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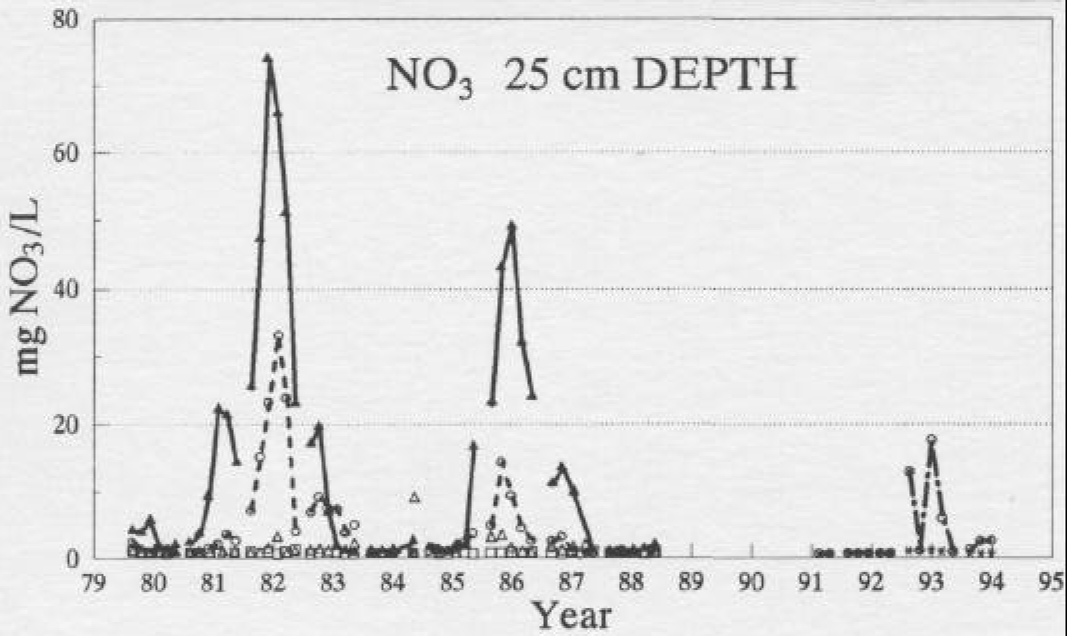
1994 ANNUAL REPORT AND RESEARCH SUMMARY OF THE COOPERATIVE FORESTRY RESEARCH UNIT



CFRU Information Report 35
December, 1994

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1994 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

Miscellaneous Report 389 December, 1994

COVER STORY THE WEYMOUTH POINT STUDIES

The Weymouth Point Watersheds Study Area

During the summer and autumn of 1979, a pair of adjacent watersheds draining into Chesuncook Lake was located on Weymouth Point, T4R12 WELS, Piscataquis County. The area is owned by Great Northern Paper. A permanent grid system was established and maps were constructed to record surficial topography, watershed boundaries, forest cover types, soil associations, study plot locations, right-of-way location, harvesting activity, herbicide treatment, and photo transect points. These maps, with related study and treatment records, have been maintained continuously since that time. The western 73 ha (180 a) watershed was selected to be the uncut control watershed. The eastern 48 ha (119 a) watershed was used for harvest and residue treatments as well as for several later evaluations of post-harvesting silviculture treatments.

This study area was chosen because

(1) no harvesting had taken place since the removal of some selected conifer stems around 1903,

(2) no road construction had occurred within the watershed boundaries,

(3) the forest cover was predominantly spruce-fir,

(4) the watersheds are large enough to supply continuous stream flow during years of average precipitation, and

(5) there was close cooperation and support by the landowner.

The soils are poorly to moderately well drained, coarse-loamy, mixed, frigid basal tills of the Chesuncook catena that were derived from slate and phyllite bedrock. The forest represents a two-aged red spruce-balsam fir stand that has developed from the 1913-1919 spruce budworm epidemic. Prior to the harvest, there was an average of 3079 trees/ha (1246 trees/a) with a total basal area of 48 m'^2/ha (209 sq ft/a). Eighty-two percent of the basal area was red spruce and balsam fir. The remaining basal area was other northern conifers and hardwoods.

This study, initiated in 1978 through a cooperative effort of CFRU and the USDA-Forest Service, is a valuable, long-term study contributing unique data from the spruce-fir forests of northeastern North America. It has become a model of broad cooperation among research organizations and personnel, and provides a documented base for subsequent studies addressing the sequence of silvicultural activities which can occur from harvest through early stand development. The integrity of the operational harvesting treatments and the large amount of residue and biomass data collected were made possible through the superb cooperation of the landowner and the harvesting machine operators. Numerous researchers and students have participated in the Weymouth Point studies. In addition to CFRU, cooperating groups and funding sources have included the USDA-Forest Service, Durham, NH; the NH Water Resources Research Center, Univ. of NH; Mclntire-Stennis; Cooperative States Research Service; Great Northern Paper Company; Department of Energy, Oak Ridge National Laboratory; the Departments of Forest Ecosystem Science, and Wildlife Ecology, University of Maine; and DowElanco Chemical Company.

During establishment the principal focus of the study was nutrient and biomass cycling within a spruce-fir ecosystem relative to whole-tree harvesting and various options for disposing of harvesting residues. It composed the Ph.D. research of C. T. Smith, Jr. (1984a). There was a description of the study establishment (Smith 1984b), and 133 selected references from the initial literature review were summarized (Smith 1985). Data of nutrient and biomass removals from the harvesting were published (Smith *et al.* 1986). Since before harvest, permanent photo transects across the treatment watershed have been maintained. Harvesting disturbances were evaluated in the early years (Martin 1988, Turcotte 1988). Plots of planted trees were placed on selected openings among the dense natural regeneration to provide comparisons as the vegetation develops. Part of the vegetation developing on the treated watershed was aerially sprayed with a release treatment to provide information on the fate of triclopyr in the watershed as well as further insight on nutrient cycling interactions (Smith *et al.* 1988, Smith and McCormack 1988). Within the natural spruce-fir regeneration, precommercial thinning and fertilizer plots were established by Russell Briggs. (see page 19, this annual report). Over the 15 years since establishment, there have been more than 50 publications and presentations based totally, or in part, on the Weymouth Point Study. Numerous professional tours and workshops have utilized the study area. The timing and variety of observations and continuing activities carried out over the 15-year history are summarized in the following chronology.

Cover photo shows the Weymouth Point Watersheds Study area as it appeared immediately after the initial harvest. The graph below shows changes in NO_3 concentration of soil solution as affected by management practices: harvesting in 1981, herbicide treatment in 1985, precommercial thinning in 1991, and fertilizer application in 1993.

Chronology of the Weymouth Point Study

Summer 1979	Watersheds defined
July 1979	Begin stream water sampling
May 1980	Begin atmospheric deposition chemistry (wet & dry)
July 1980	Construction of road for the harvesting operation
	Installation of ceramic cup tension lysimeters (soil solution sampling at depths of 25 and 50 cm)
June 1981	Begin mechanical harvest of treatment watershed
July 1981	Complete mechanical harvest, begin hand crew harvest of remaining large trees
August 1981	Hand crew harvest completed
	Soil disturbance transects established in adjacent stand
May 1982	Planting plots, first series
May 1984	Adjacent stand whole-tree harvested
August 1985	Aerial conifer release with triclopyr
May 1986	Planting plots, second series
	Discontinue atmospheric deposition chemistry monitoring
	N mineralization incubation, adjacent stand
August 1986	Complete triclopyr residue sampling
Nov. 1988	Discontinue stream water monitoring
June 1991	Establish precommercial thinning (PCT) and fertilizer plots
	Begin monitoring of air temperature and rainfall
	Drill wells into basal till for monitoring of groundwater chemistry
Sept. 1991	Begin new series of growing season collections of stream water, soil solution, and groundwater
October 1991	Install PCT treatment
May 1992	Crop tree measurements, PCT plots
May 1993	Collect foliage samples for analyses
	First fertilizer to PCT plots
July 1993	Second fertilizer to PCT plots
October 1993	Collect foliage samples for analyses
	Install litter traps
May 1994	Collection of foliage from litter traps
August 1994	Measurement of crop trees, PCT plots

Literature Cited

Martin, C.W. 1988. Soil disturbance by logging in New England: review and management recommendations. North. J. Appl. For. 5(l):30-35.

Smith, C.T., Jr. 1984a. Nutrient removals and soil leaching from a whole-tree harvest of a red spruce *(Picea rubens* Sarg.) - balsam fir *[Abies balsamea* (L.) Mill.] stand in north central Maine. Ph.D. Diss. Univ. Maine. 213 p.

Smith, C.T., Jr. 1984b. Intensive harvesting residue management alternatives and nutrient cycling in the spruce-fir *[Picea rubens* Sarg. - *Abies balsamea* (L.) Mill.] type: The Weymouth Point Study. Maine Agric. Expt. Sta. Misc. Kept. 295. 42 p.

Smith, C.T., Jr. 1985. Literature review and approaches to studying the impacts of forest harvesting and residue management practices on forest nutrient cycles. Maine Agric. Expt. Sta. Misc. Kept. 305. 34 p.

Smith, C.T., Jr., M.L. McCormack, Jr., J.W. Hornbeck, and C.W. Martin. 1986. Nutrient removals from a red spruce - balsam fir whole-tree harvest. Can. J. For. Res. 16:381-388.

Smith, C.T., Jr., J.W. Hornbeck, and M.L. McCormack, Jr. 1988. Changes in nutrient cycling following aerial application of triclopyr to release spruce-fir. Proc. Northeast. Weed Sci. Soc. 42:94-99.

Smith, C.T., Jr., and M.L. McCormack, Jr. 1988. Watershed losses of triclopyr after aerial application to release spruce-fir. Proc. Northeast. Weed Sci. Soc. 42:104-108.

Turcotte, D.E. 1988. Mechanically disturbed forest soil on three drainage classes: spatial distribution and effects on potential nitrogen availability. M.S. Thesis, Univ. of New Hampshire. 88 p.

CONTENTS

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

FIGURES

FIGURE

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TABLE

ADVISORY COMMITTEE CHAIR'S REPORT

This has been another successful year for CFRU. Happily, Dr. Robert Shepard was able to return after a long recuperation.

We have added members, completed and published research results, and maintained our financial stability. We welcome both Georgia-Pacific and Hancock Timberlands to our group and appreciate the continued support of all our members in tough financial times. We have an active membership committee working to strengthen our team. The commitment to control costs has resulted in continuing our dues at 5 cents per acre for 1995. Dues will need to rise in 1996 in order to maintain our programs.

CFRU is funding eight research projects. While maintaining our work on silviculture, pathology, ash/sludge, tree improvement, soils/site, and modeling, we have added a pine marten project. We received updated written research problem presentations and analyses from the scientists. These help us focus our efforts and will guide us in formulating a new five-year plan in 1995. A major goal for 1994 is working with members to develop a 1996-2001 research plan.

Technology transfer, training, and publications continued to be an area of focus. The combined efforts total over ninety separate events ranging from peer-reviewed papers to legislative testimony. We have continued with two specific efforts aimed directly at cooperators: the monthly technical articles for industry newsletters, and the September field meeting. CFRU scientists are an active and credible source of forestry information for Maine and beyond.

Of particular interest is the soil/site guide for softwood by Dr. Russell Briggs. This handy field book will help all the cooperators manage their land better. The hardwood sequel is now in development. Sadly for CFRU, Dr. Briggs has decided to accept a position at SUNY/ESF. We wish him luck; he will be missed.

CFRU is a fine outfit 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

Dr. R. Briggs explains the process involved in developing a site classifcation guide for northern hardwoods at the CFRU fall field tour, Lynchtown Township, Maine.

DEAN'S REPORT

Greetings and best wishes to our CFRU cooperators! I am pleased at the continued research progress that the CFRU scientists and staff have shown by way of this annual report. Important studies are on schedule, and continue to provide critical information as we move toward the twenty-year mark of this research cooperative.

I have again made numerous contacts and site visits with our CFRU cooperators, and I'm always encouraged by your support and excitement for the CFRU. Continued contact by staff members and cooperator personnel with representatives of the Hancock Timber Group has resulted in their joining the CFRU as a new member. They will be represented on the CFRU Advisory Committee by Henry Wittemore. I'm delighted that they will be joining us and look forward to working closely with them.

Candid and open discussions were held on a variety of CFRU issues at the annual retreat of the CFRU Executive Committee and the Program scientists, held in September. Of most importance was the long-range planning of the next five-year research period, and the organization of several technology transfer efforts, integral to the continued productivity of the research process. These meetings continue to build on a solid foundation of finding new ways to improve the operation and effectiveness of the CFRU.

Change is always with us. It is with considerable regret that I must announce the resignation of Dr. R. Briggs from the CFRU, effective in June of 1995. He is a most productive and valued part of the team. However, I do wish him continued success in his new position at the State University of New York, Syracuse. I know that he will continue to be a strong asset to the forestry profession.

I join each of the scientists of the CFRU in looking forward to a very challenging and rewarding 1995!

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

A discussion of soil site classification, CFRU fall field tour, Lower Cupsuptic Township, Maine.

BALANCE SHEET

1993-1994 Period
10/1/93-9/30/94

ASSETS:

BALANCE FORWARDED SEPTEMBER 30, 1993	$ 660,506.98	
FUNDS RETURNED TO CONTROL AFTER adjustments on 09/30/93	30,140.82	
INVESTMENTS 10/01/93-09/30/94	25,843.82	
CONTRIBUTIONS 10/01/93-09/30/94	411,122.00	
TOTAL ASSETS:		$1,127,613.62

EXPENSES: 10/01/93-9/30/94

ADMINISTRATION - OSTROFSKY	$ 55,581.55	
SILVICULTURE - McCORMACK SOIL	139,896.88	
SITE - BRIGGS HARDWOOD/ASH -	116,409.47	
OSTROFSKY TREE IMPROVEMENT -	92,927.31	
CARTER GROWTH/YIELD -	26,693.00	
SEYMOUR PINE MARTEN --	18,863.19	
HARRISON SLUDGE & ASH -	13,532.51	
SHEPARD TREE IMPROVEMENT -	10,261.81	
GREENWOOD	7,828.41	
TOTAL EXPENSES:		$ 481,994.13
BALANCE 09/30/94 LESS		645,619.49
DEDICATED FUNDS:		400,000.00
BALANCE ENDING 09/30/94		245,619.49

CFRU LEADER'S REPORT

This past research year has been spent productively in gathering data from numerous ongoing studies. Continued progress was made by each program and project, and is reported in full detail in the following pages. However, three events warrant particular mention. First, a most successful Hardwood Symposium was coordinated by Dr. M. McCormack, in his capacity as the H.W. Saunders Chair of Hardwood Silviculture. It was very well attended and well received by a wide audience. Second, a project was developed by Dr. D. Harrison on the relationship of timber management practices to pine marten populations. This project, ongoing for a number of years and scheduled to continue for an additional four years, is now partially funded by the CFRU. Third, Dr. R. Briggs has completed a productivity-based site classification guide for spruce-fir. The guide has been published as a concise manual and is specifically designed for field use.

In September, a successful CFRU field tour was held in western Maine, in conjunction with the fall Advisory Committee meeting. The tour, conducted near Rangeley, Maine, highlighted use of the spruce-fir site classification guide developed by Dr. Briggs, as well as his new work on hardwood site quality evaluation. The tour also included a visit to a paper birch thinning study in Grafton Township, which I have followed now for a 10-year period. The tour was attended by approximately 55 individuals.

A significant effort was made, and continues to be made, by CFRU personnel in preparing for the 1995 Society of American Foresters National Convention. The meeting will be held in Portland, Maine, and Dr. McCormack is General Chair. This meeting provides a particularly important opportunity to showcase the forest industries of Maine and New England and the forestry research that CFRU has conducted.

Dr. Russell Briggs has decided to leave the CFRU and will be joining the faculty of the State University of New York, Syracuse, by early summer 1995. Dr Briggs has been a particularly strong contributor to the CFRU research effort, and we will miss his expertise and enthusiasm on the staff. We hope that he will continue a strong professional relationship with CFRU, and we wish him the very best in his new position.

Over the next year, CFRU scientists and cooperators will be firming up plans for the next five-year research period, scheduled to start in October 1996. An appendix in this annual report contains a synopsis of research areas proposed by the scientists for this time period. The document will serve as a basis for further discussions on CFRU research priorities. This section should be carefully studied, with any comments and suggestions by cooperators provided directly to the individual scientists. A final evaluation is expected during the CFRU Advisory Committee meeting and field tour, scheduled for September of 1995.

The upcoming year will confront the CFRU with many new challenges, and is enthusiastically anticipated. The new year promises to be exciting and rewarding, as new, critical information is generated and becomes available to the forestry community.

William D. Ostrofsky, Leader
Cooperative Forestry Research Unit

SILVICULTURE

Dr. Maxwell L. McCormack, Jr.

Overview

The year reported here primarily has been a period of field gathering of data and putting long-term studies in order. This is in line with the reduced time available and foreseeable retirement of the program leader. G. Richard Schaertl successfully completed his Ph. D. program with defense of his dissertation, "Growth responses of red spruce *(Picea rubens* Sarg.) and balsam fir *(Abies balsamea* (L.) Mill.) to vegetation management with herbicides in Maine." Program Leader McCormack received special recognitions for professional contributions to the Northeastern Weed Science Society (NEWSS) and the New England Society of American Foresters. He remains active with these organizations as Chair of the NEWSS Industrial, Forestry & Conservation Section with a substantial applied forestry program for their 49th Annual Meeting in January 1995, and as the General Chair for the 1995 National Convention of the Society of American Foresters (SAF) to be, in Portland, Maine, in late October 1995. The SAF National Convention will provide a showcase for posters of CFRU research projects.

The intensive field work efforts have been efficiently administered by Research Associate Richard Dionne of the Silviculture Program. Scheduling of a teamwork approach, with mutual project support through cooperation with Assistant Scientist Ron Lemin, provided improved efficiency and productivity. The crews usually worked 10-hour days. This approach provided a high level of productive hours measuring plots with reduced travel time and costs per week of field work.

The field crew completed all the first priority scheduled plot remeasurements. In the early season, a forestry graduate student, Anthony DiNicola, participated. Return workers, forestry undergraduates Jay Horetzke and John Leighton, were an asset because of their previous experience. Two additional forestry undergraduates, Jeffrey Tapley and Kurt Zschau, completed the team. They all deserve special thanks for their dedication and thoroughness, and special recognition for persevering through one of the worst black fly seasons in memory.

The Austin Pond Study Site

A portion of the Austin Pond Study had been remeasured prior to the Annual CFRU Field Meeting in the autumn of 1993. In order to complete all measurements of the entire study within the same growing season period, the measurements were resumed during the University Spring Break in March 1994 on snow cover with a cumulative work time of 500 hours. In May and June, an additional 700 hours was spent to complete the reestablishment of all plot boundaries and corners, the tally of competing vegetation, and the measurement of crop trees. During late June and July, 850 hours were devoted to stem analyses of selected study trees on nine treatment blocks. These additional stem analyses will provide data for volume estimate confirmations on precommercially thinned and unthinned spruce and fir trees, and will be a basis for detailed evaluations of growth and development. Stem sections from the study trees and related data are currently being processed.

The Austin Pond Study was recognized in the report of the Environmental Assessment Board, which spent four years evaluating timber management on Crown Lands in Ontario[1]. The study is described on page 243 of the document and served as a partial basis for the Board's statement of findings, which included the following:

> The evidence establishes chemical herbicide spraying to be an effective means of tending and essential to the regeneration of conifer species. There is today no effective, practical or affordable alternative to herbicide tending. While we approve the continued use of herbicides in timber management planning, we are also ordering MNR to investigate new technologies and to test alternative means of tending.

Long-term Spruce-Fir Thinning Study

The two remaining sites, of the original five, of the long-term spruce-fir thinning study were also completely remeasured. This study, established during 1977-1978, has numbered crop trees with varying levels of competition from adjacent crop trees. All plots were remonumented. Study trees were located, renumbered, and retagged. Remeasurements were carried out for all the numbered study trees. Variables for each tree include dbh, total height, distance and azimuth to each competitor tree, crown radii, live crown and clear bole lengths, and classifications of crown conditions. The Scott Brook Study Site, on land of Great Northern Paper, required a cumulative total of 200 hours. At the Clayton Lake Study Site, on land owned by International Paper Company, a total of 280 hours was required for the remeasurements. These data will be assembled with previous observations to compile a report on the thinning study.

'Environmental Assessment Board. 1994. Reasons for Decision and Decision, Class Environmental Assessment by the Ministry of Natural Resources for Timber Management on Crown Lands in Ontario (EA-87-02). 2300 Yonge St., Suite 1201, Toronto, Ontario M4P 1E4. 561 pp.

The Weymouth Point Study Site

The Weymouth Point Watersheds Study Area, described elsewhere in this annual report, received its usual routine maintenance. This year approximately 40 hours were expended on maintenance of stations and transect lines that compose the permanent reference grid across the treatment and control watersheds.

The Henry W. Saunders Hardwood Silviculture Chair

Within the hardwood silviculture program, approximately 50 hours were devoted to reviewing woodlot study sites and measuring crop trees for possible future study. In late May, a two-day hardwood silviculture workshop was conducted in cooperation with the Maine Hardwood Association and sponsored, in part, by the Henry W. Saunders Professorship in Hardwood Silviculture. The first day of the workshop was an indoor technical session with contributions by William Leak and Larry Safford of the USDA-Forest Service, NEFES, Durham, NH; Steve Horsley and Chris Nowak of the USDA-Forest Service, NEFES, Warren, PA; and Ralph Nyland of the College of Environmental Science and Forestry, SUNY, Syracuse, NY. The second day was a field session on the Edgewood Tree Farm in East Holden, Maine. Several stands were visited for evaluation and discussions led by host Brooks Mills, his son John Mills, and valuable marketing perspective provided by Steve Tudor of Columbia Forest Products. Approximately 145 people participated.

ASH RESIDUE UTILIZATION AND TIMBER QUALITY IMPROVEMENT

Dr. William D. Ostrofsky

Overview

The research effort of this program has concentrated again on the assessment of effects of papermill sludge ash and wood ash applied to forest sites. Two principal site locations were monitored for the second and third year following ash applications. Preliminary work was also started on a third site located in Lexington and Concord Townships. However, due to operational difficulties, application of sludge ash was delayed. Implementation of this study is now planned for 1995. Although the research focus of the program may change over the next few years, some work may continue on these study sites on a regular basis for several more years. This completes the third year of a five-year research effort.

In August, Y. Ren completed her M.S. thesis entitled "Response and activity of a forest soil microbial population to application of papermill sludge ash". This work is an extension of the studies being conducted at the Caratunk Township study site. It has provided some essential information that will assist in managing the ash residuals resource to its maximum advantage. C. Malitz has joined the program as an M.F. graduate student and will also conduct her project at the Caratunk Township study site.

Several weeks were also spent in the remeasurement of a ten-year-old study of thinning in a paper birch stand in Grafton. Changes in stand characteristics were documented, and preparation was begun for a subsequent study and intensive analysis in 1995.

Two earlier studies on logging damage were published. The first was an intensive study of mechanical harvesting in hardwoods, and the second describes a model application of tree damage probabilities. Both studies signal potential future directions of this research program, as outlined in the "Problem Analyses" section of this report.

This year field assistance was provided by CFRU research associate P. Caron and graduate student C. Malitz. In addition, several days of voluntary help were obtained from three students visiting from the Univ. of Madrid, Spain. The students, M. Munoz, M. Alvarez, and G. Fernandez, are in their fourth year of a six-year forest engineering program.

Papermill Sludge Ash Utilization

King and Bartlett Township

Three-year post-treatment height and diameter increment of black spruce crop trees was obtained from the King and Bartlett Township study site, located on International Paper Company land. No significant differences in height growth were evident between sludge ash treatments of 0, 2, 4, and 6 tons/acre $CaCO_3$ equivalent (Figure 1). A significant but small difference was found in diameter growth, with control (0 tons/acre) trees growing faster than trees

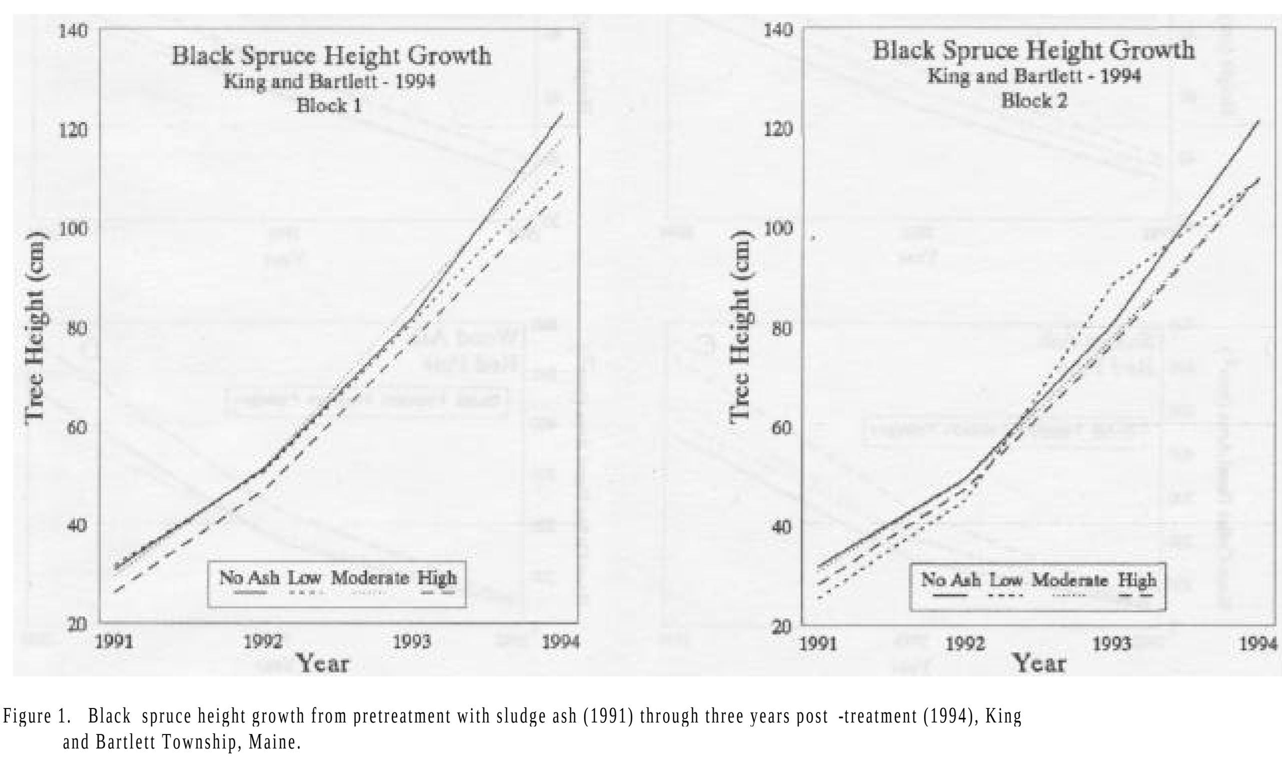


Figure 1. Black spruce height growth from pretreatment with sludge ash (1991) through three years post -treatment (1994), King and Bartlett Township, Maine.

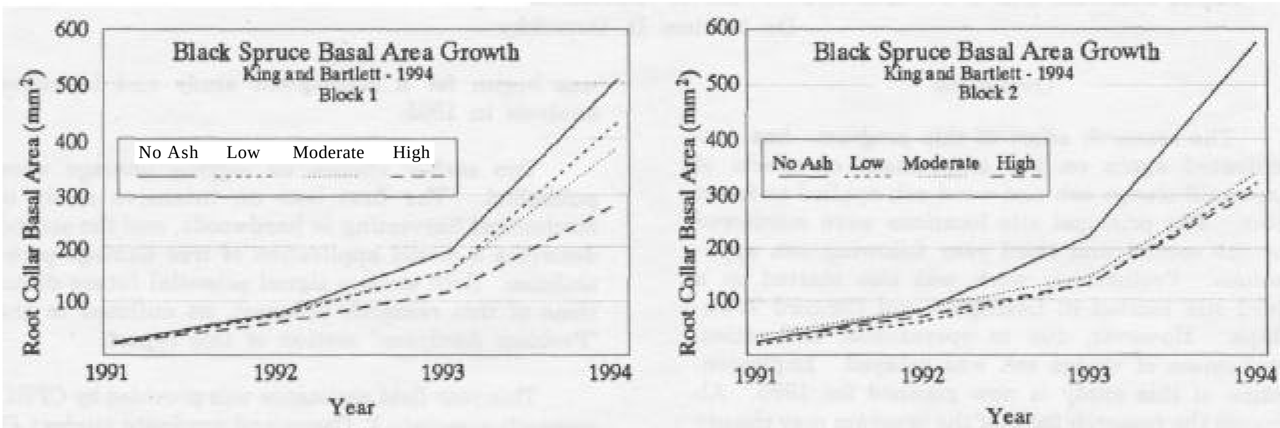


Figure 2. Black spruce basal area growth from pretreatment with sludge ash (1991) through three years post-treatment (1994), King and Bartlett Township.

in treated plots (Figure 2). This result was likely caused by increased plant competition stimulated by sludge ash during the 1992 and 1993 growing seasons. Because an herbicide treatment was applied to the area in late 1993, these small differences are not expected to persist. Foliage samples from the black spruce seedlings were also collected in 1994, and elemental analysis is currently in progress.

Heald Pond, Caratunk Township

First-year post-treatment height and diameter of sugar maple and red pine was obtained from the Heald Pond study site located on Scott Paper Company land. Treatments included application of wood ash and papermill sludge ash each at rates of 0, 3, 6, and 9 tons/acre $CaCO_3$ equivalent. Here again, as with the black spruce, results indicate no significant effect on height or diameter growth of red pine with increasing levels of applied sludge ash or wood ash (Figure 3). Similarly, neither ash residual had any effect on either height or diameter growth of sugar maple. However, differences between the two ash residuals became evident by the elemental analysis done on sugar maple foliage (Table 1).

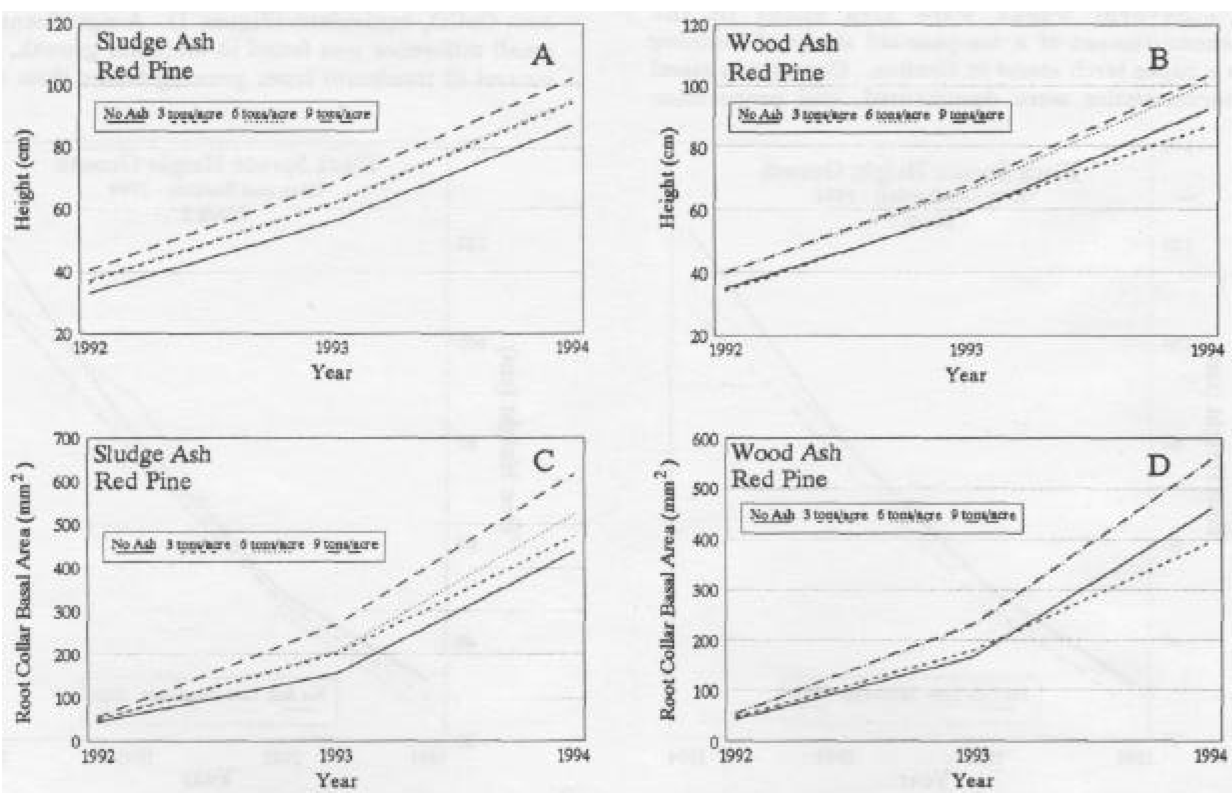


Figure 3. Height and basal area growth of red pine treated with either sludge ash (A and C) or wood ash (B and D), Caratunk Township, Maine.

Table 1. Elemental analysis of sugar maple foliage one year following papermill sludge ash application at the Heald Pond study site, Caratunk Township, Maine.

Residual	Treatment	N	Ca	K	Mg	Al	B	Cu	Fe	Mn	Zn	
Sludge Ash	Untreated	1.37	6853 "	5680 [3]	1298	819	31.8	25.5	3.17	50.8	952	293
	3 tons/acre	1.28	7425	6205	1427	841	36.6	24.5	2.96	50.5	1,017	29.4
	6 tons/acre	1.39	8832	6533	1727	764	35.5	25.9	3.31	299.7	1,010	38.8
	9 tons/acre	1.61	8887	7700	1502	817	38.9	27.8	2.97	71.8	1,259	283
Wood Ash	Untreated	1.38	7733 [b]	5745 [a]	1435	810	29.2	25.9 [a]	3.21	48.7	923	31.6
	3 tons/acre	1.32	8868	7010	1607	882	29.0	313	3.02	51.5	825	31.1
	6 tons/acre	1.32	7785	6941	1738	870	34.4	34.2	2.98	523	923	25.0
	9 tons/acre	1.36	6328	7780	1610	860	30.8	32.1	2.92	51.0	722	22.4

Values (% for N, ppm for all others) represent means from six replicate plots (54 trees).
Significant difference ($P<0.01$) between treatments, within ash type. Significant difference ($P<0.05$) between treatments within ash type.

Concentrations of Ca and K increased significantly with increasing rates of sludge ash. Concentrations of Mn, Al, and Mg also followed the same trend, although differences were not statistically significant. Although increases in Ca and K in foliage were also shown between plots treated versus untreated with wood ash, rate differences were less distinct. Application of increasing rates of wood ash also increased levels of B in sugar maple foliage. How these differences may affect sugar maple growth has not yet been determined.

A study on response and activity of a forest soil microbial population to application of papermill sludge ash was completed. Soil microbial populations were monitored 1, 8, 9, 10, 11, 12, and 13 months after application of sludge ash in September of 1992. The study has shown that bacterial populations in the forest floor are significantly affected by addition of sludge ash, increasing with application rate. Soil bacterial numbers were found to be highest in the spring, and then decreased as the season progressed. Fungal populations did not show a significant difference between treatments. No correlation was found between sludge ash rates used and microbial respiration, indicating that the ash did not inhibit microbial respiration to a detrimental level. Additional detailed results are documented in Y. Ren's M.S. thesis.

A new study on response of competing vegetation *(Rubus* spp.) to application of papermill sludge ash and wood ash was initiated at the Heald Pond study site. Brush saws were used for two consecutive years (just before and one year after ash treatment) to mechanically control competing vegetation in the study plots. *Rubus* spp. now accounts for approximately 95% of the competing vegetation in the red pine plantation, and had formed a dense, uniform canopy in all plots by mid-summer 1994.

Above-ground biomass was sampled by graduate student C. Malitz in each of the 48 original plots and in 6 additional plots where neither the brush saw treatments nor the ash treatments were applied (Figure 4). This information, along with data obtained from elemental analysis of *Rubus* foliage, will be analyzed over the next few months.

Paper Birch Thinning Study-Ten-Year Results

In 1984, a study was conducted to determine effects of thinning using whole-tree harvesting methods in a 45-year-old stand of paper birch. The site is located in Grafton Township on lands owned by Boise-Cascade Corporation. The primary objective was to quantify how variations in skid trail planning and layout would influence damage to residual crop trees. Details of the study design and the early results have been reported (Ostrofsky, Seymour, and Lemin 1986). The stand was thinned from below using the following systems: mechanical harvest with two-chain trail spacing, mechanical harvest with one-chain trail spacing, mechanical harvest with trails determined by operators (no prior layout), manual harvest with winch pre-bunching, manual felling with no removal of cut trees (thin in place), and an unthinned control area. The mechanical harvesting was done using drive-to-tree feller bunchers and grapple skidders.

After the harvest, there was a total of 640 crop trees left in all the plots; 410 (64%) were paper birch, and 133 (21%) were yellow birch. All crop trees in all plots have been measured for diameter growth and vigor (using the Shigometer), and mortality has been recorded annually. In 1994, a more intensive effort was conducted to document stand changes after 10 years. There are now 299 paper

Figure 4. Appearance of a fixed 0.25 milacre plot after above-ground biomass (primarily *Rubus* spp.) was collected, Caratunk Township, Maine.

birch and 119 yellow birch remaining, over all study plots. This represents an overall mortality of 27.1% for paper birch, and 10.5% for yellow birch over the past ten years. Due to the relatively abundant advance softwood regeneration developing, and considering the general health condition of the stand, an overstory removal is now being planned.

Current Stand Conditions

The original harvest was planned to leave a crop tree basal area of approximately 40 square feet, based on currently accepted silvicultural guidelines (Safford 1983). Most treatments resulted in slightly less basal area remaining after harvest (Table 2). Ten years following the thinning, crop tree basal area has stayed the same or declined in the one-chain, two-chain, and the operator judgement treatments due to the high mortality the stand has experienced (Table 3). Yellow birch had a generally lower mortality rate than did paper birch. The thinned stands responded positively where manual felling was conducted. The treatment where trees were thinned with no felled trees extracted (thin in place) now carry the highest basal area in crop trees. Ten-year crop tree mortality in this treatment is the same as that in the unthinned stand.

This result strongly supports the hypothesis that stand damage, and not simply the opening effect of thinning, is the major factor influencing the mortality rate. Additional evidence for this comes from the analysis of the wounding-mortality relationship (Table 4). With nearly equal populations of

Table 2. Post-harvest crop tree basal area (ftVacre) for all species, Grafton Township, Maine.

TREATMENT	BA/A 1984	BA/A 1994
1-chain trail	35	30
2-chain trail	32	33
Winch	44	50
Operator judge.	31	26
Thin in place	43	63
Unthinned	31	43

Table 3. Ten-year mortality of crop trees following a low thinning in a 45-year-old paper birch stand, Grafton Township, Maine.

Treatment	All Crop Trees Mortality (%)	Paper Birch Mortality (%)	Yellow Birch Mortality (%)
1-chain trails	54.8	45.9	0.0
2-chain trails	21.7	30.1	11.1
Winch prebunch.	17.8	16.9	33.0
Operator judge.	44.5	34.9	11.3
Thin in place	5.7	6.9	3.2
Unthinned	5.6	8.2	4.3

Table 4. Relationship between wounding and mortality of paper birch ten years following a low thinning, Grafton Township, Maine.

	Unwounded	Wounded	Total
Alive	!115 (98.2)	86 (102.7) "1	201
Dead	i 36 (52.7)	72 (55.2)	108
Total	•••••J5J–	158	309

[actual number of trees (expected)]
Chi square = 16.08, P<0.005

wounded and unwounded paper birch trees, twice as many wounded trees died as did unwounded trees. Yellow birch showed the same trends, though fewer trees were available for comparison analysis.

Growth of the surviving crop trees was calculated for the ten-year period since thinning (Table 5 and Table 6). The thinning treatment itself had little impact on growth, a disappointing result suggesting that the stand was, at 45 years old, too old to respond. Yellow birch crop trees grew approximately twice as fast as did the paper birch. Favoring yellow birch in thinnings of this type would clearly provide both a survival and growth increment advantage.

Supplementary Studies

Over the past decade, additional studies have been conducted on this site. One study has tracked crop tree vigor on an annual basis using the Shigometer. A profile of stand vigor is shown in Figure 5. Extensive analysis of this data has not

Table 5. Growth of surviving paper birch ten years following a low thinning, Grafton Township, Maine.

Treatment	Number	DBH 1984	DBH 1994	BA/A (% increase)
1-chain	14	6.5	7.3	26.2
2-chain	47	6.9	7.7	24.5
Winch	74	6.0	7.0	36.2
Operator judgement	66	6.4	7.3	30.1
Unthinned	44	5.9	6.6	25.1

Table 6. Growth of surviving yellow birch ten years following a low thinning, Grafton Township, Maine.

Treatment	Number	DBH 1984	DBH 1994	BA/A (% increase)
1-chain	6	5.3	6.5	50.4
2-chain	34	7.2	8.6	42.7
Winch	4	6.2	8.2	74.9
Operator judgement	30	6.5	7.8	47.7
Unthinned	15	4.8	5.7	41.0

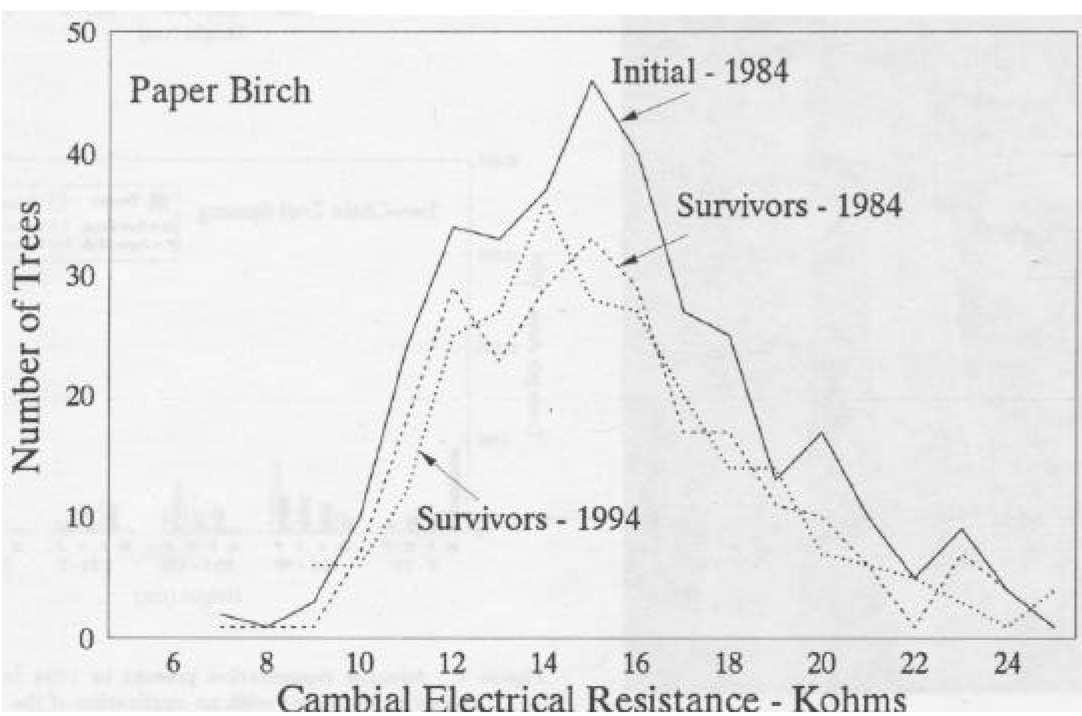


Figure 5. A cambial electrical resistance (CER) profile of paper birch crop trees at the Grafton Township study site. CER values increase as tree vigor decreases.

yet been started, but some preliminary information is available. Vigor of all crop trees ("initial" line) is plotted with vigor of trees in 1984 that survived through 1994 ("survivor" lines). Both survivor lines track closely, indicating that surviving trees have not changed substantially in vigor over the ten-year period. The difference between the initial vigor line and the surviving lines represents tree mortality. Most mortality has occurred in trees with an initial cambial electrical resistance (CER) of 15 kohms or greater. This is as expected, since the higher the CER, the less vigorous the tree is judged to be. However, mortality has also occurred in some trees of low initial CER. Subsequent analysis will be done to determine what factors (severity of wounds, proximity to trails, etc.) may be identified to help explain the mortality of these trees (Figure 6).

Figure 6. Examination of internal defects in paper birch associated with logging injuries inflicted ten years ago.

A demonstration study was also conducted on the site to examine effects of understory herbicide treatment on conifer regeneration developing after the thinning. A total of four permanent plots, each 1 chain by 2 chains in size, were divided in half. One half was then treated with an operationally recommended rate of glyphosate, and the other half left untreated. Two plots were located in the two-chain trail spacing treatment, and two were in the operator judgement treatment. The herbicide was applied with back pack mist blower in late summer of 1986, two years after stand thinning had been completed. Significant differences are now apparent in conifer and hardwood regeneration characteristics between plot locations and herbicide treatment (Figure 7, 8). Although not intended as a definitive study, the demonstration has documented on this site the potential value such treatments could have for manipulating understory species composition in similar stands.

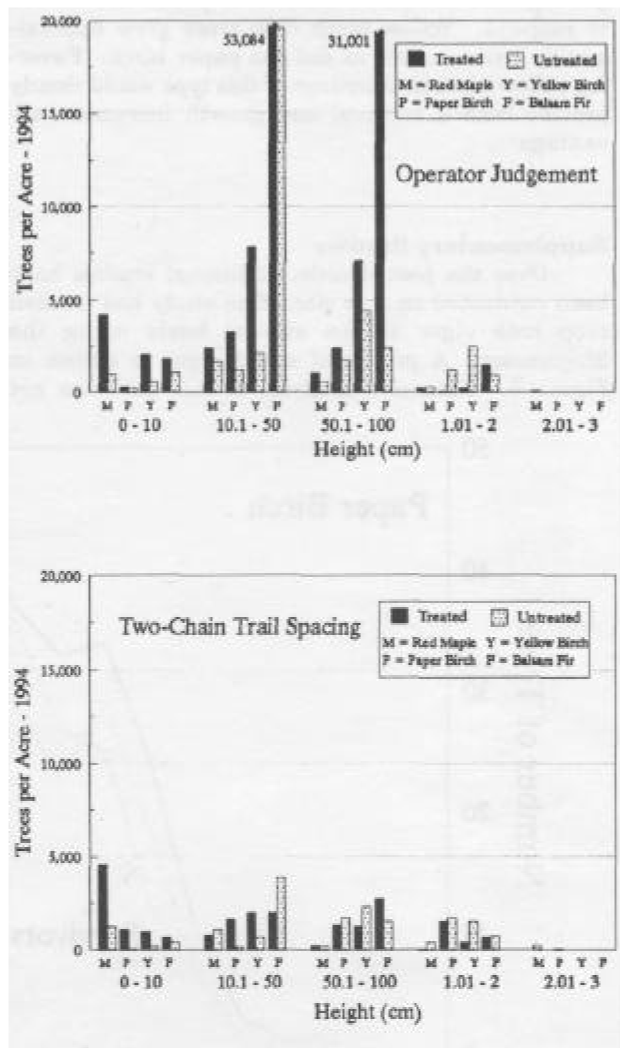


Figure 7. Advance regeneration present in 1994 in plots treated or untreated with an application of the herbicide glyphosate in 1986. The herbicide was applied two years after a low thinning in a paper birch stand, Grafton Township, Maine.

Figure 8. Appearance of a plot treated (right) and untreated (left) with a single application of glyphosate six years earlier. Essentially aD stems developed from seed or sprouts since the stand thinning was completed in 1984.

Literature Cited

Ostrofsky, W.D., R.S. Seymour, and R.C. Lemin, Jr. 1986. Damage to northern hardwoods from thinning using whole-tree harvesting technology. Can. J. For. Res. 16:1238-1244.

Safford, L.O. 1983. Silvicultural guide for paper birch in the Northeast (revised). USDA Forest Service Research Paper NE-535. 29 p.

SITE QUALITY

Dr. Russell D. Briggs

Overview

The coming year the site quality program is at a crossroad, poised for an opportunity to evaluate past successes and contemplate future research direction. I have accepted a position as Associate Professor of Forest Soils at SUNY College of Environmental Science and Forestry in Syracuse, NY. I am grateful to all of our cooperators for their strong support both in the field and within their organizations during budget discussions over the past seven years. I intend to maintain some scientific involvement with CFRU projects that I have had the privilege of working on. I am certain that the site quality program will continue to advance the operational application of soils information to forest management.

The site quality program continues to be a productive component of CFRU; publication of the site classification field guide this past June (Briggs 1994) was an important benchmark. The 15-page pocket-size guide is the culmination of a research effort that actually began in the mid-1950s when two scientists (Drs. M. McClintock and H. Young) with far-reaching vision began to explore the relationship between red spruce growth and soil-site characteristics. Scientific understanding of that relationship progressed steadily over the years as researchers at the University of Maine and at the U.S. Forest Service continued to pursue the topic. The resulting data base, as well as recent research in managed stands, formed the basis for the field guide. If you do not yet have a copy, it is available upon request from CFRU, where your research dollars continue to provide an excellent return on investment.

The intensive effort directed towards understanding the relationship between conifer growth and soil-site characteristics draws to a close with completion of Joseph Pitcheralle's M.S. thesis "Relationship Between Balsam Fir Growth Response to Precommercial Thinning and Soil Chemical Properties". Program emphasis has shifted towards the more complex hardwood systems. The shift began two years ago with examination of the utility of Leak's habitat types for predicting species composition on the mountain slopes of western Maine. Jeff Dubis' successful defense of his M.S. thesis "Relationship of Species Composition to Habitat Types on Mountain Slopes in Western Maine" provided the background information to begin evaluating productivity. Mark Leathers, M.S. candidate, spent the 1994 field season in western Maine collecting data to evaluate productivity of sugar maple within and between four different habitat types: wet compact till, dry compact till, shallow to bedrock, and enriched. Mark was assisted by Shane Duigan,'undergraduate forestry student, and Linda Snow, undergraduate education student supported by a Department of Energy grant.

Work on the project to assess the feasibility of developing landscape-specific models to identify soil drainage class (an important variable strongly influencing site quality) by application of a variety of landform analysis algorithms to digital elevation models, was suspended during the past year. Brad Catling (M.F. candidate) spent the past two semesters taking courses towards his teaching certificate and plans to continue with the project in November 1994.

A one-year no-cost extension (to 1 May 1995) was obtained for the Weymouth Point Watershed project grant, examining the relationship between surface water chemistry, precommercial thinning (PCT), and crop tree growth. The extension allowed us to continue monitoring stream water and soil solution chemistry during 1994 as well as aboveground litter production. Continued periodic monitoring of crop tree growth response and water chemistry is anticipated to advance our understanding of the long-term impacts of forest management on nutrient cycling dynamics in a spruce-fir forest ecosystem. I cannot overemphasize the fact that the scientific value of this paired watershed research project increases each year with continuation of the stream and soil solution chemistry record. Ronald C. Lemin, Jr., CFRU Assistant Scientist, and Rick Dionne, CFRU Research Associate with the Silviculture Program, continue to carry out the field work.

Dr. M.L. McCormack, Jr., responsible for the original harvest impacts study design, installation, and execution, continues to oversee activities at Weymouth Point by assuming primary responsibility for maintenance of the watershed boundary, survey grid, and the Telos trailer which provides field crew support.

Site Quality and Productivity

Spruce and Fir

Although field work has shifted into the hardwood systems, analysis of data collected in conifer forest systems continues to yield information. Dr. Jim Steinman's exhaustive analysis of the spruce and fir height development patterns in even-aged, unmanaged spruce-fir stands (collected by graduate students under the direction of Dr. Ralph Griffin), has generated a new set of site index curves, recently submitted for review to the Canadian Journal of Forest Research (Steinman et al. *in review)*. The entire data base was carefully screened to remove effects of early suppression on growth and development. Consequently, these curves (Figures 9 and 10) represent an improvement over those published earlier by Vicary et al. (1984).

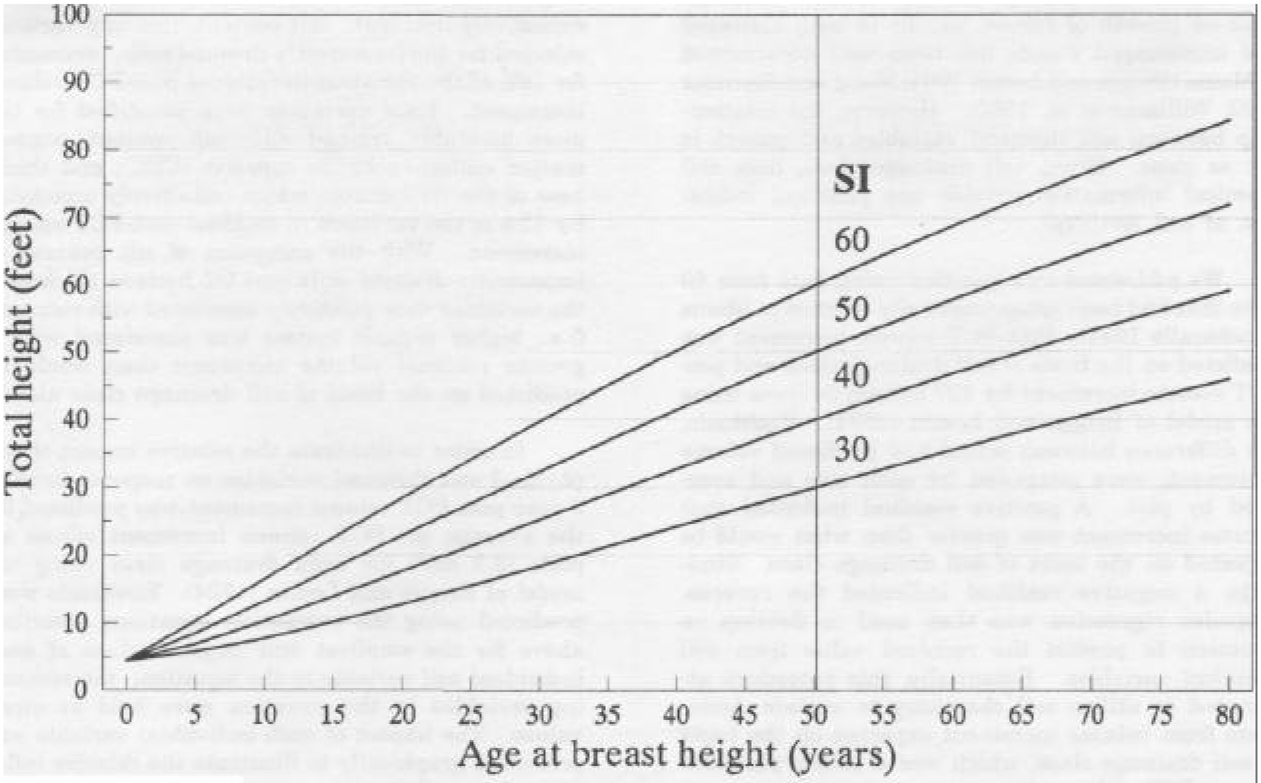


Figure 9. Site index curves for red spruce based on 146 trees from 73 plots established in fully stocked, even-aged, unmanaged spruce-fir stands (Steinman et al. *In review).*

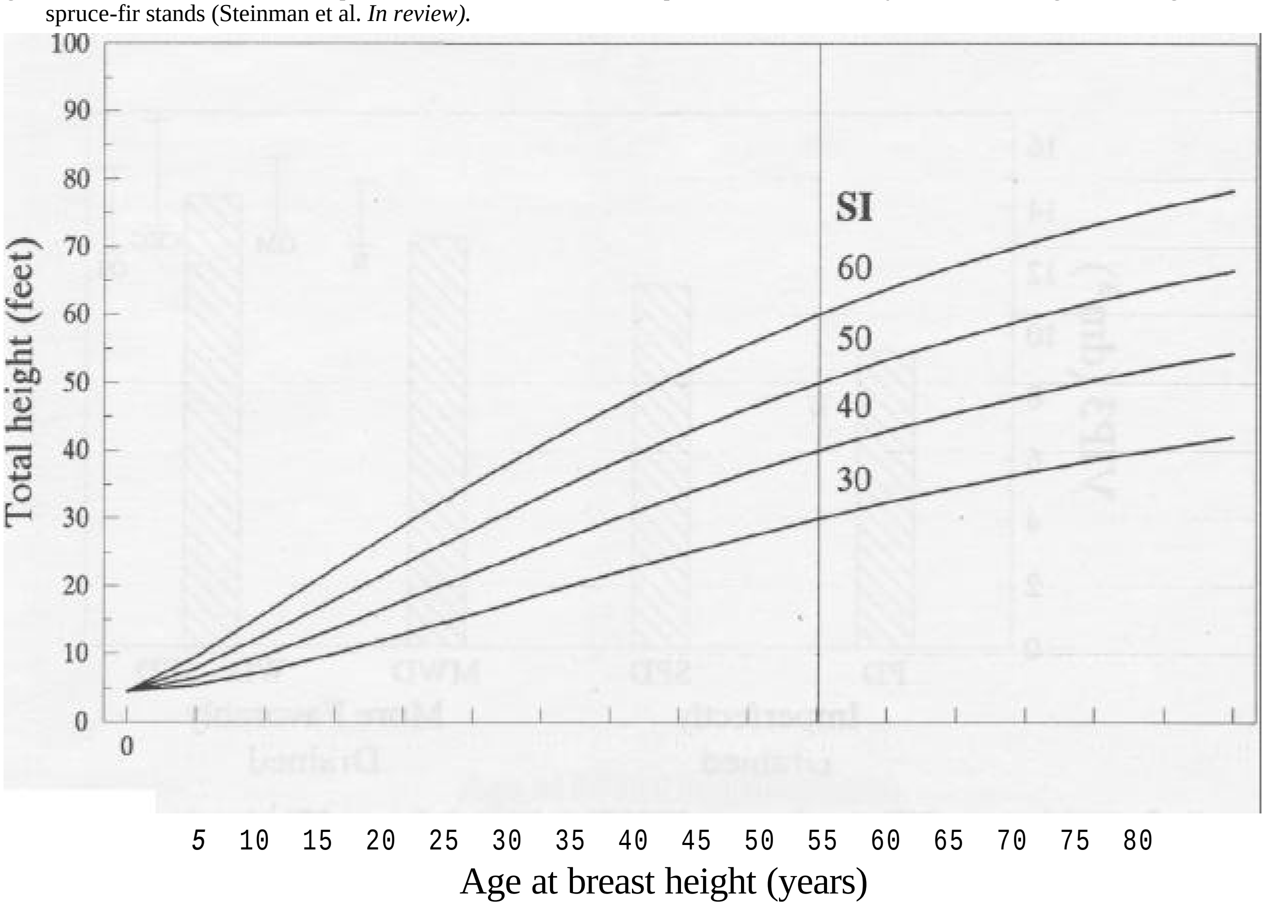


Figure 10. Site index curves for balsam fir based on 98 trees from 49 plots established in fully stocked, even-aged, unmanaged spruce-fir stands (Steinman et al. *In review}.*

The overwhelming influence of soil drainage class on growth of spruce and fir in both managed and unmanaged stands has been well documented in Maine (Briggs and Lemin 1994; Meng and Seymour 1992; Williams et al. 1990). However, the relationship between soil chemical variables and growth is not as clear. Given soil drainage class, does soil chemical information provide any practical indication of soil fertility?

We addressed this question using data from 60 plots that had been precommercially thinned in Maine (Pitcheralle 1994). Post-PCT volume increment was predicted on the basis of soil drainage class and pre-PCT volume increment for 427 balsam fir trees using the model of Briggs and Lemin (1994). Residuals, the difference between actual and predicted volume increment, were computed for each tree and averaged by plot. A positive residual indicated that volume increment was greater than what would be expected on the basis of soil drainage class. Similarly, a negative residual indicated the reverse. Stepwise regression was then used to develop an equation to predict the residual value from soil chemical variables. Essentially, this procedure attempted to utilize soil chemistry to explain deviations from volume increment expected on the basis of soil drainage class, which was a strong predictor of post-PCT volume increment.

The best results were obtained using B horizon soil data stratified into drainage groups (imperfectly = poorly and somewhat poorly drained; more favorably drained = moderately well, well, and somewhat excessively drained). Silt content, the only variable selected for the imperfectly drained soils, accounted for 19% of the variation in residual post-PCT volume increment. Four variables were identified for the more favorably drained soils: silt content, organic matter, cation exchange capacity (CEC), and thickness of the O2 horizon, which collectively accounted for 42% of the variation in residual post-PCT volume increment. With the exception of silt content of imperfectly drained soils and O2 horizon thickness, the variables were positively associated with response (i.e., higher organic matter was associated with a greater residual volume increment than would be predicted on the basis of soil drainage class alone).

In order to illustrate the relative impact of soil physical and chemical variables on response to PCT, 3-year post-PCT volume increment was predicted for the average pre-PCT volume increment across all plots (3.8 dm^3) for each drainage class using the model of Briggs and Lemin (1994). Residuals were predicted using the regression equations described above for the smallest and largest values of each individual soil variable in the equation; the remaining variables in the equation were held at mean values. The impact of each individual variable was presented graphically to illustrate the relative influence that soil texture, organic matter, CEC, and thickness of the O2 horizon exert individually within a soil drainage group (Figure 11).

Given favorable soil drainage, higher levels of

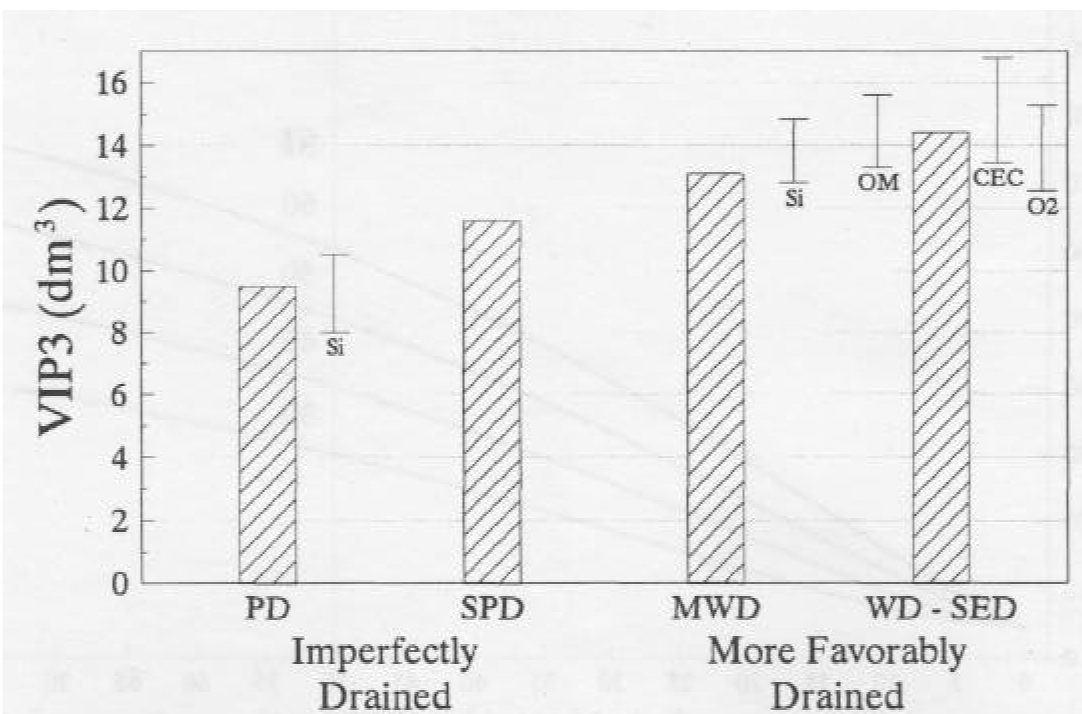


Figure 11. Predicted 3-year post-PCT volume increment (VI3POST) for balsam fir for a pre-PCT volume increment of 3.8 dm^3 for each of four soil drainage classes. Bars identifed with soil variables show the range in VI3POST that can be attributed to those soil variables.

organic matter, CEC, and finer textures are associated with greater growth response of balsam fir. However, the added expense and effort associated with measurement of soil chemical variables may preclude practical application of this relationship on a wide-ranging basis. Nevertheless, it is clear that the factors associated with increased soil fertility do have a positive influence on tree growth.

Hardwoods

Species Composition

Analysis of vegetation and soil data collected from 134 sample plots distributed across mountain slopes in western Maine shows that the habitat classification system developed for the White Mountain National Forest in New Hampshire (Leak 1982) was sufficiently broad to describe the site conditions encountered in western Maine. However, species composition for a given habitat type (HT) in western Maine differed from that of the corresponding HT in New Hampshire; many of the HTs in Maine had *a* greater proportion of sugar maple and a lower proportion of red maple. Species composition as well as physical descriptions for each of the 10 HTs, too lengthy to list here, are provided by Dubis (1994).

The dry compact till HT, characterized by moderately and well drained soils underlain by dense basal till within two feet of the soil surface, was among the most common HTs encountered. Sugar maple constituted approximately 40% of the basal area, with American beech and yellow birch accounting for an additional 33% (Figure 12). The wet compact till HT, characterized by somewhat poorly and poorly drained soils underlain by dense basal till was dominated by yellow birch (36% of the basal area), followed by sugar maple (23% of the basal area) (Figure 13). Conifers dominated on the coarse textured outwash and sandy sediment HTs (Figure 14).

One of the most interesting outcomes of this effort has been the realization that habitat type is a more useful indicator of species composition than is soil drainage class alone in these hardwood forest systems. An excellent example is provided by the enriched HT, located at landscape positions where slope gradient changes from steep to gentle in a short distance. This HT is characterized by substantial moisture (ranging from somewhat poorly to moderately well drained) and nutrient inputs. Soil material is often colluvial and seeps are common. However, the water is continually in motion and aerated. Sugar maple dominates the enriched HT, constituting greater than 70% of the basal area (Figure 15).

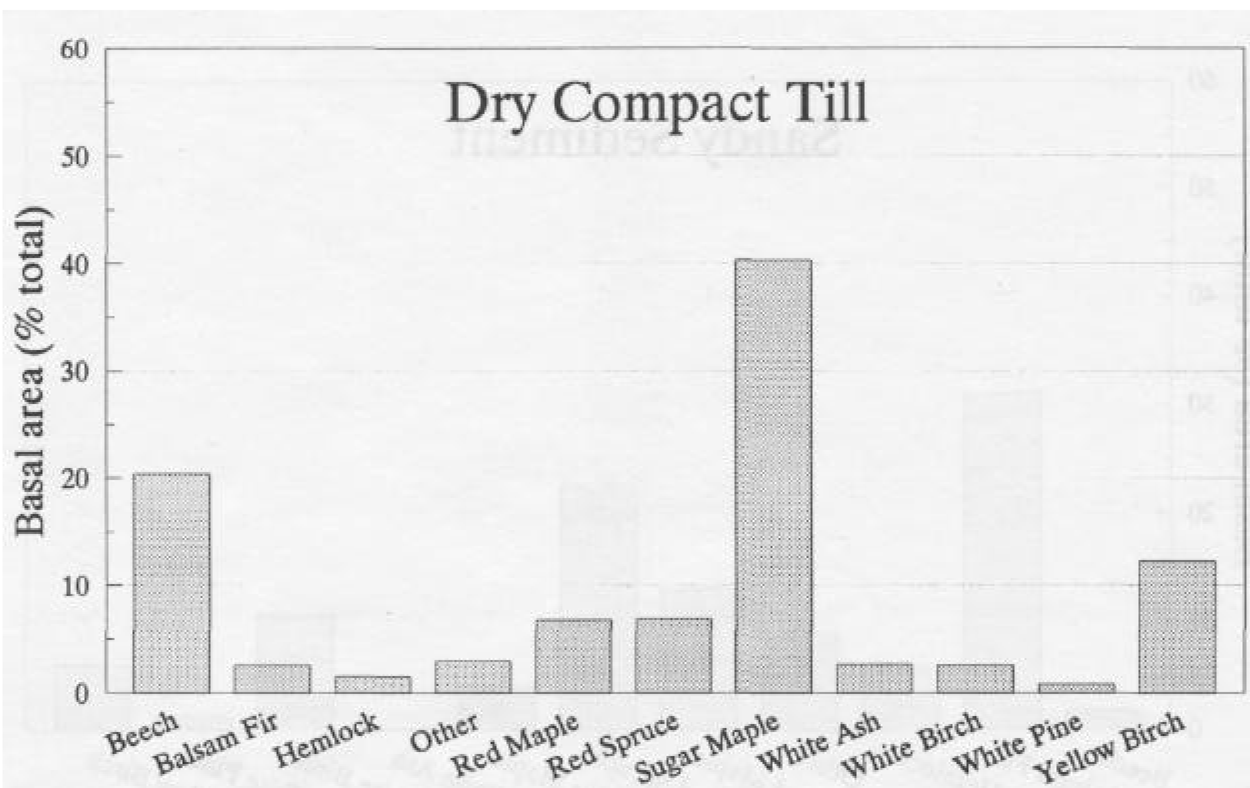


Figure 12. Distribution of basal area by species for the 33 plots located on the dry compact till habitat type in western Maine.

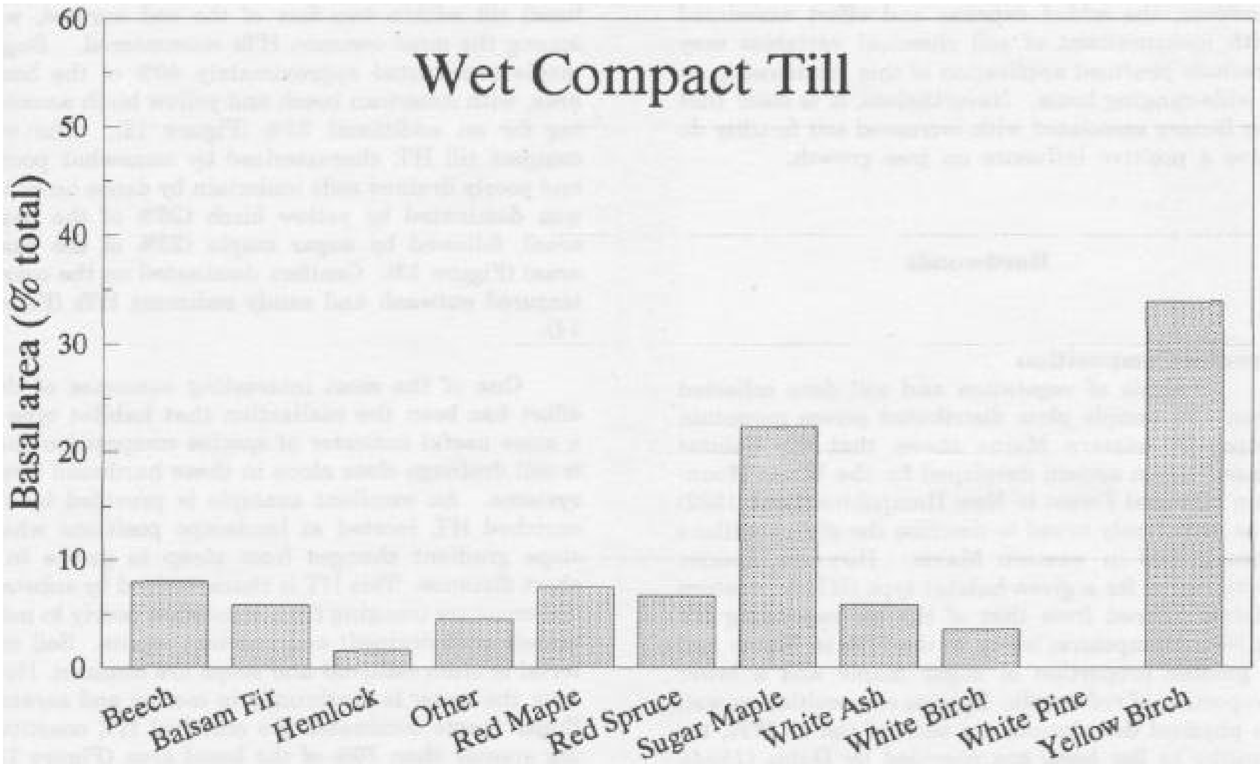


Figure 13. Distribution of basal area by species for the 13 plots located on the wet compact till habitat type in western Maine.

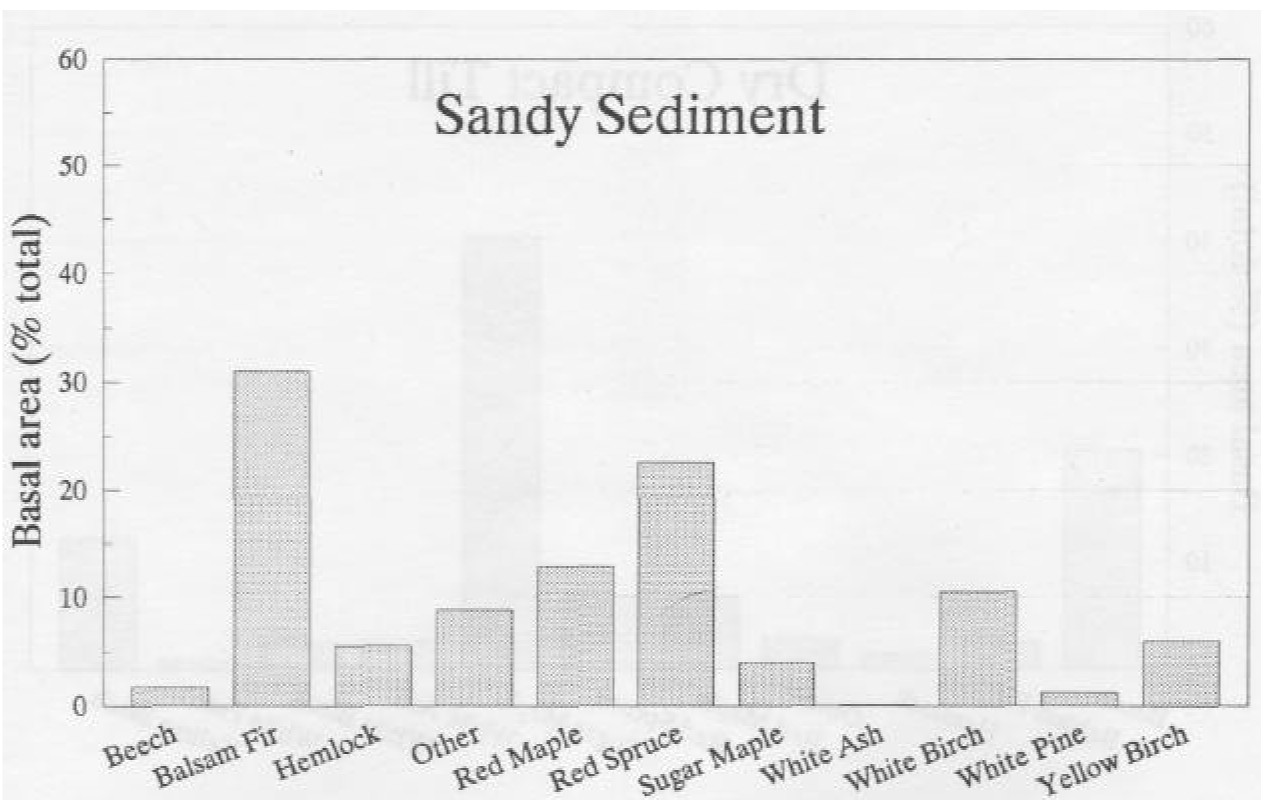


Figure 14. Distribution of basal area by species for the 7 plots located on the sandy sediment habitat type in western Maine.

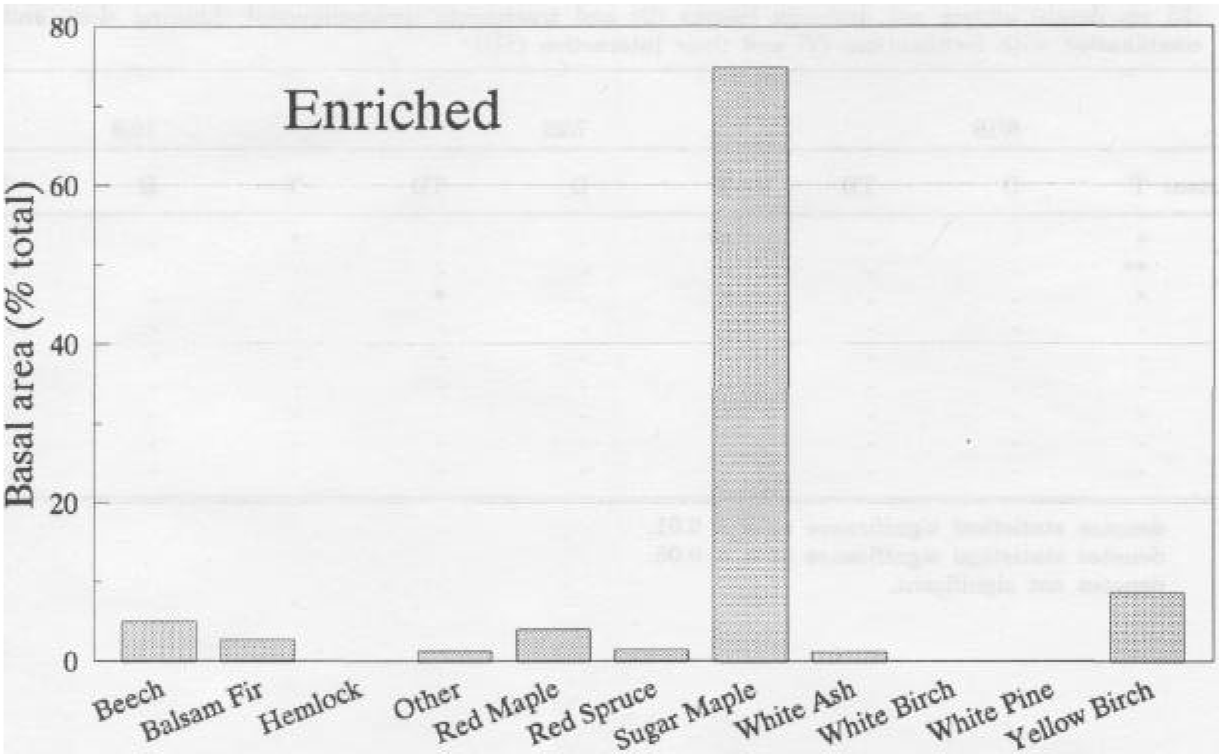


Figure 15. Distribution of basal area by species for the 7 plots located on the enriched habitat type in western Maine.

The next task is to address differences in productivity within and among HTs; variability in species composition contributes to the complexity of this endeavor. Analysis of the data collected during the 1994 field season by Mark Leathers, evaluating productivity of sugar maple among four HTs, is just beginning. This may prove to be one of the most exciting (if not challenging) areas of this investigation to date.

Precommercial Thinning and Soil Solution Chemistry

Recall that the study consists of three treatments (control, PCT alone, and PCT in combination with fertilization=+FERT) replicated 3, 4, and 2 times, respectively, on poorly drained (PD), somewhat poorly drained (SPD), and moderately well drained (MWD) soils. The PCT treatments were applied in October 1991. Fertilization treatments (ammonium nitrate in split applications at 100 kg N/ha each) were applied on 19 May and 7 July 1993. Analysis of covariance was used to test null hypotheses of equal mean dbh and height growth (initial pretreatment measures as covariates) among soil drainage classes and treatments (PCT alone and in combination with fertilization). Analysis of variance was used to test null hypotheses of equal mean nutrient concentrations among soil drainage classes and treatments. *A priori* linear contrasts were used to evaluate drainage class (PD vs. SPD; SPD vs. MWD) and treatment (CON vs. PCT; CON vs. +FERT) effects.

Last year we reported that precommercial thinning had no effect on soil solution nutrient concentrations in the rooting zone (25 cm below soil surface) during the first growing season following treatment. Nitrate and ammonium were not even detected in the soil solution samples; those trends continue. This year we focus on crop tree growth response as well as 1994 soil solution chemistry data.

Three-year height and dbh increment of spruce and fir crop trees, adjusted for pretreatment height and dbh covariates, respectively, showed a statistically significant increase in response to PCT. Fertilization in addition to PCT had no statistically significant effect beyond that of PCT alone. Three-year height and dbh increment of treated plots averaged 0.87 in. and 2.9 ft, respectively, in comparison to 0.65 in. and 2.6 ft for untreated controls.

Soil solution data from the three sampling periods in 1994, the second year following fertilization, show that nitrate, ammonia, and K levels are still influenced by fertilization (Table 7), at 25 cm below the soil surface. Although average nitrate levels on fertilized plots in 1994 decreased substantially relative to those in 1993 (growing season immediately following fertilization), they are still significantly higher on fertilized plots relative to untreated controls (Table 8). Nitrate concentrations at the bottom of the root zone (50 cm) on fertilized plots did not differ statistically from control plots after June 1994, suggesting minimal losses due to leaching. A portion of the added N continues to cycle within the tree-soil system.

Table 7. Summary of significant tests from ANOVA testing null hypothesis of equal mean nutrient concentrations (25 cm depth) among soil drainage classes (D) and treatments (precommercial thinning alone and in combination with fertilization) (T) and their interaction (TD).[a]

	6/16			7/20			10/8		
Nutrient	T	D	TD	T	D	TD	T	D	TD
NO_3				**		.		*	
NH_4	**		.						
K	*			*	.	*	.	.	.
Ca			.						
Mg			.						
Mn			.						
Fe			.						
Al			.						
Na			-						

denotes statistical significance at a = 0.01.
denotes statistical significance at a = 0.05.
denotes not significant.

Table 8. Soil solution nitrate concentrations (ppm) obtained from shallow and deep lysimeters during the 1993-1994 sampling period.

	1993					1994		
Trt-	Jun 4	Jul 7	Aug 18	Sep 16	Oct 9	Jun 6	Jul 20	Aug 16
				25 cm Lysimeter				
CON	0.00	0.05	0.26	0.01	0.00	0.10	0.0.0	0.01
PCT	0.24	.12	.08	.00	.00	.10	.03	.02
+FRT	12.13	.36	16.86	5.12	.11	.60	2.01	2.03
Contrasts'''								
C vs P	ns	ns	ns	ns	ns	ns	ns	ns
C vs F	**	*	•*	*	ns	*	**	•
				50 cm Lysimeter				
CON	0.04	0.03	0.00	0.00	0.00	0.09	0.00	0.05
PCT	.37	.05	.46	.00	.33	.09	.17	.04
+FRT	6.84	.25	6.41	.30	2.61	.26	1.53	1.69
Contrasts[6]								
C vs P	ns	ns	ns	ns	ns	ns	ns	ns
C vs F	**	•	•	ns	ns	ns	•	ns

"Treatments were CON=control, PCT= precommercial thinning, +FRT= PCT + fertilization with 200kg N/ha.

'Statistical significance of linear contrasts testing the null hypotheses that mean nitrate concentration for PCT - CON = 0 or +FERT - CON = 0. * and ** indicate rejection of hypothesis at a = 0.05 and a = 0.01, respectively; ns denotes not significant.

Verification of Climatic Zones

As part of a joint venture with Dr. Ivan Fernandez to evaluate the relationship between rates of nutrient cycling and climatic variables, four transects (Figure 16) were established across the climatic gradient identified by Briggs and Lemin (1992). Recall that stand criteria for plot location included (i) closed canopy hardwoods having a red maple component and (ii) well and moderately well drained glacial till soils. Air and soil temperature has been monitored (below the overstory canopy) using continuously recording data loggers. In order to illustrate differences in energy input among these eight locations, heat accumulation above a 5°C threshold was computed for each month (except for winter) and graphed by location (Figures 17-19).

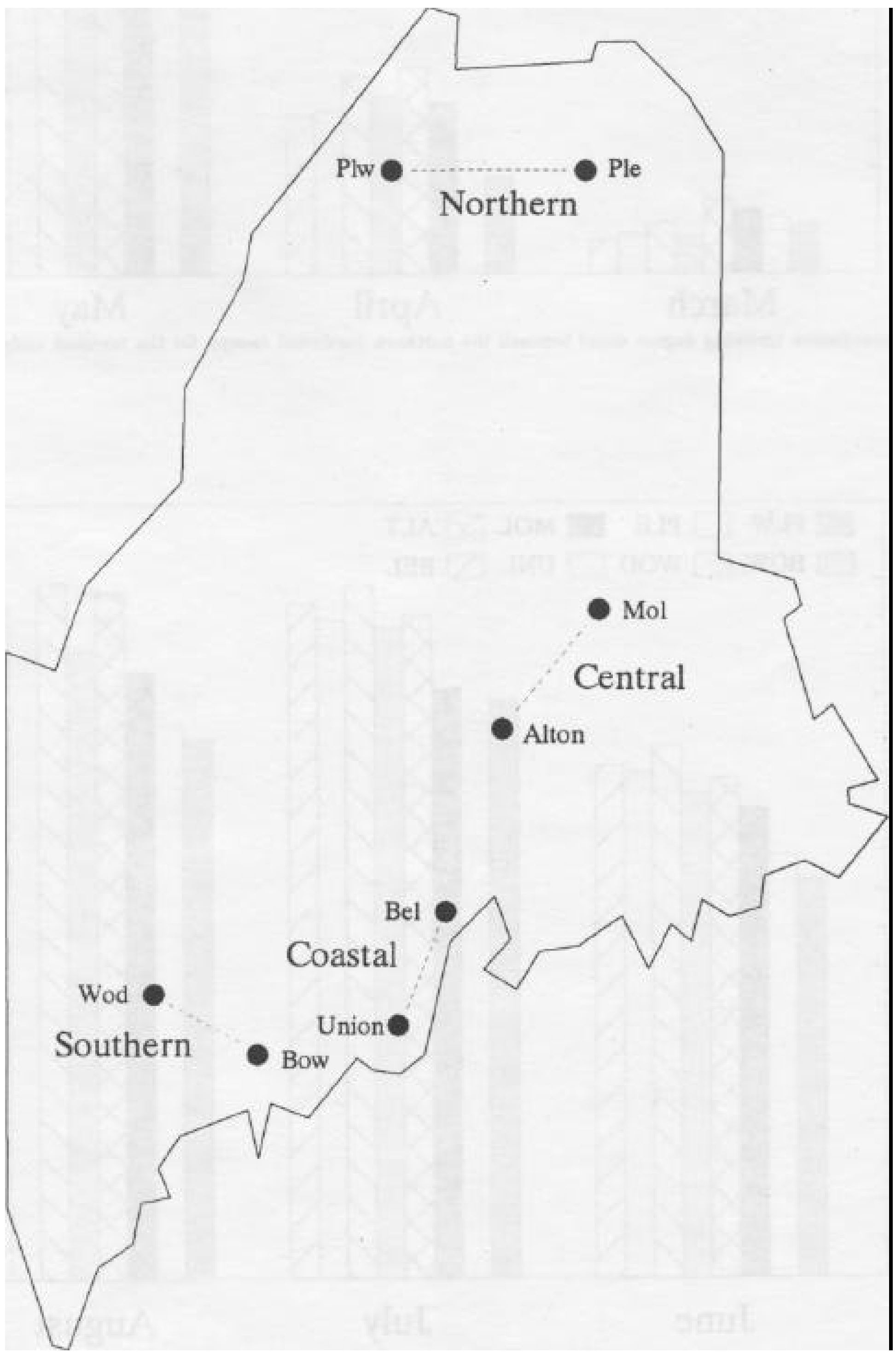


Figure 16. Location of the four transects for collection of meteorologic data.

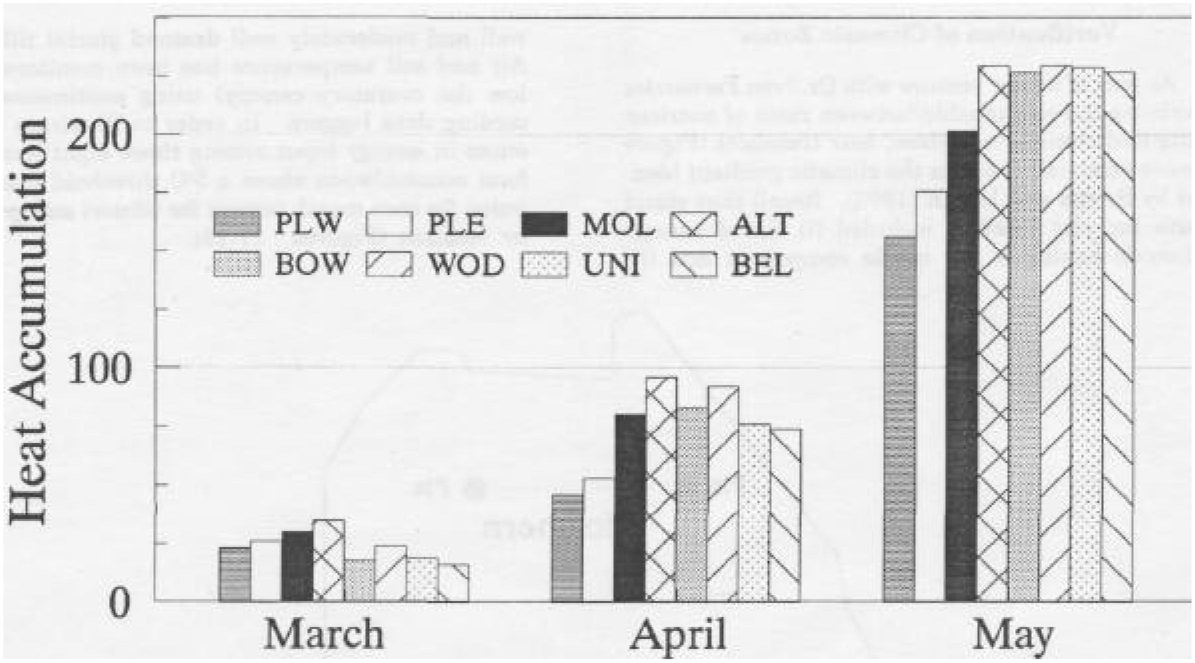


Figure 17. Heat accumulation (growing degree days) beneath the northern hardwood canopy for the transect endpoints during the spring.

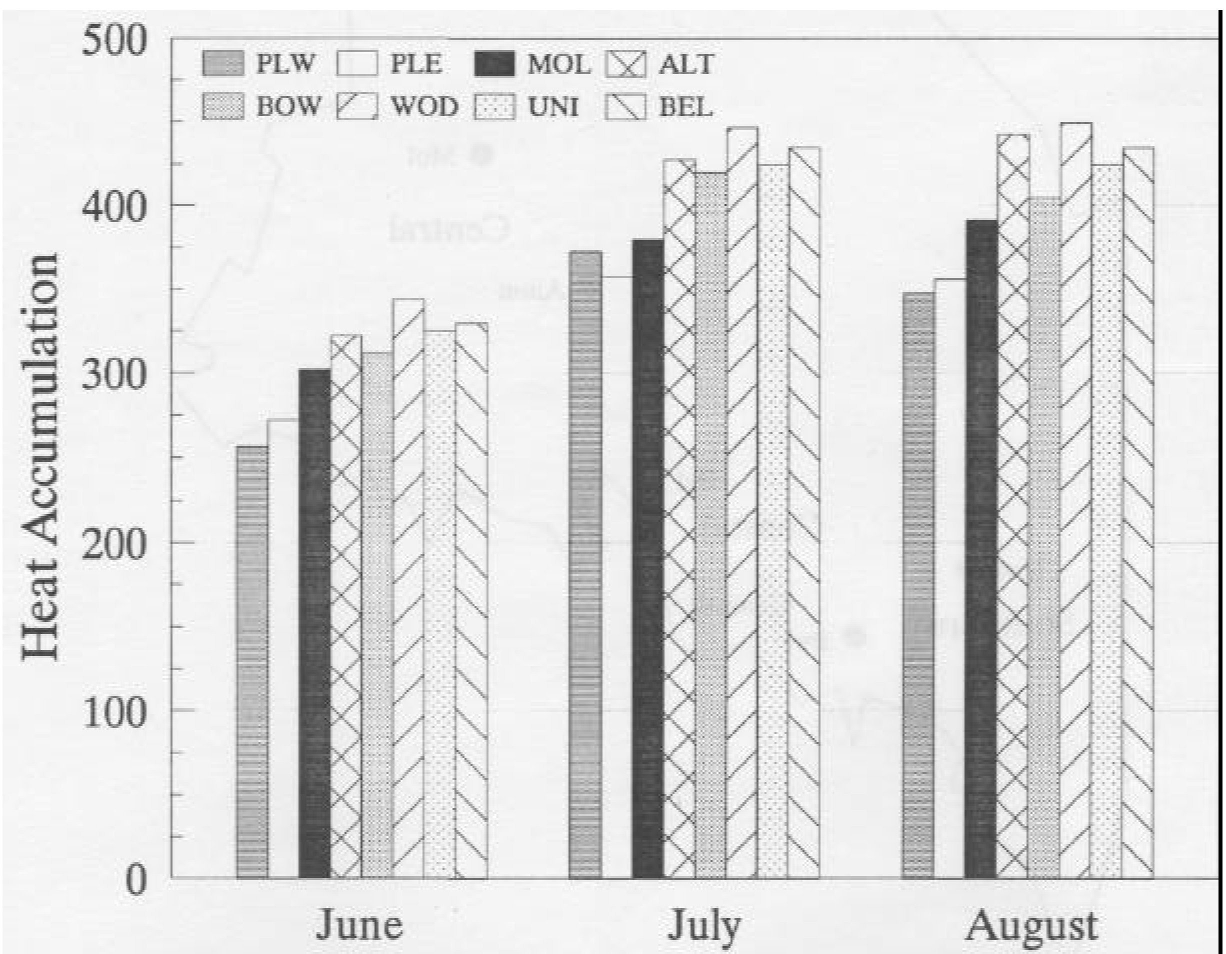


Figure 18. Heat accumulation (growing degree days) beneath the northern hardwood canopy for the transect endpoints during the summer.

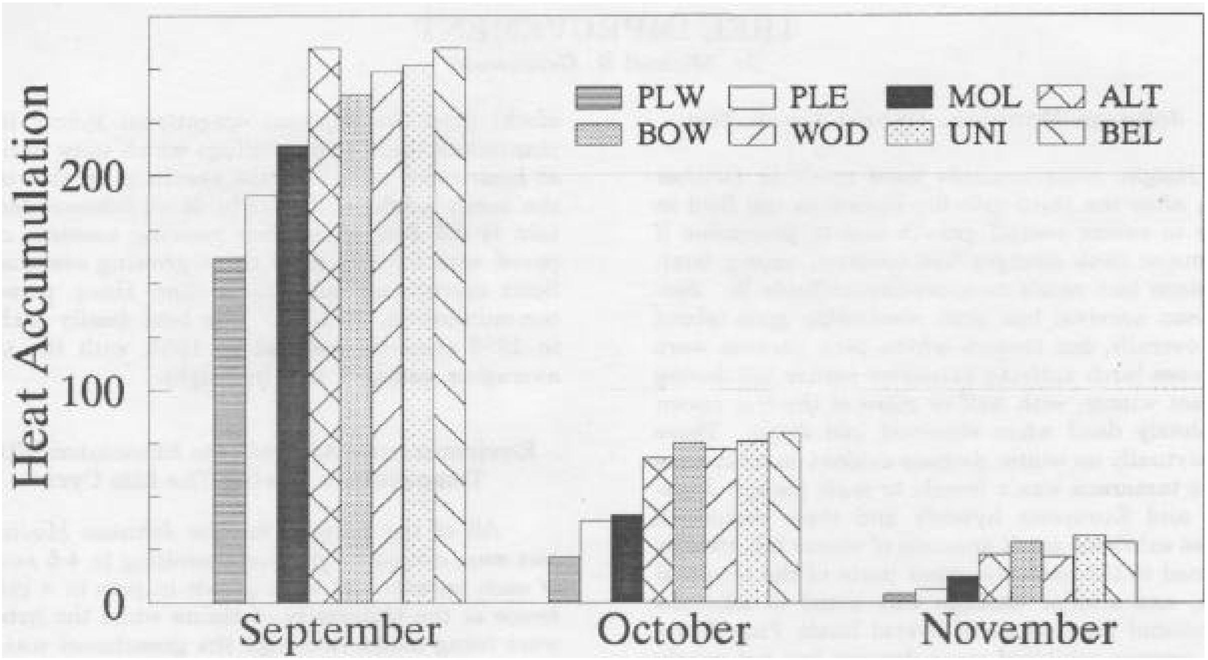


Figure 19. Heat accumulation (growing degree days) beneath the northern hardwood canopy for the transect endpoints during the fall.

The pattern of increasing energy inputs below the overstory canopy from the northwest (PLW = Portage Lake West) to the south central (ALT = Alton) sites was consistent among seasons. Energy input then drops slightly proceeding from ALT to Bowdoin (BOW), then increases slightly at the Woodstock (WOD) site. Although the latter increase is opposite of expectations on the basis of latitude and longitude, aspect may play an important role. The WOD site is located on a southwest aspect whereas the BOW site is situated on a northerly aspect. Unfortunately, the availability of candidate sites that met the majority of selection criteria (upland, well drained soils with a closed canopy northern hardwood stand; research access and no disturbance for four years) constrained site selection and limited our capacity to match slope and aspect.

Literature Cited

Briggs, R.D. 1994. Site classification field guide. Maine Agric. and For. Expt. Sta., Misc. Pub. 724.

Briggs, R.D., and R.C. Lemin, Jr. 1992. Delineation of climatic zones in Maine. Can. J. For. Res. 22(6):801-811.

Briggs, R.D., and R.C. Lemin, Jr. 1994. Soil drainage class effects on early response of balsam fir *(Abies balsamea* (L.) Mill.) to precommercial thinning. Soil Sci. Soc. of Am. J. 58(4):1231-1239.

Dubis, J.J. 1994. Relationship of species composition to habitat types on mountain slopes in the western Maine biophysical region. M.S. Thesis, Univ. of Maine. *In preparation.*

Leak, W.B. 1982. Habitat mapping and interpretation in New England. USDA NE For. Expt. Sta., Res. Pap. NE-496, 28 p.

Meng, X., and R.S. Seymour. 1992. Influence of soil drainage on early development and biomass production of young, herbicide-released fir-spruce stands in north central Maine. Can. J. For. Res. 22:955-967.

Pitcheralle, J.D. 1994. Effect of soil texture and chemical characteristics on the early growth response of balsam fir to precommercial thinning. M.S. Thesis, Univ. of Maine.

Steinman, J.R., R.S. Seymour, and R.D. Briggs. Predicting height development and site index of red spruce and balsam fir in even-aged stands: A comparison to other studies. *In*

Vicary, B.P., T.B. Brann, and R.H. Griffin. 1984. Base-age invariant polymorphic site index curves for even-aged spruce-fir stands in Maine. Maine Agric. Expt. Sta. Bull. 802.

Williams, R.A., B.F. Hoffman, and R.S. Seymour. 1990. Comparison of site index and biomass production of spruce-fir stands by soil drainage class in Maine. For. Ecol. Manage. 41:279-290.

TREE IMPROVEMENT

Dr. Michael S. Greenwood

Johnson Mountain Hybrid Larch Test

Height measurements were made in October 1994, after the third growing season in :he field in order to assess overall growth and to dewrmine if any major rank changes had occurred among families since last year's measurements (Table 9). Second-year survival has been reasonably good (about 86% overall), but crosses where both i arents were Japanese larch suffered extensive winter kill during the last winter, with half or more of the live crown completely dead when observed last June. There was virtually no winter damage evident on all crosses where tamarack was a female or male parent. Japanese and European hybrids and their reciprocal crosses exhibited small amounts of winter kill, usually confined to the extreme upper parts of the terminal shoot, and similar damage was noted in adjacent operational plantations of hybrid larch. Pure European crosses exhibited some damage but not nearly as severe as that noted on pure Japanese crosses.

The correlation between overall tree height in 1993 and 1994 was r=0.6, and with som<? exceptions family rankings were about the same in both years. Overall height increment in the test was about two feet in 1994 and was diminished somewhat due to moose browse. The height increment of the trees from the five best families ranged from 2 to 3 feet in 1994, compared with 1.5 to 2.4 feet for the five worst families. Although the test was established with much smaller seedlings (6-month-old container stock) than the adjacent operational hybrid larch plantations (bare root seedlings which were initially at least twice as tall as the seedlings in this test), the mean height of JxE hybrids at Johnson Mountain is 5.3 feet after three growing seasons, compared with 5.5 feet after three growing seasons for Scott operational plantations (Carl Haag, personal communication, 11-1-94). The best family (JxE42) in 1993 remains the best in 1994, with the trees averaging nearly 7 feet in height.

Table 9. Performance (height growth) by five best and five worst (in 1993) full-sib hybrid larch crosses at Johnson Mountain in 1993 and 1994, where J = Japanese, E = European and T = Tamarack).

	Ht. (Feet)		Number of Trees	
	1993	1994	1993	
Best		6.7	29	2
	3.7	5.9	29	8
	3.6	5.5	29	28
	3.6	5.5	18	29
	3.4	5.9	28	16
E				
xJ42 TxT				
TxJ20				
TxJ50				
TxE65	3.3			
Worst				
ExE21	2.4	4.2	29	28
ExE13	2.4	4.8	27	25
ExE41	2.4	3.7	29	28
ExE14	2.3	3.7	29	28
JxJ61	2.2	3.7	29	28

Environmental Aftereffects Associated With Temperature During The Life Cycle

All of the parents for the Johnson Mountain test were cloned by grafting (resulting in 4-5 ramets of each parent) and were grown in pots in a greenhouse at the University of Maine while the hybrids were being made. Although the greenhouse was not heated during the winter, the temperature averaged several degrees higher inside the greenhouse than out throughout the year. In November 1991, some ramets of each parent were moved outside adjacent to the greenhouse, while identical ramets of the same parents remained inside. In the springs of 1992 and 1993 a number of identical crosses were made using the same cloned parents both inside and out. The reasons for making identical crosses in different environments are two reports by Johnsen in 1989 (Scand. J. For. Res. 4:317-341) that crossing environment (Central Norway, 64° N lat. vs. Southern Norway, 58° N lat.) affected both the height growth and frost hardiness of the progeny of Norway spruce crosses made on the same maternal genotype in both locations. Surprisingly, progeny from the southern location exhibited significantly more height growth and less frost hardiness than progeny from the north. Similar results have subsequently been obtained for other conifers, and similar responses have been reported for similar experiments in other plants. These observations suggest that crossing environment (during the formation of gametes, fertilization, and subsequent embryo development) may affect progeny performance in a way directed towards adaptation to that environment.

Based on these results we are testing the hypothesis that temperature differences will have similar effects on larch. More specifically, we are testing a hypothesis that this effect will be observed in three different species of larch and that this effect, if present, may differ by species and cross. We have sown (last December) seed made from 12 identical crosses (all made at the same time, differing only in that seed was produced either inside or outside the greenhouse) in a heated greenhouse. The germinated seedlings were subsequently repotted and allowed to continue their growth in the greenhouse

throughout the last summer. The experimental design consisted of four blocks containing four reps each of all 12 crosses represented by adjacent pairs of indoor (I) and outdoor (O) full-siblings. This design is intended to maximize the sensitivity of detection of I vs. O differences in growth, frost hardiness, and other parameters.

The heights (measured after bud set in late September) of the four categories of crosses made in this study are shown in Table 10. The results show that crosses between tamarack parents tended to be taller if made outside, while crosses between Japanese, European, and their hybrid tended to be taller if made inside. ANO'VA. of all crosses revealed that, as expected, cross heights were significantly different ($p<0.0001$). While the effect of I vs. O was not significant ($p<0.381$), the cross by environment interaction was highly significant ($P<0.0001$), suggesting that I vs. O affected height differently for different crosses. ANOVAs were subsequently performed on heights of tamarack crosses only (which tended to be taller when made outside) and on the combination of all Japanese, European, and their hybrid crosses (which tended to be taller when made inside). The effect of I vs. O on height was significant or nearly so for both groups ($p<0.002$ and $p<0.053$, respectively). The results, although based on a small number of crosses, do tend to confirm that crossing environment does affect height growth, but differently by species and cross. The differences in height cannot be accounted for by differences in germination vigor between seeds produced inside and out.

In cooperation with Bill Livingston, the frost tolerance of foliage from all the trees in the study were measured in late August, but no differences were detected among crosses or environment. Since the shoots were still actively growing at that time, these measurement were made before the onset of dormancy. Further measurements will be made on dormant buds in December.

In order to characterize the genetic basis for the differences in phenotype due to crossing environment, Keith Hutchison's group (supported by a grant from the Northern Global Change Program) has examined the distribution of an allele of the cab (chlorophyll ab binding protein) gene family in I vs. 0 full-siblings, where a 1:1 segregation of the allele between the I and 0 full-sibs would be expected. Using a cab probe, they have shown that in some crosses there is a significant departure from the expected 1:1 ratio. Furthermore, using RAPD markers for genes linked to the cab gene, they have also shown than these genes do not segregate in the expected 1:1 ratio, which raises the possibility that crossing environment may somehow affect the distribution of chromosomal segments to progeny. The implications of these findings are far reaching, but at the very least they suggest that trees may have novel genetic mechanisms for coping with environmental change.

Table 10. Height growth (in feet) by identical crosses made on identical parents (grafted scions) grown inside and outside a greenhouse, after one growing season.

	Ht. (Feet)				
Cross	In	Out	# Trees In	#Trees Out	# Crosses
TxT	1.9 4.4	2.5 4.3	9	86	4
JxJ	3.5 4.0	3.3 3.5	0	53	
ExE			53	65	3
ExJ			69	42	
			41		3
					2

TREE IMPROVEMENT

Dr. Katherine K. Carter

Japanese larch is a fast-growing tree species which has gained some popularity for plantation uses in the Northeast. However, it is often susceptible to cold damage in northern New England. Graduate student Gao Jinrun investigated the seasonal development of cold tolerance, and genetic variation in cold tolerance, for 16 families and eight provenances of Japanese larch growing in Maine. If there is significant genetic variation in cold tolerance among Japanese larch families, the more cold-tolerant families can be selected for future planting and breeding programs.

Sixteen Japanese larch families growing in a plantation in Fairfield, Maine, and eight provenances of Japanese larch growing in a plantation in Talmadge, Maine, were selected for the research. Three trees were sampled for each genetic source. For each tree, 21 to 28 branch tips (2 cm long) were collected for laboratory trials of cold hardiness. We thank Dr. William Livingston for use of his laboratory facilities for relative conductivity (RC) measurements.

Samples were collected from Talmadge on September 28 and November 9, 1993, and March 1, 1994, and from Fairfield on October 5 and November 16, 1993, as well as March 18, 1994. To measure the cold tolerance of different sources, branch tips were placed in test tubes (3 tips per tube) and exposed to temperatures ranging from 3°C (control) to -65°C. After cold exposure, distilled water was added to the tubes. Chemicals of the cells damaged by freezing leak into the water, thus raising the electrical conductivity (EC) of the solution. After autoclaving the samples, final conductivity (ECK) was measured. Freezing damage was then assessed by calculating the relative conductivity (RC=EC/ECK*100) and comparing RC values among the families and provenances.

Sampling throughout the year revealed changes in average cold hardiness as the season progressed. In late September and early October, Japanese larch was hardy enough to withstand damage by low temperature of -5°C, but not hardy at -10°C or lower. In November and March, Japanese larch was tolerant to temperatures as low as -20°C, but not hardy for temperatures of -30°C or lower. Actual air temperatures recorded at weather stations in central Maine during the winter of 1993-94 were higher than the cold hardiness level of Japanese larch in late September, October, November, and most of the time in March. But minimum air temperature was near **or** below the expected cold hardiness level of the larch in December, January, and February (Figure 20). In

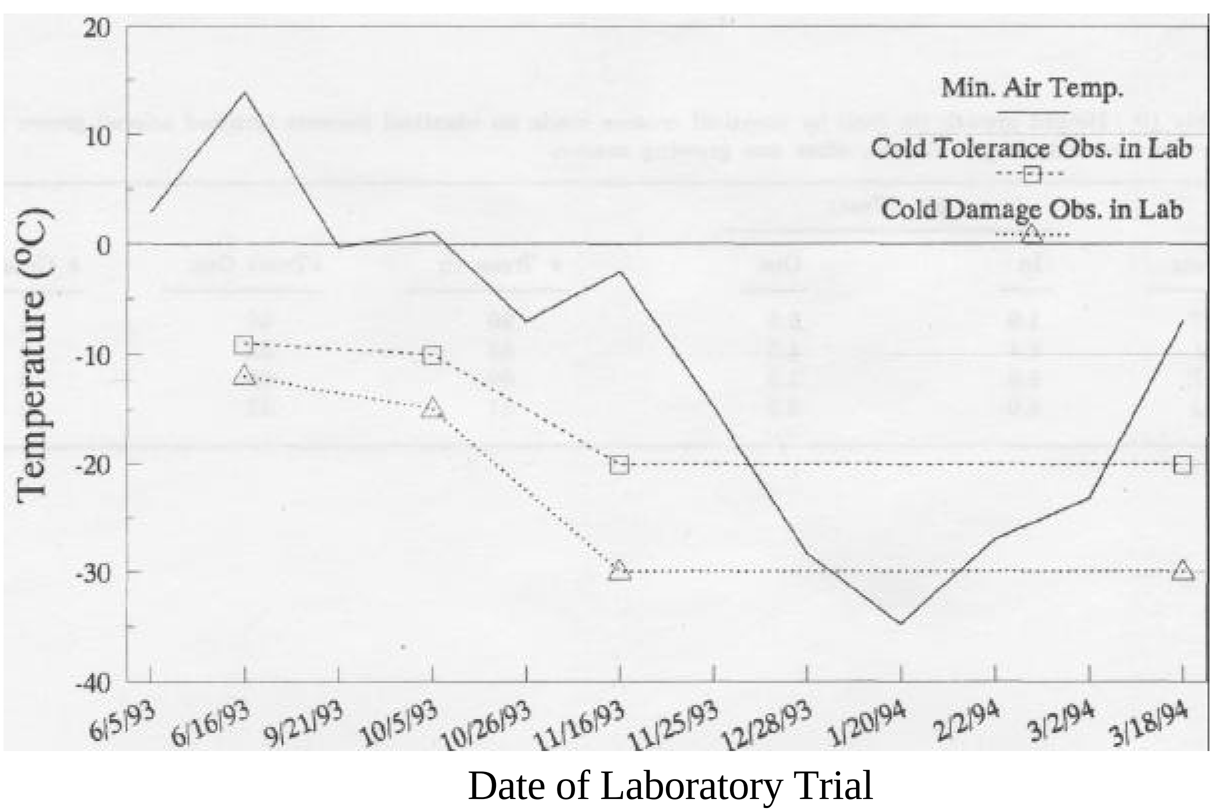


Figure 20. Laboratory test cold-tolerance levels and cold damage threshold temperatures for Japanese larch, and actual minimum air temperatures at local weather stations in 1993-94.

the spring of 1994, some trees at Fairfield showed dead branch tips, evidence of overwinter cold damage.

For all the laboratory trial dates, there were significant differences in RC among Japanese larch families (Figure 21). The differences were evident from the first trial in late September. Japanese larch families #20 and #21 are more resistant to low temperature, while families #42 and #47 are sensitive to cold injury. Laboratory RC measures of cold damage were compared to actual observations of winter injury in the Fairfield plantation. The best correlation of laboratory RC with actual winter damage score was for RC values measured in October at a test temperature of -30°C (r=0.62, p=0.02). Using measures such as this, it may be possible to select cold-tolerant Japanese larch families and provenances for planting in areas where severe winter temperatures are likely.

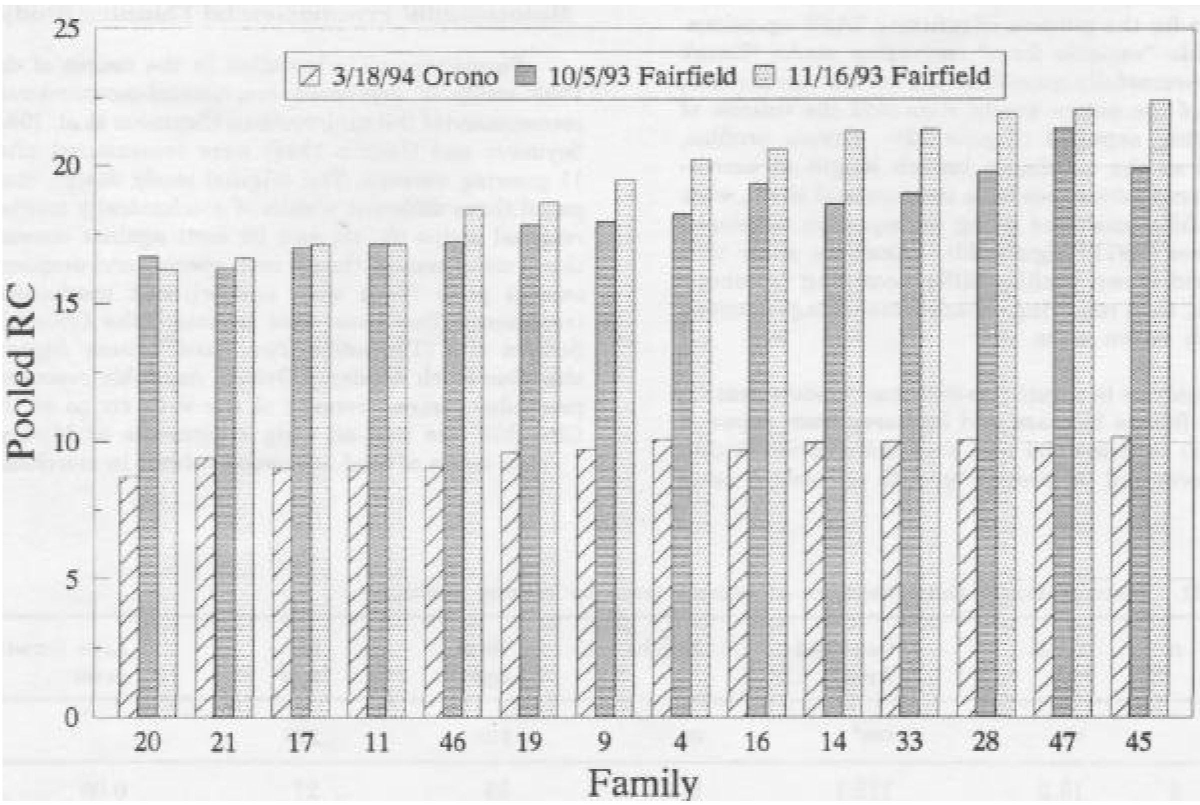


Figure 21. Electrolyte leakage (pooled RC) of Japanese larch families in response to cold temperature exposure on three sample dates, 1993-1994.

GROWTH AND YIELD

Dr. Robert S. Seymour

Modification of the TASS Model for Maine Conifers

Work progressed on several studies designed to adapt the TASS (Tree and Stand Simulator) model for Maine conifer species. Detailed stem analysis data from 39 balsam fir trees having well-developed nearly symmetrical crowns characteristic to each of four crown classes (Table 11) collected in 1992-1993 have been analyzed by Ph.D. candidate Daniel Gilmore for the purpose of refitting TASS equations. A flexible 'Variable form" regression model (Kozak 1988) successfully quantifies the vertical profile (i.e., taper) of the entire woody stem and the volume of conducting sapwood (Figure 22). Crown profiles, defined as the maximum branch length at successively longer distances from the terminal shoot, were successfully modelled using an equation developed by Honer (1971; Figure 23). Analyses show that stem and crown profiles differ according to canopy position, thus requiring separate modelling functions for each crown class.

Analysis is ongoing to construct models that (1) predict foliage biomass and leaf area from sapwood area; (2) describe the leaf area distribution within the crown; and (3) predict "growth efficiency" using three different parameters. The stemwood volume increment per unit of *crown volume* (the empirical measure used in the current version of TASS) is being compared with two more biologically based measures: volume increment per unit of *sapwood area* at bh, and volume increment per unit area of *foliage.*

Remeasurement of 1983 Mechanical-Motormanual Precommercial Thinning Study

Permanent plots installed in the course of the 1983 study of combined mechanical-motormanual precommercial thinning systems (Seymour et al. 1984; Seymour and Gadzik 1985) were remeasured after 11 growing seasons. The original study design compared three different widths of mechanically created residual strips (6, 10, and 20 feet) against conventional motormanual (brush saw) spacing and unspaced control plots (both with and without mechanical treatment). Two sites were treated: the Churchill Stream site (Thorndike Twp.) and Misery Stream site (Sandwich Academy Grant). Available resources precluded remeasurement of the wide strips at the Churchill site and all strip treatments at Misery.

In terms of total stemwood volume in merchant-

Table 11. Mensurational characteristics of sample trees by canopy position.'

Crown class[b]	n	DBH	Sapwood Area'	Height	Total age	bh age'	Live crown ratio
			cm-	m	yrs	yrs	
OG	9	15.2 (5.7-30.5)	112.7 (23.9-229.5)	9.3 (4.4-16.6)	53 (20-81)	27 (11-60)	0.90 (0.76-0.98)
CD	10	20.2 (9.5-29.7)	110.4 (32.8-216.9)	16.6 (7.6-19.6)	59[d] (25-84)	47 (18-65)	0.49 (0.31-0.77)
IT	10	10.8 (5.3-14.5)	28.5 (7.0-64.8)	12.7 (7.2-16.0)	50[d] (22-79)	42 (18-62)	0.35 (0.18-0.68)
SP	10	6.2 (2.5-10.2)	6.0 (2.6-10.0)	7.6 (4.0-12.8)	42[d] (17-63)	33 (10-47)	0.19 (0.04-0.36)

• Range of data in parenthesis
[b] OG = open-grown, CD = codominant, IT = intermediate, SP = suppressed
[c] Measured at 1.3 m
[d] Total age data only available for nine trees due to decayed heartwood

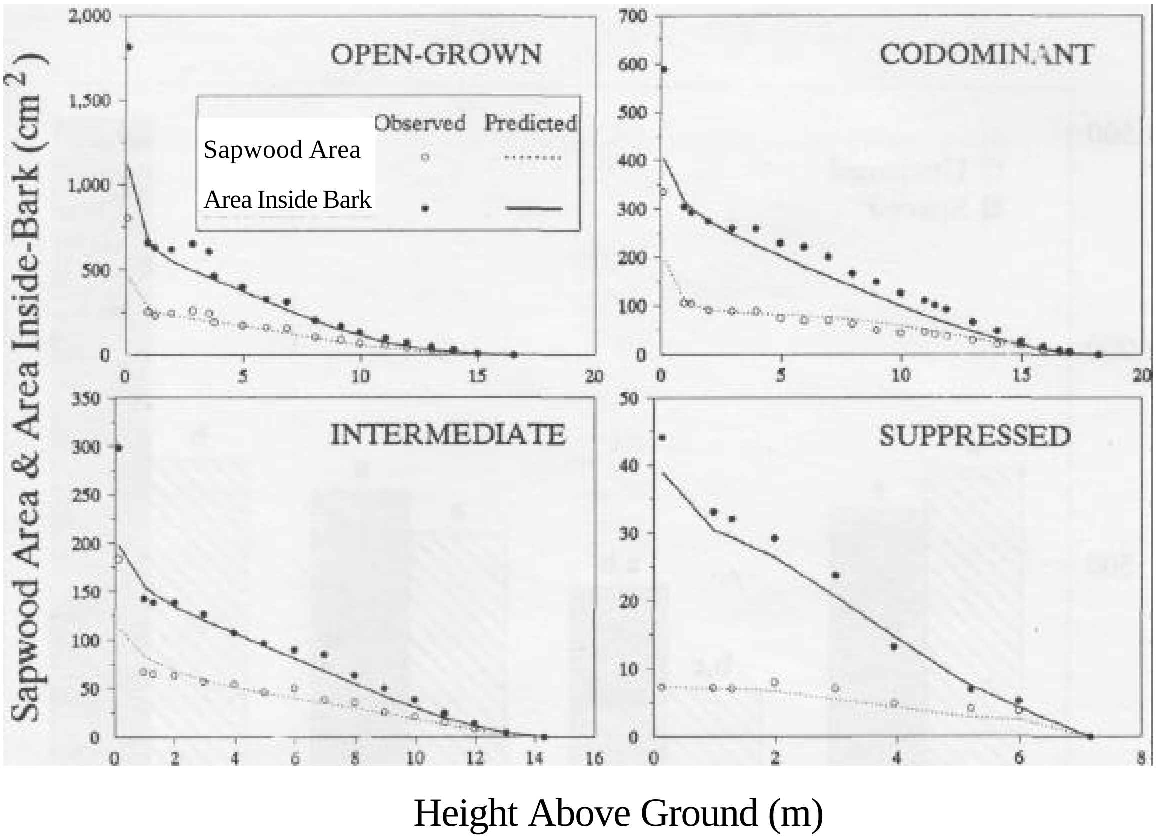


Figure 22. Observed and plcdicted sapwood area and cross-sectional inside-bark area for balsam fir trees characteristic to each of four crown classes.

able trees 3.6" dbh and larger, only the Misery site showed a dramatic response, with volume of the thinned plots double that of the unspaced controls (Figure 24). The spaced narrow strips at Churchill also showed a statistically significant response over their comparable unspaced controls, but not in comparison to other treatments at this site. These comparisons are somewhat clouded, however, due to plot-level variation in site index. Note that both poorly responding treatments had site indices 8-10 feet less than the spaced plots. As expected, average dbh values (all trees 2.0" dbh and larger) are consistently larger on the spaced plots, with a 2.3-inch difference at the Misery site. No differences in volume production are apparent between the 10-foot mechanical treatment (the operational treatment at that time) and the completely motormanual operations at the Churchill site. The narrow strips show lower volume production mainly because such a high percentage of the original stand was removed mechanically, effectively leaving the entire plot area somewhat understocked. Because these stands are below the age when substantial ingrowth will occur, especially on the unspaced plots, further measurements and analysis will be necessary to fully capture the effect of mechanical thinning.

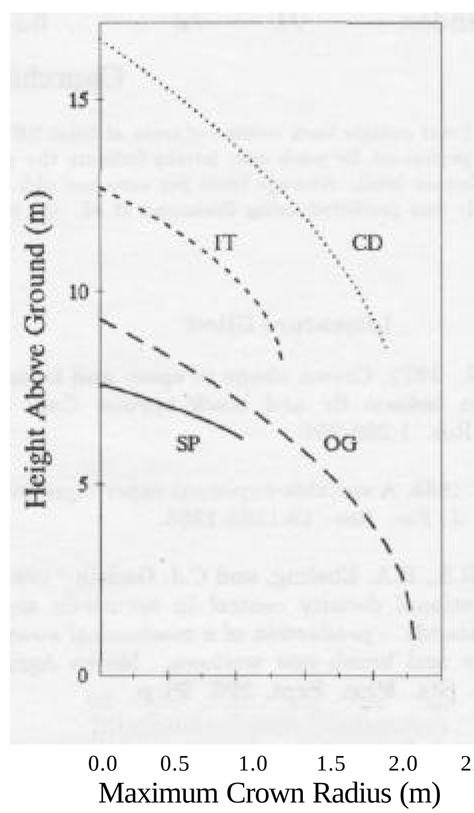
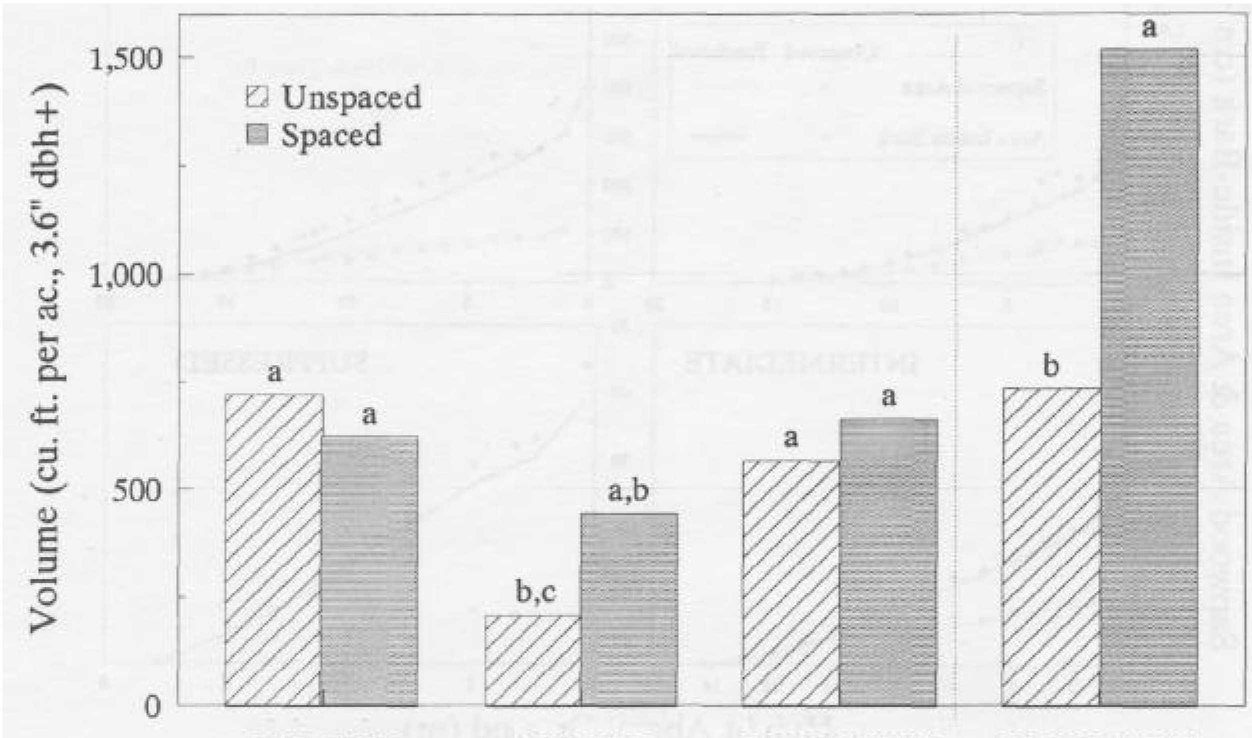


Figure 23. Illustration of predicted maximum crown radius values from the tree top down to the widest point of the crown for trees characteristic of each crown class (OG = open grown; CD = codominant; IT = intermediate; SP = suppressed).



10 ft. strips

Trees per acre 2045 850
Mean DBH 3.1 3.8
Site index 71 72

6 ft. strips Motor manual Motor manual

1700 75 2612 990

2.6 0 2.8 238

62 3.6 68 5 600

3.7 3.0 5.3

68 63 73

Misery Site (bh age 24)

Churchill Site (bh age 19)

Figure 24. Total outside bark volume of trees at least 3.6" dbh, for the different treatment and control plots. Separate ANOVA's were performed for each site; letters indicate the groupings of a least significant difference mean separation at the 5% significance level. Average trees per acre and dbh are for trees at least 2.0" dbh. Balsam fir site index (base age 50 yrs at BH) was predicted using Steinman et al. *(In review).*

Literature Cited

Honer, T.G. 1971. Crown shape in open- and forest-grown balsam fir and black spruce. Can. J. For. Res. 1:203-207.

Kozak, A. 1988. A variable-exponent taper equation. Can. J. For. Res. 18:1363-1368.

Seymour, R.S., R.A. Ebeling, and C.J. Gadzik. 1984. Operational density control in spruce-fir sapling stands - production of a mechanical swath cutter and brush-saw workers. Maine Agric. Expt. Sta. Misc. Rept. 296. 26 p.

Seymour, R.S. and C.J. Gadzik. 1985. A nomogram for predicting precommercial thinning costs in overstocked spruce-fir stands. North. J. Appl. For. 2:37-40.

Steinman, J.R., R.S. Seymour, and R.D. Briggs. Predicting height development and site index of red spruce and balsam fir in even-aged stands: A comparison to other studies. *In*

SLUDGE AND ASH

Dr. Robert K. Shepard

Introduction

During 1994, emphasis was placed upon remeasurement of plots in the three stands where treatment effects on tree growth were evident at the time of the previous measurements. Plots in two of these stands had been treated with a mixture of primary and secondary papermill sludge. Plots in the third stand had been treated with a mixture of wood ash and secondary papermill sludge. Results are presented for each stand individually. In addition to the growth measurements made after the 1994 growing season, foliage samples were taken from all stands.

Stand 1 - Coplin Plantation

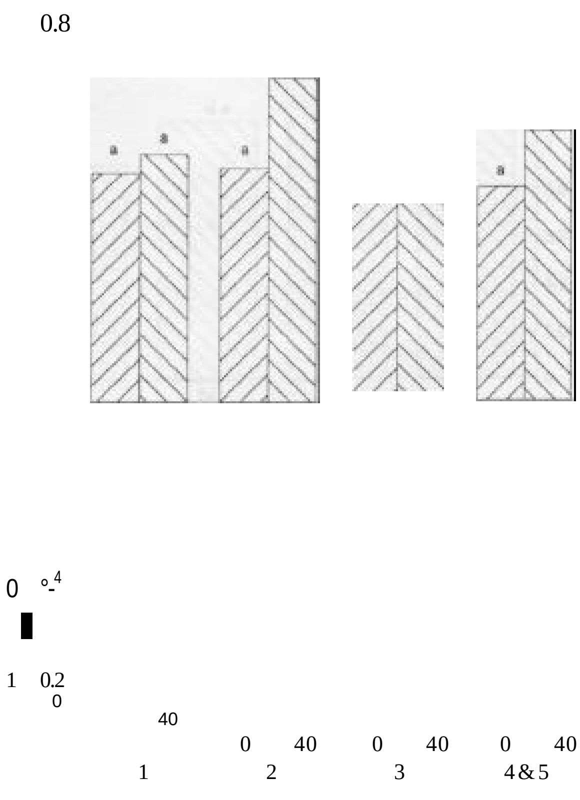
The study area is a clearcut planted to red pine. A mixture of primary (80% by weight) and secondary (20% by weight) papermill sludge was applied in early October 1989. The mixture was applied to five 0.05-acre plots by machine as part of an operational spreading of most of the clearcut. There were also five control plots. The application rate was approximately 40 dry tons per acre. Most trees were 4 to 8 feet tall when the sludge was applied. Treated trees averaged 1.2 inches and control trees averaged 1.1 inches in stem diameter.

A significant increase in stem diameter growth, which was measured 3 feet above the ground, was observed in 1991, the second growing season after application (Figure 25). This significant increase continued through the 1994 growing season (Figure 25). During the five years following application (1990-1994), the treated trees grew 0.6 inch more than the control trees. The future trend in diameter growth is unclear, but it is reasonable to assume that growth of the treated trees may continue to outpace that of the control trees in the near term.

The improved diameter growth appears to be due at least partly to increased foliar nitrogen concentrations (Figure 26). These higher concentrations are especially evident during the first two years following treatment. In 1992, there was little difference between treated trees and control trees, and it is anticipated that this will be true also for foliage samples taken after the 1994 growing season.

The higher foliar nitrogen concentrations resulted in the production of larger needles and thus a greater photosynthesizing area. Needles produced by treated trees in 1990 were 40% heavier than needles produced by control trees. Although needle weights were not determined after the 1991 growing season, a similar effect on needle growth likely occurred in that year also.

Diameter growth increased in spite of a large increase in the amount of competing vegetation, especially during the first several years after treatment. In 1990, raspberry biomass in treated plots was 2.5 times greater than in control plots, and foliage nitrogen concentrations were significantly higher. Evidently, the red pine were large enough when the sludge was applied so that they were able to withstand the increased competition from the raspberry and to respond positively to the sludge application.



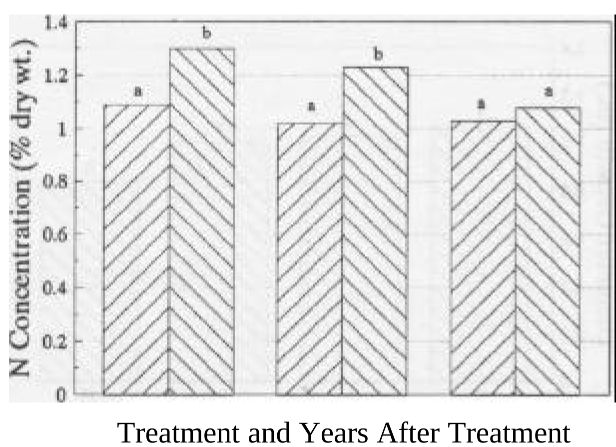


Figure 25. Annual diameter growth of planted red pine at different times after treatment with a mixture of primary and secondary papermill sludge at rates of 0 and 40 dry tons per acre. Measurements were made at a stem height of 3 feet. Bars for a given measurement time having the same lower case letter are not significantly different (P=0.05).

0 40 0 40 0 40

1 2 3

Treatment and Years After Treatment

Figure 26. Nitrogen concentrations of current-year foliage from red pine at different times after treatment with a mixture of primary and secondary papermill sludge at rates of 0 and 40 dry tons per acre. Bars for a given sampling time having the same lower case letter are not significantly different (P=0.05).

Stand 2 - Letter E Township

A mixture of primary (80% by weight) and secondary (20% by weight) papermill sludge was applied operationally to a red pine plantation in September 1989. The application rate was highly variable over very short distances and ranged from 0 to more than 60 dry tons per acre. Approximately 30 seedlings were selected for each of the following general ranges of application rate: 0 dry tons per acre, 5 to 15 dry tons per acre, 15 to 30 dry tons per acre, and more than 30 dry tons per acre. The seedlings selected were generally 2 to 3 feet tall when the area was treated.

Stem diameter growth, measured at 1 foot above the ground, exhibited a general decrease with increasing sludge application rate for the period 1993 and 1994 (Figure 27). The difference between the control and the maximum study rate of 30 + dry tons per acre was significant, as was the difference between the 5 to 15 dry tons per acre rate and the maximum rate. The same trend of stem diameter growth occurred during the first three years following application (Figure 28). During the period 1990 through 1994, diameter growth of the controls was 0.5 inch greater than diameter growth of seedlings that received the highest rate. The differences in diameter growth were not due to initial differences in stem diameter. Pretreatment diameters for the four groups of seedlings were, for successively increasing application rate, 0.44, 0.45, 0.47, and 0.45 inch. Foliar nutrient concentrations suggest no reason for the differences in diameter growth.

The reduced rate of diameter growth at the highest application rate is attributed, therefore, primarily to intense competition from raspberry and hardwoods. Although the amount of competing vegetation surrounding each seedling was not quantified, it was visually evident that this vegetation was denser in those areas that received the heaviest rate. During the first three years of the study, most of the seedlings in the highest application areas were overtopped and obscured by this vegetation.

Height growth during the two-year period 1993-1994 did not differ significantly among treatments (Figure 29). This is in contrast to the first three years, when the height growth of seedlings that received the maximum sludge application rate was significantly less than height growth of seedlings at the other three rates. Smaller growth of the maximum rate seedlings is attributed to intense competition. A very important aspect of the results from this plantation is that although the seedlings that were subjected to the highest application rate, especially, experienced reduced diameter growth for the entire five years and reduced height growth for the first three years, mortality was not increased. In fact, mortality among the study trees was virtually nonexistent during the five-year period.

Stand 3 - Tl R8 WELS

Treatments consisted of a combination of wood ash and papermill secondary sludge applied to plots in a clearcut planted to black spruce. The residual combination was applied at four different rates, at three different times during the spreading season, and for 1, 2, or 3 years in succession, providing 36 different treatment combinations. The first set of treatments was applied in late May 1988, and the last set in late September 1990. Analyses performed on data collected through the 1991 growing season indicate that the differences in growth that existed were due to differences in application rate. Time of application and number of years of application were not significant.

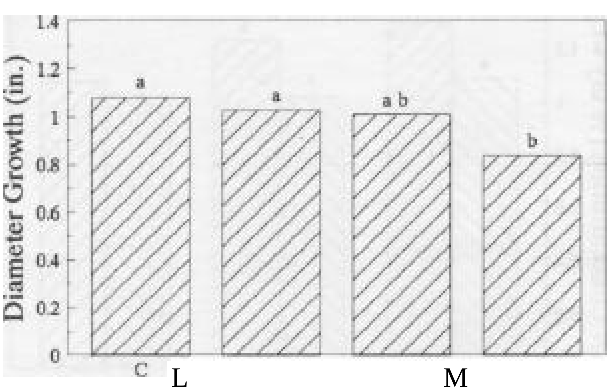


Figure 27. Diameter growth of planted red pine during the fourth and fifth growing seasons after treatment with a mixture of primary and secondary papermill sludge at four rates. Measurements were made at a stem height of 1 foot. C=0 dry tons per acre; L=5 to 15 dry tons per acre; M=15 to 30 dry tons per acre; H=more than 30 dry tons per acre. Bars having the same lower case letter are not significantly different (P=0.05).

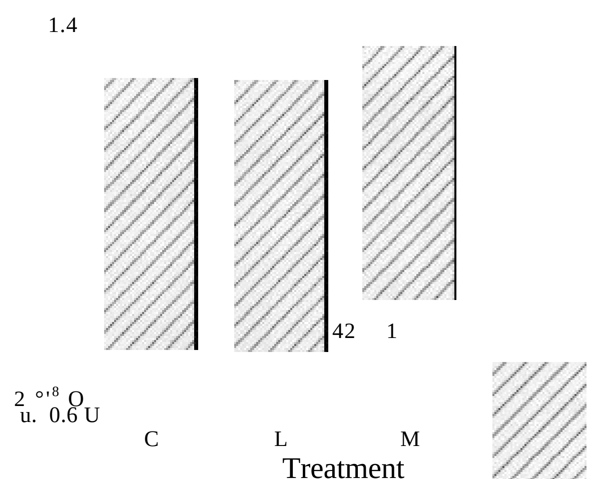


Figure 28. Diameter growth of planted red pine during the first three growing seasons after treatment with a mixture of primary and secondary papermill sludge at four rates. Measurements were made at a stem height of 1 foot. C=0 dry tons per acre, L=5 to 15 dry tons per acre; M=15 to 30 dry tons per acre, H=more than 30 dry tons per acre. Bars having the same lower case letter are not significantly different (P=0.05).

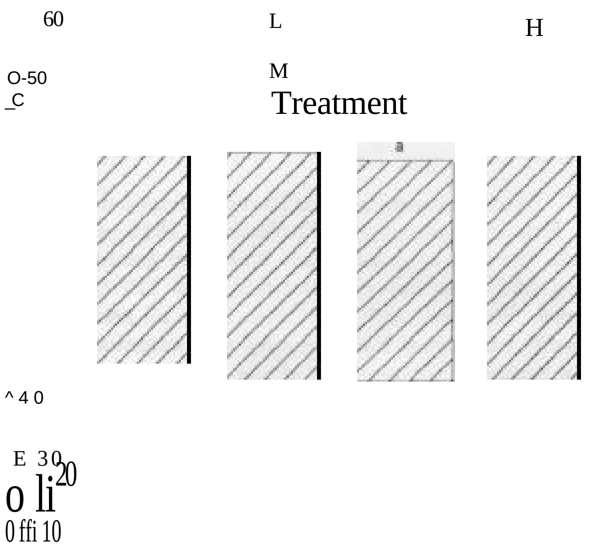


Figure 29. Height growth of planted red pine during the fourth and fifth growing seasons after treatment with a mixture of primary and secondary papermill sludge at "four rates. C=0 dry tons per acre; L=5 to 15 dry tons per acre; M=15 to 30 dry tons per acre; H=more than 30 dry tons per acre. Bars having the same lower case letter are not significantly different (P=0.05).

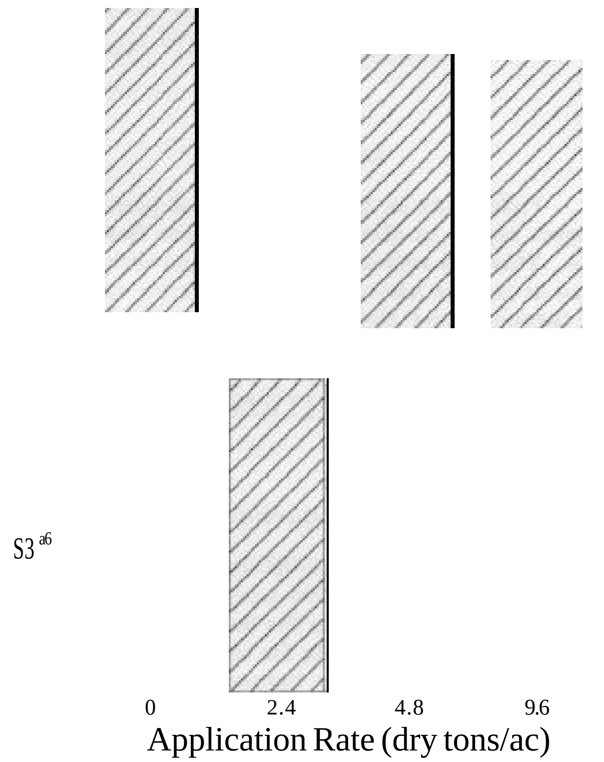


Figure 30. Diameter growth of planted black spruce during the fifth through seventh growing seasons after seedlings were first treated with a combination of wood ash and secondary papermill sludge. Seedlings were treated one, two, or three times. Measurements were made at a stem height of 1 foot.

Three-year stem diameter growth data (measurements made at 1 foot above ground) for the period 1992 through 1994 have not been statistically analyzed, but they display a distinct trend of decreasing growth with increasing application rate (Figure 30). This trend is similar to that observed for the period from 1988 through 1991. The largest difference, 0.2 inch, is between the 2.4- and 4.8-tons-per-acre rates, with little difference between either the 0- and 2.4- or the 4.8- and 9.6-tons-per-acre rates. The data also suggest a weak relationship between diameter growth and the number of times that treatments were applied. Diameter growth of trees that received three applications was 0.1 inch less than that of trees that received only one application, irrespective of application rate.

As in Township E, the slower growth at higher application rates is attributed to more intense competition, primarily from herbaceous vegetation. During the 1989, 1990, and 1991 growing seasons the seedlings were subjected to especially intense competition. Seedlings in many of the plots were overtopped and totally obscured by this vegetation. Plot borders were clearly visible, based on differences in vegetation amount between plots and adjacent areas. Differences in amount of herbaceous vegetation were still evident when measurements were made in October 1994, four growing seasons after the last treatments were applied.

Results from the above studies suggest that tree size at time of treatment plays a major role in response to treatment. Application of residuals to newly established conifer stands in clearcut areas may lead to reduced seedling growth due to stimulation of competing vegetation. Herbaceous vegetation and hardwoods are more nutrient demanding than conifers and are more likely to respond to the addition of sludge and ash. The early nutrient requirements of the conifers will probably be satisfied by fertilizer placed in the individual containers (assuming containerized seedlings) and from the nutrients released by the decomposing forest floor. Nutrients contained in sludge and ash will be utilized mostly by competing vegetation. At least one additional set of measurements in the above study areas seems appropriate to better quantify the extent and duration of the treatment effects on growth.

The most favorable stage(s) in stand development to apply sludge and ash would be at about the time of initial crown closure, or later, when the trees have attained merchantable size. In both cases the effects of competing vegetation would be slight or nonexistent. Some tree removal would be necessary, however, to provide access to such stands.

EFFECTS OF TIMBER HARVESTING AND TRAPPING ON POPULATION CHARACTERISTICS, HABITAT SELECTION, AND AREA OCCUPANCY BY AMERICAN MARTENS IN NORTHERN MAINE: THE BAXTER PARK STUDY

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 for comparing the effects of trapping and timber harvesting^ (T4 Rll) and timber harvesting without trapping (T5 Rll) on marten population characteristics and habitat selection. The research in the industrial landscape (T4 Rll, T5 Rll) is being funded by Maine Department of Inland Fisheries and Wildlife (MDIFW), the Maine Agricultural and Forest Experiment Station (MAFES), and the Department of Wildlife Ecology (DWE), University of Maine. Project personnel included David Payer (Ph.D. student), Thomas Hodgman (research associate), David Phillips (M.S. student), H. Joseph Lachowski (M.S. student) and Aaron Drake (undergraduate technician). 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 project sponsors in 1999.

Objectives

The specific objectives of this phase of our project are

1) to document and compare seasonal habitat selection by martens in an untrapped forest preserve, an untrapped industrial forest, and a trapped industrial forest;

2) to document and compare population characteristics (i.e., home range size, inter- and intrasexual 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 May to September 1994

We trapped martens from 18 May-15 July 1994 in T5 Rll WELS (T5), T4 Rll WELS (T4) and Baxter State Park (BSP). There was a total of 45 initial marten captures. Each captured marten was sexed, weighed, measured, examined for reproductive status, aged, ear tagged and radiocollared. Subsequent monitoring identified 36 of the martens as residents on one of the three study sites. There were 13 residents in BSP (9 M, 4 F), 9 in T5 (5 M, 4 F), and 12 in T4 (6 M, 6 F).

We monitored radiocollared martens daily from 20 May-30 September. We obtained 1510 relocations from the following sources: 850 from ground telemetry, 550 from aerial telemetry, and 110 from captures. 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).

During September 1994 we retrapped nine residents (3 in BSP, 2 in T4, 4 in T5) whose radiocollars were expected to fail within 90 days and affixed new radiocollars. We also trapped and radiocollared two new female martens (one each in T5 and T4). The latter martens have remained on their respective study sites through 31 October, and thus appear to be residents. We plan to monitor all residents weekly through 31 December, then intensively via snow machine and aircraft from January through March 1995.

Three townships (T5 Rll, T6 Rll, and T6 RIO) have been closed to commercial furbearer (except beaver and bear) trapping by the Maine Department of Inland Fisheries and Wildlife (DIFW) during 1994 and 1995 to facilitate our study of effects of trapping on marten populations. We are working with DIFW to enforce this closure and have posted signs regarding the closure and objectives of our study in strategic areas throughout our study site.

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. For 1995, additional funding of $10,998 has been obtained via Maine Forest Service (MFS), and MDIFW has committed $5,700 of in kind support. This will allow us to proceed with all objectives as proposed. Proposed research activities in the industrial forest are fully funded via MDIFW, MAFES, and DWE.

A proposal was submitted to the National Council of the Paper Industry for Air and Stream Improvement (September 1994) to request 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 compare microhabitat characteristics between forested areas (> 6 m in height) with different intensities of use by resident, nonjuvenile martens in the industrial forest with trapping closure and in Baxter Park. Our hope is that this 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. If funded, this work will occur during 1995-96 in T5 Rll and in Baxter State Park.

Results from Associated Studies

Graduate student David Phillips completed his M.S. thesis titled "Social and spatial characteristics and dispersal of marten in a forest preserve and industrial forest" in August 1994. The abstract from this thesis follows.

Results from previous research suggest that American marten *(Maries americana)* require mature forest habitat; however, the relationship of trapping and timber harvesting to performance of marten populations is not well documented. I compared sex-specific indices of performance (i.e., density, age structure, sex ratio, percentage of females lactating, home-range area, percentage of occupied area, and intrasexual overlap of home ranges) for 61 nonjuvenile (1 year) marten (27 M, 34 F) that were radio-monitored in a forest preserve (Baxter State Park), with measures of performance for 28 nonjuvenile marten (14 M, 14 F) monitored in an industrial forest (Telos). The preserve was closed to trapping and timber harvesting for > 35 years, and the industrial forest was characterized by intensive trapping and extensive timber harvesting.

Density of nonjuvenile resident marten during summer in the forest preserve was higher than the density in the industrial forest. Mean sex-ratios of nonjuvenile marten were similar to 1:1 in Baxter and Telos. Male marten were older in the forest preserve; fewer yearlings (1-2 years) and more adults (2 years) were livetrapped in the preserve. Alternatively, no difference in age structure of females or in the proportion of nonjuvenile (1-year-old) females lactating occurred between sites. The proportion of adult (2 years) females that lactated in early summer was not different between sites.

Lower density in the industrial forest was associated with increased range size and reduced spatial overlap for nonjuvenile males; however, I observed no difference in range size between lactating females in the forest preserve and the industrial forest. Male ranges were larger than ranges of lactating females in the industrial forest; however range areas did not differ between sexes in the forest preserve. A lower percentage of the industrial forest was occupied by marten, and males occupied a greater percentage of the available area than females on both sites. I observed greater intrasexual overlap among male ranges in the high density than in the low density population; however, female marten shared < 2% of their range area with consexuals on both sites. My data suggest that males in the low density population increased range area to increase access to mates and that social pressure was greater for males in the high density population. Overall measures of population performance did not differ between marten inhabiting the forest preserve or the industrial forest. Females may occupy ranges of comparable habitat quality in logged and unlogged areas via habitat selection at the landscape scale. Recently harvested forest stands are disproportionately excluded from marten ranges, thus effects of logging appeared to result from reduced density in harvested landscapes.

The influence of season on population density, and size and location of marten ranges has not been documented. Knowledge of seasonal variation in population characteristics would improve interpretations of the seasonal importance of specific habitats. I examined seasonal and annual variation in population density and range area, and documented the extent of range fidelity for marten of each sex in the forest preserve.

Density of nonjuvenile marten in the Baxter preserve varied by only 0.09 marten/km^2 across 3 winters (1 Nov - 31 Mar) and by 0.16 marten/km^2 across 3 summers (15 May - 31 Oct). Mean density did not differ between summer and winter; however, density of males during winter was consistently higher than females. Indices to sex-specific range area did not differ between early- (1 Nov - 31 Dec) and late- (1 Jan - 31 Mar) winter for males and females or between winter and summer for males and females. All of 19 males and 5 of 13 females monitored > 1 season exhibited a high degree of range fidelity; however, some females abandoned previously established ranges and began wandering over large areas, and additional females were wandering when livetrapped. Male ranges may have shifted in late-winter in response to wandering females that established resident ranges; however, males maintained access to areas used during the previous summer. My data suggest that females abandoned their range in response to increased social pressure associated with high population density, whereas males shifted or shared area with consexuals in the high density population.

Knowledge of dispersal characteristics of juvenile marten could assist managers in developing strategies to maintain viable populations in commercial forest landscapes; however, specifics of dispersal and survival probabilities of newly independent juvenile marten have not been documented. I documented timing, distance, rate of travel, and directionality during dispersal, and documented survival probabilities for 28 juvenile (1 year) marten (14 M, 14 F) that were radiocollared in the Baxter park preserve.

Dispersal of juvenile marten began prior to August 27; there were no sex-specific differences in timing or rate of travel during dispersal. I observed no difference in minimum distance travelled during dispersal for males or females. Directions of final dispersal relocations were distributed uniformly around the study area, and marten exhibited a random walk pattern of movement during dispersal. Natural mortality of juvenile marten was high prior to trapping season; however, marten surviving to mid-November had a high probability of surviving to spring. Fur trapping should be conducted as early as possible to minimize additive mortality and increase recruitment of juvenile marten. Local populations of marten should be spaced <12.0 km to ensure exchange of individuals, thus enhancing viability of metapopulations.

1994 PUBLICATIONS RESULTING FROM RESEARCH SUPPORTED BY THE CFRU

Bragg, W.C., W.D. Ostrofsky, and B.F. Hoffman, Jr. 1994. Residual tree damage estimates from partial cutting simulation. Forest Prod. J. 44(7/8): 19-22.

Briggs, R. 1994. Site classification field guide. CFRU Tech. Note 6, Maine Agric. For. Expt. Sta. Misc. Pub. 724.

Briggs, R.D., R.C. Lemin, Jr., and J.W. Hornbeck. 1993. The Weymouth Point clearcut watershed study - Precommercial thinning (PCT). p. 332. *In:* Soil Science Society of America Annual Meeting, Cincinatti, OH. Nov 7-12, 1993. Agronomy Abstracts.

Gao, J., and K. Carter. 1994. Genetic variation in cold tolerance of Japanese larch in Maine, p. 99. *In:* Forest Biodiversity in a Changing Environment, 13th North American Forest Biology Workshop, 14-16 June 1994. Baton Rouge, LA. (Abstract).

Gilmore, D., R.D. Briggs, and R.S. Seymour. 1994. Identification of low productivity sites for European larch *(Larix decidua* Miller) in Maine, USA. New Forests 8:229-297.

Lemin, Jr., R.C., and R.D. Briggs. 1993. Stem volume equations for young precommercially thinned balsam fir, *Abies balsamea* (L.) Mill., and spruce *(Picea* spp.), in Maine. Maine Agric. For. Expt. Sta. Misc. Rept. 384.

McCormack, M.L., Jr. 1994. Reductions in herbicide use for forest vegetation management. Weed Tech. 8:344-349.

Nichols, M.T., R.C. Lemin, Jr., and W.D. Ostrofsky. 1994. Impact of two harvesting systems on residual stems in a partially cut stand of north ern hardwoods. Can. J. For. Res. 24:2:350-357.

O'Hara, K.J., R.S. Seymour, S.D. Tesch, and J.M. Guldin. 1994. Silviculture and our changing profession. Leadership for implementing shifting paradigms. J. Forestry. 92(1):8-13.

Ostrofsky, W.D. 1994. Impacts of partial harvesting on stand quality and forest health, p. 53-59. *In:* Proceedings: Twenty-Second Annual Hardwood Symposium of the Hardwood Research Council. Cashiers, North Carolina. 108 p.

Pitcheralle, J.D. 1994. Effect of soil texture and chemical characteristics on the early growth response of balsam fir to precommercial thinning. M.S. Thesis, Univ. Maine. 75 p.

Ren, Y. 1994. Response and activity of a forest soil microbial population to application of papermill sludge ash. M.S. Thesis, Univ. Maine. 44 p.

Schaertl, G.R. 1994. Growth responses of red spruce *(Picea rubens* Sarg.) and balsam fir (Abies *balsamea* (L.) Mill.) to vegetation management with herbicides in Maine. Ph. D. Diss. Univ. Maine. 154 p.

Seymour, R.S. 1994. The Northeastern Region. p. 31-79. *In:* Regional Silviculture of the United States, third ed., J. W Barrett, ed., Wiley and Sons, N.Y. 643 p.

Shepard, R.K., W.D. Ostrofsky, and Y. Ren. 1994. Application of papermill sludge ash and wood ash to forest land: Early effects on vegetation and soil microbes, p. 69. *In:* Biographies and abstracts. Forest Products Society 48th Annual Meeting. Portland, Maine.

AFFILIATED PUBLICATIONS

Rice, R. W, and R. K. Shepard. 1993. Moisture content variation in white pine lumber dried at seven northeastern mills. Forest Prod. J. 43(11/12):77-81.

Roos, K.D., J.E. Shottafer, and R.K. Shepard. 1994. The effect of juvenile wood on the properties of aspen flakeboard. Maine Agric. For. Expt. Sta. Tech. Bulletin 152. 18 p.

ADDITIONAL TECHNOLOGY TRANSFER ACTIVITIES BY CFRU PERSONNEL

Briggs, R.D., M.L. McCormack, Jr., and C.T. Smith, Jr. Forest management impacts on nitrogen cycling: The Weymouth Point study. Nitrogen in the Environment: Sources, Impacts, Management. Orono, ME. October 8, 1993.

Briggs, R.D. Incorporating site quality in the selection of sites for precommercial thinning. Boise Cascade Bingham district. October 20, 1993.

Briggs, R.D., R.C. Lemin, Jr., and J.W. Hornbeck. The Weymouth Point clearcut watershed study - Precommercial thinning (PCT). Presentation to Soil Science Society of America Annual Meeting, Cincinnati, OH. November 7-12, 1993.

Briggs, R.D. The role of soils in forest productivity and health - Soil: the foundation. Presented at the SAF National Convention. Indianapolis, IN. November 7-10, 1993.

Briggs, R.D. Site quality, forest productivity, and forest health - is there a consistent relationship? Communications for industry newsletters. December 1993.

Briggs, R.D. Invited Participant: Task Force on Soil Interpretations for Forestry. SCS, Lincoln, NE. March 14-17, 1994.

Briggs, R.D. and M.L. McCormack, Jr. Successful Plantation Management - A Practical Guide. Presented at "The Role of Conifer Plantations in New York". SUNY College of Environmental Science and Forestry, Syracuse, NY. June 14-15, 1994.

Briggs, R.D. Soil-site relationships in the Northern Forest. One week field oriented course, Eagle Hill Wildlife Research Station, Steuben, ME. August 7-12, 1994.

Briggs, R.D. Site Quality Assessment. Field tour and presentation to CFRU cooperators. Grafton, ME. September 1, 1994.

Briggs, R.D. Soils/Silviculture Workshop. Field tour and presentation to Georgia-Pacific Corp. Research and Forestry Field Staff. Orient, ME. September 27-28, 1994.

Carter, K.K. Genetic variation in seedling root growth and its relationship to early post-planting growth in Japanese larch. Communications for industry newsletters. November 1993.

Carter, K.K., and J. Gao. Genetic variation in cold tolerance of Japanese larch in Maine. Poster presentation, New England Society of American Foresters, Manchester, NH. March 22-24, 1994.

Carter, K.K. CFRU Executive Committee, Research Progress Review. Orono, ME. June 28, 1994.

Dubis, J.J., and R.D. Briggs. Species composition and Leak's habitat types in the western mountains of Maine. New England SAF Annual Meeting, Manchester, NH. March 22-24, 1994.

Eschholz, WE., K.S. Raymond, F.A. Servello, and B. Griffith. Effects of glyphosate use on winter habitat and nutritional ecology of moose in Maine. Poster presented at the 49th Northeast Fish and Wildlife Conf., Atlantic City, NJ. 1993.

Gao, J., and K. Carter. Genetic variation in cold tolerance of Japanese larch in Maine. Poster presentation, New England Society of American Foresters, Manchester, NH. March 22-24, 1994.

Greenwood, M.S. Environmental Aftereffects—The Presence of the Past? Communications for industry newsletters. March 1994.

Greenwood, M.S. Advice to International Paper Company re: Anatomy of rooted cuttings. May 24, 1994.

Greenwood, M.S. CFRU Executive Committee, Research Progress Review. Orono, ME. June 28, 1994.

Greenwood, M.S. Tree breeding. Presentation to Summer Meeting, Maine Christmas Tree Association, Orono, ME. July 23, 1994.

Greenwood, M.S. Consultation with Fraser Paper on Tree Improvement. August 16-17, 1994.

Greenwood, M.S. Advise Westvaco scientists on time of female strobilus development in loblolly pine. August 20, 1994.

McCormack, M.L., Jr. SAF National Convention. Indianapolis, IN. November 7-10, 1993.

McCormack, M.L., Jr. Georgia-Pacific, Woodland, ME. December 8, 1993.

McCormack, M.L., Jr. Growers branching out in quest for perfect tree. Interview by Associated Press in Bangor Daily News, December 13, 1993.

McCormack, M.L., Jr. Radio interviews. Bangor, ME. December 13, 1993.

McCormack, M.L., Jr. 1995 National Convention, Society of American Foresters (General Chair), Arrangements Committee Meeting, Portland, ME. May 5, 1994.

McCormack, M.L., Jr. Society of American Foresters, National Program Committee Meeting, Bethesda, MD. May 9-11, 1994.

McCormack, M.L., Jr. Hardwood Silviculture Workshop, Orono, ME. May 25-26, 1994.

McCormack, M.L., Jr. Hardwood Silviculture in Europe. Supper seminar. Orono, ME. May 25, 1994.

McCormack, M.L., Jr., and R.D. Briggs Successful Plantation Management - A Practical Guide. Presentation at the two-day conference "The Role of Conifer Plantations in New York". SUNY College of Environmental Science and Forestry, Syracuse, NY. June 14-15, 1994.

McCormack, M.L., Jr. Christmas tree biology. Presentation to Summer Meeting, Maine Christmas Tree Association, Orono, ME. July 23, 1994.

McCormack, M.L., Jr. Christmas tree biology field workshop. Summer Meeting, Maine Christmas Tree Association, Stillwater, ME. July 23, 1994.

McCormack, M.L., Jr. Herbicide efficacy field workshop. International Paper Co., Stratton, ME. July 27, 1994.

McCormack, M.L., Jr. 1995 National Convention, Society of American Foresters (General Chair), Arrangements Committee Meeting, Portland, ME. July 28, 1994.

McCormack, M.L., Jr. Cloning could create the perfect Christmas tree. The Maine Alumnus. Published by the University of Maine General Alumni Association. Spring/Summer 1994.

McCormack, M.L., Jr. Woodlot forestry with Brooks Mills. Alabama Farmers Federation 1994 Forestry Tour, Eddington, ME. August 8, 1994.

McCormack, M.L., Jr. Tour of Baskahegan operations with Chuck Gadzik. Alabama Farmers Federation 1994 Forestry Tour, Kossuth, ME. August 10, 1994.

Ostrofsky, WD. Tree harvesting, tree wounds and forest health. Communications for industry newsletters. October 1993.

Ostrofsky, W.D. Decline diseases and ecosystem sustainability. Workshop participant. USDA Forest Service Research Initiative, Syracuse, NY. October 19-21, 1993.

Ostrofsky, W.D. Paper birch seedbed trial: Stand growth and development after twenty-four years. Presentation to the Maine Hardwood Association Annual Meeting, Bradley, ME. October 27, 1993.

Ostrofsky, W.D. Field Tour Participant - Hardwood Management, Scott Paper Co., Bingham, ME. November 16, 1993.

Ostrofsky, W.D. Timber harvesting practices: Impacts on forest diseases. Presentation to the Northeastern Forest Insect Work Conf. Manchester, NH. March 24, 1994.

Ostrofsky, W.D. Partial harvesting in northern hardwoods. Presentation and field tour to Great Northern Paper staff and logging contractors. Oakfield, ME. May 10, 1994.

Ostrofsky, W.D. Impacts of partial harvesting on stand quality and forest health. Presentation to 22nd Ann. Hardwood Symposium, Hardwood Research Council. Cashiers, NC. May 14, 1994.

Ostrofsky, W.D. Forest pest activities, tree defects, and hazard tree assessment. Communications for industry newsletters. June 1994.

Ostrofsky, W.D. Evaluation and identification of hazard trees. Presentation to Forest Logging Safety and Hazard Trees Workshop. Sanford, ME. June 21, 1994.

Ostrofsky, W.D. Bureau of Public Lands, Maine Dept. Conservation Silviculture Advisory Committee. Tour participant. Big Squaw and Little Squaw Mountain Townships, ME. July 11-12, 1994.

Ostrofsky, W.D. A paper birch thinning study: Ten-year results. Field tour and presentation to CFRU cooperators. Grafton, ME. September 1, 1994.

Ostrofsky, W.D. Damage to residual trees from partial cutting of northern hardwood stands and effects on forest productivity. Presentation to Georgia-Pacific forestry staff. Orient, ME. September 27-28, 1994.

Raymond, K.S., WE. Eschholz, F.A. Servello, and B. Griffith. 1994. Effects of the herbicide glyphosate on winter browse availability and utilization by moose. Paper presented at the 50th Northeast Fish and Widl. Conf., Burlington, VT. 1994.

Ren, Y, and W.D. Ostrofsky. Response of soil microbial populations to application of papermill sludge ash. Poster presentation, 74th Ann. Winter Meeting, New England Division, SAF. Manchester, NH. March 1994.

Safford, L.O., and W.D. Ostrofsky. 1994. A 35-year record of stand development following seed tree regeneration and seedbed treatment for paper birch. 1958-1993. Poster presentation, 74th Ann. Winter Meeting, New England Division, SAF. Manchester, NH. March 1994.

Servello, F.A. Moose/herbicide research, Scott Paper Co. December 14, 1993.

Servello, F.A., W.E. Eschholz, and K.S. Raymond. 1993. Softwood release with herbicides: Enhancing moose habitat? Joint Conference of New England Society of American Foresters and Maine Chapter of The Wildlife Society, Portland, ME. March 4, 1993.

Seymour, R.S. New Forestry concepts. Munsungan Conference, Orono, ME. January 5, 1994.

Seymour, R.S. Presented testimony before the Joint Energy and Natural Resources Committee on L.D. 1764. Augusta, ME. February 14, 1994.

Seymour, R.S. Concepts and application of New Forestry. Invited seminar presented to Univ. New Brunswick Forestry Association, Fredericton, NB. February 16, 1994.

Seymour, R.S. A New Forestry for the Acadian Forest. Invited keynote address presented to the plenary session of Sylvicon, the annual meeting of professional, governmental, industrial, and academic foresters held in Fredericton, NB. February 17, 1994.

Seymour, R.S. What is New Forestry? Communications for industry newsletters. May 1994.

Seymour, R.S. CFRU Executive Committee, Research Progress Review. Orono, ME. June 28, 1994.

Seymour, R.S. High yield spruce-fir silviculture. Presentation to GNP Forestry Staff, Millinocket, ME. July 14, 1994.

Seymour, R.S. Silvicultural prescription review tour, Champion Forestry Staff, Field tour. July 26, 1994.

Shepard, R.K. Wood properties and tree age. Communications for industry newsletters. April 1994.

Vreeland, J.K., F.A. Servello, and D.B. Griffith. Effects of glyphosate on availability of summer foods for white-tailed deer in Maine. Poster presented at the 50th Northeast Fish and Widl. Conf., Burlingt, VT. May 1-4, 1994.

COOPERATIVE FORESTRY RESEARCH UNIT ADVISORY COMMITTEE

1994 Membership

The CFRU Advisory Committee sets priorities and reviews proposals for the Cooperative Forestry Research Unit. Members active during all, or part, of 1994 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, Scott Paper Company
Robert Frank, USDA Forest Service
Charles Gadzik, Baskahegan Company
Dennis Gingles, International Paper Company
Russ Hewett, Pride Manufacturing Company
Peter Ludwig, Champion International Corporation
Ronald Mallett, Maine Power Services
John D. Stowell, Timberlands, Inc.
Phil Sullivan, J.D. Irving, Limited
Peter Triandafillou, James River Timber Corporation
John Trobaugh, Georgia-Pacific Corporation

CFRU STAFF (September 30, 1994)

Program Leaders

William D. Ostrofsky, Associate Research Professor of Forest Resources (CFRU Leader)
Maxwell L. McCormack, Jr., Research Professor of Forest Resources Russell D. Briggs, Associate 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 1994

Baskahegan Company Bethel
Furniture Stock, Inc. Boise Cascade
Corporation Bouchard, H.O., Inc.
Browning-Ferris, Industries
Champion International Corporation
Dead River Company Fairfield
Energy Venture, L.P. Field
Timberlands Finestkind Tree Farms
Fraser, Inc. Georgia-Pacific Corp.
Great Northern Paper, Inc.-Bowater
Haynes, H.C., Inc. Huber, J.M.
Corporation International Paper
Company Irland Group, The Irving,
J.D., Ltd. Isaacson Lumber
Company James River Timber
Corporation Knight Tree Farm

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

OTHER ORGANIZATIONS PROVIDING SUPPORT FOR CFRU PROJECTS

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

Mclntire-Stennis
Monsanto Agricultural Products Company
USDA Northeastern Forest Experiment Station
USDA State & Private Forestry

APPENDIX A

Terminology

SCIENTIFIC NAME	COMMON NAME
Abies balsamea (L.) Mill.	Balsam fir
Abies spp.	Fir
Acer rubrum L.	Red maple
Acer saccharum Marsh.	Sugar maple
Betula alleghaniensis Britton	Yellow birch
Betula papyrifera Marsh.	Paper birch
Fagus grandifolia Ehrh.	American beech
Fraxinus americana L.	White ash
Fraxinus pennsylvanica Marsh.	Green ash
Jugulans nigra L.	Black walnut
Larix decidua Mill.	European larch
Larix laricina (Du Roi) K. Koch	Tamarack
Larix leptolepis (Sieb. & Zucc.) Gord.	Japanese larch
Larix spp.	Larch
Picea abies (L.) Karst.	Norway spruce
Picea glauca (Moench) Voss	White spruce
Picea mariana (Mill.) B.S.P.	Black spruce
Picea rubens Sarg.	Red spruce
Picea spp.	Spruce
Pinus banksiana Lamb.	Jack pine
Pinus monticola Dougl.	Western white pine
Pinus rigida Mill.	Pitch pine
Pinus resinosa Ait.	Red pine
Pinus strobus L.	White pine
Pinus sylvestris L.	Scots pine
Populus spp.	Aspen
Pseudotsuga menziesii (Mirb.) Franco	Douglas-fir
Rubus idaeus L.	Common red raspberry
Rubus spp.	Raspberry
Tsuga canadensis (L.) Carr.	Hemlock
Castor canadensis Kuhl	Beaver
Maries americana Turton	American marten
Ursus americanus Pallas	Black bear

APPENDIX B

Program and Project Problem Analyses

The following program and project descriptions are summaries of problem analyses developed and presented by the three CFRU program scientists (Dr. R.D. Briggs, Dr. M.L. McCormack, Jr., and Dr. W.D. Ostrofsky) to the CFRU Advisory Committee in January of 1994. A review of the work of each project scientist was also conducted during the summer of 1994. These brief descriptions outline potential subjects for study during the next five-year research period. The summaries form the basis for development and discussion of CFRU research priorities for the period from October 1996 through September 2001.

SILVICULTURE

Dr. Maxwell L. McCormack, Jr.

Only problems are summarized. Research projects or approaches to addressing the problems are not specified.

The working environment for silviculture influences the character of the problems, setting of priorities, and determination of the approaches for conducting research on identified problems. Some considerations include the following.

1. The nature of forests and forestry practices require **well-documented, long-term research** to provide reliable data to form accepted bases for sound forest management decision making and realistic forestry practices legislation. There is a need for **continuity of commitment to defined silvicultural objectives.** This need is confounded by turnover in ownership and forest management personnel. Downsizing has caused a loss of management intensity due to fewer qualified foresters per unit of land area managed.

2. There is an increasing recognition of opportunities to culture multiple benefits from managed forests. **Recognition of timber production and values** within **a landscape perspective needs to be enhanced. It is important to focus on sound timber production practices which coincidentally provide benefits to other components of multiple use, landscape needs, and amenity values.**

3. Forestry practices legislation and regulations motivated by public sentiment, whether sound or principally emotional, are part of the forestry working environment.

4. Some current attitudes toward forest land use suggest an **increased need for intensively established and cultured plantations of improved forms of quality trees.** Advancement of this concept would require in-depth **documentation of practices to support an efficient and productive plantation component.**

5. Variations in sizes and types of ownership result in a variety of approaches and policies for carrying out silviculture practices in forest stands that otherwise might be treated similarly.

As research is carried out and data from past efforts are reviewed, the methods and vehicles for transmitting the resultant information should be evaluated, updated, and improved. Consumer responses and **appraisals of technology transfer effectiveness are an important part of the total research program.**

There is a need for integrating existing information, from CFRU and other appropriate information sources, to **form operational field guides and record keeping systems which can function as first approximation base lines for silviculture decision making.** These guides would also provide a framework for continuity of silvicultural practices and long-term objectives as well as for identifying the need for short-term studies to fill in missing details.

Such base lines should be **referenced to a system indicating site classification, habitat types and/or indicator species.** This could be carried out through the soil-site framework developed within CFRU by Russell Briggs. This approach is a starting point which will require modification and continuous refinement.

This will build consistency and confidence in developing silviculture prescriptions and help to focus attention on projection of probabilities for different results from different silvicultural options. **Natural systems must be understood and their responses to treatments reliably anticipated.** Are site changes distinct or continuous? Can site classifications be determined in a way that they coincide with operationally feasible treatment/harvesting areas?

Consistent documentation of operational practices can contribute to a valuable learning base. This would provide a means for direct involvement by operational personnel. They could interact directly as new information is assimilated into the system.

An operational silviculture check list could provide a convenient means for field personnel to indicate a minimum list of features that characterize a site and operation (e.g., site quality, drainage, seasonal conditions, prominent vegetation in the overstory and understory, prospects for regeneration, suitable equipment, operator qualifications, etc.).

Species for Consideration

The complex forests of our region provide a variety of options and opportunities from cultured stands of mixed species. Of the conifers, there are nine indigenous species of commercial value, and currently, three exotic species worthy of consideration. Of the deciduous, broadleaf species, there are at least nine that deserve attention for improved silviculture practices for stand rehabilitation and the production of high-quality, high-value products. Managers need specific guides for manipulating species composition and mixed species stands in order to gain full advantage of our rich forest with respect to desirable landscape attributes, wildlife habitats, watershed yields, and commercial timber production options.

Site Quality Classification

Site classification must be an integral part of effective silviculture practice. This plays an important role in incorporating growth and yield considerations as well as assigning priorities for specific silvicultural practices. Operationally, complete site quality classifications should be extended to include such features as road access, possible transportation systems, "viewshed" exposures, and proximity to manufacturing plants or markets. This topic has received some attention in past CFRU silviculture problem analyses, and is now addressed within a dedicated program under the direction of Dr. Briggs.

Genetic Tree Improvement

In many cases, outplantings for evaluation of tree genetics in our region have not been maintained at a level of culture (e.g., very little effective, state-of-the-art suppression of competing vegetation) consistent with the role of such stock as it should be employed in operational plantations. Consequently, the data from such plots will be of limited value in providing applicable information for intensive plantation production. Therefore, additional, or modified, evaluations might be necessary. In the event there is an increased need for plantation production of timber, **the role of forest genetics would be significant and would require an increased research effort.** Work with spruces, larches, and pines would be especially important.

Increasing attention to production of high-value hardwood species justifies a **review of existing knowledge and needs for supporting intensive silviculture of hardwoods.** An additional topic that has received inadequate attention is **the role of forest genetics in regeneration composition where systems are dependent on natural regeneration.**

Intermediate Practices

An area of opportunity, an area of neglect — the perennial problems of overstocked small diameter stands and definition of crop tree diameter objectives within realistic rotations. Guidelines are needed for employment of intermediate practices in intensively managed stands of the future as well as treating the spontaneous young stands that exist now. After-the-fact, remedial, catchup treatment approaches persist. Guides for, and documented examples of, **timely** silvicultural entries to focus attention on **anticipating** stand vegetation dynamics and the maintenance of growth momentum, rather than responding to established undesirable conditions, are needed. **The need for properly timed entries to culture naturally regenerated stands, and the need for focusing on appropriate numbers of crop trees per unit of land area continue to be of paramount importance.**

Thinning Techniques. Commercial thinnings can culture stands being developed for large diameter, high-value, individual tree stems and can modify species composition to improve stand quality. Precommercial thinning can be important in improving overstocked stands of natural regeneration.

At least two important considerations must be kept in mind. First, **thinning is not for every stand;** careful choices must be made according to stand conditions and site quality. Second, **it is essential to enter a stand in a timely manner.** Often, stand treatment is too late when crop trees have lost their ability to respond effectively, and the stand vulnerability to wind damage has increased. Some of the needs to improve the execution of operational thinnings are

1. non-labor intensive methods for carrying out effective precommercial thinning;
2. mechanized systems for commercial thinning, which leave healthy residual stands in a condition to respond positively;
3. guides to assist managers in deciding **when** to thin; and
4. guides to provide standards for numbers of crop trees per unit of land area with consideration for final crop tree characteristics and how those crop trees should be expected to respond to selected levels of thinning.

Early Stand Dynamics

Harvesting is the absolute basic level of vegetation management and forms the character of future stands. Methods of harvesting must be available that assure

1. maintenance or improvement of site quality;
2. undamaged residual crop trees with good potential for future growth and development;
3. no disturbance that will aggravate and escalate competition from undesirable vegetation;
4. no consequent conditions to foster insect and disease problems;
5. appropriate conditions to facilitate planting, **or** seeding, when artificial regeneration is intended to follow the harvesting;

6. appropriate seed beds for natural seeding when new natural regeneration is desired; and

7. protection and enhancement of existing natural seedlings or advanced regeneration.

Rather than evaluating harvesting systems solely on the basis of productivity and cost per unit of wood roadside, procedures are needed to incorporate harvesting values based on considerations such as the seven items listed above. Another important part of the "harvesting package" is the value of procedures for effective interaction with, and understanding by, the harvesting contractors.

Regeneration Systems. Natural or artificial? No. It is natural **and** artificial. As mentioned earlier, where artificial regeneration is desired and appropriate, we must have sound systems to ensure establishment and productive development. The technology exists, but is yet to be properly executed in Maine. Incorporation of selected plantings within natural regeneration systems could be employed to improve stand composition and productivity.

One of our greatest assets is the prolific natural regeneration of our forests. This could be more effectively exploited with better understanding of seedling origin and early history. **Techniques for improving stocking and species composition of natural regeneration, especially relative to specific harvesting systems, need to be developed.**

Undesirable Vegetation. Competition to crop trees from undesirable vegetation is a well-documented problem which requires silvicultural modification in order to achieve desirable species composition and the best possible growth rates on sites of average to above average quality.

An important problem requiring attention is the significance of **understory vegetation as an impediment to crop tree growth.** This is proving to be a recognized problem in other regions, but to date, has not been adequately addressed in our region.

There is a need to stay abreast of advances in delivery technology and other developments in vegetation management technology. Because of a greatly reduced presence of technical support by manufacturers, more local resources will be required to satisfy this need.

Other Considerations

There are many. It is a matter of priorities within limited resources. Pruning of potentially high-value crop trees and fertilizer applications are two examples. Comments, questions, and additional concerns are hereby requested (McCormack, 5755 Nutting Hall, Orono, ME 04469-5755; FAX 207-581-2833 thanks).

Silvicultural Techniques for Improving Forest Health

Dr. William D. Ostrofsky

Introduction and Program Objectives

An original problem analysis for this program was developed in 1982 and specified the importance of researching ways to improve hardwood timber quality. That analysis listed six basic problem areas (objectives) which would, with practical research applied, result in hardwood timber quality improvement. As the program evolved, the objectives were broadened to include softwood quality issues as well. Most research problem areas outlined in the first problem analysis still remain as valid candidates for high-priority research.

Past efforts were mainly focused on limiting external defects associated with stand management practices (primarily harvesting damage) (Objective 2); assessment of internal defects and tree vigor (Objective 3); and reduction of impacts of primary pests through intensive management (Objective 4). One problem area (Objective 5, relation between site quality and timber quality) may be addressed indirectly through another CFRU program area. The two other problem areas (Objective 1, Silvicultural control of branches and branch defects, and Objective 6, relation of timber quality to product quality) have not yet been addressed.

These problems as well as related issues of forest health and productivity are still seen as major impediments to realizing optimum forest values, regardless of how "value" is measured. **Past involvement of this CFRU program with forest health issues has placed it in an exceptional position to take advantage of the current public and private industrial concern and support for maintaining and/or improving forest health.**

Background and Justification

Public concern over the health of forests has risen steadily since the "acid rain" days of the mid-1970s. The issue of forest health has recently been regionally and nationally recognized as a high-priority area for research from several different analyses. For example, an innovative forest health strategic plan has been published by the USDA Forest Service, and new forest health monitoring and assessment activities have been implemented over the past three years. The Northeastern Forest Experiment Station is actively working on development of a forest insect and disease module to be an integral part of the Northeast Decision Model. Research on air quality and pollutants was rated in the top ten of 44 priority areas by the forest industry for the Northeast region. In an analysis for the northeastern region by the Hardwood Research Council, two of the three research topic areas ranked highest of 13 high-priority forest management topics include (1) impact of forest practices on changes in tree quality over time and (2) hardwood health in relation to pollutants, and root, stem, and foliar pathogens.

The concept of forest health is now defined much more broadly than simply the damaging impacts of insects and diseases on commodity values, although these impacts are still critically important. The broader view of forest health encompasses considerations for "ecosystem sustainability." Abiotic and biotic disease and insects strongly influence forest ecosystem dynamics, both as agents of stress and as beneficial agents in the processes of forest succession and sustainability. The USDA Forest Service has defined a desired state of forest health as a condition where biotic and abiotic influences on the forest (for example, pests, atmospheric pollution, **Silvicultural treatments, and harvesting practices)** do not threaten resource management objectives now or in the future. **The benefits to members of CFRU of continuing and expanding a strong research presence in this subject are apparent.**

The following is a brief description of some of the forest health issues that are regarded as being most critical to the management of forests, and particularly to Maine's industrial forests. The list should not be considered complete.

Recommendations for New Studies

1. Interaction of harvesting methods and health of residual stands. High-quality stems for future harvest will depend upon healthy, vigorous growing stock following harvesting operations. Approximately 80% of the 571,630 ha of hardwood stands alone harvested in Maine from 1970 to 1980 were cut using some partial cutting strategy. The Forest Practices Act and adoption of "New Forestry" techniques (by at least some landowners) ensures that partial cutting methods will continue to be commonly used. Silvicultural approaches to stands that are not classically structured as either even-aged or true uneven-aged, but are more often two- or multiple-aged stands, are still evolving. Harvesting systems that increase logging productivity while also minimizing mechanical injury to residual trees, **including advance regeneration and saplings, are** necessary to ensure that Silvicultural objectives are realized both in terms of product recovery and ecosystem sustainability.

As Silvicultural systems are evolving, largely as a result of historical cutting practices which have changed the nature of the working industrial forest, so too are harvesting methods and harvesting equipment. The latest method, now gaining in acceptance as a harvesting alternative in Maine, is the use of single-grip harvesters. While designed for and most efficiently used in softwood stands, they could also have an important role to play in mixedwood and younger (smaller?) hardwood stands, as well. While generally recognized as less damaging to residual trees (stands), there is little documentation or quantification of the advantages that this method could afford. Such documentation is critical if the relatively high cost of the equipment is to be justified. Knowledge of the effectiveness of this method with respect to stand characteristics that would support its use may expand use to other harvesting situations and reduce operating costs.

This is one example of how continuing the residual stand damage evaluations would be an important component of a forest health program. Other systems or harvesting methods may be equally suitable for experimentation in the search for harvesting techniques that are biologically, environmentally, and economically improved over present methods.

2. Health assessment **and productivity improvement of natural advance regeneration of hardwoods and conifers.** As with continuing efforts on the impacts of harvesting methods to residual stands, additional work is needed on assessing the effects of harvesting on advance regeneration. Although securing regeneration *per se* is not often considered a problem in the New England forests, more attention to regeneration composition and quality (another health perspective) would provide important advantages to intensive forest management efforts.

It is possible that traditional commodity or product-oriented forestry will be practiced on fewer acres in the future, as demand for other forest uses increases. Since many forest health problems are species specific, more detailed attention will need to be paid to the earlier phases of stand establishment and development. This is especially important for mixedwood stands. Information is needed on management strategies designed to manipulate species composition of regeneration resulting from various partial harvesting practices.

Techniques to manipulate species composition to a desired prescription continue to be a basic need for northeastern forests. Due to recent advances in site quality work and herbicide technology information from other CFRU programs, opportunities now exist to develop state-of-the-art prescriptions for obtaining optimum regeneration standards.

Assessment of the quality of the advance regeneration is another topic that demands attention. Decisions are presently made, for example in softwood stands undergoing pre-commercial thinning (PCT), where future crop trees are selected. Selection of the trees is largely based on spacing requirements and an intuitive estimation of the potential quality and health of the tree under consideration. Criteria needed for assessing hardwood regeneration are even less well defined, and likely will require a later "window of application" than those used for softwoods. Particular interest has been expressed by several cooperators in improving understanding of precommercial thinning options in hardwood stands, and in controlling undesirable stem form of hardwoods including forking and epicormic branching.

Guidelines need to be developed and/or refined to assist managers in determining which trees represent the lowest risk of failure, and those that represent the highest. "Failure" in this case may be either direct mortality, slow or unproductive growth, or poor quality or form upon reaching maturity. Finally, to be practical, the timing of the use of the guidelines needs to be coordinated with some stand management practice(s) (PCT, thinning, herbicide treatment, etc.).

3. Forest health and silvicultural manipulation of stands. Many damaging agents operate continuously throughout the forests and occasionally become important enough to seriously hamper forest production. One of these problems, long recognized as a serious threat to forest productivity in Maine, is the beech bark disease. Active research has been ongoing by the USDA Forest Service on stand management techniques that could be used to alleviate damage from the disease. Several past CFRU projects of this program are also in place, and could be readily expanded to add to the information on disease management alternatives. The USDA Forest Service study is scheduled to terminate in 1995-96. Fate of long-term information from this and other studies remains in question.

The impact that the beech bark disease has had on forest (woody plant) biodiversity is another aspect of the forest health issue upon which research should focus. Significant, but natural and rather subtle, changes have been brought about by this particular disease in many stands throughout Maine. There is a need to increase the awareness that changes in biodiversity can be the result of a natural process and are not restricted to immediate impacts of the more visible forest practices with which biodiversity changes are often associated.

Use of herbicides to control beech regeneration is also a candidate for future research. Use of selective herbicides to manipulate regeneration of hardwoods for the development of hardwood stands has not been attempted on an operational scale in Maine. Recent observations and practices from Europe could be highly beneficial in both improving forest health by managing the beech bark disease and also in regeneration manipulation, a research need stated earlier.

Another topic area currently being developed is the use of papermill sludge ashes and wood ashes for amelioration of sites prone to unacceptable losses of elements (primarily calcium) due to harvesting removals and/or affected by pollution inputs. These efforts could lead to increased outside funding, and they provide a natural continuity between the current five-year research period and the next one.

4. Opportunities to "showcase" responsible management **and healthy forests.** Just as there are opportunities for improving the condition, appearance, and health of the managed forests, there is also the opportunity to "showcase" examples where forest management practices have accomplished this goal.

The timing seems appropriate for exploiting the positive effects of forest management on forest and ecosystem health to a public already conditioned to the terms. This effort would largely be a technology transfer or, more appropriately, a communications effort. Being responsibly concerned with and taking action to improve forest health is a tremendous public relations opportunity. At least one cooperator has already taken advantage of this aspect with regard to beech stand management.

5. Continuing Projects. Research on land spreading papermill sludge ash and wood ash should continue on a maintenance basis on established plots and study locations. No new work on land spreading of papermill residuals is proposed for the new five-year research period.

Due to this program's involvement in forest health related issues from 1982 through 1990, several opportunities exist to expand studies on several established study sites. Particularly, sites that already have some considerable documentation of conditions and treatments offer an exceptionally cost-effective opportunity for research exploitation.

Site Quality And Site Classification

Dr. Russell D. Briggs

Introduction

Increasing demands continue to be placed on Maine forest lands for the production of wood and fiber. At the same time, increased levels of public concern over noncommodity values are providing constraints on the land base that is intensively managed for production of timber products. Conflicts between commodity production and noncommodity values continue, often the subject of vigorous, sometimes heated debate. There are two possible outcomes: (i) reduce current product output along with associated economic benefits, or (ii) utilize intensive forest management to maintain current levels of production on fewer acres.

The capability to assess the level of productivity that can be expected for a given site is a critical component of rational allocation of management input to forest land. The relationship between site characteristics and vegetation development is the fundamental basis of silviculture and forest management. Matching site attributes with silvical characteristics has been a dominant theme, guiding the choice of species to be favored in tending operations or to be utilized in reforestation. That theme was expanded upon during the past 35 years with tremendous scientific effort devoted to the identification of soil-site variables influencing forest productivity and their subsequent application to site classification.

Studies of the relationship between growth and soil-site variables in Maine, ongoing since the early 1950s, have focused on spruce and fir. Results from past studies combined with recent work have been incorporated into a site classification guide. The field guide utilizes soil drainage class, soil texture, and soil depth to classify sites into five productivity classes for spruce and fir.

The overall objective and approach of the Site Quality and Classification program remains the same: to develop a practical productivity-oriented site classification system for use in Maine. The shift in emphasis towards the hardwood species will effectively extend the classification system beyond the spruce-fir forests, which are most common at the extremes of soil drainage class, to cover the entire landscape.

Although the primary focus of this program is development of a site classification field guide, the research base must remain broad. Full advantage should be taken of supplemental funding that becomes available when it has the potential to enhance our understanding of the interaction of site quality and management.

Individual Projects

1. Site Classification • Hardwoods. Incorporating hardwoods into the productivity-oriented site classification system presents a challenge far beyond that posed by conifers. The pure, even-aged conifer (spruce-fir and fir-spruce) stands are relatively simple systems at the same successional stage. Unmanaged stands are generally restricted to the lower third of the spectrum of site quality. The intensively managed (herbicide release, PCT) young fir-spruce stands probably extend at least into the middle third of the site quality spectrum. In contrast, hardwood stands occupy land encompassing the full range of site quality, and usually include multiple species and age classes characterized by a complex stand history. Periodic harvests ranging in intensity from light thinning to group selection have altered species composition and affected growth of the remaining trees.

Maine is a large state, which spans more than four degrees each of latitude and longitude. Consequently, physiography and climate vary across the state. The biophysical regions delineated by McMahon provide an initial stratification for evaluating the relationship between soil-site variables and tree growth. The biophysical regions, delineated on the basis of physiography, vegetation, and climatic variables, overlap reasonably well with the climate zones delineated by Briggs and Lemin in 1992. Maps of both have been presented in past CFRU annual reports.

Within those broad regions, an examination should be completed of relationships between species composition and soil-site characteristics. The applicability of the habitats identified for the White Mountain National Forest (WMNF) in New Hampshire currently are being assessed. The Western Mt. biophysical region was chosen for the initial work, due to its proximity to the WMNF.

The USDA Forest Service is currently in the process of developing a national hierarchical framework for ecological units, which form an ecological basis for ecosystem management for the National Forests and Grasslands. Although Maine has very little federal land, it is important to be aware of how this system relates to the site classification system developed by the CFRU.

2. Site Quality - Precommercial Thinning (PCT). Although the field work has been completed, significant effort was devoted to reexamination of the data following scientific review associated with submission for publication in Soil Science Society of America Journal. Effort is also expended each year in technology transfer and training for dissemination of results to foresters. This project will be phased out following review and publication of the soil chemistry data along with completion of M.S. thesis by Joseph Pitcheralle. Short-term response (3-yr volume increment) of balsam fir to PCT, in combination with results of past work in unmanaged mature stands, was used to classify sites into separate site types by productivity classes.

3. PCT, Water Quality, and Crop Tree Response: The Continuing Saga of the Weymouth Point Watershed. This project is a prospective study across soil drainage class, providing the opportunity to examine effects of both PCT and fertilization on soil solution chemistry in addition to crop tree growth response. Furthermore, this project has provided the means to continue monitoring stream chemistry on the treated and clearcut watersheds.

Continued, periodic monitoring of stream and soil solution chemistry of this historic watershed is critical to increase our understanding of the long-term impacts of forest management on nutrient cycling dynamics in a spruce-fir forest ecosystem. Investing in the maintenance of a temporally complete record of stream chemistry for a watershed with documented management history will continue to attract financial support for future research. It is worthwhile to point out that the availability of the water chemistry record at the Weymouth Point watershed for 1979-1988, in existence due to the efforts of Drs. Maxwell McCormack and C. Tatersall Smith, was an important contributing factor to our success in obtaining funding for the current study.

4. Verification of Climate Zones. Efforts are currently underway to verify the climate zones delineated by Briggs and Lemin in 1992, in association with Dr. Ivan Fernandez, as part of a larger project to evaluate the relationship between rates of nutrient cycling and climatic variables. Four transects were established across the climatic gradients. Plots were established in closed canopy hardwood stands having a red maple component growing on well and moderately well drained glacial till soils. Red maple was chosen because of its presence throughout the entire state. Air and soil temperature has been monitored at the transect ends using continuously recording data loggers.

Results from this four-year project will improve our understanding of nutrient cycling across a climatic gradient, significantly expanding our knowledge base across upland sites.

5. Water Quality and BMPs. There is an opportunity to install a monitoring study to evaluate the impacts of BMPs on maintenance of stream water quality during and following harvesting. Approximately $30,000 is available for a one-year project to monitor water quality (chemistry, sedimentation) with and without BMPs. Given the recent problem with camp owners suggesting that harvesting had resulted in higher P levels in a small lake, such a project seems timely.

The Future: 1996-2001

The difficulties with assessing productivity of mixed species stands that have been repeatedly entered for extraction of products guarantees that site classification will still be an active research area as the turn of the century approaches. However, significant progress is anticipated in our understanding of species composition, soil-site characteristics, and the degree of variability in productivity within and between sites.

There is also opportunity for advancement from joint research among the three major projects within CFRU. Detailed characterization of those sites used in the vegetation management work of Dr. McCormack for which pre- and post-treatment vegetation data exist may lead to improved understanding of regional differences in vegetation response following harvesting and tending operations. Characterization of sites that may be used to evaluate forest health by Dr. Ostrofsky may provide useful information.

After a discussion with Dr. Maxwell McCormack, I concur with his assertion that standardized collection of site data across ownerships would greatly advance our understanding of the impacts of site quality on vegetation dynamics. Every forester should make an effort to record the site type (as indicated by soil drainage class, texture, and soil depth) along with associated dominant species of trees, shrubs, and herbs, of the sites visited during the course of operations. It would take very little effort to ensure that each vehicle contain a packet of standardized forms (which could be developed by CFRU). This information would be periodically entered into the company CIS and stored as an attribute file, along with continued observations of vegetation growth and development following any treatment.

Such a data base would be useful for analysis inhouse as well as collectively across ownerships (by CFRU), resulting in production of a site-specific field guide advising which species of competing vegetation would be problematic following harvesting. Such a guide would be periodically reviewed for consistency with continued observations. Over the long term, it would provide excellent documentation of competing vegetation as well as species composition and differential successional pathways across site types.

Taken alone, the effort required to routinely collect this minimal data would be relatively small. I recognize that the majority of foresters are already operating at extended capacity due to repeated downsizing. Significant long-term gains can be anticipated as a result of collecting standardized site data, and it should be seriously considered. In terms of practical knowledge, those gains will likely be AT LEAST as important or useful as the results generated by any individual CFRU research project.

Sludge and Ash

Dr. Robert K. Shepard

Historical Statement

The research on sludge and ash was initiated in 1987. The primary objectives of this research are to study the effects of these residuals on (1) growth of commercially important conifers, (2) foliar nutrient concentrations, (3) soil chemical properties, and (4) growth of competing vegetation. Plots have been established at six locations around the state. Treatments consist of different application rates of tl) a mixture of secondary papermill sludge and wood ash, (2) a mixture of primary and secondary papermill sludge, and (3) wood ash. Only one of the three residuals or residual combinations was applied to plots in a given stand. The first treatments were applied in 1988.

Current Projects

The locations at which studies have been established, and the objectives of each study follow.

1. **Tl R8 WELS -** effects of four rates, three times of application, and application for one, two, or three successive years of a mixture of second ary papermill sludge and wood ash on planted black spruce diameter and height growth, com peting vegetation, soil chemical properties, and foliar nutrient concentrations.

2. **Northfield Twp. -** effects of five rates of wood ash on diameter growth of planted red pine, competing vegetation, soil chemical properties, and foliar nutrient concentrations.

3. **T14 R5 WELS -** effects of four rates of wood ash on soil chemical properties.

4. **Jim Pond Twp. -** effects of two rates of a mixture of primary and secondary papermill sludge on diameter growth of planted red pine, soil chemical properties, and foliar nutrient con centrations.

5. **Coplin Pit. -** effects of two rates of a mixture of primary and secondary papermill sludge on growth of planted red pine, soil chemical prop erties, competing vegetation, and foliar nutri ent concentrations.

6. **Letter E Twp. -** effects of four rates of a mix ture of primary and secondary papermill sludge on diameter growth, height growth, and foliar nutrient concentrations of planted red pine.

Expected Directions

1. Continued measurement of studies in which treatment effects still exist. It is important to determine the magnitude and duration of both positive and negative effects.

2. A study of the effects of papermill sludge or wood ash on growth of older conifer stands. Such stands should be relatively immune to the effects of competing vegetation and closer to the age at which additional growth due to treatment could be harvested.

3. Research on the properties of wood from short-rotation stands and how this wood may differ from that presently being harvested from much older stands. This would include physical properties, mechanical properties, and pulp yields. This research would complement re search that I am presently conducting on wood properties.

Tree Improvement

Dr. Michael S. Greenwood

Introductory Note

While modest, the support provided by CFRU for the following two projects has been essential to keep them going. The hybrid larch program was begun with assistance from Dr. K. Carter, and complements some of her work. In addition, the growth performance of larch hybrids has formed the basis for some of Dr. R. Seymour's projections that show that plantation establishment may be more cost effective than natural regeneration. The role of plantations in the framework of attempts at ecosystem management (or New Forestry practices) requires extensive evaluation.

Production and Testing of Fast-Growing Conifer Families

Project history and objectives. The objective of this project is to evaluate hybrid larch families and to develop cost-effective procedures for multiplying specific families. The study, initiated in 1987, is in the process of screening over 50 full-sib families for fast-growing, well-adapted crosses (both intra- and inter-specific) between three larch species. All crosses have been produced, a manual on managing a breeding orchard published, and a field test established in collaboration with Scott Paper Co.

Current projects. The Johnson Mountain hybrid larch test has been through two growing seasons — see this report for second year growth results.

Expected direction.

* 1995-2000. Mass production of selected hybrid families via rooted cuttings is planned for further evaluation by establishment of additional field tests at the Penobscot Experimental Forest and elsewhere.

  1996. Cutting hedges will be established using the remaining seed from the breeding program; additional seed for some crosses will be produced in Scott's Unity larch seed orchards in the spring of 1995.

  1996. Production and establishment of rooted cuttings.

Environmental Aftereffects on Genetic Variation in NE Conifers

Project history, objectives. The objective of this study is to verify the hypothesis that completion of a tree's life cycle under increased temperature results in progeny that exhibit greater height growth and lower frost hardiness, changes that seem directed towards adaptation to warmer temperatures. Such apparently directed changes have been observed in identical crosses of Norway spruce and Scots pine produced in environments with differing average temperatures. The project was begun in 1991, to compare identical crosses made inside and outside the greenhouse using identical parents of three species of larch. A common garden comparison of these crosses was begun in 1993, and the results of the first measurements are reported in this annual report.

Current projects. Continuing height growth measurements and frost hardiness determinations on 12 families which were made indoors and out.

Expected direction. Verify these results on other native species, such as jack pine, pitch pine, and possibly black or red spruce, which are much easier to breed than larch, and characterize the molecular genetic basis for the observed phenotypic changes.

1995-96. Establish new breeding populations of jack pine, pitch pine, possibly black spruce.

* 1996-97. Make crosses.

* 1997-2000. Evaluate crosses.

Tree Improvement

Dr. Katherine K. Carter

Tree improvement has been a part of the CFRU :arch effort since its founding in 1976. The CFRU port for tree improvement research has always n in the form of supplemental funding, in support he primary funding for the project which is pro- :d through the College, by state and federal funds.

Overall Project Objective

To carry out research directed toward increas- the productivity of Maine forest lands through application of genetic improvement techniques. project emphasizes field research, with support- laboratory and greenhouse research.

Program History

Research in the tree improvement project can oughly grouped into three time periods. During first period, 1974-79, a large number of prov- ıce tests were established along with exotic spe- trials and experiments related to greenhouse ving and field planting techniques. Both soft- ıds and hardwoods were included in the research. ing the period 1980-90, research emphasized ıarily softwood species. In addition to provenance s, research expanded to include family tests, -tree selection, and clonal propagation techniques. :e 1990, the project has included continuing uation of existing in-ground tests to determine ;-term growth, as well as expanding into some e laboratory studies of characteristics that are ly to be related to field growth. These areas ıde

- genetic influences on root growth,
- genetic variation in cold tolerance,
- early selection techniques (with Dr. M. Greenwood),
- genetic variation in wood qualities, and potential for genetic test plantations to determine genotypic response to climate.

Some of the types of information gained through project include the following.

Provenance (seed source) tests and exotic spe cies trials, including black spruce, jack pine, green ash, white ash, white spruce, balsam fir, Douglas-fir, black walnut, Norway spruce, larches, Scots pine, and western white pine.

Progeny tests, containing open-pollinated half- sib families from the Northeast, including white spruce, Japanese larch, black spruce, tamarack, balsam fir, and paper birch.

Related lab testing including juvenile-mature correlation useful for early selections (black spruce and jack pine); RGP tests of seedlings to help identify families with good post-planting performance; wood specific gravity values for exotic larches; and cold tolerance variation among Japanese larch families.

Current Projects and Future Directions

The project currently focuses on extracting the maximum amount of information from the many field trials already established. Earlier evaluations focused on initial survival and early growth; now that many of the tests are on the order of 15 years old, more reliable information regarding genetic variation in long term growth and yield can be obtained. Provenance and family tests of black spruce, jack pine, larch species, and Scots pine are each replicated at two or more locations in Maine. Growth rates at this age are expected to have stabilized and measurements over the next five-year period should allow reliable identification of optimum planting stock. Comparisons will also be made to earlier measurements in these same plantations to identify any changes in growth patterns that may have occurred over the years. Comparisons can also be made for the same genetic entities growing on different sites, to examine the effects on growth. Variation in stem form appears to be large in several species, including larch, jack pine, and Scots pine. Trees will be evaluated to determine the genetic component of this variation in form. More work could also be done on wood qualities; however, if this is to be pursued additional funding would be required.

In response to concerns about the potential for future climate change and its effect on forest growth in Maine, it would also be useful to examine genetic traits that would be relevant in this context. Two trait clusters that are known to be under some degree of genetic control in most species, and that have important implications for tree adaptability to differing climates, are cold hardiness (both maximum levels, and patterns of development and loss of hardiness), and shoot extension (a combination of phenology and shoot elongation rate). Genetic variation in these traits can most conveniently be established by examining variation among half-sib families. Family plantations that are duplicated in more than one climatic zone in Maine exist for white spruce, black spruce, tamarack, Japanese larch, and hybrid larch. Examination of variation in cold hardiness and shoot extension phenology and rate in these plantations could identify genetic variation among families and also may provide information about the influence of climatic variation on family growth and survival.

Research as described in the preceding two paragraphs (except for the wood quality analyses) could be carried out over the next five years, given continued funding at the current level.

Growth and Yield

Dr. Robert S. Seymour

Background

In the 1990 review of future CFRU research rities, growth and yield research was one of the ranking concerns of the CFRU cooperators. In onse, a long-term program was begun to develop owth simulator for managed northern conifers. ing sabbatical leave sponsored in part by CFRU, quired the TASS (Tree and Stand Simulator) el from the British Columbia Ministry of Forests all, 1991. The TASS Model - unlike other pos- e growth simulators for the Northeast such as TWIGS or FIBER - is capable of "growing" in- dual trees in three-dimensional space. The re- ng model thus has the unique capability to ict yields and compare results from silvicultural ments where spatial patterns are important, ı as corridor thinning with follow-up spacing, mercial thinning patterns in developing pole-size ds, and optimum plantation spacing.

Current Projects

Adapting the model to Maine conifers involves e complementary lines of research:

basic research (field and laboratory) on tree growth processes, such as crown architecture, leaf-area:sapwood relationships, and growth efficiency (measured as the amount of stem wood produced per unit of growing space or leaf area). Results of these studies are used to formulate the regression equations necessary to convert TASS from BC species to Maine conifers.

establishment and remeasurement *of long-term field studies* to test key model functions and validate future model predictions about stand development. Although model development offers the quickest method of addressing current silvicultural decisions and future yields, modelling must be coupled with extensive "real world" data on tree growth and stand development. Recent improved access to the long-term research results from the USDA Forest Service's Penobscot Experimental Forest has provided an important, irreplaceable data set, and work is currently underway to compare young stand development under various shelterwood regeneration regimes.

computer programming and *software development* to adapt the existing TASS software. Currently, no CFRU resources are directed explicitly to this objective.

Accomplishments during the past several years have been modest and have been focused mainly on the first two areas.

Future Directions (1996-2001)

Prototype version of TASS-Maine. A version of TASS that "grows" managed balsam fir stands will be available early in this 5-year period. The basic biological research for fir should be completed before 1996; potential obstacles are the availability of additional CFRU resources directed to computer programming and software modification.

Yield predictions for managed fir stands under various silvicultural regimes. Once the prototype model is operational and validated against existing databases, we plan to carry out and publish analyses of several important silvicultural issues. Initial simulated comparisons will focus on managed, naturally regenerated even-aged stands dominated by fir, since this is the primary species used in prototype development. Current high-priority issues include the method, residual density, and timing of future commercial thinnings in developing young stands, and how these treatment decisions are affected by prior precommercial operations such as herbicide release and spacing.

Extension to species other than balsam fir. If preliminary model applications are .promising and funding is available, additional field studies will extend the model to other important conifers. Additional species will include red spruce, white spruce (plantations), eastern white pine, and possibly eastern hemlock and plantation larch.

Extension to multi-cohort and mixed-species stands. TASS, as now formulated, is applicable mainly to even-aged monocultures. A long-term goal, if the above items are accomplished, is to adapt TASS to grow other kinds of stands, including those with mixed-aged and mixed-species structures. Such a model would be valuable in comparing proposed ecologically based silvicultural systems with conventional production silvicultural regimes.

Martens And Forestry

Dr. Daniel J. Harrison

Problem Statement

American marten are widely considered to ıire mature and overmature conifer-dominated tats. These habitats are of economic importance ıe forest products industry and to regional econo- ; over large areas of North America. In Maine sts, trends towards younger age distributions, ter rotations, and an increased deciduous com- ent have raised concerns about the future suit- ty of forests for marten. Maine supports the est population of marten south of Canada, and ılations in adjacent states and provinces have ntly experienced significant population declines. act, marten have received special status desig- on in Vermont (endangered) and Newfoundland eatened). Marten are considered to be a good cator species for mature and overmature forests use of their large spatial requirements and their eived requirement for older forests. The species onsidered as an old growth indicator species in majority of western forests where the species ırs. Most research with marten has been con- ed in the western United States where forests less diverse in both structure and species com- tion. Additionally, most previous studies have ı constrained by small samples sizes of radio- ıred animals. Marten in the Northeast may be to use a wider variety of forest types because species diversity and increased vertical height rsity. Additionally, levels of horizontal and struc- l diversity required by marten may occur at er ages in eastern forests with a mixed species ponent. Marten are widely sought for their fur, it is difficult to separate the relative influences mber harvesting and trapping on marten popu- ıns where both activities occur.

Associated Projects

1988-91: Social organization, summer habitat selection, survival, and population sustainability of marten were investigated in an industrial forest (T4 Rll, T5 RID characterized by extensive forest harvesting and intensive trapping.

1990-94: Density, reproduction, home range areas, seasonal habitat selection, and survival of marten were monitored in a forest preserve (Baxter Park) without recent timber harvesting or trapping. Results were compared between the industrial forest site with trapping and the forest preserve. Additionally, dispersal of marten from the forest preserve to the industrial forest was investigated.

3. **1990-94:** Measure microhabitat characteristics at summer and winter rest sites used by radio-collared marten. Compare sites used among seasons and evaluate microhabitat selection by comparing occupied sites to random points distributed throughout the study site.

4. **1992-95:** Incorporation of spatial data for radio-collared marten to assess influence of fragmen tation on occupancy of residual forest patches. Test for correlations among fragmentation in dices and home range areas of individual marten.

5. **1994-98:** 50% of the industrial forest site (T5 Rll) is being closed to timber harvesting. We will simultaneously monitor density, home range areas, seasonal habitat selection, and survival on the industrial forest with trapping (T4 Rll), the industrial forest without trapping (T5 Rll), and within the forest preserve (Baxter Park). Comparisons are designed to isolate the indi vidual influences of trapping and timber har vesting on marten populations.

6. **1994-96:** Assess relative difference in small mammal populations, which serve as primary foods for marten, between different forest types based on stand composition, stand age, and structural (vertical and horizontal) diversity.

Expected Directions

1. I have proposed a study to the National Council of the Paper Industry for Land and Stream Improvement to assess differences in microhabi tat characteristics associated with different levels of use intensity by marten. This work would take advantage of the large database of marten relocations on our existing sites, and would provide an opportunity to interface our landscape level analyses with stand-level for estry recommendations.

2. Incorporation of our findings into a multi-town ship GIS to develop a marten habitat supply model. Attempt to interface the marten model with forest management objectives to achieve compatible and economically viable uses.