees for six nutrients — calcium, magnesium, phosphorus, aluminum, boron and manganese. Calcium, phosphorus and magnesium concentrations were higher; aluminum, boron and manganese concentrations were lower. It is worth noting that iron and copper were not significantly affected until the fifth growing season after the sludge was applied. Increased concentrations are attributed to the addition of those specific nutrients in the sludge and to changes in availability resulting from higher soil pH. Lower concentrations are presumed to be due primarily to reduced availability due to the higher soil and forest floor pH and to possible interference with uptake caused by higher concentrations of some of the nutrients from the sludge application.

**Letter E Township**

**Growth Response:** The reduced growth observed at the 1 ft stem height was also evident in the breast height measurements made after the 1994 growing season (Figure 26). The trend among application rates was the same at breast height as lower in the stem, with trees that received no sludge having the largest dbh and trees that received the maximum rate having the smallest dbh. The difference was about 0.5 in. Although the differences between dbh of the control trees and the trees that received the low and medium rates was not significant, the overall trend suggests that a treatment effect was probably responsible for the differences. The smaller dbh is probably due to more intense competition from herbaceous vegetation and hardwoods.

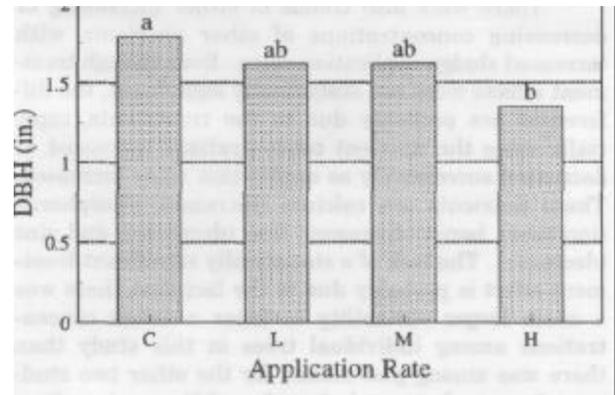


Figure 26. Dbh of red pine after the 1994 growing season treated with a mixture of primary and secondary papermill sludge in September 1989. C = 0 dry tons/ac, L = 5 to 15 dry tons/ac, M = 15 to 30 dry tons/ac, H = 30+ dry tons/ac. Means having the same lower case letter are not significantly ( $P = 0.05$ ) different.

Height growth was not affected by the sludge application, although total five-year height growth of the control trees was 6 in. greater than height growth of trees that received the maximum rate.

**Foliar Nutrient Concentrations:** For 1994 foliage, only magnesium (Figure 27) and manganese concentrations (Figure 28) differed significantly among treatments; magnesium increased with application rate and manganese decreased. The increase in magnesium is probably due to the magnesium added in the sludge and a higher soil pH, which increases availability of soil magnesium. Reduced manganese is probably due to the reasons stated previously.

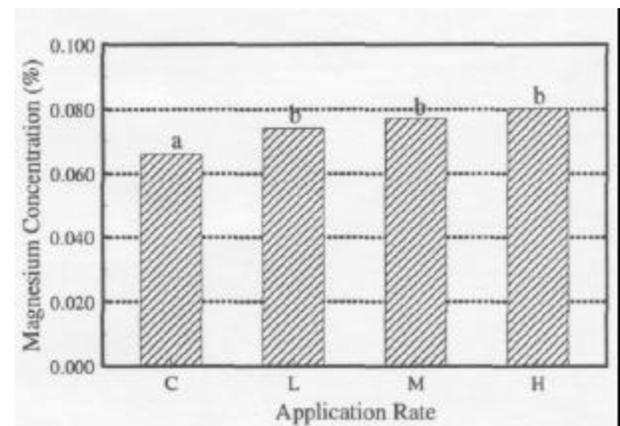


Figure 27. Magnesium concentrations in the 1994 foliage of red pine treated with a mixture of primary and secondary papermill sludge in September 1989. C = 0 dry tons/ac, L = 5 to 15 dry tons/ac, M = 15 to 30 dry tons/ac, H = 30+ dry tons/ac. Means having the same lower case letter are not significantly ( $P = 0.05$ ) different.



There were also trends of either increasing or decreasing concentrations of other nutrients with increased sludge application rates. Even though treatment effects were not statistically significant, the differences are probably due to the treatments, especially since the nutrient concentrations increased or decreased successively as application rates increased. These nutrients are calcium (increase), phosphorus (increase), boron (decrease), iron (decrease), and zinc (decrease). The lack of a statistically significant treatment effect is probably due to the fact that there was a much larger variability in foliar nutrient concentrations among individual trees in this study than there was among plot means for the other two studies, where each mean is based on foliage taken from a number of trees.

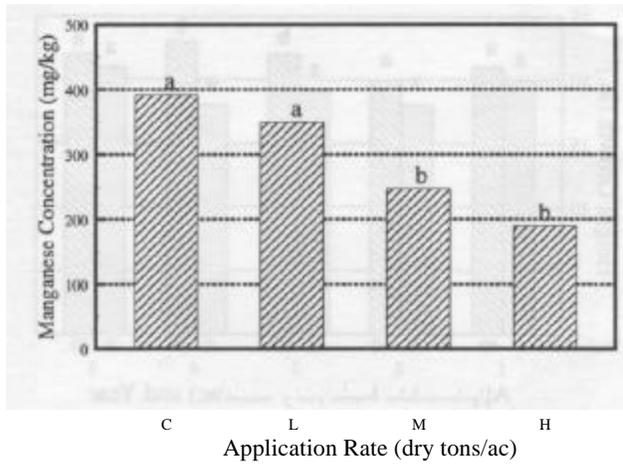


Figure 28. Manganese concentrations in the 1994 foliage of red pine treated with a mixture of primary and secondary papermill sludge in September 1989. C = 0 dry tons/ac, L = 5 to 15 dry tons/ac, M = 15 to 30 dry tons/ac, H = 30+ dry tons/ac. Means having the same lower case letter are not significantly ( $P = 0.05$ ) different.



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

Dr. Daniel J. Harrison

### Introduction

Field work on the CFRU-funded portion of our project began in May 1994 within the Baxter Park site. This site represents the baseline without trapping or timber harvesting, and is designed to compare the relative effects of trapping and timber harvesting (T4 RII) and timber harvesting without trapping (T5 RII) on marten population characteristics and habitat selection. The research in the industrial landscape (T4 RII, T5 RII) is being funded by Maine Department of Inland Fisheries and Wildlife (MDIFW), the Maine Agricultural and Forest Experiment Station (MAFES), the Department of Wildlife Ecology (DWE), University of Maine, and Maine Forest Service. Associated projects are also being supported by the National Council of the Paper Industry for Air and Stream Improvement (NCASI). Project personnel included D. Payer (Ph.D. student), T. Chapin (Research Associate), T. Hodgman (Research Associate), H. J. Lachowski (M.S. student), A. Drake (undergraduate technician), D. Wroe (technician), and numerous summer student employees. Payer's dissertation will address a comparison of marten population characteristics and habitat selection among the three treatments. This work will be completed during 1998, and will represent the basis of a single final report to be submitted to CFRU in 1999.

### Objectives

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

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

### Progress During October 1994 to September 1995

We trapped martens from 19 May to 8 July 1995 in T5 RII WELS, T4 RII WELS, and Baxter State Park (BSP). There were a total of 55 (22 females, 33 males) initial captures of marten in 1995, compared with 48 captured during 1994 prior to the trapping closure. Each captured marten was sexed, weighed, measured, examined for reproductive status, aged, ear

tagged, and radiocollared.

We monitored radiocollared martens from the air on a weekly basis from 1 October to 31 December 1994. From 1 January to 31 March 1995, we monitored 29 remaining resident marten (captured during 1994) approximately three to five times weekly from the ground via snow machines and weekly from aircraft. Animals captured during the spring 1995 trapping effort were monitored four to six times weekly from the ground and weekly from aircraft from 1 June 1995 to 30 September 1995. To date, we have obtained approximately 6000 locations of radiocollared martens among the three study sites. We have sufficient data from all residents to specify individual home ranges and examine habitat use patterns (placement of the home range on the landscape, habitat selection within the home range, and use of 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, T6 RII, and T6 RIO) were closed to commercial furbearer (except beaver and bear) trapping by the MDIFW during 1994 and 1995 to facilitate our study of effects of trapping on marten populations. We are working with MDIFW to enforce this closure, and have posted signs regarding the closure and objectives of our study in strategic areas throughout our study site. During early 1996, we will initiate rulemaking to extend this closure for the fall 1996 trapping season.

### Funding

As proposed, CFRU funding covers 50% of the costs to operate the Baxter Park study area. Because field work did not begin until May 1994, CFRU funding, in addition to \$3,000 "in kind" support (flying time, contract labor, vehicles) provided by MDIFW was sufficient to cover field operations during FY 1994. During FY 1995, additional funding of \$10,998 was provided by Maine Forest Service (MFS), and MDIFW committed \$5,700 of in-kind support. This allowed us to proceed with all objectives as proposed. Proposed research activities in the industrial forest continue to be fully funded via MDIFW, MAFES, and DWE.

The NCASI has provided funding to expand the study to include an evaluation of microhabitat characteristics in areas receiving different intensities of use by martens. The specific objective of this work

is to document and to compare microhabitat characteristics between forested areas (vegetation > 6 m in height) with different intensities of use by resident, nonjuvenile martens in the industrial forest with trapping closure and in Baxter Park. This information will allow us to integrate the landscape-level findings from the larger study with stand-specific recommendations on ways to maintain habitat suitability for martens in harvested stands. This work is occurring concurrently with CFRU-funded research during summers 1995 and 1996 in T5 RII WELS, and in Baxter State Park.

## Results From Associated Studies

### I. Forest Landscapes and Marten

**Background:** Available literature suggests that extensive timber harvesting may detrimentally influence habitat quality for marten. The specific characteristics of landscape pattern that affect marten habitat use are poorly understood. Marten have been documented to use remnant stands as small as 300 m<sup>2</sup>. However, characteristics such as isolation of stands have not been examined relative to use by marten. We investigated the influence of spatial characteristics of forest patches, such as size, shape, and isolation, on spatial use of habitat by marten in an industrial forest landscape. We also related measures of landscape pattern in marten home ranges with home range size, to evaluate the influence of landscape pattern on area requirements.

This component of our project was designed to (1) assess the relationship of spatial characteristics of residual forest patches with marten use of habitat in an industrial forest landscape, and (2) evaluate the relationship between landscape pattern and home range area of marten. Data were collected via radio telemetry locations for 34 adult marten collared and monitored on land owned by Bowater, Great Northern Paper Co., in Piscataquis County, Maine (T4 RII and T5 RII WELS), during May 1989 through April 1991. Analyses have been completed, and a final report will be available by 15 December 1995.

**Summary of Results:** American marten are generally considered an associate of mature forests, and their populations are susceptible to over-harvesting and habitat loss. Despite the potential for clearcutting to fragment habitat of area-sensitive, forest-dependent species such as marten, few studies have evaluated the influence of landscape pattern on use of habitat and spatial distribution of marten in areas with extensive timber harvesting. Thus, we examined relationships among measures of landscape pattern and spatial use of habitat by 33 (17 male and 16 female) resident and 32 (17 male and 15 female) non-resident adult (>1 year) marten in an extensively logged landscape.

Area of forest stands (>6 m in height) used by resident marten (median = 27 ha, n = 12) was greater ( $P < 0.003$ ) than stands that contained no locations (median = 1.5 ha, n = 128); no stands <2.7 ha (n = 88) contained locations (n = 1,188) of residents. Further, stands used by residents were closer to the nearest stand larger than 2.7 ha (i.e., the smallest stand that contained locations) ( $P = 0.057$ ) and to a large (637 km<sup>2</sup>) forest preserve ( $P = 0.075$ ) than stands that contained no locations. However, there was no difference in distance to nearest stand of any size ( $P = 0.219$ ) between stands used by residents and stands that contained no locations. We also examined the potential influence of landscape pattern on spatial use of habitat by marten at four spatial scales ranging from 10 to 250 ha. At all four spatial scales, grid cells that contained locations of resident marten had a higher percentage of forest >6 m in height ( $P = 0.008$ ) and intersected stands of greater area ( $P = 0.006$ ) than cells that contained no locations. At cell sizes of 125 ha and 250 ha, used cells intersected fewer residual stands ( $P = 0.024$ ). Analyses for non-residents revealed similar effects of stand area and isolation, despite that non-residents exhibited greater variability in characteristics of stand use. Home ranges (n = 27) of all resident adult marten were composed of >60% forest cover >6 m in height. Shape indices were not different ( $P = 0.490$ ) between used cells and cells that contained no locations. Marten used forest types within their home ranges irrespective of forest edges. Although distances between marten locations and forest edge were significantly different ( $P = 0.049$ ) from expected, expected distances exceeded observed distances by only 10 m. The median size of the largest forest stand in marten home ranges was 1.5 km<sup>2</sup> for females and 2.5 km<sup>2</sup> for males; thus, contiguous forest patches of 1.5-2.5 km<sup>2</sup> may be necessary to maintain resident marten in logged landscapes. Our results concur with companion studies that concluded marten select habitat at a landscape scale, and indicate that landscapes characterized by few, large, residual forest stands close in proximity received greater occupancy by resident marten than areas with small isolated stands. Thus, forest planning aimed at reducing fragmentation via retaining large residual stands may help to maintain resident adult marten in extensively logged landscapes.

FINANCIAL SUPPORT: MDIFW, MAFES, OWE, NCASI

### II. Seasonal Habitat Selection by Marten in a Forest Preserve

**Background:** Some of the highest densities of marten recorded occur in Baxter State Park, an area of contiguous forest with an abundance of mature hardwoods (beech, birch, and maple). This association seems contrary to the habitat associations that have been developed for marten, based primarily on studies in the western U.S. Some studies in the eastern U.S. have documented that marten may use mixed-

wood or even hardwood stands extensively. Habitat quality for marten may be related to the amount of structure on the forest floor. If the amount of ground structure is not related to cover type, assessment of habitat selection based on cover types alone may be misleading. Thus, in the West, where softwood forests have more ground structure than hardwoods (aspen), cover-type selection probably reflects marten habitat associations. In the East, however, the relationship between cover type and ground structure may be less distinct. To better understand the habitat associations of marten in the East, we investigated selection for major forest types by marten in a forest preserve and related our findings to previous studies that we had conducted on habitat selection by marten in an industrial forest.

Specific objectives were to (1) test for stand- and landscape-scale habitat selection by resident adult marten in a large forest preserve, and (2) compare habitat selection by marten inhabiting a forest preserve versus marten in a trapped, industrial forest landscape. We monitored habitat selection by 38 resident adult marten in Baxter State Park, Maine, October 1990 through April 1993. We compared our results to similar analyses conducted for 28 resident adult marten that were monitored on an industrial forest site (T4 R 11, T5 R11 WELS) owned and managed by Bowater, Great Northern Paper Co. during May 1989 through April 1991. Marten densities on the industrial forest site were substantially lower than in the forest reserve; this was partly a result of intensive fur trapping on the managed area. Analyses have been completed, and a final report will be available by 15 December 1995.

**Summary of Results:** At the landscape scale, nearly all of the available habitat was used by marten; home ranges of radiocollared individuals included 70%-84% of our study site during the three years of the study. At the stand scale, however, marten used forest types disproportionate to availability ( $P = 0.030$ ) within their home ranges during summer (1 May-31 October). Stands with substantial spruce-budworm mortality (<50% overstory canopy closure) had the highest selection index, which was significantly higher ( $P = 0.003$ , pairwise rejection level = 0.008) than the mature (>12 m in height), well-stocked (>50% canopy closure) mixed-wood forest type. No significant differences in selection index were detected among mature well-stocked coniferous, deciduous, or mixed-wood forest types. During winter (1 November-30 April), marten used forest types proportionately to availability within home ranges ( $n = 8$  males, 1 female). Our results suggest that marten do not require dense or coniferous canopy cover and are consistent with the hypothesis that vertical and horizontal structural complexity may be a more important habitat component than age or species composition of the forest overstory. Thus, post-harvest techniques, such as on-site delimiting and slash management, may provide opportunities to enhance the quality of

regenerating forest stands for marten habitat. Although structural complexity may often be associated with age and species composition of forests, the regional and site-specific nature of these associations leads us to conclude that conservation practices should focus on structural attributes that influence quality of forested habitats for marten, regardless of age and species composition of trees. Further research to identify threshold amounts of specific structural features (e.g., volume of downed logs, density of snags) required by marten and experimental designs that separate the specific effects of trapping versus timber harvesting would provide valuable information about marten habitat relationships, and would assist in balancing management activities in landscapes where both timber harvesting and trapping occur.

FINANCIAL SUPPORT: MDIFW, MAFES, OWE, NCASI

### III. Seasonal Selection of Habitats Used for Resting Sites by Marten in Maine

**Background:** Structural characteristics of habitats used for resting by American marten have been studied throughout the western portion of the species' range. Resting sites are generally associated with forest attributes that provide vertical or horizontal structure, such as trees, snags, downed logs, stumps, root masses, rock crevices, and squirrel middens. Availability of suitable resting sites is generally thought to be important to marten survival because these sites provide thermal cover, protection from predators, and access to prey beneath the surface of the snow. Previous studies have often assumed that structural attributes of forests that provide suitable rest sites are limiting in managed forests and that availability of rest sites increases with the age and softwood dominance within a forest stand. Hence, we attempted to evaluate the relative importance of structural characteristics, age, and species composition by evaluating selection for forest attributes at sites used for resting by adult marten. Our study site was located in Baxter State Park, Maine, which is a large forest preserve where marten are protected from fur trapping. Specifically, we identified forest type, and structural features (e.g., stumps, tree species, root masses) used for resting, and quantified structural characteristics (e.g., down logs, visual obstruction, snags, stem density) at den sites and at random points distributed throughout home ranges of radiocollared marten. We characterized rest sites and random sites separately by season, and based our results specifically on rest sites used by 28 adult (>1 year) marten during summer ( $n = 73$  sites) and 36 marten during winter ( $n = 69$  sites). We evaluated differences in seasonal rest site use, quantified differences in structural characteristics between major forest types, evaluated whether marten rest sites were distributed in forest types disproportionately to availability, and used a logistic-modelling approach to evaluate important habitat parameters that might distinguish used sites from random sites.

**Summary of Results:** American marten use a variety of resting sites between foraging episodes, and the vertical position of resting sites may vary by season. Marten tend to rest above the ground during summer, and almost exclusively beneath the snow surface during winter. Marten may select resting sites based on forest structure, but may be opportunistic in rest-site choice based on the relative availability of potential sites. We compared the types of resting sites used during summer versus winter, and compared measures of forest overstory, understory, and ground structure between resting sites and random sites in north-central Maine, from January 1991 to January 1994. During summer, marten tended to rest in trees or snags, whereas during winter, marten usually rested in subnivean sites ( $P < 0.001$ ). The distribution of resting sites among forest overstory types did not differ from the distribution of random sites during summer ( $P = 0.164$ ) or winter ( $P = 0.510$ ), despite that coniferous stands had significantly ( $P = 0.007$ ) more logs on the forest floor and standing snags than did both mixed and deciduous stands. Multivariate logistic regression models resulted in few differences in measurements of forest overstory, understory, and ground structure between resting sites and random sites during summer or winter. Although the logistic models were significant, few variables had significant effects, and the models poorly predicted locations as resting sites or random sites. Our data indicate that rest-site selection for the characteristics of forest overstory, understory, and ground structure that we measured was universally weak. We conclude that potential resting sites occurred above thresholds at which resting sites limit use of habitat by marten. We recommend further study to document thresholds of forest structure required by marten, and to examine the influence of current timber harvesting trends on long-term forest structure.

FINANCIAL SUPPORT: MDIFW, MAFES, OWE, NCASI

#### **IV. Influence of Microhabitat Characteristics on Intensity of Forest Use and Productivity of Martens in Maine: Implications for Forest Practices**

**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 marten require mature, conifer-dominated forests, and may provide opportunities to manage for the structural characteristics of forests required by marten 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 to (1) document and compare microhabitat characteristics between forested areas (>20 ft in height) receiving different intensities of use (number of locations/area) by successful martens (i.e., based on survival and reproductive history) in an industrial forest and a forest preserve; and (2) develop stand-level recommendations regarding silvicultural techniques, harvesting methods, and slash management strategies to maximize habitat quality for martens.

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

Use of microhabitat characteristics will be analyzed separately for the industrial forest site and the forest preserve, and for leaf-on and leaf-off periods. We will use step-wise multiple regression to compare the number of marten relocations/cell (response variable) to habitat characteristics of each cell (explanatory variables). Pearson correlation coefficients for all possible pairs of habitat variables will be examined to identify correlations that could confound subsequent analyses. Highly correlated variables will be collapsed as necessary. Discriminant analyses will be applied to cells in high, medium, low and no use strata to identify combinations of microhabitat characteristics associated with marten habitat use. Results of the latter analyses will be compared to the fitted regression models to check for agreement in terms of variables included.

For each study site, we will identify cells receiving high or medium use in leaf-on and leaf-off periods. We will use logistic regression to model differences in microhabitat characteristics between areas of concentrated use during leaf-on versus leaf-off periods, and between the industrial forest and the forest preserve.

#### **Progress During FY 95 And Future Plans:**

We overlaid >3000 locations of marten collected during 1989-91 and 1993-94 on our study site in T4 R11 and T5 R11 WELS with available road access and excluded all locations >400 m from roads. We then overlaid a 16 ha grid and chose 15 grid cells in each of the following three treatments (1) forested with no use by resident marten; (2) forested with use by resident marten; and (3) regenerating with no use by resident marten prior to the trapping closure. Within each of the 45 grid cells, we have sampled microhabitat characteristics at eight sampling stations.

During 1996 we will repeat the grid cell selection and sampling protocol within Baxter State Park, except that we will substitute cells with severe spruce-budworm kill for regenerating cuts. The final report for the project will be available in November 1997.

FINANCIAL SUPPORT: NCASI, MAFES, DWE, MDIFW

#### **V. Relationships Between Small Mammal Densities, and Macro- and Microhabitat Characteristics of Forests in Northern Maine**

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

Hence, we are investigating the relationship between microhabitat characteristics, densities of small rodents, and forest stand age and species composition. Specific objectives are to (1) document seasonal food habits of marten on our industrial forest site (T4 R11, T5 R11 WELS) in northern Maine; (2) 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) quantify differences in structural complexity in different stand types; and (4) evaluate which stand, microhabitat, and structural characteristics are the best predictors of small mammal densities.

Food habits of marten will be quantified from marten scats collected during field activities over the past six years. Small mammals are being live-trapped in five habitat types (mature mixedwood, mature hardwood, mature softwood, regenerating forest, and stands with severe spruce-budworm damage). Also, snowshoe hare densities are being indexed on each grid by counting pellets on transects distributed throughout the trap grids. Microhabitat characteristics will be 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. We will develop a multivariate model to identify which habitat attributes are the best predictors of small mammal densities. These results will be compared with associated studies designed to identify which habitat attributes are the best predictors of use intensity of forest grid cells by marten. We hope to identify which structural features could be managed for in harvested forest stands to maintain use by marten and their principal prey species.

**Project Status and Future Plans:** During June through August 1995 we totaled 1,852 captures of 867 individuals (56% red-backed voles [*Clethrionomys gapperi*], 28% deer mice [*Peromyscus maniculatus*], 12% shrews [*Sorex cinereus*, *Blarina brevicauda*]) in 7,808 trap nights of effort. Microhabitat characteristics were sampled at 320 sampling stations distributed among the five habitat types. Transects (n = 240) for snowshoe hare pellet counts were established and cleared of all pellets at the beginning of the leaf-off season.

Small mammal trapping protocol will be repeated during summer 1996 and snowshoe pellets will be counted at the end of the leaf-off season. Data analysis will be conducted during fall 1996, with an anticipated completion of the final report by March 1997.

FINANCIAL SUPPORT: DWE, MAFES

#### **VI. Comparison of Survival and Cause-Specific Mortality Rates of Marten in an Industrial Forest and a Forest Preserve**

**Project Status:** This phase of the project has been completed. An abstract of the scope and primary findings follows:

Comparisons of survival characteristics for untrapped populations of marten in unharvested forests are needed to evaluate the influence of human activities on population performance in managed landscapes with both timber harvesting and trapping. Although survival rates have been estimated for marten in areas with trapping and logging, comparable data from an untrapped and unlogged area are lacking. Thus, we monitored 33 adult (>1 yr) female and 26 adult male martens in an untrapped forest preserve in northcentral Maine from October 1990 to April 1994. We documented causes of natural mortality, estimated semiannual survival rates, compared predation-caused mortality rates between sexes, and compared survival characteristics for the population in the forest preserve with published information from an adjacent trapped population in an extensively logged landscape. We documented eight mortalities during 5,390 marten-days for females, and four mortalities over 10,488 marten-days for males within the forest preserve. Five of eight females and one of four males died from predation; undetermined natural causes resulted in the remaining six documented deaths of marten within the preserve. Additionally, of 17 marten (eight adults, nine juveniles) that left the preserve, three were caught by trappers and four died of predation. Within the preserve, daily survival during 1 May to 15 December was not different from rates during 16 December to 30 April for females ( $P = 0.10$ ) or males ( $P = 0.54$ ). Annual survival rates were higher ( $P = 0.01$ ) for males than females, in contrast to reports from trapped populations. Further, females experienced higher ( $P = 0.03$ ) annual mortality from predation than males. Survival rates during 1 May to 15 December were higher ( $P < 0.001$ )

for adult marten in the forest preserve than in the trapped and logged landscape. However, natural mortality rates (1 May - 15 December) were not different between the two areas for adult females ( $P = 0.39$ ) or adult males ( $P = 0.14$ ). Our results do not support published conclusions that marten in unlogged areas experience lower natural mortality than mar-

ten in logged areas. Trapping mortality accounted for most of our observed differences in survival of marten between the trapped and logged landscape and the forest preserve.

FINANCIAL SUPPORT: MDIFW, MAFES, DWE

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- Gilmore, D.S., R.S. Seymour, W.A. Halteman, and M.S. Greenwood. 1995. Canopy dynamics and the morphological development of *Abies balsamea*: effects of foliage age on specific leaf area and secondary vascular development. *Tree Physiology* 15:47-55.
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- Briggs, R.D. Site quality and balsam fir response to precommercial thinning. Natural Resources Conservation Service, Orono, ME. March 2, 1995.
- Briggs, R.D. Maintaining soil productivity. 75th Annual Winter Meeting, New England Division, SAF. Burlington, VT. March 20-23, 1995.
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- Ostrofsky, W.D. Vice-Chair (Program Chair), Northeastern Forest Pest Council, and session moderator at the joint meeting of the Northeastern Forest Pest Council, Northeastern Forest Insect Work Conference, and New England Division, SAF. Burlington, VT., March 19-21, 1995.
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**COOPERATIVE FORESTRY RESEARCH UNIT  
ADVISORY COMMITTEE  
1995 Membership**

The CFRU Advisory Committee sets priorities and reviews proposals for the Cooperative Forestry Research Unit. Members active during all, or part, of 1995 were

Si Balch, Boise Cascade Corporation (Chair)  
Anthony Filauro, Great Northern Paper (Vice Chair)  
Everett Deschenes, Fraser, Inc. (Financial Officer)  
Thomas A. Morrison, Maine Bureau of Public Lands (Member at Large)  
G. Bruce Wiersma, Dean, College of Natural Resources, Forestry and Agriculture  
John Cashwell, Seven Islands Land Company  
Douglas Denico, S.D. Warren Company  
Robert Frank, USDA Forest Service  
Dennis Gingles, International Paper Company  
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Ronald Mallett, Maine Power Services  
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Phil Sullivan, J.D. Irving, Limited  
Peter Triandafillou, James River Timber Corporation  
John Trobaugh, Georgia-Pacific Corporation  
Henry Wittemore, Hancock Timber Resource Group

**CFRU STAFF  
(September 30, 1995)**

**Program Leaders**

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

**Professional Staff**

Ronald C. Lemin, Jr., Assistant Scientist  
Peter Caron, Research Associate Richard J.  
Dionne, Research Associate Eleanor G.  
Heinz, Administrative Assistant

**Cooperating Professors**

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

## CFRU COOPERATORS

1995

Baskahegan Company  
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Hancock Timber Resource Group  
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Irland Group, The  
Irving, J.D., Ltd.  
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James River Timber Corporation  
Knight Tree Farm  
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Madden, F.A., Inc.  
Maine Bureau of Public Lands  
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Pride Manufacturing Company  
Robbins Lumber Company  
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Saunders Brothers  
Seven Islands Land Company  
Sewall, James W. Company  
Timberlands Corporation  
Totman, General Clayton O.  
Wales, Rodney H. & Son  
Warren, S.D. Company  
Western Maine Nurseries

## OTHER ORGANIZATIONS PROVIDING SUPPORT FOR CFRU PROJECTS

Cooperative States Research Service  
DowElanco  
Maine Agricultural & Forest Experiment Station  
Maine Forest Service

McIntire-Stennis  
Monsanto Agricultural Products Company  
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 rubrum</i> L.	Red maple
<i>Acer saccharum</i> Marsh.	Sugar maple
<i>Betula alleghaniensis</i> Britton	Yellow birch
<i>Betula papyrifera</i> Marsh.	Paper birch
<i>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>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 Pitch
<i>Pinus rigida</i> Mill.	pine Red pine
<i>Pinus resinosa</i> Ait.	White pine
<i>Pinus strobus</i> L.	Loblolly pine
<i>Pinus taeda</i> L.	Aspen Douglas-
<i>Populus</i> spp.	fir Red oak
<i>Pseudotsuga menziesii</i> (Mirb.) Franco	Raspberry
<i>Quercus rubra</i> L.	
<i>Rubus</i> spp.	
<i>Alces alces</i> L. <i>Blarina</i>	Moose
<i>brevicauda</i> Say <i>Castor</i>	Shorttail shrew
<i>canadensis</i> Kuhl <i>Clethrionomys</i>	Beaver
<i>gapperi</i> Vigors <i>Lepus</i>	Red-backed vole
<i>americanus</i> Erxleben <i>Martes</i>	Snowshoe hare
<i>americana</i> Turton <i>Peromyscus</i>	American marten
<i>maniculatus</i> Wagner <i>Sorex</i>	Deer mouse
<i>cinereus</i> Kerr <i>Ursus americanus</i>	Masked shrew
Pallas	Black bear



## APPENDIX B CFRU RESEARCH PRIORITIES 1996-2000

RANK	CATEGORY	VOTE POINTS	EMPHASIS AND ACTIVITY STATUS AT CFRU
	SITE CLASSIFICATION & PRODUCTIVITY OVER TIME	72	HIGH PRIORITY -ACTIVE CURRENT RESEARCH
2 3	SILVICULTURE-SW	56.5	HIGH PRIORITY -ACTIVE CURRENT RESEARCH
4 5 6 7	GROWTH & YIELD	54	HIGH PRIORITY -ACTIVE CURRENT RESEARCH
8	SILVICULTURE-HW	53.5	HIGH PRIORITY -ACTIVE CURRENT RESEARCH
	TREE IMPROVEMENT	35	HIGH PRIORITY -ACTIVE CURRENT RESEARCH
	HARVESTING	33	HIGH PRIORITY - NEED TO DEVELOP RESEARCH
10	WILDLIFE MGT.	26	HIGH PRIORITY -ACTIVE CURRENT RESEARCH
11	WOOD TECH	15	WAITING FOR CONCRETE PROJECT AND FUNDING PROPOSAL
	PEST MANAGEMENT	13	MODERATE PRIORITY - MONITOR RESEARCH IN PROGRESS
	SLUDGE AND ASH	10	MODERATE PRIORITY - WRAPPING UP CURRENT RESEARCH
	ECONOMICS	9	LOW PRIORITY - MONITOR RESEARCH IN PROGRESS ELSEWHERE
12	INVENTORY	8	AS ABOVE
13	WETLANDS	6	AS ABOVE
14	ECOSYSTEM MGT	5	AS ABOVE
15	LANDSCAPE PLANNING	3	AS ABOVE
16	RECREATION	2	AS ABOVE
17	SOCIAL EFFECTS	1	AS ABOVE
17	REMOTE SENSING	1	AS ABOVE
18	ATMOSPHERIC & CLIMATE	0	AS ABOVE
18	EXPERT DECISION MODELS	0	AS ABOVE

QUESTIONNAIRE RANKED 8/1/95 8:30 AM

**SITE CLASSIFICATION AND  
PRODUCTIVITY OVER TIME**  
**Research Priorities - 1996-2001**  
**(Ranked #1, 72 Points)**

**Focus:** Development of a practical productivity-oriented site classification system for use in Maine. Emphasis is to be placed now on hardwood species. A detailed study plan will be forthcoming after the program position, now vacant, is filled.

**Product Goals:**

- Site productivity identification guide, to complement the softwood guide now available
- Improved understanding of the relationship of soil-site characteristics with species composition and productivity of mixedwood stands
- Continuation of monitoring of stream and soil solution chemistry, and nutrient dynamics at the Weymouth Point Watersheds study area, and assessment of impacts to water quality and site productivity with various management treatments over time.
- Integration of hazard rating for pests with site evaluation.

**SOFTWOOD SILVICULTURE**  
**Research Priorities - 1996-2001**  
**(Ranked #2, 56.5 Points)**

**Focus:** Outlined below are subject areas of interest/concern identified by CFRU members and by Dr. Maxwell McCormack in a problem analysis prepared in 1995.

I. Silvicultural Prescriptions

A Evenaged/Unevenaged Management

- Examine the growth, yield and cost/benefits of unevenaged management.
- Maximize softwood regeneration in mixedwood stands.
- Manage understory vegetation to enhance crop tree development.
- Investigate mechanized thinning in young commercial-sized stands.
- Practices and equipment to minimize damage to residual stands.
- Investigate chemical and mechanical methods to control stand density.
  - a. Timing of entry(s) into stand.
  - b. Frequency of entry.
  - c. Number of crop trees per unit area.

B Intensive Management of Natural &  
Artificial Regeneration.

C Control of Competing Vegetation.

- Screen new herbicide and adjuvant products.

- Improve delivery technology.
- Investigate alternative vegetative management techniques.

II. Wood Quality as Affected by Forest Management Practices.

**Product Goals** (not in priority order): The Product Goals section focuses on specific tasks to be accomplished during the next five-year period.

- Continue research projects now in progress and report findings.
- Develop silvicultural prescriptions to maximize softwood regeneration in mixedwood stands.
- Outline methods to intensively manage natural and artificial regeneration.
- Develop cost-efficient methods to thin juvenile softwood stands of non-commercial size.
- Develop cost-efficient methods to thin young commercial-sized softwood stands.
- Investigate changes to wood quality as affected by forest management practices and report findings.

**GROWTH & YIELD**  
**Research Priorities - 1996-2001**  
**(Ranked #3, 54 Points)**

**Focus:** Volume yields for native species in normal species mixtures, recognizing differences for site quality and management method.

**Product Goals:** An analytic summary and evaluation of existing growth and yield models (FIBER, FORMAIN, NED, TWIGS, MFPS, BAILEY'S NEW BRUNSWICK MODELS and others). This should direct cooperators to the best currently available tools for their use. It should also include recommendations of what work should be done to finish or improve Maine's capabilities.

- A comparison of these tools to TASS and a cost estimate of completing development of TASS to a usable stage.
- An analysis of some of the optimizing models now available (FORPLAN, WOODSTOCK, and others).
- A booklet of printed yield curves for both hardwood and softwood species as well as curves for natural combinations of these species. This booklet should include either separate curves or at least indications of changes in yield expected on the different Briggs site classes and under different management methods.
- Specific research should be directed at response to various management methods and growth of natural combinations of species
  - hardwood
  - softwood
  - mixed wood
  - growth of plantation species

**HARDWOOD SILVICULTURE**  
**Research Priorities -1996-2001**  
**(Ranked #4, 53.5 Points)**

**Focus:** Site identification for species or species groups. Productivity expectations, with silvicultural management guidelines for specific species regeneration and yields of volume and value. Additionally, hardwood plantations are of growing interest.

**Product Goals:**

- Site productivity identification guide, to complement the softwood guide produced by Briggs.
- Guidelines to identify potential problems, and/or to avoid and/or to control non-commercial competition such as hobble bush, striped maple, and mountain maple.
- Guidelines for selective control of commercial species either through chemical or other management methods.
- Guidelines to obtain regeneration of chosen species.
- Thinning guide for young hardwood stands; either PCT or very early commercial work.
- Adaptation, calibration, or analysis of the suitability of Leak's USFS hardwood management guide for the White Mountains, Bailey's New Brunswick guide, Hornbeck's Ecology of Hardwoods guide and Safford's White Birch guide to various climatic zones in Maine.
- Guidelines and options for stands of lower value commercial species and/or poorly formed trees.
- Guidelines for maintaining or improving the quality of postharvest partially cut stands. Ways to control epicormic branching and disease.

**TREE IMPROVEMENT**  
**Research Priorities - 1996-2001**  
**(Ranked #5, 35 Points)**

**Focus:** Outlined below are subject areas of interest/concern identified by CFRU members and by Drs. Michael Greenwood and Katherine Carter in project summaries prepared in 1995.

I. Softwood Tree Improvement

- Production and testing of fast-growing families of hybrid larch.
- Provenance studies and family tests of selected species.
- Wood quality and stem form as affected by tree improvement.
- Cold hardiness and shoot extension as affected by climatic change.
- Methods for the early selection of genetically superior individuals.
- Establishment of new breeding populations of black spruce.
- Examine the growth and yield of trees outplanted in long-term field trials.
- Examine varieties of white pine resistant to weevil and blister rust.

II. Hardwood Tree Improvement

- Production and testing of families of hybrid poplar/ aspen, with emphasis on silvicultural, regeneration, and disease/insect problems.

**Product Goals:** The Product Goals section focuses on specific tasks to be accomplished during the next five-year period.

- Continue with work now in progress on hybrid larch and report results.
- Summarize long-term provenance tests, exotic species trials, and progeny tests and report findings.
- Summarize the black spruce orchard trials initiated in the 1980s and report findings.
- Examine the production and testing of poplar/aspen, with emphasis on silviculture, regeneration, and disease/insect problems. Report results or status of projects.
- Investigate varieties of white pine that are resistant to weevil damage and blister rust and report findings.

**HARVESTING**  
**Research Priorities - 1996-2001**  
**(Ranked #6, 33 Points)**

**Focus:** The effects of harvesting on the next forest, either through its impacts on the residual stand, regeneration or site productivity.

**Product Goals:**

- An analytic summary of existing research dealing with in-woods processing (single or double grip cut to length systems). This should focus on how these systems are likely to perform in Maine under typical forest conditions.
- An analysis contrasting in woods systems with typical equipment now in use in Maine.
- These analyses should address the physical and monetary values (short and long term) of as many of the following points as possible:
  - wood productivity,
  - residual trees,
  - existing regeneration,
  - site condition for planting or seeding,
  - susceptibility to insects or disease,
  - propagation of undesirable competition,
  - long-term site productivity, and
  - acres devoted to roads, trails and landings.
- Specific research should be directed at areas other than productivity/costs that are not answered satisfactorily by existing data.
- A harvesting method and equipment recommendation guide for landowners based on existing forest conditions and desired outcomes.

**WILDLIFE MANAGEMENT**  
**Research Priorities - 1996-2001**  
**(Ranked #7, 26 Points)**

Focus: Understanding the effects of the normal management methods now in use in Maine on indigenous wildlife species, with particular emphasis on habitat or ecological land type indicator species.

**Product Goals:**

- Completion of the marten study.
- Development of a matrix of serai stage/stand capability or ecological land types for significant habitats.
- Guidelines for spatial arrangement, adjacency, and range sizes desirable to accommodate the normal mixes of species.
- Understanding of habitat and water quality requirements of native fish, in relation to characteristics such as silt, temperature, and others.
- Identification of indicator species, if they exist, of important forest habitats.
- Identification of any special habitat requirements of species of particular importance to Maine.

**WOOD TECHNOLOGY**  
**Research Priorities - 1996-2001**  
**(Ranked #8,15 Points)**

**Focus:** The focus of this research area is currently being developed. A specific questionnaire has been mailed to several hundred wood products facilities. Questionnaire data will be summarized over the next several months. Current CFRU cooperators have identified a few specific areas of interest, and these are listed below.

**Product Goals:**

- Wood quality changes, including pulp yields, as affected by silvicultural and other forest management practices. Emphasis on softwood species, but not to exclude important or abundant hardwood species.
- Wood quality assessment of trees from tree improvement plantings. Trees in many plantings are now entering the appropriate size classes for testing.
- Primary processing, including milling and machinery.
- Hardwood manufacturing.
- Establish an applied research and extension effort with (new) mill cooperators. Specific research problems to be determined. Focus will likely be on primary processing.