CFRU Information Report 43

1998 ANNUAL REPORT AND

RESEARCH SUMMARY OF THE

COOPERATIVE FORESTRY RESEARCH UNIT

COLLEGE OF NATURAL SCIENCES, FORESTRY, AND AGRICULTURE

MAINE AGRICULTURAL AND FOREST EXPERIMENT STATION

UNIVERSITY OF MAINE

ORONO, MAINE 04469

Miscellaneous Report 411 December 1998

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

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ADVISORY COMMITTEE CHAIR'S REPORT

This has been a year of change for CFRU. Personnel have changed, and the Advisory Committee has voted to make significant changes to the structure of the Unit. It is my belief that the changes will result in a stronger, more efficient CFRU.

Dr. William Ostrofsky has left the Unit after many years of service. He has taken a position managing the Office of Professional Development. I would like to congratulate Bill and thank him for his years of excellent service to the CFRU.

Dr. Bob Wagner joined CFRU this year as the Unit's silviculturist. Bob has extensive experience managing cooperatives in the Western U.S. and Canada, and brings expertise in silviculture, vegetation management, and public perceptions of forest management.

Shortly after arriving, Bob, with approval of the Advisory Committee, decided to accept a tenure track position with the Forest Ecosystem Science Department. This position is tied to the Penobscot Experimental Forest and the Forest Ecosystem Research Project, and receives funding from the USFS and the University of Maine. The Advisory Committee has agreed to cover Bob's summer salary and provide operating dollars, on a two-year trial basis.

Bob has already added value to the Unit with new research, work on the restructuring committee and organizing an excellent summer field tour. The summer tour was at the Black Brook Forest on J.D. Irving land in New Brunswick. I would like to thank the forestry staff at Irving for their time and openness in discussing their forest management strategies.

A number of large land transactions put the status of a significant portion of the CFRU land base in question. Approximately 3.2 million of the 9 million acres in CFRU changed hands in 1998. As of the time of this writing, Plum Creek, who purchased the SAPPI lands, has elected to remain in CFRU. I will make every effort, in concert with the Advisory Committee and Dean Wiersma, to keep these acres in the system.

1998 proved to be a critical year in CFRU funding. The Unit is required to maintain a reserve fund of one year's budget. This reserve fund had accumulated a substantial surplus, and the Unit has been operating under deficit budgets for a number of years to reduce that surplus.

In addition, budgets have been essentially flat for the past ten years, while salary and benefit costs have increased. The net result has been a 45% reduction in operating funds for the Unit.

1998 was the last year that the Unit could operate with a deficit, and the resulting loss in funds would have been catastrophic. Polling of the Advisory Committee indicated that there was no support for the required increase in dues to make up the deficit. In addition, the pending sales of large blocks of land in Maine put the stability of the contributing land base in question.

For these and other reasons, the Advisory Committee held a series of meetings this summer to determine the future of CFRU. It was clear that we could no longer afford to fund a Unit with three full-time scientists and support staff, yet the Committee wanted to preserve the Unit's tradition of applied research and long-term relationships with scientists.

The Committee approved a new structure for CFRU that is project based, where funding for scientists and technicians is primarily on a project-by-project basis. As envisioned, a director, who would coordinate research being done by project scientists, would guide the Unit. The proposed structure substantially reduces the amount of fixed salary dollars and increases funds available for discretionary spending on projects, and thus allows the Unit to more easily respond to changing research priorities and changes in the land base. Scientists, who could come from both inside and outside the University of Maine, would submit proposals for Advisory Committee approval, based on established research priorities.

The Advisory Committee will be voting on a final version of this structure, along with a transition plan in January of 1999. The coming year will complete the cycle of change begun in 1998 and establish the Unit in its new form for the year 2000.

I extend my appreciation and thanks to the CFRU scientists and staff, the Advisory Committee, and Dean Wiersma. This has been a difficult year, and everyone has worked hard for the benefit of the Unit. I have every confidence that we have embarked on a process that will result in a stronger, more responsive CFRU.

Peter Triandafillou, Chair
CFRU Advisory Committee

DEAN'S REPORT

Significant efforts have been spent during the last year to develop a new operating structure for the Cooperative Forestry Research Unit. These efforts have already resulted in many changes to the CFRU, and will likely result in still further changes. Throughout this period, it has always been the intent of the cooperating industries and the University of Maine to continue to improve our research partnership in the years to come. Change is often not an easy process. However, I am confident that when the new CFRU structure is in place and functioning it will be an organization able to meet the forest research demands of the 21st century in a strong and effective manner.

In the face of widespread and substantial adjustments that have occurred in the very recent past within the state, the forest industry, and the forest itself, it was felt a new organizational approach was needed if CFRU were to survive and be effective. This restructuring will result in a more efficient use of the support funding, and the scientists' time. Central to the restructuring has been a reduction in the commitment to full-time CFRU faculty salaries. This was necessary in order to release critically needed funding for operating support.

This has resulted in personnel changes that have not been easy, and do not come without associated costs of their own. There is still much work to be done. However, CFRU will now be in a better position to strategically address the substantial list of research priorities it has developed. I look forward to working with all the cooperators, scientists, and staff as we mold a more financially secure, stronger, and more efficient research organization.

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

BALANCE SHEET
1997-1998

Period 10/1/97-9/30/98

ASSETS:

BALANCE FORWARD SEPTEMBER 30, 1997	$92,812.63	
INVESTMENTS: 10/01/97 - 09/30/98	$39,123.22	
CONTRIBUTIONS RECEIVED 01/01/98-09/30/98	$433,029.00	
Less FY99 Budget (Approved 08/21/98) Balance	$453,000.00	
on Hand 09/30/98		**$111,964.85**

FY98 BUDGET (Included in this budget are special funds for McLaughlin's project $17,706.64)		$540,840.64
EXPENSES: 10/01/97-09/30/98		
5-6-42810 Administration-Ostrofsky	67,441.71	
5-6-4281 1 Silviculture-Wagner	91,719.75	
5-6-42812 Soil Site-McLaughlin	138,964.33	
5-6-42813 Weymouth Point-McLaughlin	31,003.62	
5-6-42814 Ash/Hardwood-Ostrofsky	98,390.75	
5-6-42815 Wood Quality-Shepard	6,865.80	
5-6-42816 Tree Improvement-Greenwood	13,584.95	
5-6-42817 Tree Improvement-Carter	28,187.75	
5-6-42818 Growth/Yield-Seymour	4,917.24	
5-6-42819 Pine Marten-Harrison	32,724.99	
TOTAL EXPENSES: 10/01/97-09/30/98		513,800.89
UNSPENT FY98 BUDGET (BUDGET ALLOCATED)		$27,039.75

Balance on Hand 09/30/98	111,964.85
FY99 Budget Ostrofsky (10/02/98) returned to Control	55,782.00
Unspent FY98 Budget returned to Control	27,039.75
Total Unallocated Funds	**194,786.60**

CFRU LEADER'S REPORT

The restructuring of the Cooperative Forestry Research Unit has been an overriding concern for the staff and scientists during the past year. However, despite a year of changes, significant progress has been made on a number of research priorities.

Early in 1999, Dr. Robert Wagner was hired to fill the Silviculture Program position left vacant by the retirement of Dr. Maxwell McCormack in 1997. Subsequent program changes have occurred, as detailed earlier in the Dean's report. Dr. Wagner now fills a dual role of Program Leader for the Forest Ecosystem Research project at the Penobscot Experimental Forest, and also a a Silviculture project leader for CFRU. Because these projects are very closely related, Dr. Wagner's new research effort will involve development of a high level of cooperation and integration of the research efforts. A strong start has already been made, with new projects on herbicide efficacy and the preparation of a silviculture problem analysis underway. A new project on precommercially thinned spruce-fir stands nearing a first commercial harvest was started this summer at the Penobscot Experimental Forest in my program. Dr. McLaughlin has continued his work with hardwood site classification, and has several new research initiatives developing on BMPs and water quality issues. These efforts have been at the center of developing new and appropriate management guidelines to ensure continued forest health and productivity. The project scientists have also continued productively on a number of studies. Dr. Greenwood is developing a project examining planting of gaps with fast-growing hybrid larches. Dr. Carter and graduate student L. Mann have completed an evaluation of Norway spruce provenances. The effects of various intensive management practices on wood quality of balsam fir, red spruce, white spruce, and red pine have been under investigation by Dr. Robert Shepard. The American marten project, which CFRU halfsupported as one of a number of sponsors over the past four years, is now entering its final year of planned study. The completion of this study will result in much new and critical information for land managers.

The many changes with which CFRU has had to deal with over the past year has provided a challenging work environment for all. To accomplish what is outlined in the following research summaries has taken a good deal of resolve and concentration, given the increased demands that the restructuring has brought. I thank all the scientists and staff for their patience and understanding, and for the professionalism that they have shown in these often stressful times, and I complement them on their achievements.

William D. Ostrofsky Director
Office of Professional Development
(Formerly) Leader, CFRU

SEASONAL TOLERANCE OF RED SPRUCE AND BALSAM Fm TO GLYPHOSATE, IMAZAPYR, AND TRICLOPYR APPLICATIONS

Dr. Robert G. Wagner

Introduction

Glyphosate herbicide registered as Accord® and Roundup® (Monsanto Corp.) has been widely used to control competing vegetation for conifer release in Northeastern U.S. forests. Refinement of Roundup® prescriptions, after its introduction in the late 1970s through the late 1980s, had achieved relatively consistent vegetation control with minimal conifer injury. Replacement of Roundup® with Accord* plus Entry II® combinations in the late 1980s marked a significant change in product formulation. While Accord® has produced results similar to that of Roundup®, changes in the formulation also have produced noticeable increases in conifer injury by Maine forest landowners (January 1998 Monsanto roundtable meeting, Bangor, ME).

Similar changes in spruce injury with glyphosate also have been recently noted in Canadian forests. Vision® herbicide (a Canadian registered glyphosate product for forest use that is the same as the original U.S. Roundup® product) applications at 4.0 to 6.0 L/ha in mid-September, have produced a noticeable increase in the amount of needle browning and potential growth loss in white spruce. Such injury has not been a common occurrence.

Based on this recent operational experience in the U.S. Northeast and Canada, developing a better understanding of the relationship between glyphosate application and conifer injury was identified as an important issue by CFRU cooperators. In addition, imazapyr (Arsenal®) is often applied in mixture with Accord® to enhance the spectrum of vegetation control, but can produce significant conifer injury. Triclopyr (Garlon 4®) also is registered for conifer release and known to have a limited "window" of application to minimize injury to conifers. Documenting the seasonal tolerance of red spruce and balsam fir to applications of these herbicides also is important to improving conifer release in the northeastern U.S..

Phenological Indicators of Herbicide Tolerance

Significant gains could be made if a practical field method (i.e., quantitative, calibrated, and technically simple) were available that could determine when during the growing season spruce and fir are relatively tolerant to glyphosate, imazapyr, and triclopyr application. Current work sponsored by Monsanto Canada at the Ontario Forest Research Institute in Sault Ste. Marie, Ontario, indicates that tolerance to glyphosate in black spruce is primarily the result of *avoidance* of glyphosate uptake rather than physiological *tolerance* to chemical. Based on this finding, a variety of methods for judging the development of avoidance mechanisms in balsam fir and red spruce have been proposed. These methods are based on the principle that avoidance of uptake is largely the result of the deposition of wax on needle surfaces.

Needle epicuticular wax characteristics and wettability are believed to be the direct factors that affect glyphosate uptake by conifers. Experiments have demonstrated clear effects of light, temperature, and water status on the quantity and quality of epicuticular waxes. In conifers, wax biosynthesis is thought to cease within a few months of needle elongation. Typically wax biosysnthesis would be sufficient by mid-August to permit herbicide application. However, field conditions during relatively wet years, or specific microsites where conifers are in low light, high humidity, low wind conditions, may result in lower wax biosynthesis and greater potential for herbicide uptake.

A new method for judging the degree of shoot lignification holds some promise as a means for developing a practical field method for assessing spruce tolerance to herbicide application. The timing of shoot lignification from the base to the apex of newly expanding shoots may be related to the timing of needle maturation and wax deposition. The procedure adapted by F. Vaclavik (unpublished) for measuring shoot lignification involves splitting stems longitudinally, treating with an acid and phloroglucinol solution, and observing for color change. A red staining of the xylem, near the tip of the stem, indicates that the stem is fully lignified, the needles fully developed, and as a result herbicide uptake should be low. This lignification test can potentially serve as an indirect measure of herbicide resistance.

The initiation and development of terminal buds is another indirect method for judging needle maturation and safe glyphosate application. Templeton et al. (1993) demonstrated practical methods for dissecting conifer buds and proposed that bud development indicates the seasonal progression of physiological condition of spruce seedlings. Determining the nature of the relationship between bud development, needle maturation, and herbicide resistance also may provide a useful indicator of herbicide tolerance.

One of the effects of needle maturation and wax accumulation on needles is increased resistance to water loss through stomata and directly through the surface of the needle. Similarly, needles with thick waxy depositions more easily shed herbicide droplets that settle on them, and the wax layer reduces the entry of water and herbicide into needle tissues. An indirect means of determining extent of wax accumulation is to measure the rate of water loss from detached needles. This "cuticular transpiration" (so named because it measures water lost through the needle surface or cuticle after the stomata close) also may serve as a means of determining readiness for herbicide application.

Experiment Installed

In June 1998, Bob Wagner (CFRU) installed an experiment in cooperation with Dr. Steve Colombo (Ontario Forest Research Institute) to examine seasonal patterns of herbicide tolerance for red spruce and balsam fir in Maine. The study was installed on a site selected on International Paper Corp. lands in cooperation with Tom Small and Dennis Gingles. Dr. Maxwell McCormack (Monsanto Corp.) and Ron Lemin (Timberland Enterprises, Inc.) provided technical advice on the experimental design as well as providing chemical. Rick Dionne (CFRU) provided lead technical support for the project. Bill Sherksnas (Dow Corp.) and Butch Harrison (American Cyanamid) contributed chemical support.

The objectives for the experiment are

1) to document the seasonal pattern of injury to young red spruce and balsam fir following typical applications of glyphosate, imazapyr, and triclopyr; and

2) to examine the relationship between degree of conifer injury produced by these herbicides during the growing season and a variety of phonological indicators (including visual classification of phonological stage, bud development, cuticular transpiration, and phloroglucinol staining).

A randomized complete block, split-plot, design with three replications (blocks) was installed on a site near Medway, ME, which contains high densities of red spruce and balsam fir. A total of 150 treatment plots (seven timings x seven herbicide treatments x three blocks plus three untreated subplots) were established, treated, and measured. Ten healthy trees of each species were tagged in each plot and injury of each recorded in October 1998. The plots will be measured again in the summer of 1999. The treatments include

1) Accord® (2 qts) in 5 gals water/ac;
2) Accord* (2 qts) + Entry II^{s} surfactant (20 fl oz) in 5 gals water/ac;
3) Accord® (2 qts) + Entry II® surfactant (20 fl oz) + Arsenal Applicators Concentrate® (2 oz) in 5 gals water/ac;
4) Arsenal Applicators Concentrate® (2 oz) in 5 gals water/ac;
5) Arsenal Applicators Concentrate*(4 oz) in 5 gals water/ac;
6) Vision® (2 qts) in 5 gals water/ac;
7) Garlon 4® (2 qts) in 5 gals water/ac; and
8) No treatment.

Each herbicide treatment was applied at periodic intervals to capture seasonal patterns of herbicide tolerance for each tree species. The timing of treatments was: June 1, June 22, July 13, August 3, August 24, September 21, and October 6.

Five indicators of phonological stage for spruce and fir were sampled on each treatment date to examine correlations between conifer injury from each herbicide treatment and phenology. The indicators measured were:

1) _Bark color_ - proportion (0 - 100%, to nearest 10%) of bark on terminal leader that is green in color.

2) _Bud development_ - stage of bud formation and num ber of needle primordia in terminal buds.

3) _Leader extension_ - proportion (0 to 100%) of final leader extension completed.

4) _Cuticular transpiration_ - rate of moisture loss in shoots (g water loss / g needle weight / hour).

5) _Phloroglucinol staining_ - proportion (0 - 100%, to nearest 10%) of leaders staining red to indicate lignification.

Preliminary Results

Data analysis will occur during the winter of 1999 to compare conifer damage resulting from each combination of treatment and timing. Preliminary observations indicate a strong seasonal response of injury to both conifer species. Visible injury for all treatments, except imazapyr alone, was substantial before the first week of August. After early August, visible injury was near zero, confirming current target dates for the beginning of herbicide spray applications in the region. Adding Entry II surfactant increased the degree of injury for both species before August. There appears to be no substantial difference in injury between Accord + Entry II and Vision (Roundup) based on early observations. Spruce and fir exhibited similar degrees of injury for all treatments, except for Garlon 4, which produced more visible injury in fir than in spruce.

Although imazapyr alone produced no visible foliage injury this year, we found that injury was quite visible in the bud primordia developed during the season of application; thus revealing the nature of leader suppression commonly observed in the subsequent year after treatment. As a result, we will be using bud primordia counts as a means to evaluate current year injury for imazapyr-alone treatments.

Regression analysis will be used to determine which of the phenological indicators provide the best prediction of herbicide injury for each species. During the season, we found the phloroglucinol staining to be not very useful as the stems stained the full length of the leaders from the beginning of the experiment. As a result, this technique was not continued after the fourth timing. Figure 1 indicates the pattern of seasonal development for four phenological indicators. Results from this analysis will be reported at future CFRU meetings and in a published report in 1999.

References

Templeton, C.W.G., K.D. Odium, and S.J. Colombo. 1993. How to identify bud initiation and count needle primordia in first-year spruce seedlings. For. Chron. 69:431-437.

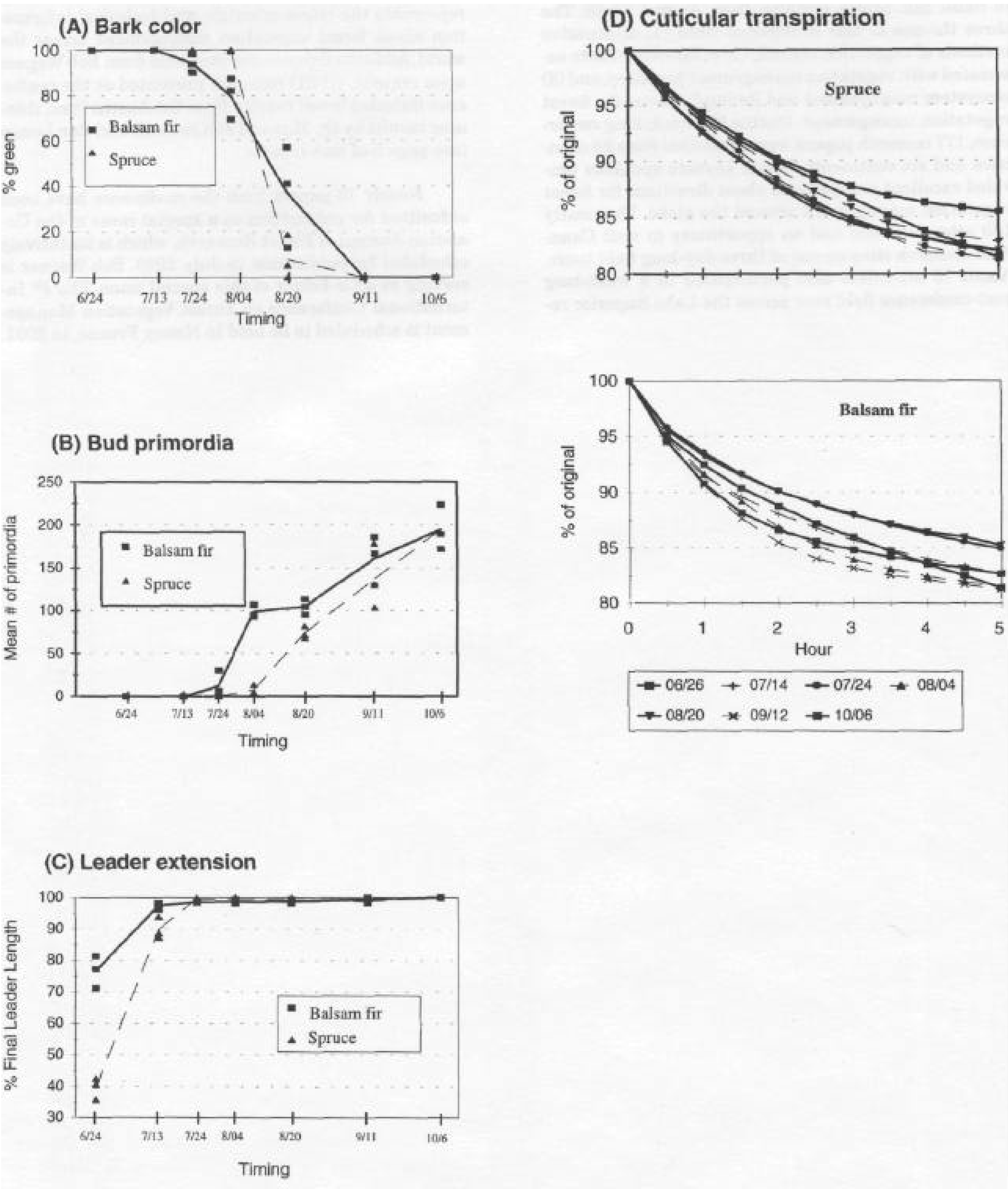

Figure 1. Pattern of development for four phonological indicators: (A) bark color, (B) bud primordia, (C) leader extension, and (D) cuticular transpiration. These indicators will be evaluated for their ability to predict the degree of herbicide injury to red spruce and balsam fir.

CFRU Participation in Third International Conference on Forest Vegetation Management

The Third International Conference on Forest Vegetation Management was Co-Chaired by Bob Wagner in Sault Ste. Marie, Ontario, from August 24-28. The three themes of this conference were (1) alternative methods of vegetation control, (2) ecosystem effects associated with vegetation management practices, and (3) ecosystem management and its implications for forest vegetation management. During the week-long conference, 177 research papers were presented from 28 countries and six continents. Seven keynote speakers provided excellent perspectives about directions for forest vegetation management around the globe. The nearly 180 attendees also had an opportunity to visit Canadian research sites on one of three day-long field tours. About 15 attendees also participated in a week-long post-conference field tour across the Lake Superior region.

Bob Wagner distributed copies of the conference proceedings to all CFRU Advisory Committee members at the October meeting. The 508-page proceedings includes three-page summaries of all technical papers and represents the latest scientific and technical information about forest vegetation management across the world. Additional copies are available from Bob Wagner upon request. CFRU research presented at the conference included latest results from the Austin Pond thinning results by Dr. Maxwell McCormack and Ron Lemin (see page 5 of this report).

Nearly 70 papers from the conference have been submitted for publication in a special issue of the Canadian Journal of Forest Research, which is tentatively scheduled for publication in July 1999. Bob Wagner is serving as a Co-Editor of this special issue. The 4th International Conference on Forest Vegetation Management is scheduled to be held in Nancy, France, in 2001.

CROP TREE CONDITIONS AFTER ONE HERBICIDE RELEASE AND PRECOMMERCIAL THINNING OF NATURAL SPRUCE-FIR REGENERATION IN NORTHWESTERN MAINE*

Maxwell L. McCormack, Jr. and Ronald C. Lemin, Jr.

Introduction

This study originated as a three-year efficacy study of aerially applied herbicides for release of natural regeneration of spruces *(Picea rubens* Sarg., *P. mariana* (Mill.) B. S. P., *P.glauca* (Moench) Voss), and fir *(Abies balsamea* (L.) Mill.). Treatments were applied seven years after a 40-ha mechanical winter clearcut of a predominately coniferous stand. At time of treatment there were well-distributed spruces, fir, and a scattering of white pine *(Pinus strobus* L.) under a heavy cover of soft maples *(Acer rubrum* \^.,*A.pensylvanicum* L.), paper birch *(Betula papyrifera* Marsh.), aspen *(Populus tremuloides* Michx.), pin cherry *(Prunuspensylvanica* L. f), willow spp. *(Salix* L. spp.), alders *(Alnus* B. Ehrh. spp.), and brambles *(Rubus idaeus* var. *strigosus* (Michx.) Maxim.). Though site quality is mediocre, the mixture of species overtopping a good distribution of conifer regeneration composed a representative set of vegetation conditions for the study. A motivation for this work was the need to evaluate new herbicides at a time when the common treatments of 2,4-D and 2,4,5-T were expected to be no longer available. Vegetation dynamics have maintained interest beyond the original study period. Assessment of herbicide suppression of competing vegetation and improvement of species composition was reported two years after treatment (McCormack and Newton 1980). In the ninth year after herbicide application all vegetation development, and the spruce-fir growth in various degrees of competition, and in relation to initial treatments, were reported (Newton *et al*. 1992«, 1992£). Following the ninth year measurements, an operational precommercial thinning (PCT) was carried out by contract work crews using motor-manual equipment. The sequence of silvicultural treatments on these plots represents operational practices in use by large industrial forest landowners for culture of natural regeneration in the region. This report focuses on conditions of the stand and selected crop trees 23, 16, and seven growing seasons, respectively, after harvest, herbicide release, and PCT.

Materials and Methods

The original plots were slightly larger than 1 ha and were located across the harvested area based on a preliminary vegetation survey in order to have conditions as uniform as possible. Two randomized plots were sprayed with each treatment. Treatments included glyphosate at 1.7 and 3.3 kg ha'[1], triclopyr amine at 2.2 and 4.4 kg ha'[1], 2,4,5-T at 2.2 and 3.3 kg ha', triclopyr amine plus 2,4-D ester at 2.2 plus 2.2 kg ha'[1], and 2,4-D plus 2,4,5-T esters at 1.1 plus 1.1 kg ha-' and 2.2 plus 2.2 kg ha"[1], all as acid equivalents. There were two control plots maintained for long-term measurements. Additional treatments were not silviculturally effective and were dropped from consideration. Because glyphosate and triclopyr are currently the standards among forest landowners, and were the most effective in this experiment, they were selected as the basis for this report. Phenoxy treatments are included for historical perspective.

Herbicides were applied, in water, by a Bell 47G3 helicopter equipped with D-6-46 nozzles on a conventional boom delivering a spray pattern with a droplet volume median diameter of approximately 400 to 500 microns. Total volume was 37.4 L ha'[1] in four swaths per plot guided by live flaggers on the ground and a spotter flying with the pilot. All treatments were completed during a single morning spray session in early August 1977. Effects were considered analogous to those occurring in continuous coverage of large operational programs. In autumn following the ninth growing season after herbicide treatment, each of the original plots was divided through the center with a clearly marked line. Half plots, grouped for operational feasibility of the contractor, were designated for PCT. The second half plot remained unthinned. Operational guidelines of the landowner, selecting spaced spruce or fir in the most dominant position, were followed and completed before winter.

In winter 1994-1995 all trees were tallied on 0.024- and 0.163-ha rectangular sample plots, respectively, within each non-PCT and PCT treatment. Height-diameter relationships were developed for calculation of stem volumes using equations by Lemin and Briggs (1993). In each treatment several crop trees were randomly selected for stem analysis. Disks were removed from the boles at 0.15, 0.6,1.37,2.13, and, hence, every 0.91 m along the stems. Tree rings were measured in the laboratory for calculation of tree volumes at three years prior to, at the time of, and five years after PCT. To survey treatment effects on crop tree crowns, total crown biomass was collected from a total of 20 of the stem analysis trees located on two control-, two triclopyr- and one glyphosate-treated plots. Branches and foliage biomass for each tree was packaged and returned to the laboratory for total dry weight determinations.

Results and Discussion

To facilitate this evaluation, 20 field plots were grouped into six treatments for discussion. Three combinations of herbicide treatments were formed: (C) two control plots; (BSE) best initial silvicultural effectiveness, ten plots treated with triclopyr or glyphosate; and (MS) moderate vegetation suppression, eight plots treated with phenoxy herbicides. Each of these was half-treated with PCT. Table *1* summarizes the spruce and fir data for the six treatments.

*Adapted from Wagner, R.G. and D.G. Thompson (comp.). 1998. Third International Conference on Forest Vegetation Management: Popular summaries. Ontario Min. Nat. Resour., Ont. For. Res. Info. Pap. No. 141. Pp. 193-195.

Table 1. Comparison of Spruce and Fir Trees (>9cm dbh) Nine Years After PCT.

Treatment#	Spruce and Fir (trees ha'[1])	Avg Tree Volume (dm^1)	Avg Quadratic Mean Dbh (cm)
C no PCT	41.86 b*	15.42 b	5.10 b
BSE no PCT	527.15 ac	35.85 a	10.84 a
MS no PCT	214.56 be	27.60 ba	9.05 a
C with PCT	595.89 ac	40.52 a	11.38 a
BSE with PCT	766.75 a	41.98 a	11.85 a
MS with PCT	669.99 ac	45.87 a	11.93 a

*Plots are grouped: C=2 control plots; BSE=10 plots, glyphosate or triclopyr ; and MS=8 plots, phenoxy treatments.
* In columns, numbers followed by the same letter are not significantly different. Student-Newman-Keuls pairwise comparison ($p<0.05$).

For the same selected treatment groups, stem analysis data were tested, using analysis of covariance, for treatment effects on tree volume growth. Three volumes were determined for each tree, (1) three years prior to PCT, (2) at the time of PCT, and (3) five years after PCT. These provided annual volume increments for comparison of growth rates before, and after, PCT for each herbicide treatment group. Using growth three years prior to PCT as the covariate, six volume growth equations and their parameters were simultaneously fit for the six treatment combinations. Individual pairwised tests of the intercept parameters indicated that there was no significant difference ($p<0.05$) for the six equations. However, the slope parameters showed a significant difference ($p<0.05$) between volume growth rates for PCT compared to without PCT within each herbicide treatment group.

Analysis of total tree crown biomass from the 20 sampled trees failed to indicate a significant difference among the selected herbicide treatment groups. In addition to the covariate variable, dbh^2 x total tree ht, PCT was the only significant predictor of crown biomass. Tree crown dry weights are summarized in Table 2.

Table 2. Biomass dry weights for 20 tree crowns.

Treatmenttt	Avg Tree Crown Dry Wt (kg)*	n
C no PCT	8.065 a**	3
BSE no PCT	8.685 a	6
C with PCT	17.470 b	3
BSE with PCT	18.139 b	8

#Plots are grouped: C=2 control plots; BSE=1 glyphosate and 2 triclopyr plots.
*Values are least squares means for 20 trees sampled from 4 plots.
**In columns, numbers followed by the same letter are not significantly different ($p<0.05$).

The study was originally intended as a short-term evaluation of herbicide efficacy. However, observations during 16 growing seasons have provided information on the effects of individual silvicultural treatments, during early stages of development, following harvest of a mixed growth stand managed for spruce and fir crop trees. Release from overtopping competition provided benefits to crop trees, but after PCT, thinning effects became dominant. Based on interviews with PCT workers, effective herbicide treatments facilitated the thinning.

Acknowledgments

The Cooperative Forestry Research Unit (CFRU), University of Maine, with which the authors formerly were employed, has maintained this project since its inception. Dr. Michael Newton, Oregon State University, was an active participant during the first 10 years. Cooperation of the original landowner, Scott Paper Company, and its successors, is gratefully acknowledged.

References

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SILVICULTURAL TECHNIQUES FOR THE IMPROVEMENT OF TIMBER QUALITY AND FOREST HEALTH

Dr. William D. Ostrofsky

Overview

In October of 1997, a presentation was made on beech management at the Society of American Foresters National Convention. The presented work was research which MS graduate student T. Zschau developed as part of her program, which she had completed earlier in 1997. Information developed through her thesis was also presented at several other workshops.

In early January 1998, several severe and widespread ice storms resulted in considerable damage to trees and forests throughout Maine. Due to the level and extent of the damage, forestry and general public groups requested information on how best to manage affected trees and forest stands. As a result, several technology transfer efforts were made to assist in answering questions related to storm-damaged forests during the year. In many areas, the effects of this storm will be occurring for a considerable time to come, and several new research projects are being developed by both state and federal agencies. This new focus is sure to lead to the development of substantial new information regarding timber quality and overall forest health.

In July, I was appointed to the Henry W. Saunders Chair of Hardwood Silviculture. This is a great honor for me, and will provide me with an expanded opportunity to continue researching timber quality issues. The development and updating of technology transfer materials related to hardwood quality and forest health will be my initial objective. Other projects that will further the culture and value of the hardwood resource are currently being explored.

Two new research projects were initiated during 1998 in the Timber Quality/Forest Health Program. A small study was installed to test the effectiveness of stem girdling by burning to kill defective American beech stems in beech bark disease-affected hardwood stands. Data is being collected on mortality and on sprouting of roots and stems of the girdled beech. However, the majority of time during the 1998 field season was spent on a study designed to assess the rooting characteristics in precommercially thinned spruce-fir stands. This project was started with the efforts of S. Tian, a new Ph.D. graduate student who arrived in January. The initial phase of this work was conducted at the Penobscot Experimental Forest in Bradley, Maine. Once again Mr. P. Caron, CFRU Research Associate, provided expertise and assistance throughout the field season, and contributed greatly to both the beech project and the spruce/fir project.

In September, I accepted the position of Director of the Office of Professional Development in the Department of Forest Management. Although I expect to maintain close ties with the CFRU, by way S. Tian's research project, my involvement will be as a project scientist, rather than as a program scientist.

Improvement of Hardwood Stands Affected by Beech Bark Disease

Losses in hardwood stand productivity and quality continue to occur on a significant level as a direct result of the beech bark disease. The disease also has a serious negative effect on stand composition, with affected forests accumulating disease-susceptible beech stems over time. Stand conversion practices, heavy cutting prescriptions, and the use of herbicides can significantly reduce beech, and greatly improve stand composition, but such practices are not acceptable alternatives in all stand situations or for all ownerships. There continues to be a strong need to develop and test alternative management options for a variety of stand situations.

Individual stem treatment methods is one class of alternatives that offers good potential for improving beech-dominated stands that have not been severely degraded in composition. This approach may also prove useful in stands where relatively high numbers of resistant beech (beech resistant to the beech scale insect and the disease) occur. The selective removal of only the most susceptible and most debilitated stems requires a method that can be applied on a stem-by-stem basis. A technique of tree girdling with the use of heat is one timber stand improvement method that has not been widely tested in Maine. Heat applied via a propane heating torch to the bark of undesirable stems will quickly kill the cambial tissues and girdle the target stem.

The objectives of this study are to assess the effectiveness of stem girdling of beech by heat and to determine the capacity of treated stems and their root systems to sprout after treatment. During March two areas were selected for the study. One area is located on lands administered by the Bureau of Parks and Lands near Duck Lake (T4 ND). A second trial is located on lands owned by the Timber Company in Waite. Appreciation is extended to R. Barr and R. Chandler of the Timber Company, and to G. Ritz, Maine Bureau of Parks and Lands, for assistance in locating these study sites. A small area at each location was selected that contains dense stands of defective beech in a variety of size classes. One hundred beech stems in each of three diameter classes (0.5 in.-2.5 in.; 2.6 in.-4.5 in.; 4.6 in.-6.5 in.) at each site were girdled in mid-March using a propane burner (Figure 2). In addition, at the Duck Lake site two areas of about an acre in size were treated as a TSI operational trial.

Figure 2. CFRU Research Associate P. Caron uses a propane burner to girdle defective beech stems in a hardwood timber stand improvement trial.

A complete evaluation of the results after one growing season has not yet been completed. Initial observations have shown that treated trees die over an extended period of time. Virtually all treated trees leafed out in the spring. Crown flagging and branch death slowly became evident in late summer and fall. Most trees in the two smaller size classes tested had been completely girdled (Figure 3), with evidence of stem swelling above the girdle, and epicormic sprouting below the girdle by early September (Figure 4). Root sprouting resulting from the treatment was not evident.

It is thought that because the trees leafed out this first year, energy reserves stored in the roots were depleted. The swollen areas of stem above the girdle indicates that much of the photosynthate produced this year did not return to the roots, further weakening the trees. Consequences of the physiological responses should be more evident during the next growing season. Tree response and stem evaluations will be conducted over the winter months, and again in late 1999, after the second growing season post-treatment.

Figure 3. A beech stem girdled through the vascular cambium by the heat treatment.

Figure 4. Stem swelling and epicormic sprouting of a girdled beech stem one growing season after treatment.

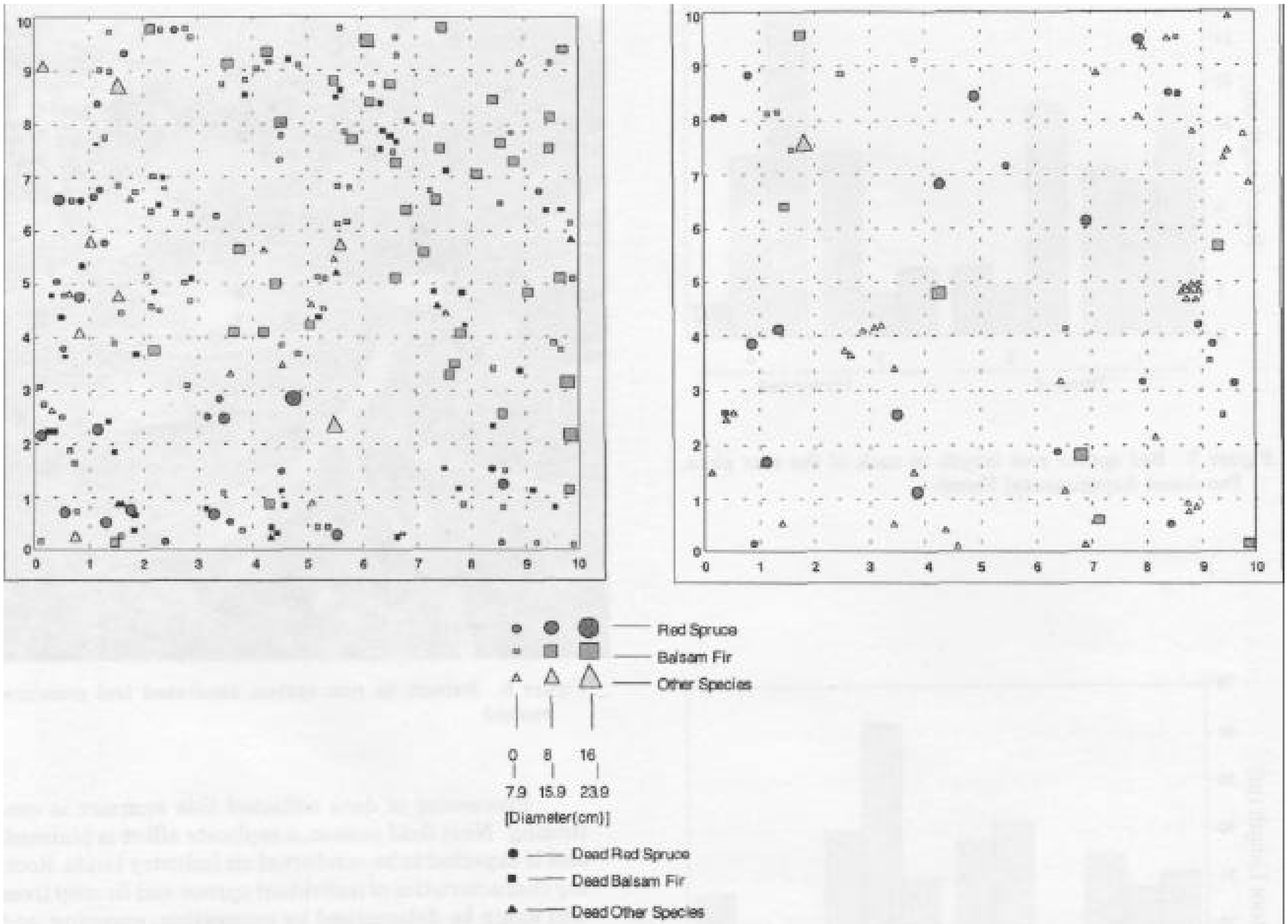

Figure 5. Plot maps of tree locations in the unthinned (left) and thinned (right) spruce-fir stand, Penobscot Experimental Forest, Bradley, Maine.

Condition and Development of Root Systems of Fir and Spruce Following Precommercial Thinning

The majority of time during the summer field season was spent on a project to evaluate the effects of precommercial thinning on root structure and development of spruce and fir. The primary objective of the study, conducted by graduate student S. Tian, is to compare root systems of precommercially thinned (PCT) fir and spruces nearing commercial treatment size, with those in unthinned stands. The study will help to answer questions regarding wind firmness of PCT and non-PCT stands following early, or first, commercial thinnings, will quantify root biomass, and will provide information on root and butt decay characteristics and incidence. Work to date has been conducted at the Penobscot Experimental Forest in Bradley, Maine. The assistance of J. Brissette and T. Skratt, USDA Forest Service, in locating the site and allowing its use for this study is greatly appreciated.

At the Penobscot Experimental Forest, two 10-m X 10-m plots were established in each of a thinned and unthinned spruce-fir stand. The plots were located in a 33-year-old even-aged stand, which had been precommercially thinned at age 17 to a spacing of 8 X 8 ft., and in an adjacent, unthinned area of the same stand. All trees in the plots were mapped (Figure 5), and the five largest spruce along with the five largest fir in each plot were selected for detailed examination. Three 1-m X 1-m subplots in each plot were selected and excavated for preliminary root observations. Selected data from the subplot excavations are shown in Figures 6, 7, and 8.

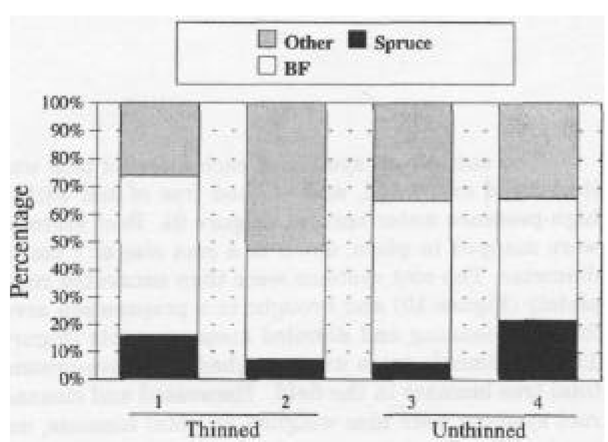

Figure 6. Percentage length of roots by species in each of the four plots, Penobscot Experimental Forest. Data determined from three 1-m x 1-m subplots in each plot.

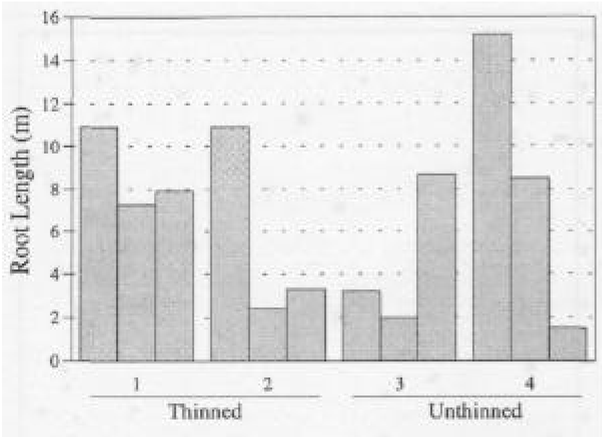

Figure 7. Red spruce root length in each of the four plots, Penobscot Experimental Forest.

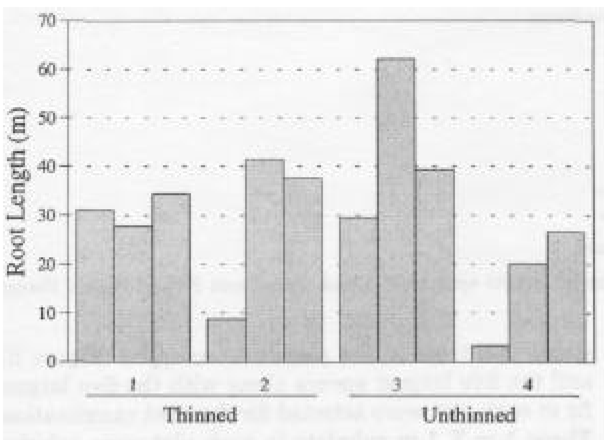

Figure 8. Balsam fir root length in each of the four plots, Penobscot Experimental Forest.

The entire root system of each selected tree was then hand excavated, and washed free of soil with a high-pressure water sprayer (Figure 9). Root systems were mapped in place, down to a root size of 1 cm in diameter. The root systems were then excavated completely (Figure 10) and brought to a preparation area for final cleaning and detailed measurements (Figure 11, 12). Sample trees were weighed for above-ground total tree biomass in the field. Excavated and cleaned root systems were also weighed for total biomass, using a series of root diameter classes. Decayed roots and stump sections were noted, and are being sampled for identification of pathogens.

Figure 9. Balsam fir root system excavated and pressure-washed

Processing of data collected this summer is continuing. Next field season, a replicate effort is planned, and is expected to be conducted on industry lands. Rooting characteristics of individual spruce and fir crop trees will again be determined by excavation, mapping, and extraction. In addition to examining trees in a thinned and unthinned stand of the same age, we also plan to collect data on unthinned trees now of the size that would support a commercial harvest. This treatment will provide the study with a stem size comparison of root system characteristics, as well as an age comparison.

Figure 10. Red spruce root system removed in tact from the site.

Figure 11. Balsam fir root system obtained from a thinned plot, Penobscot Experimental Forest. Note considerable tap root development, compared with typical spruce root system shown in Figure 12.

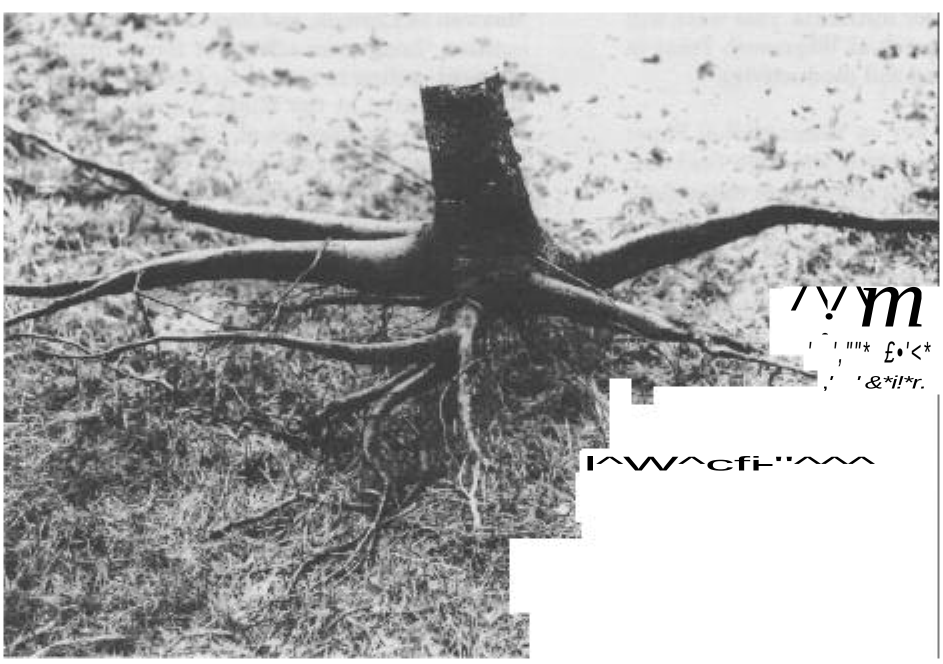

Figure 12. Red spruce root system obtained from a thinned plot, Penobscot Experimental Forest.

SITE QUALITY

Dr. James W. McLaughlin

Introduction

This has been a very challenging year for the Soil-Site Program and the CFRU as a whole. On the political front, the 118th Maine Legislature has mandated that the Maine Department of Conservation establish benchmarks for water quality by January 1,1999, and soil productivity by January 1, 2001. Also, as most people are likely aware, a major restructuring of the CFRU is currently in progress. Therefore, this will be my last contribution to the CFRU Annual Report and Research Summary as a full-time CFRU scientist. Despite the political and restructuring challenges, the Soil-Site Program has made significant progress in forest soil and water quality research that will help the Cooperators in land management decisions, from both policy and improved forest yield standpoints.

Assistant Scientist Stephanie Arnold continues to be a vital member of the Soil-Site Program. Stephanie is crucial to the coordination of a multitude of projects, conducting field work and statistical analyses for the Soil-Site Program, as well as for the CFRU as a whole, and assisting in the preparation of study plans and designs.

We have completed the field work for the hardwood classification project, and we should complete the data analysis portion of that work during winter 1998-1999. The field guide will then be forthcoming. We have also been very active at Weymouth Point. We initiated a precommercial thinning (PCT) study for softwoods, with the emphasis on soil carbon (C), nitrogen (N), and phosphorus (P) cycling. We are also continuing with the long-term monitoring and have conducted an intensive soil sampling for nutrients. This work will augment the previous research at Weymouth Point in defining forest practices and soil productivity.

We also initiated a study on International Paper Company and SAPPI lands during the 1998 field season to address forest harvesting and stream water quality issues. The study is entitled "Water Quality Effects of Variable Management Techniques in High-Gradient Streams Across Managed Forest Landscapes in Western Maine." We have been successful in obtaining funds from the National Council of the Paper Industry for Air and Stream Improvement through a grant to study varying buffer zone widths in relationship to clearcut harvesting and selection harvesting upslope from buffer zones, with a 40% timber volume removal within the buffer zone. We are also collaborating with Dr. John Hagan of Manomet Center for Conservation Sciences on a buffer zone study with the Shifting Mosaic Project.

The previous two Annual Report and Research Summaries for Site Quality have focused on the site classification work. Therefore, this year's Annual Report and Research Summary will focus on the Weymouth Point nutrient cycling work and stream water quality work. I have also chosen to focus this year's report on the Weymouth Point and stream water quality studies because of the legislative mandates for soil productivity and water quality benchmarks.

Weymouth Point

The Weymouth Point project is a paired-watershed study in northcentral Maine on land owned by Great Northern Paper, Inc.. The study was initiated by Dr. Maxwell McCormack and Tattersall Smith, formerly of CFRU. The study area developed primarily as a result of the 1913-1919 budworm epidemic. The control watershed is 73 ha (180 ac), and the harvested watershed is 48 ha (118 ac). The initial whole-tree harvest was conducted in 1981. For further descriptions see Smith (1984).

There were three initiatives concerning Weymouth Point during the 1997 and 1998 field seasons; continuation of long-term database, precommercial thinning (PCT) and soil C, N, and P cycling relationships, and an intensive soil nutrient analysis of the control and harvested watersheds. I am also preparing a review paper on forest practices and soil nutrient cycling in the northern United States and eastern Canada that will be completed this winter. The Weymouth Point study will be a significant contributor to the review.

Long-term monitoring

A manuscript concerning the long-term trends in soil solution and stream chemistry was prepared by Drs. Russell Briggs (formerly of CFRU), James Hornbeck (USDA Forest Service, Durham, NH), Charles Smith, Maxwell McCormak, and Ron Lemin (formerly of CFRU) entitled "Long-term effects of forest management on nutrient cycling in spruce-fir forests." The manuscript was presented at the Ninth Annual North American Forest Soils Conference at Lake Tahoe, CA, and it has been submitted for peer-review publication. One of those coauthors should be contacted by anyone interested in information concerning the manuscript.

Precommercial thinning and soil C, N, and P relationships

Richard Cobb, a Master of Science student in the Department of Forest Ecosystem Science, is conducting the PCT/C, N, and P cycling project. The treatments are PCT (8-ft. x 8-ft. spacing), no PCT, and the control watershed. Six plots have been established for each treatment. Treatments are further stratified by soil drainage class, with three plots established on moderately well drained and poorly drained soils for each treatment. Response variables include N and P mineralization, soil solution chemistry, emphasizing dissolved organic C, dissolved organic P, and dissolved organic N, and soil respiration. The laboratory work is still in progress, so there are no results to present at this time.

I anticipate that results will be presented at the April, 1999 CFRU Advisory Committee meeting. The work will be coupled with the other activities conducted at Weymouth Point and other regional projects to put together a precise conceptual model of forest practices and soil nutrient cycling for spruce-fir forests.

Soil nutrients

The soil sampling and nutrient analyses were conducted in 1997. The three biggest differences between watersheds were exchangeable calcium (Ca), exchangeable magnesium (Mg), and organic C. Calcium concentration and content in the mineral B horizons was higher in the harvested watershed compared to the control (Table 3). There were no differences in exchangeable Mg in the Bs horizon for either concentration (Table 3) or content (Table 4). However, Mg concentration in the BC horizon of the harvested watershed was about 40% higher (Table 3) and content was 46% higher (Table 4) in the harvested compared to the control watershed. The base cation contents were similar to those reported by Johnson et al. (1988) for the Weymouth Point Water shed.

The total pool of exchangeable Ca in the harvested watershed was almost twice that for the control watershed (Table 4). Virtually all of the Ca increase in the harvested watershed, relative to the control watershed, occurred in the B horizon. There was no difference in total pool of exchangeable Mg between watersheds. Johnson et al. (1991) showed a similar response for exchangeable Ca and Mg three years following harvesting whole-tree harvesting a northern hardwood watershed at Hubbard Brook. Hix and Barnes (1984) also reported a two-fold increase in exchangeable Ca content in the lower mineral soil of a clearcut hemlock stand compared to a control stand in Michigan.

There was also 30% higher exchangeable Ca concentration in the forest floor of the harvested compared to the control watershed. That increase, however, did not result in an increased content of Ca in the harvested watershed, likely due to less forest floor occurring in the harvested than control watershed. However, the increase in Ca concentration in the harvested watershed indicates that Ca is being mobilized in the forest floor, then transported into deeper soil horizons where the Ca is precipitated out of solution on soil cation exchange sites to greater degrees than in the control watershed. The Ca differences were also associated with increased soil pH in the harvested compared to the control watershed (Table 3).

The higher Bs and BC horizon Ca, and BC horizon Mg in the harvested watershed was also associated with increased Ca^{2+} and Mg^{2+} concentrations in the stream draining the harvested watershed compared to that for the control watershed. Concentrations of both Ca^{2+} and Mg^{2+} in the stream draining the harvested watershed has been temporally increasing, whereas Ca^{2+} and Mg^{2+} concentrations in the stream draining the control watershed have remained fairly constant over time (Figure 13).

There was no difference in concentration or content of soil exchangeable K (Tables 3 and 4). Romanowicz et al. (1997) reported an increase in mineral soil exchangeable K eight years after whole-tree harvesting at Hubbard Brook, over pre-harvest levels. They further suggested that the increases in exchangeable K due to harvesting likely resulted in a temporal increase in stream K^+ concentrations in the stream draining the harvested watershed at Hubbard Brook, that was also observed. Those results are similar to the results of exchangeable Ca and Mg at Weymouth Point.

Table 3. Soil chemical concentrations for Weymouth Point Watersheds.

Control	pH	Ca"	K	Mg	C	TN
					%	
FF	3.4	2125*	615*	370*	47	1.48
Bs	4.6	53*	28*	11	5.1*	0.15
BC	4.6	30*	20*	8.6*	1.8	0.07
Cd	4.7	35	18	14	1.1	0.05
Harvested						
FF	3.6	3081	421	298	41	1.39
Bs	4.9	110	16	12	3.2	0.14
BC	5.1	60	12	14	1.1	0.05
Cd	4.65	35	18	14	1.2	0.05

[a] NH_4Cl extractable Ca, K, Mg; C is organic carbon; TN is total nitrogen
*Significant differences between control and harvested watershed at P<0.05

Table 4. Soil chemical contents for Weymouth Point Watersheds.

Control	Ca"	K	Mg	C	TN
FF	186	47	29	51,900*	1,543
Bs	204*	101	44	188,860*	6,167
BC	88*	52	30*	53,324	2,100
Total pool	478*	200	103	294,084*	9,810
Harvested					
FF	181	30	21	39,440	1,210
Bs	396	63	40	117,930	4,700
BC	252	63	56	49,940	2,069
Total pool	861	167	121	221,180	9,144

[a] NH_4C1 extractable Ca, K, Mg; C is organic carbon; TN is total nitrogen * Significant differences between control and harvested watershed at P<0 05

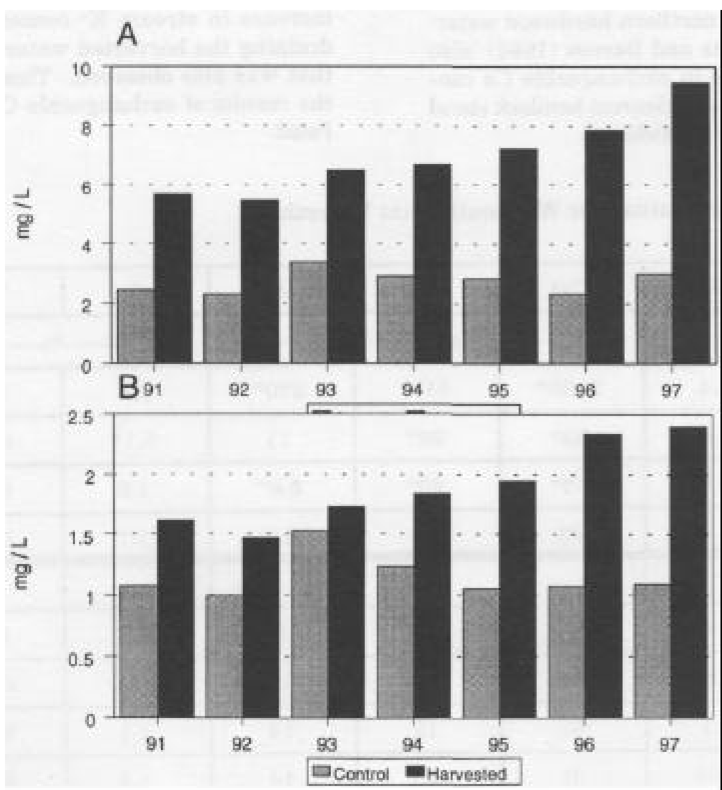

Figure 13. Stream Ca^{2}* and Mg^{2}* concentrations in streams draining the harvested and control watersheds at Weymouth Point. (A) Ca^{2}* and (B) Mg^{2}*.

Organic C concentration and content tended to be higher in the soil of the control compared to the harvested watershed (Tables 3 and 4). The forest floor organic C pool in the harvested watershed was 25% lower than that in the control. Organic C content in the mineral soil of the harvested watershed was about 30% lower than that in the control watershed. McLaughlin et al. (1996) reported a similar response of soil organic C in response to whole-tree harvesting a black spruce-tamarack forest in Michigan. In contrast to the organic C results from Weymouth Point and Michigan, Johnson et al. (1995) reported that whole-tree harvesting a hardwood stand at Hubbard Brook resulted in no changes in mineral soil C content three or eight years after harvesting. The differences between the studies likely is due to soil factors, particularly iron (Fe^{3+}) and aluminum (Al^{3+}) in the mineral soil. These two ions precipitate C out of solution when it comes into contact with Fe^{3+} and Al^{3+}. Therefore, a higher Fe^{3+} and Al^{3+} content in the mineral soil at the New Hampshire site (McDowell and Likens 1988) would result in greater C precipitation than that for the Michigan site, which is very low in Fe and Al (McLaughlin et al. 1994).

The C difference between watersheds at Weymouth Point is important from soil productivity, compaction, and hydrological perspectives. We are currently investigating C sorption to the mineral soil, soil solution C, and soil respiration to improve our understanding of the C dynamics at Weymouth Point. We will also be applying forest hydrology and nutrient cycling models to the Weymouth Point data set during the next year.

Water Quality Effects of Variable Management Techniques in High-Gradient Streams Across Managed Forest Landscapes in Western Maine

The stream water quality project was started in June 1998. Melanie Ruhlman, a forest hydrologist with International Paper Company's Southland's Forest Experiment Station in Bainbridge, GA, deserves a great deal of credit for her time, effort, and financial support in establishing and expanding the stream water quality project. In addition, Trout Unlimited's National Office in Arlington, VA, has provided financial support to conduct brook trout population and spawning habitat work. Darlene Siegel is the graduate student on the project. Darlene is seeking a Master of Science Degree under the Ecology and Environmental Science Program at the University of Maine.

Project objectives

There are four major objectives to the work:

Objective #J: To conduct site characterization that identifies conditions influencing the ability of a particular landscape to meet riparian zone management and stream health goals, particularly cold-water fisheries habitat and prevention of additional sediment and nutrient loadings to downstream water bodies. The physical and ecological processes in watersheds serve as a foundation for more site-specific conditions and identification of appropriate riparian zone width in relation to forest management.

Objective #2: To develop robust indicators of high-gradient, first-order streams across multiple forest ownership using U.S. Environmental Protection Agency guidelines (Barbour et al. 1997). We will focus on buffer zone width in relation to clearcut and selection harvesting to develop the robust indicators. For this study, we will test a series of parameters for potential use as indicators of stream health based upon hydrological, physical, chemical, and biological attributes (Table 5).

Objective #3: To provide biological and chemical data that can aid in Total Maximum Daily Loads (TMDLs) development for high-gradient, first-order streams in western Maine using the measurements listed in Table 5.

Objective #4: To develop a field guide for the forest industry to use for the maintenance of the healthy high-gradient, first-order streams based upon the results of this study.

Table 5. Variables used for establishment of indicators of high-gradient, first-order stream health and the development of TMDLs in western Maine.

Biological parameters	Hydrological parameters	Physical parameters	Chemical parameters
Benthic macro invertebrate s	Stream flow	Total suspended solids	NH_4^+-N
Brook trout population structure	Channel width	Total dissolved solids	NO_3^--N
Brook trout spawning habitat	Channel cross-section	Turbidity	Total nitrogen
	Discharge	Temperature	Ortho-phosphorus
		Bed substrate	Total phosphorus
			Dissolved oxygen
			Dissolved organic carbon
			PH
			Electrical conductivity

Project design

The project is being conducted in high-gradient, first-order streams in western Maine. We selected four watersheds in Haynestown Township (T5R6) in conjunction with International Paper Company and three watersheds in Kibby Township in conjunction with John Hagan of Manomet Center for Conservation Sciences on land owned by SAPPI. Part of the Kibby Township work (possibly other sites, as well) will be incorporated into the Shifting Mosaic Model of industrial forest management. Other sites will be located in conjunction with other cooperators, including Mead Corporation. The other locations will be determined once the land transactions in western Maine are completed. The site on International Paper Company land will be maintained as the core site for all future work in the western Maine region.

The following streams for the International Paper Company's lands are being used:

1) Spaulding Brook - scheduled for a 1998 winter and 1998 summer harvest, with an intact 75 or 150 ft. buffer zone, depending upon slope.

2) Durgin Brook - scheduled for a 1998 summer and 1999 winter harvest, with an intact 75 or 150 ft. buffer zone, depending upon slope.

3) Dud Brook - a reference stream with no planned ac tivity.

4) Cold Brook - a reference stream with no planned ac tivity.

Overstory vegetation for the watersheds is mixedwood. Soils are within the Dixfield-Colonel-Lyman-Brayton catena. Drainage classes range from well drained Dixfield to poorly drained Brayton. Soil texture ranges from coarse-loamy to fine-sandy loams.

Figure 14 shows the stream type that we are studying. We have established two sampling reaches for each of the four streams. For the harvested watersheds (Durgin and Spaulding Brooks), we are sampling one 200-m stream reach, both upstream and downstream from the harvesting operations (Figure 15).

Figure 14. Example of high-gradient, first-order stream being studied.

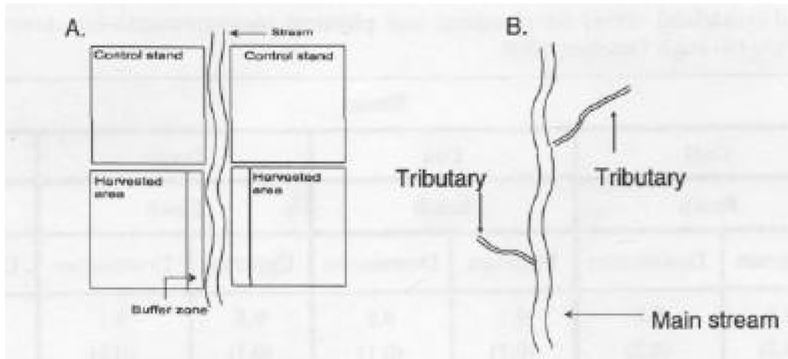

Figure 15. Sample design for harvested stream water quality study. (A) Harvested watershed with intact buffer zone. (B) Sampling stream with tributaries.

Variables being measuring are shown in Table 5. We have also selected two tributaries that drain harvested portions of each harvested watershed (Figure 15) and have established sampling stations within the mouth of each tributary, and immediately upstream and downstream of the main stream from each tributary. The same design is being used for the reference streams (i.e., two sampling reaches and two tributaries). The measurements shown in Table 5, except brook trout population structure and spawning habitat, are also being measured measured for each tributary and immediately downstream and upstream from each tributary.

Accomplishments to Date

We have conducted a site classification of the watersheds, based on the following: (1) topography, (2) surficial geology, (3) bedrock geology, (4) soil drainage class, (5) soil textural class, (6) percent slope, (7) species composition, basal area, density, and regeneration in buffer zones, and (8) understory vegetation in buffer zones for the International Paper Company site.

Table 6. Variables used for stream habitat assessments.

Large woody debris	Embedded ness
Channel width	Canopy angle
Geomorphic channel units pools, runs, riffles	Aspect
Stream type	Bank height
Ffoodplain width	Bank angle
Bank width	Bank vegetation
Stream depth	Bank stability
Stream velocity	Bank substrate
Bed substrate	

We have also conducted stream habitat assessments for each stream following the US Geological Survey's protocol (Meador et al. 1993). The variables listed in Table 6 are being measured for stream habitat assessment.

Some of the measured stream physical and chemical parameters are shown in Table 7. The reference streams have similar physical and chemical parameters for the two reaches. The treated streams, however, have higher temperatures and turbidity at the downstream reaches compared to the upstream reaches (Table 7). We have not yet conducted statistical analyses on the data, and, therefore, do not know if the differences are statistically meaningful. In addition, we have not yet incorporated the biological measurements into the database. Therefore, it is not known at this time whether the differences in physical and chemical parameters have any biological relevance. We will know more about the biological relevance of those measurements over the next few months.

Stream Health Indicator Development

We are also developing indicators of high-gradient, first-order stream health. Data analysis will follow that outlined by EPA's Revision to Rapid Bioassessment Protocols For Use in Streams and Rivers (Barbour et al. 1997). This is a four-stage approach to bioassessment development. Stage 1 will consist of the development of reference conditions from the data collected from the western Maine sites, located in the reference areas. Stage 2 will classify the streams based upon their physical and chemical attributes. Final classification will be confirmed with the benthic macroinvertebrate species composition and chemical, physical, and hydrological data. Stage 3 will develop an index based upon the reference condition for comparison with harvested areas.

Indicator development will be accomplished using the biological metrics. The reference conditions will serve as the benchmark for assessment. In general, the 25^{th} percentile (lower quartile) of reference expectations is used, and it is assumed that 25% of the reference streams may be below the expectations for a particular

Table 7. Mean and (standard error) for chemical and physical measurements for stream water quality. Data are averages from July through October, 1998.

	Stream							
	Cold		Dud		Durgin		SpauMing	
	Reach		Reach		Reach		Reach	
Constituent	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Dissolved oxygen (mg/L)	9.2 (0.2)	9.6 (0.2)	9.7 (0.1)	9.9 (0.1)	9.8 (0.1)	9.1 (0.2)	9.8 (0.1)	9.2 (0.2)
Temperature CO	12.9 (0.6)	12.3 (0.5)	11.4 (0.4)	12.2 (0.3)	12.3 (0.5)	13.3 (0.5)	11.8 (0.4)	13.0 (0.4)
pH	7.1 (0.02)	7.3 (0.03)	7.0 (0.03)	7.4 (0.05)	7.1 (0.04)	7.0 (0.05)	7.0 (0.03)	7.0 (0.03)
Conductivity (uohms/cm)	29.9 (2.1)	27.5 (1.0)	29.7 (1.2)	26.1 (0.9)	22.2 (1.0)	23.1 (0.5)	23.4 (1.2)	28.5 (0.6)
Turbidity (NTU)	0.6 (0.02)	0.5 (0.02)	0.4 (0.03)	0.3 (0.01)	0.5 (0.02)	0.8 (0.04)	0.3 (0.02)	1.1 (0.2)

metric. Stage 4 will be to test the site assessment. This will be accomplished by comparisons of harvested sites and reference-site groups using established percentile of the population distribution of the reference conditions for the metrics. This will allow discrimination between impaired and unimpaired conditions. An example of how the system works is: For those metrics whose index increases in response to perturbation, any value below the upper quartile (75^{th} percentile) of the reference distribution receives the highest score. Thus, using the appropriate quartile as the threshold, a score of 5 represents the maximum value of the reference population; a score of 3 represents a lower condition; and a score of 1 represents the greatest degradation (Figure 16). In this example, a stream with metric value of 1 would be considered impaired. A stream with a metric value of 3 would require close scrutiny and further sampling to judge whether or not it was impaired (Harbour et al. 1997).

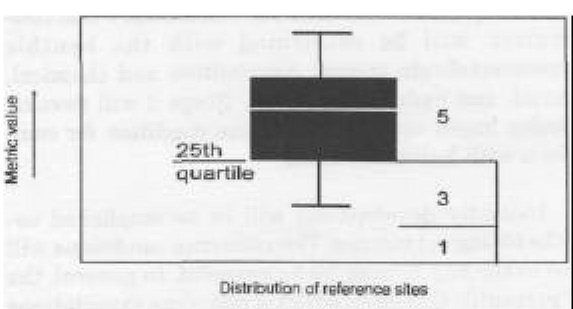

Figure 16. Basis of metric scores for bioassessment (from Barbour et al. 1997).

Future work

We have been successful at obtaining a grant from the National Council of the Paper Industry for Air and Stream Improvement to expand the study to include different buffer zone widths in relation to clearcut harvesting and selection harvesting upslope from the buffer zone, with a 40% timber volume removal from the buffer zone. I have also submitted a proposal to the USDA-National Research Initiative Program to investigate nutrient cycling within buffer zones. I am currently in deliberations with Trout Unlimited for additional funding for the brook trout work. In addition to population and spawning habitat delineations, I believe another critical piece of the puzzle is defining the feeding habits of brook trout, and relate that to competition with other fish species.

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PROPAGATION AND EVALUATION OF FAST-GROWING LARCH HYBRIDS: INCREASING SOFTWOOD STOCKING LEVELS BY PLANTING GAPS

Dr. Michael Greenwood and Dr. Robert G. Wagner

Introduction

Some forest industries are supplementing natural regeneration by planting black spruce and other conifers. Hybrid larch (an open-pollinated hybrid between Japanese and European larch, which is produced in Germany) is being successfully established in plantations in western Maine, and in the first two years of growth produces more than double the height growth of black spruce or red pine (Carl Haag, personal communication). A hybrid larch breeding program was established in 1987 at the University Maine to create a variety of larch hybrids, including 17 crosses between Japanese and European parents, in order to demonstrate the amount of variation among hybrid crosses in terms of height and diameter growth. The parents were all chosen from well-adapted seed sources in plantations in the eastern and northcentralU.S.. Some of the hybrid families have shown increases in height growth of over 30% after five years in comparison to the hybrid larch now being planted on Plum Creek ownership (see column 4, Table 8). These families are also the best hybrids in the test and greatly outperform either parental species.

We are currently producing larch hybrid families by controlled crosses at Plum Creek's hybrid larch orchard located at Unity, Maine, and have worked out procedures for mass producing these crosses using rooted cuttings where limited quantities of seed are available. These crosses are being established in progeny tests for further evaluation. We propose to continue to evaluate these crosses on a variety of sites.

Less than half the existing spruce-fir forest in Maine is fully stocked and more than 40% is poorly to moderately stocked, with stocking ranging from 10% to 60% (Griffith and Allerich 1997). Even fully stocked areas may suffer from uneven distribution of softwood regeneration. In addition, the area of forest classified as spruce-fir has declined by 21% since 1984. The use of herbicides to control hardwood competition affecting naturally regenerated balsam fir and red spruce also kills hardwoods in gaps where there is no natural soft wood regeneration. Re-populating some of these gaps by planting them with fast-growing conifers, including hybrid larch, poplar, or other conifers that are suitable for the site represents an opportunity to greatly increase softwood productivity on this land. If the absence of conifer regeneration in gaps is simply due to inadequate seed fall, rather than unfavorable microsite conditions or pathological factors, then gap planting can be successful (Figure 17).

Experimental plan: Our objectives over the next several years are

1) to continue to evaluate the performance of the hy brid larch test at Johnson Mountain, and to mass pro duce seed or cuttings from selected full-sib families for the establishment of test plantations.

2) to establish experimental gap plantings in understocked areas following aerial herbicide applica tion on selected industrial sites, which includes selec tion and evaluation of appropriate sites for gap plantings, following survival and growth of planted families, and evaluating development of competing veg etation.

Table 8. Percentage gain in height from selecting the five tallest families over the mean of interspecific hybrids, the mean for the three species, and the pooled mean of the two commercial checks (standard error in parentheses). Data from Baltunis et al. 1998.

Family	% over interspecific hybrid mean	%over species mean	% over commercial checks
EJ11	11.9 (2.9)	25.4 (3.3)	36.6(3.6)
EJ42	10.3(3.1)	23.6(3.5)	34.6(3.8)
TE43	8.2(4.6)	21.2(5.1)	32.0(5.6)
JE65	7.7(4.0)	20.7(4.4)	31.5(4.8)
JE61	6.5(3.1)	19.4(3.5)	30.0(3.8)

Figure 17. Opening in natural regeneration following herbicide release, which could be planted with either larch or spruce.

Evaluation of hybrid families: More than 90 bushels of open pollinated hybrid larch cones have been harvested at SAPPI's Unity seed orchard in the late summer of 1998 (Carl Haag, personal communication). In addition a large number of controlled crosses have been made over the last three years, and progeny tests of these crosses have been established. In addition, a rooting bench has been constructed at the University of Maine, and cuttings from young seedlings have been rooted with a high rate of success (95% for cuttings from one-year-old seedlings). Thus ample open-pollinated hybrid larch seed is available for producing seedlings representing many families for plantation establishment. The seed orchard is large enough to produce seed for planting programs far in excess of SAPPI's needs and could potentially be a source of seed for many other planting programs.

Experimental gap plantings: Plants from five to 10 families or seed sources of larch, balsam fir, black, red or norway spruce (number will depend on gap size) will be established in single tree plots, with about 50 plants per family per gap. Gaps for planting will be selected from herbicide-treated areas based on size and effectiveness of herbicide application, and should have a minimum size of 0.5 acre. The experimental designs for these tests are being worked out in collaboration with Bob Wagner.

Benefits: Ten-year-old operational hybrid larch plantations on SAPPI land are producing wood at a rate of 0.9 cords/ac/year, with the rate of production expected to more than double over the next 10 years (Carl Haag, personal communication). A 30% increase in height growth may translate into a volume gain of about 90%, so if hybrid families similar to those shown in Table 8 could be planted instead of the currently available hybrid seed, much larger gains than those reported so far are possible. But are these families adapted to a wide variety of sites? Hybrid larch is potentially intolerant of wet sites and may be damaged by frost in low areas. To obtain the maximum gain, the hybrids must be free to grow, which will require optimal management.

According to the latest USFS inventory, there are about 750,000 acres of spruce-fir forest in Maine with no or poor stocking levels (0%-34%) and almost 2,500,000 acres with moderate stocking (35%-59%). However, even when moderate stocking levels are present, the growing stock trees are not uniformly distributed about the site. Poorly stocked land should be brought back into production by clearcut followed by planting, while conifers on much of the moderately stocked land will be released with herbicides. Following herbicide release on this land, large unproductive gaps are created which could be planted with larch hybrids or other species exhibiting extremely fast early growth. For example, families EJ11 and EJ42 had reached mean heights of more than 4 m in five years and might have the potential to overcome competition with minimal release effort. Hybrid larch must be evaluated along with other species such as balsam fir that can be established with minimal after care. Gaps and access roads are now being planted successfully after herbicide release on Fraser ownership (which they call fill planting, Kevin Topolinski, personal communication). These plantings occupy a significant percentage of the area, and have the potential to greatly increase softwood production.

This project was approved at the last advisory committee meeting, and I am looking forward to implementing it.

Linkages with other projects: Site selection and experimental design will be carried out in consultation with Bob Wagner, and the proposed work will compliment his other projects which emphasize improvement of intensive silivculture of natural regeneration.

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NORWAY SPRUCE PROVENANCE TESTS: RESULTS AT AGE 18

Dr. Katherine K. Carter and Laurie J. Mann

Norway spruce *(Picea abies* (L.) Karst.) was one of the earliest conifer species to be widely planted in Maine. Ashman (1962) reported that nearly 1,500 acres of Norway spruce had been planted prior to 1932. Some of these early plantations had impressive growth; for example the 1921 Brazier plantation in Brighton, Maine, produced an average of 1.2 cords/A/yr in its first 54 years of growth, including two merchantable thinnings during that time (Klaiber 1977). The good growth of many of these older plantations led to the establishment, in 1979, of a rangewide provenance study of Norway spruce at three locations in Maine, in an effort to identify the most desirable seed sources for future plantings. These three test sites (near Rowland, Bingham, andTelos) include seed sources collected from throughout the European range of Norway spruce, and grouped into the following five regions: Finland, Sweden/Denmark, Germany, Central Europe (including Romania, Czechoslovakia, and southern Poland), and the Baltic region (including northeastern Poland, Belarus, and western Russia). In addition, one seed source (labelled 'C') represents seed collected from the highly productive Brazier Plantation, and another (#450) is a secondary source from an Ontario plantation. At each of the three planting sites, four-tree row plots from each provenance are arranged in a randomized complete block with five replications, for a total of 20 trees per provenance. All planting sites were located in clearcut forest areas with sandy loam soils, but the soil depth and drainage differed among sites.

Survival 18 years after planting ranged between 60% and 70% in each of the three test locations. Most of the mortality occurred in the first few years after planting, and might be related to small planting stock or to heavy early competition at some sites. Mortality in later years was largely due to damage from animals or human activity.

Damage from the white pine weevil *(Pissodes strobiPeck..)* was evident on the majority of trees in each plantation. Although the percentage of trees weevilled varied among provenances, the differences were not significant in most cases. There was a tendency for taller trees to suffer more weevil attacks. However, most trees recovered well and had a single dominant leader, even after multiple weevil attacks.

Tree height was measured at all three locations in 1997, 18 years after plantation establishment (age 20 from seed). Overall mean height was greatest at Telos (5.0 m/ft or 16.4 m/ft), a site with deep, well-drained soil that is well suited to Norway spruce (Table 9). At Bingham, on an excessively well drained site, height averaged 4.6 m (15.2 ft). Growth was poorest (4.0 m or 13.1 ft) at Rowland , where parts of the planting site were poorly drained. Within each plantation, the range of individual provenance mean heights was wide, typically encompassing a spread of 20% to 30% above or below the plantation average. The tallest individual provenances at each site were at Telos, #495 from southern Poland, mean height = 6.4 m (21.0 ft); at Bingham, #456 from Belarus, mean height = 5.3 m (17.4 ft); and at Rowland, #455 from Belarus, mean height = 4.8 m (15.7 ft). At all three plantations, provenances from Central Europe, the Baltic region, and Germany were generally taller than provenances from Finland or Scandinavia. Four provenances ranked in the top one-third for height at all three planting locations: #452 from northem Germany, #459 from Czechoslovakia, #479 from Romania, and #632 from the Baltic region. The Brazier and Ontario seed sources were not superior, except at Telos where Brazier was the second tallest provenance. Provenances from Finland and Scandinavia, including Denmark, were among the shortest at all three sites and should be avoided for planting in Maine. At Rowland, for example, trees from Finnish seed sources were 24% shorter than trees from the Baltic region. Finnish seed sources were also the earliest trees to break bud in the spring, and there was an overall negative correlation between early bud break and provenance height.

Results from these provenance trial are similar to those from trials in New Brunswick and the Lake States region, where Norway spruce from the Central Europe and Baltic regions were also superior to other seed sources (Fowler and Coles 1980).

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Table 9. Norway spruce provenance height 18 years after planting, at three Maine sites.

Region and ID #	Mean Height (meters) at Howland	Bingham	Telos
Baltic States			
453	3.94	4.41	4.76
455	4.75	4.95	4.55
456	4.05	5.29	5.32
490	3.88	4.92	5.01
498	3.77	4.15	5.35
625	4.51	4.72	--
627	3.68	4.20	--
628	3.95	4.10	5.36
629	4.24	4.82	--
630	4.05	4.63	5.36
631	4.43	4.64	5.18
632	4.57	5.09	4.57
679	4.56	4.45	--
Finland			
462	3.13	5.04	--
464	3.47	4.43	3.00
470	3.45	3.82	--
471	2.78	4.22	--
Sweden/Denmark			
460	3.23	4.05	--
473	3.79	4.33	4.85
474	3.95	4.53	--
478	3.64	4.29	5.40
488	3.97	4.63	4.40
489	4.19	4.81	5.06

Region and ID#	Mean Height (meters) at Howland	Bingham	Telos
Central Europe			
454	3.91	4.54	--
458	3.93	4.81	--
459	4.39	5.26	5.13
479	4.26	5.16	5.24
480	4.37	4.41	5.00
481	4.25	4.89	5.43
482	4.27	4.64	4.83
483	4.36	4.02	4.94
491	4.31	4.64	4.84
492	4.18	4.48	5.22
493	4.24	4.86	4.16
494	4.16	4.70	4.91
495	4.41	5.16	6.40
496	4.13	4.51	5.03
497	4.42	4.78	4.98
Germany			
452	4.39	4.94	5.43
484	3.66	5.14	4.32
485	4.48	4.45	4.89
486	4.08	4.60	--
487	3.98	5.01	3.80
Other seed sources			
C -- Brazier	3.83	4.74	6.30
450--Ontario	4.02	5.04	4.27
Plantation mean ht(m)	4.00	4.64	5.00

WOOD QUALITY RESEARCH

Dr. Robert K. Shepard

Introduction

During 1998 research continued on various aspects of the wood properties of red spruce and balsam fir and projects on the wood properties of red pine and white spruce were completed. This report describes the work on red spruce and balsam fir and presents several of the more important results of the work on red pine and white spruce. What will probably be the last growth measurements in red pine plantations in western Maine treated with papermill sludge in 1989 were made prior to the beginning of the 1998 growing season. The results of these measurements are also presented.

The research on red spruce and balsam fir is divided into three projects. The status of each is described below. Also included is a brief statement of the objectives of each project as well as work anticipated for each during 1998-1999.

Effects of Precommercial Thinning on Wood Properties

The objectives of this study are to determine the effects of precommercial thinning on the specific gravity, strength, and stiffness of balsam fir and red spruce wood. Balsam fir is being examined first, because it is more prevalent in precommercially thinned stands, and suitable balsam fir is easier to find.

In 1998, a considerable amount of time was spent locating suitable stands. The primary impediment was in locating stands that contained a suitable area to serve as a control. Six dominant balsam fir were felled in a balsam fir stand precommercially thinned in 1984 and six dominant trees were also felled in a small portion of the same stand that was not thinned. The trees are approximately 27 years old at breast height. DBH of released trees was generally from 8 to 9 in. and of control trees from 5.5 to 6.5 in.

A bolt containing the length of stem between 4 ft and 9 ft was taken from each tree, and a flitch, centered on the pith, was sawn from each bolt. At a point as close to breast height as possible, a small board will be cut from each flitch extending from bark to bark. This board will be planed to a thickness of 1/8 in. so that the board still contains the pith. Small specimens, called microbending specimens, will be cut along opposite radii, beginning at the pith and extending to the bark. These specimens are cut with the long dimension parallel to the growth rings and are 1/8 in. thick, 2 1/4 in. long, and one growth ring or a minimum of 1/8 in. wide, but containing a complete set of growth rings. Except where the growth rings are very narrow, most specimens contain only one or two rings. No specimen will be cut to contain growth rings from both the pre- and post-treatment periods. At some point on the flitch above where the first board was cut and as close as possible to that board, a second board will be cut and used for microbending specimens. However, only specimens of wood produced immediately prior to and after the year of precommercial thinning will be cut.

The small size of microbending specimens makes them well suited for assessing the effect of both age (rings from pith) and ring width on specific gravity, bending strength, and stiffness. Using testing equipment available in the Forest Products Laboratory of the Department of Forest Management at the University of Maine, it is possible to obtain a value for each of the three properties for each specimen. If any, or all, of the properties is affected by the large increase in ring width that occurred following the precommercial thinning, the effect should be detectable through appropriate analyses of the values of the properties obtained from the microbending specimens.

Effects of Thinning in Older Stands on Wood Properties

The objective of this study is to assess the possible effects of thinning in older (originating after the spruce budworm outbreak of 1910-1920) red spruce stands on specific gravity, bending strength, and stiffness of the wood. Although thinning in old stands may never occur on a large scale, it is being done, and the acreage thinned may increase in the future. Therefore, the possible effects of such thinning should be investigated.

Twenty dominant or large codominant trees were felled in a red spruce stand; average age is 70-75 years at breast height. Ten trees were taken from plots thinned in 1983 as part of another study, and 10 trees were taken from unthinned control plots. Bolts, and subsequently flitches, were prepared from all trees following the same procedure as in the previous study. Boards for microbending specimens, to be used for determinations of specific gravity, bending strength, and stiffness, were cut at two points on the flitch, the first near breast height and the second a short distance above.

Specimens will be cut beginning at some distance interior to the 1983 growth ring and from the 1984 growth ring through the last growth ring. A sufficient number of rings interior to 1983 will be sampled to establish the relationship between wood properties and age for the pretreatment period. If there is sufficient time, specimen preparation will begin at the pith. For the second board, specimens will be cut in pairs on each radius, one specimen from wood produced immediately preceding and one from wood produced immediately after the thinning. Thus, for each of the second boards, there will be two pairs of specimens, one pair per radius. Because comparable specimens will also have been prepared from the lower board, there will be four sets of paired specimens per tree. As in the previous study, appropriate analyses will show whether or not the wood properties were affected as growth increased following the thinning.

Factors Affecting the Wood Properties of Red Spruce

The primary objective of this study is to assess the effects of drainage class, stand, individual tree, age (rings from pith), and growth rate on specific gravity, bending strength, and stiffness of red spruce in unmanaged stands generally 65 to 75 years old at breast height. The secondary objective is to obtain sufficient data for balsam fir and for red spruce-black spruce hybrid stands of similar age to the red spruce stands in order to compare their wood properties with the wood properties of red spruce. Information obtained from this study may have value in maximizing the end product use of existing stands as well as in projecting characteristics of wood from short-rotation stands.

During 1998 five stands were sampled, two red spruce stands on poorly drained sites, one red spruce stand on a moderately well drained site, a hybrid stand on a poorly drained site, and a balsam fir stand on a moderately well drained site. Six dominant or large codominant trees were felled in each stand. A bolt was removed from each tree and a flitch sawn from each bolt as in the two previous studies. At about breast height or slightly above, bending specimens were cut along opposite radii. The bending specimens are 0.57 in. wide x 0.57 in. deep x 10 in. long and centered on growth rings 5, 20, 35, and 50 from the pith. These specimens are yet to be tested. During 1998, specimens from 12 stands (72 trees) were tested. Eight red spruce stands each on poorly, somewhat poorly, moderately well drained soils have been sampled. Three balsam fir stands and three hybrid stands have also been sampled. All stands are in northcentral Maine.

At present, data from only seven stands have been analyzed. All of these stands are on moderately well drained soils. The results show much larger differences among ages within stands than among stands. Specific gravity at age 50 was approximately 8% greater than at age 5, and strength and stiffness were 1 1/2 to 2 times greater. All properties increased through age 50.

General Results from Red Pine and White Spruce Research

This research investigated the relationships between wood properties and age as well as kiln drying defects for both species. Emphasis was on possible differences between young, relatively fast growing stands and old, slower growing stands, the stands of each species having dominant and codominant trees of approximately the same DBH. Some of the more important results are presented here. This research was largely completed before wood quality work became a part of the CFRU research effort.

Red pine

Longitudinal shrinkage measurements made on small specimens showed that shrinkage was greatest in the growth rings closest to the pith and decreased with increasing distance from the pith, remaining approximately constant after the fifteenth growth ring. Overall, shrinkage in the first 15 rings was 2 to 3 times greater than in older rings. This helps to explain why boards sawn close to the pith tend to twist and warp more than boards that are sawn farther from the pith and that contain older rings.

Lumber was sawn from the bottom 8-ft log from trees from both stands. Kiln-drying defects were greater in lumber from the 55-year-old plantation than in lumber from the 120-year-old natural stand. The amount of warp was greater in boards containing the pith or sawn close to the pith than in boards sawn farther from the pith (Figure 18). Lumber from the natural stand graded higher than lumber from the plantation, largely due to fewer knots.

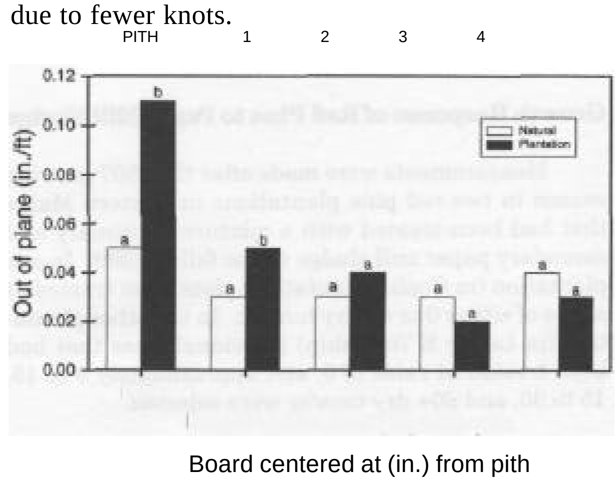


Figure 18. Out-of-plane in boards at different positions relative to the pith sawn from the bottom 8-ft logs of red pine from a 55-year-old plantation (solid bars) and a 120-year-old natural stand (open bars). Boards were sawn from 10 logs in each stand. Bars having the same lower case letter were not significantly different (P=0.05).

White spruce

Results for white spruce were generally similar to those for red pine. Lumber sawn from the bottom 8-ft logs from trees from a 33-year-old plantation exhibited considerably more kiln drying defect than lumber from a 57-year-old plantation. As an example, longitudinal shrinkage was more than twice as great in boards from the young plantation as in boards from the old plantation (Figure 19).

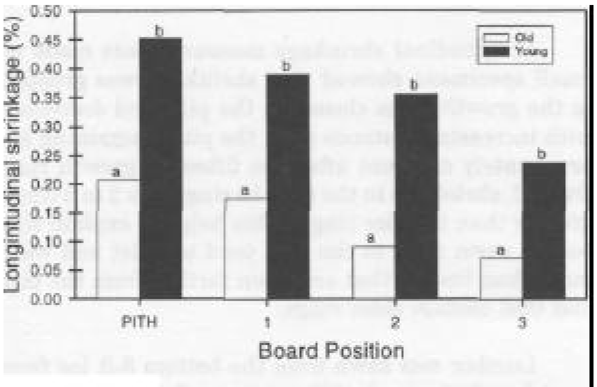


Figure 19. Longitudinal shrinkage in boards at different positions relative to the pith sawn from the bottom 8-ft logs of white spruce from a 34-year-old plantation (solid bars) and a 57-year-old plantation (open bars). Boards were sawn from 10 logs in each stand. Bars having the same lower case letter were not significantly different (P=0.05).

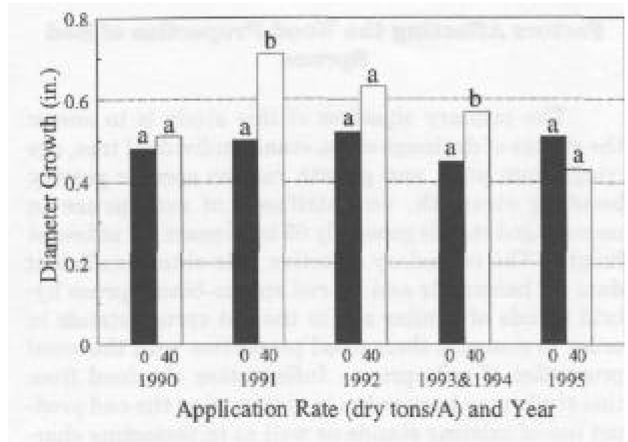


Figure 20. Diameter growth, at a stem height of 3 ft, of planted red pine treated with a mixture of primary and secondary papermill sludge at rates of 0 and 40 dry tons/ac. The sludge was applied in October 1989. Means having the same lower case letter are not significantly different (P=0.05). Growth for 1993 and 1994 is the mean for the two years.

Growth Response of Red Pine to Paper Mill Sludge

Measurements were made after the 1997 growing season in two red pine plantations in western Maine that had been treated with a mixture of primary and secondary paper mill sludge in the fall of 1989. In one plantation (in Coplin Plantation) plots were treated at a rate of either 0 or 40 dry tons/ac. In the other plantation (in Letter E Township) individual trees that had been treated at rates of 0, and approximately 5 to 15, 15 to 30, and 30+ dry tons/ac were selected.

The results of measurements made in the first plantation (Figure 20) clearly show: (1) a diameter growth response occurred during the second through fifth growing seasons after treatment and (2) growth in each group of plots was approximately equal during the three growing seasons after response concluded. As a result of the growth pattern shown in Figure 20, after the 1997 growing season the DBH of treated trees was approximately 0.5 in. greater than the DBH of control trees. At this time it is uncertain for how long the difference in DBH between the two groups of trees will persist. Competition in this plantation was primarily from raspberry, which was stimulated by the sludge. However, many of the red pine were 6 ft tall or taller when the sludge was applied and were capable of both withstanding the raspberry competition and benefitting from the sludge.

Results from the second plantation are different from those from the first plantation. In this plantation the sludge treatment caused a significant reduction in stem diameter growth. The reduction in diameter growth probably occurred because the small size of the seedlings when the sludge was applied (seedlings averaged less than 2 ft tall when the area was treated) made them susceptible to the deleterious effects of competition, primarily from raspberry, but also from hardwood sprouts that were stimulated by the sludge. The effect of the sludge became more pronounced as application rate increased and lasted for five growing seasons. During the last three growing seasons, diameter growth was approximately the same at all treatments. The end result of the eight-year growth pattern is reflected in DBH after the 1997 growing season (Figure 21), when the difference in DBH between the control and the maximum rate was approximately 0.5 in. As with the first plantation, it is uncertain for how long the differences in DBH will last.

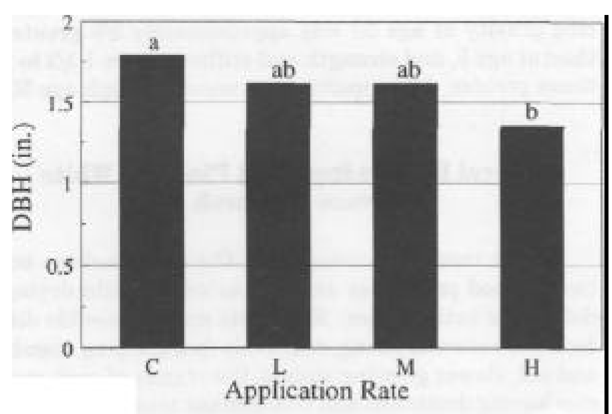


Figure 21. DBH of planted red pine eight growing seasons after treatment with a mixture of primary and secondary papermill sludge at rates of 0 (C), and approximately 5 to 15 (L), 15 to 30 (M), and 30+ (H) dry tons/ac. The sludge was applied in September 1989. Means having the same lower case letter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

INFLUENCE OF PARTIAL HARVESTING ON AMERICAN MARTEN AND THEIR PRIMARY PREY

Dr. Daniel J. Harrison and Angela K. Fuller

Background and Scope

Habitat loss has been cited as a major cause of extinction of American marten *(Martes americana)* from parts of its original range. Research conducted on the effects of forest harvesting on American marten have focused primarily on clearcutting. Forest harvesting practices in Maine are evolving to include increased reliance on partial harvesting (residual basal area > 30 ftVacre) and reduced reliance on clearcutting (residual basal area < 30 ftVacre); 92% of all timber harvesting in Maine during 1996 was characterized as partial harvesting by the Maine Forest Service. The influence of partial harvesting on marten habitat selection at the stand scale has been studied little, and the influence of partial harvesting on marten in a landscape matrix where extensive areas of regenerating clearcuts occur is speculative. Further, the influence of partial harvesting on primary prey species utilized by marten has been studied little. Thus, we will investigate the responses of marten at the substand, stand, and landscape scales to predict the influences of large-scale partial harvesting on habitat quality of marten and their primary prey species. We will use our findings in conjunction with results from companion studies to develop management recommendations for partially harvested stands to maximize their suitability for marten.

Choice of forest stands by marten is also associated with food abundance, and it has been suggested that marten populations are proximally food regulated. We are comparing small mammal densities in partially harvested stands to mature and regenerating forest stands and relating densities to microhabitat features, including coarse woody debris. Small mammals were live-trapped in 1997 and 1998 on 20 trapping grids in six forest types (n = 7 partial harvest, 7 mature mixedwood, 2 mature hardwood, 2 mature softwood, and 2 regenerating clearcut). Microhabitat features were measured at the trapping grids and will be used to evaluate the influence of stand and microsite variables on the abundance of small mammals. During a companion study in 1995, microhabitat features were measured on trap grids for small mammals, which were located in mature (n = 11) and regenerating (n = 2) forest stands. We are using capture data in conjunction with microsite characteristics to evaluate differences in small mammal abundance across stand types, to evaluate microsite differences across stand types, and to model the relationship of small mammal density to microsite characteristics.

Objectives

1) Compare changes in use of the landscape by marten before and after partial harvesting.

2) Document stand-scale patterns of habitat selection by marten whose home ranges have been influenced by partial harvesting and compare to patterns of habitat selection of marten in areas without partial harvesting.

3) Estimate small mammal and snowshoe hare densities in partially harvested stands and compare with mature and regenerating forest stands.

4) Document and compare overstory, understory, and coarse woody debris characteristics among partially harvested stands and mature forest stands.

Project Status

We monitored 19 marten (10M, 9F) whose territories comprised >20% partially harvested stands during the leaf-on seasons (May - October) in 1997 and 1998. Additionally, we monitored five marten whose home ranges comprised > 20% partially harvested stands during the leaf-offseason (November - April) in 1997-1998. Approximately 1,300 telemetry locations have been obtained from ground and aircraft. We replaced transmitters on seven marten during October 1998 that we plan to follow intensively during the leaf-off season of 1998-1999.

Small mammal trapping was conducted in partially harvested and mature stands and resulted in 1,326 captures of 601 individuals (63% red-backed voles, *Clethrionomys gapperi*, 24% deer mice, *Peromyscus maniculatus*, 13% shrews, *Sorex cinereus* and *Blarina brevicauda)* during 7,595 trap-nights in 1997 and 758 captures of 400 individuals (49% red-backed voles, 32% shrews, 15% deer mice, and 4% jumping mice, *Napaeozapus insignus)* during 7,589 trap-nights in 1998. Microsite characteristics were sampled at 112 locations distributed across seven grids used to census small mammals within partially harvested stands. Grids were located in forest stands that were partially harvested during 1992 through 1995. Snowshoe hare pellets were counted in spring of 1998 on 5 m x 30 cm transects on the innermost 12 trapping stations within each grid used to census small mammals. Further, microsite characterisitics were surveyed during summer 1998 on random transects distributed throughout partially harvested stands to allow us to compare structural characteristics of partially harvested stands with residual, clearcut, and insect defoliated stands that were surveyed during companion studies

Future Plans

We will monitor martens intensively from the ground and fixed-wing aircraft during fall 1998 and winter 1999. Field work will be completed on 30 April 1999 and analysis and report writing will be primary tasks during May through September 1999. The expected date of project completion is December 1999.

Funding

Funding for this project has been provided by the Maine Cooperative Forestry Research Unit, Maine Department of Inland Fisheries and Wildlife, and the Maine Agricultural and Forest Experiment Station.

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

Dr. Daniel J. Harrison and David C. Payer

Scope

Much recent research with implications for management of the American marten *(Maries americana)* in the U.S. and Canada has focused on habitat alteration associated with timber harvesting. Although habitat loss through timber harvest has contributed to declines of some marten populations, the relative contribution of increased marten harvest following the construction of forest roads has not been fully elucidated. This is a significant oversight in light of the species' vulnerability to overharvest associated with ease of capture, low reproductive rates, and relatively high pelt value. In fact, overtrapping has been implicated in large-scale declines of marten populations during the early 1900s, and has also contributed to declines in some modern populations.

The effects of timber harvesting and trapping on marten population viability must be isolated to effectively maintain marten populations while providing reasonable opportunities for sustained use of forest products (i.e., timber and fur). We have isolated these effects by concurrently studying marten habitat associations in three contiguous sites in northcentral Maine at three spatial scales, i.e., position of the home range on the landscape (landscape-level selection), selection for overstory characteristics within the home range (stand-level selection), and use of microhabitat features within selected occupied areas. We are also comparing population characteristics of marten among these sites. The three study sites differ in regards to habitat alteration and trapping pressure as follows: (1) timber harvest and trapping; (2) timber harvest and no trapping; and (3) no timber harvest or trapping.

Field work on the CFRU-funded portion of our project began in May 1994 within the Baxter Park site. This site is within a forest reserve without recent (> 35 years) trapping or timber harvesting, and serves as the baseline for evaluating the relative effects of trapping and timber harvesting (T4 Rll WELS), and timber harvesting without trapping (T5 Rll WELS) on marten population characteristics and habitat selection. Additional funding to support this work was provided by the Maine Forest Service (MFS) and the Maine Department of Inland Fisheries and Wildlife (MDIFW). Companion studies in the adjacent industrial landscape (T4 Rll WELS, T5 Rll WELS) were funded by MDIFW, the Maine Agricultural and Forest Experiment Station (MAFES), and the Department of Wildlife Ecology (DWE), University of Maine. Associated projects have also been supported by the National Council of the Paper Industry for Air and Stream Improvement (NCASI). Project personnel during 1997-1998 included David Payer (Ph.D. student), Scott Becker (technician), and Guthrie Zimmerman, Thomas Gorman and Nicholas Wildman (student technicians). Field work was completed on 30 September 1998 and analyses and writing of the final report are ongoing and will continue during 1998-1999. D. Payer's dissertation will be completed by 30 September 1999, and will address a comparison of marten population characteristics and habitat selection among industrial forest lands with and without trapping, and a forest reserve (three treatments). That dissertation will represent the basis of a single final report to be submitted to all project sponsors in 1999.

Objectives

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

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 intra-sexual home range overlap, density, age and sex structure, survival, and percent, females lactating) of martens in an untrapped forest preserve, an untrapped industrial forest, and a trapped industrial forest.

3) to quantify and separate the influences of trapping and timber harvesting on marten populations by assimilating results from objectives #1 and #2.

Funding

As proposed, CFRU funding covered 50% of the direct costs to operate the Baxter park study area from 1994 to 1997. The remaining share of direct costs were provided by MFS, and via substantial "in kind" funding provided by MDIFW, DWE, and MAFES. An additional year of field work (1998) was funded by MDIFW and MAFES within the industrial landscape to allow the marten population within the area closed to trapping to reach its full population potential. That change has extended the completion date for the overall project to 31 December 1999. All funding was provided, as scheduled, which allowed us to proceed with all objectives as proposed. Companion studies of marten on adjacent industrial forest were fully funded during 1994 through 1998 by MDIFW, MAFES, and DWE.

The National Council of the Paper Industry for Air and Stream Improvement provided additional support during 1 April 1995 to 31 March 1997. This funding was to evaluate and compare microhabitat characteristics in areas receiving different intensities of use (high use, low use, no use) by martens. The specific

objectives of this work were to document and to compare microhabitat characteristics between forests (> 20 ft. in height) with different intensities of use by resident, non-juvenile martens, and to compare microhabitat characteristics between stands affected by natural disturbance (spruce-budworm mortality) versus logging. This work is occurring within the industrial forest treatment area (trapping closure) and within Baxter park. The goal is to integrate the landscape-level findings from the extensive study with site-specific recommendations on ways to maximize habitat suitability for martens in harvested stands. Field work for this portion of the project occurred simultaneously with ongoing radio telemetry studies of marten during summers 1995 and 1996 in T5 Rll WELS, and in Baxter State Park. The final report for this project was completed during 1998 and will be published as a NCASI Technical Bulletin during 1999. Copies will be provided to all CFRU cooperators.

Progress During October 1997 to September 1998

Influence of forest harvesting and trapping on marten:

Township T5 Rll WELS was closed to commercial furbearer (except beaver and bear) trapping by the Maine Department of Inland Fisheries and Wildlife during 1994, 1995, 1996, and 1997 to facilitate our evaluation of effects of trapping on marten populations. We continued to work with MDIFW to enforce the closures, and project personnel posted signs in strategic areas throughout the three townships to inform trappers of the duration of the closure and the objectives of our study. Additionally, a mailing was sent to all licensed trappers in Maine to inform them of changes resulting from recent rule-making.

We trapped and radio collared 230 martens (89 females, 141 males) within T5 Rll WELS, T4 Rll WELS and Baxter State Park (BSP) during 1994 through 1997, additionally 21 marten were captured and radio collared in T5 Rll WELS during 1998. Each captured marten was sexed, weighed, measured, examined for reproductive status, aged, ear-tagged, and radiocollared. The number of adult male marten resident on the Baxter Park study site ranged from eight to 17 individuals during 1991 through 1997, whereas the number of resident adult females ranged from two to ten. Recent changes in numbers of marten captured in 1997 compared to 1996 was +5% in the forest reserve (BSP), -31% in the industrial site without recreational trapping, and -47% in the industrial site with recreational trapping. Densities of deer mice *(Peromyscus maniculatus)* and red-backed voles *(Clethrionomys gapperi)* declined 67% between 1995 and 1996, which appeared to have caused a reduction in survival and recruitment of juvenile marten into the population of resident adults during the winter of 1997. Small mammal populations rebounded in summer of 1997, which resulted in better recruitment into the populations inhabiting industrial forest sites during winter 1998. Thus, we extended field work and the trapping closure for an additional summer in T5 Rll WELS to allow that site to reach its full population potential. The additional year of closure resulted in greater numbers of resident marten captured in that township in 1998 compared to 1997. The additional year of data for our site with timber harvesting and without trapping allows us to better evaluate the carrying capacity of harvested landscapes, and preliminary results suggest that increased population densities of martens can be maintained for at least three years in managed, untrapped forests relative to managed, trapped forests.

We monitored radiocollared martens from the air on a weekly basis from 1 October 1997 to 30 September 1998. Resident marten were monitored approximately one to four times weekly from the ground and aircraft. From 1 May 1994 through of 30 September 1998, greater than 13,000 locations of collared martens were obtained. To date, we have obtained sufficient data from 53 resident marten within the reserve, 46 residents in T4 Rll WELS, and 63 residents in T5 Rll WELS to specify individual home ranges and to examine habitat use patterns (placement of the home range on the landscape, habitat selection within the home range, and use of microhabitat characteristics).

We continued to monitor population density, individual survival, and reproductive success of captured marten in T5 Rll WELS during 1997-1998. In conjunction with information collected during 1994 through 1997, these data are being analyzed to compare habitat quality and several measures of demographic performance among populations of marten exposed to the three forest harvest/trapping treatments.

Preliminary analyses for both leaf-on and leaf-off seasons, suggest that marten in the industrial forest township closed to trapping (N=63 marten during leaf-on and 21 marten during leaf-off) exhibited stand-scale selection; i.e., young forest stands were avoided relative to mature and immature stands. In the industrial forest township open to trapping, no stand-scale selection was evident; habitats within home ranges of adult marten (N=37 marten during leaf-on and 11 marten during leaf-off) were used in proportion to availability. However, marten in the township closed to trapping exhibited selection against young forest and regenerating cuts at the scale of the landscape, presumably because marten occurring in areas of higher density were unable to position their territories in areas without extensive forest harvesting.

In the forest reserve, preliminary results suggest that adult marten did not demonstrate strong patterns of selection during the leaf-on (N=49 marten) or leaf-off (N=7 marten) seasons at the scale of the forest stand; habitat types within home ranges (i.e., mature, closed canopy deciduous, coniferous and mixed forest stands, and stands regenerating following severe spruce-budworm defoliation 10-20 years previously) were used in relative proportion to availability. Further, landscape-scale selection was not exhibited by marten that inhabited the forest reserve.

Analyses of habitat selection by marten will continue to proceed during 1998-1999.

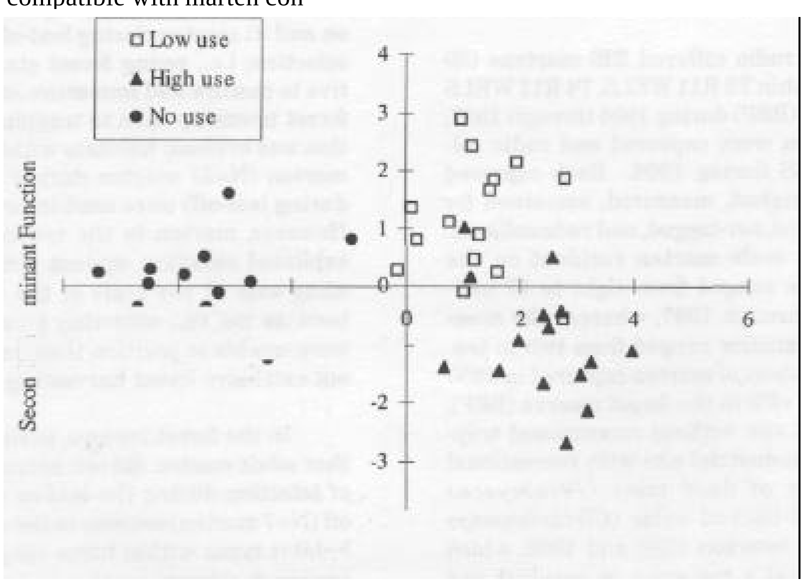
Marten habitat choice at the microhabitat-scale:

Scope: American marten *(Martes americand)* require complex vertical and horizontal structure, which has often been associated with mature and over-mature conifer forests within the western portion of the species' range in North America. Structural attributes of forests such as trees, snags, and other coarse woody material provide subnivean access to prey and resting sites during winter, function as important habitat components for primary prey species (e.g., red-backed voles, deer mice), provide resting and den sites (e.g., cavities in large trees), and provide marten with protection and escape from predators. Structural complexity is often greatest in mature and over-mature forests; however, there may be potential to enhance habitat quality for marten in harvested forests if structural characteristics are maintained above required levels. Further, the marten is increasingly viewed as an indicator of forest health, and management of harvested stands to maintain habitat suitability may provide an umbrella for conserving a variety of forest-dependent vertebrates.

Stand-scale habitat selection by marten is thought to reflect a choice for stands with microhabitat characteristics that provide an abundance of horizontal and vertical structure. However, the relationships of marten use of forests with structural attributes has not been quantified, except for den and rest sites, which do not appear to be limiting in the forests of Maine. A verified relationship between use intensity of forested stands with structural sub-stand attributes will provide opportunities to manage for the structural characteristics of forests required by marten within a wider variety of forest age classes and species types than has previously been considered compatible with marten conservation. Hence, our specific objectives were (1) to document and to compare microhabitat characteristics between forested areas (> 20 feet in height) receiving different intensities of use (# locations/area) by successful martens (i.e., based on survival and reproductive history) in an industrial forest and a forest preserve; and (2) to develop stand-level recommendations regarding silvicultural techniques, harvesting methods, and slash management strategies to maximize habitat quality for martens. Further, comparisons of microhabitat features between regenerating clearcuts (generally receive little use by marten) and regenerating budworm kills (receive extensive use by marten) have been conducted to identify microhabitat features that might be managed in the future to maximize use of stands by marten following forest harvesting.

The areas defined by the minimum convex polygon encompassing marten locations on each study site were partitioned into 16 ha grid cells, and intensity of use was quantified for each cell. We sampled overstory, understory, and microhabitat variables at eight sampling sites randomly distributed within each cell. Fifteen grid cells per use category were sampled in areas defined as receiving high use, low use, and no use in the industrial forest, and 18 grid cells were sampled in areas of both high use and low use in Baxter State Park. Each cell had a minimum of one sampling station per every 2.5 ha.

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



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Discriminant Function

Figure 22. Canonical scores plot from a discriminant function model that predicts spatial patterns of habitat use by American marten as a function of habitat characteristics in T4 Rll WELS and T5 Rll WELS, northcentral Maine. The first discriminant function, depicted as the horizontal axis, separates used from unused cells. Significant variables in that first discriminant function were tree height (greater in used cells) and snag volume (greater in used cells). Cells receiving high versus low use by marten were discriminated by a second function represented by the vertical axis. The predominant variable contributing to the second discriminant function was basal area of deciduous trees (greater in cells receiving high use than in cells receiving low use).

To investigate patterns of habitat use in relation to microsite characteristics, we constructed parsimonious multivariate models that predict use intensity of an area by marten as a function of a subset of overstory, understory, and downed woody debris features. In the industrial forest, areas receiving marten use were distinguished from unused areas primarily by characteristics related to stand maturity (Figure 22). Specifically, used areas had taller trees, greater snag volumes and higher live-tree basal areas than unused areas that were regenerating following clearcutting 10-20 years previously (Table 10). Areas receiving high use were further characterized by higher deciduous basal areas than low-use areas (Table 10). These marten-habitat relationships were consistent with habitat associations of preferred small mammal prey species, as described in a companion study. Marten appeared to be selecting habitat to maximize access to prey, as well as to minimize their exposure to mammalian predators.

Based on our studies, we recommend that harvested stands be managed to maintain overstory features above the thresholds required by marten. We suggest that basal areas of live-trees and snags (> 5 in. dbh) be maintained above 80 sq ft/a, including a basal area of snags > 20 sq ft/a. Further, our data indicate that marten select stands where mean tree height was > 30 ft, thus we recommend that the mean height of residual trees and snags be maintained at a minimum of 30 ft. Our results suggest that several forms of partial harvesting may be compatible with maintaining habitat quality of forest stands for marten. Ongoing research (A. Fuller and D. Harrison, unpublished data) is being funded by CFRU to quantify the structural characteristics, relative prey densities, and spatial use patterns by marten within home ranges that are comprised of at least 20% partially harvested stands.

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

Although our research indicates that there is potential to modify harvesting practices to maintain habitat quality for marten at the scale of the forest stand, results from companion studies indicate that landscape-scale patterns of forest harvesting must be simultaneously considered when managing for within stand habitat features. Previous research in Maine and Utah indicate that extensive clearcutting can fragment marten habitat. For example, home-range-sized areas (1-2 square miles) with > 30% recent clearcutting do not appear to maintain resident marten. Our results suggest that the potential for adverse fragmentation effects can be minimized in landscapes with extensive forest harvesting if stand-scale silvicultural practices are designed to maintain habitat suitability after harvesting. Although limited clearcutting is compatible with the maintenance of resident marten, these areas are avoided by marten for 20-30 years after cutting. Thus, strategies to maximize fiber production that are consistent with maintaining suitable habitat for marten will require a combination of traditional harvesting approaches (e.g., clearcutting), partial harvesting within the guidelines established above, and maintenance of residual areas dominated by mature trees and snags. Further refinement and testing of our recommended guidelines will result from ongoing studies of marten habitat quality within partially harvested areas.

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

Table 10. Mean (standard error) values of habitat variables in 16-ha cells receiving high use, low use, or no use by American marten in an industrial forest in Maine. Habitat variables were measured in 0.04-ha plots during June-August 1995.

		Marten use intensity		
Habitat variable	P-value[a]	High use (n=15)[h]	Low use (n=15)[b]	No use (n=15)[b]
Volume of stumps (mVha)	< 0.001	9.50 (0.77)*	7.66 (0.93)*	14.00 (0.70)*
Volume of exposed root masses (trf/ha)	0.230	17.18 (3.68)	25.48 (5.44)	27.49 (3.97)
Volume of downed tags (rrf/ha)	0.538	54.79 (7.77)	58.58 (7.78)	65.57 (4.65)
Basal area of live deciduous trees (m^2/ha)	< 0.001	12.22(1.01)*	5.20(1.12)*	4.70 (0.99)**
Basal area of five coniferous trees (mVha)	< 0.001	14.25(1.25)*	21.80(1.97)**	9.50(1.13)*
Density of live trees (no./ha)	< 0.001	1053.89 (79.30)*	943.24 (102.57)*	322.58 (87.82)**
Tree height (m)	< 0.001	10.14(0.30)*	10.46 (0.26)*	6.65 (0.24)**
Canopy closure (%)"	< 0.001	99.07 (0.44)*	97.52 (0.88)*	80.20 (4.29)**
Litter depth (cm)	< 0.001	2.58 (0.15)*	1.56 (0.22)**	1.79(0.12)**
Understory deciduous stem density (no./ha)[c]	0.010	4546.46 (550.09)*	2813.42 (746.21)*/**	2153.39 (505.81)**
Understory coniferous stem density (no./ha)[c]	0.112	4583.33 (772.24)	8676.25 (1896.64)	5379.79 (1033.22)
Foliage density, < 0.5 m	< 0.001	71.16(3.74)*	81.34 (2.94)*	96.58 (0.78)**
Foliage density, 0.5-2.0 m	< 0.001	46.86 (4.48)*	62.36 (4.61)**	89.95 (1.47)***

'Single factor analysis of variance, df = 2,42.
""Asterisks indicate results of post hoc pairwise comparisons for variables with P_< 0.05. Means with different numbers of asterisks are significantly different (P < 0.05, Tukey test [Zar 1984:186-190]).
'Square root transformation (Zar 1984:241-242).
[d]Arcsine transformation (Zar 1984:239-241).

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Pitt, D.G., M.T. Dumas, R.E. Wall, D.G. Thompson, L. Lanteigne, W. Hintz, G. Sampson, and R.G.Wagner. 1998. Efficacy of *Chondrostereumpurpureum* applications on target hardwood species in Eastern Canada, pp. 254-256. *In* Proc. Third International Conference on Forest Vegetation Management: Popular Summaries. *Compiledby* R.G. Wagner and D.G. Thompson. Ont. Min. Nat. Resourc., Ont. For. Res. Inst., Sault Ste. Marie, For. Res. Info. Pap. No. 141.

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Robinson, D.E., R.G. Wagner, F.W. Bell, and C. J. Swanton. 1998. Mechanisms of nitrogen competition of jack pine *(Pinus banksiana* Lamb.) seedlings competing with important forest plantation weeds, pp. 287-289. *In* Proc. Third International Conference on Forest Vegetation Management: Popular Summaries. *Compiled by* R.G. Wagner and D.G. Thompson. Ont. Min. Nat. Resourc., Ont. For. Res. Inst., Sault Ste. Marie, For. Res. Info. Pap. No. 141.

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Shropshire, C., R.G. Wagner, C.J. Swanton, and F.W. Bell. 1998. Light attenuation patterns under competitive forest plant canopies, pp. 311-313. *In* Proc. Third International Conference on Forest Vegetation Management: Popular Summaries. *Compiled AyR.G.* Wagner and D.G. Thompson. Ont. Min. Nat. Resourc., Ont. For. Res. Inst., Sault Ste. Marie, For. Res. Info. Pap. No. 141.

Ter-Mikaelian, M.T., R.G. Wagner, F.W. Bell, and C. Shropshire. 1998. Is par better than cover for predicting growth of jack pine seedlings? pp. 329-331. *In* Proc. Third International Conference on Forest Vegetation Management: Popular Summaries. *Compiledby'R.G.* Wagner and D.G. Thompson. Ont. Min. Nat. Resourc., Ont. For. Res. Inst., Sault Ste. Marie, For. Res. Info. Pap. No. 141.T

Ter-Mikaelian, M.T, F.W. Bell, and R.G. Wagner. 1998. Influence of competing vegetation on jack pine *(Pinus banksiana* Lamb.) and black spruce *(Picea mariana* (Mill.) B.S.P.) diameter growth, pp. 15-18. *In* Third International Conference on Forest Vegetation Management: In-conference Tour Guide. *Compiled by* D.G. Pitt and F.W. Bell. Ont. Min. Nat. Resourc., Ont. For. Res. Inst., Sault Ste. Marie, For. Res. Info. Pap. No. 141a.

Wagner, R.G., J. Flynn, and R. Gregory. 1998. Public perceptions of risk and acceptability of forest vegetation management alternatives in Ontario, pp. 345-347. *In* Proc. Third International Conference on Forest Vegetation Management: Popular Summaries. *Compiled by* R. G. Wagner and D. G. Thompson. Ont. Min. Nat. Resourc., Ont. For. Res. Inst., Sault Ste. Marie, For. Res. Info. Pap. No. 141.

Wagner, R.G., T.L. Noland, and G.H. Mohammed. 1998. Critical-period thresholds for northern conifers associated with herbaceous vegetation: 5th year results, pp. 348-350. *In* Proc. Third International Conference on Forest Vegetation Management: Popular Summaries. *Compiledby* R.G. Wagner and D.G. Thompson. Ont. Min. Nat. Resourc., Ont. For. Res. Inst., Sault Ste. Marie, For. Res. Info. Pap. No. 141.

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ADDITIONAL TECHNOLOGY TRANSFER ACTIVITIES BY CFRU PERSONNEL

Briggs, R.D., J.W. Hornbeck, C.T. Smith, R.C. Lemin, Jr., and M.L. McCormack, Jr. 1998. Long-term effects of forest management on nutrient cycling in spruce-fir forests. Paper presented at the ninth North American Forest Soils Conference, Lake Tahoe. August 9-14, 1998.

Carter, K.K. White spruce provenance study and companion plantation. Presentation to CFRU field tour, Bradley, Maine. September 24, 1997.

Carter, K.K., and D. Iriantono. Black spruce genetic selection and family tests: 13-year results. Poster presentation to the New England SAF meeting, Manchester, New Hampshire. March 24-26,1998.

Carter, K.K., and L.J. Mann. Recommended Norway Spruce provenances for Maine. Industry newsletters. September 1998.

Fuller, A.K., and D.J. Harrison. Use of partially harvested stands by American marten: a preliminary analysis. Poster presented at Euro-American Mammal Congress, Santiago de Compostela, Spain. July 23, 1998.

Greenwood, M.S. Interviews for Channel 2-WABI, Portland Press Harold, Associated Press, Maine Times, Toledo Blade. Ice Storm 1998 - Effects of ice in the forest and impact on ornamental trees. January 1998.

Greenwood, M.S. Advice to International Paper regarding historical use of black spruce as a plantation species. March 11, 1998.

Greenwood, M.S. Advice to S.D. Warren on breeding strategies for hybrid larch orchard in Unity. February 1998.

Harrison, D.J. Advised New Brunswick Department of Natural Resources and Energy on a preliminary marten habitat supply model developed for Maine. December 23, 1997.

Harrison, D.J. Potential habitat for eastern timber wolves in Maine. Eastern Wolf Recovery Meeting, Pinkham Notch, NH. September 29, 1998.

Harrison, D.J. Interview with Providence Journal on coyote behavior and ecology. August 31, 1998.

Harrison, D.J. Interview with Wall Street Journal on coyote behavior and ecology. August 31, 1998.

Harrison, D.J. Served as scientific advisor at meeting of the Newfoundland marten recovery team, Grand Falls-Windsor, Newfoundland. May 13-16, 1998.

Harrison, D.J. Serve as scientific advisor to marten demographics study conducted by Western Newfoundland Model Forest and Canadian Forest Service.

Harrison, D.J. A short summary of results from ongoing studies of American marten in Maine. Newfoundland Marten Recovery Team, Grand Falls-Windsor, Newfoundland. May 13,1998.

Harrison, D.J., and A.K. Fuller. Status of ongoing studies of American marten. Presentation to Maine Trappers Association, Augusta, ME. March 27, 1998.

Harrison, D.J. Policy and ecological issues influencing wolf recovery in eastern North America. Presentation to ecology class, Univ. of Maine, Orono. December 8, 1997.

Harrison, D.J., and D.C. Payer. Substand-level habitat use by American marten: recommendations for foresters. Presentation to Advisory Committee, Cooperative Forestry Research Unit, Orono, Maine. April 29, 1998.

Harrison, D.J. Interviewed for article in fall 1997 issue of Maine Perspective magazine on wolf-habitat research project.

Harrison, D.J. Interviewed by National Geographic Science Magazine for article on urban coyotes. October 15, 1997.

Harrison, D.J. Provided radio-telemetry equipment and technical advice to Acadia University for wolf research project in Quebec. January 1998.

Harrison, D.J. Provided technical review of final report on marten-habitat studies in Oregon for U.S. Forest Service. February 1998.

Harrison, D.J. Provided advisement to Irving Corp. on proposed study protocol for marten in New Brunswick. February 1998.

Harrison, D.J. Provided technical advice to Environmental Defense Fund regarding habitat issues for marten in Tongass National Forest, Alaska. January 1998.

Harrison, D.J. Interviewed by Boston Globe regarding wolf research for newspaper article. October 15, 1997.

Harrison, D.J. An assessment of potential habitat for eastern timber wolves in the northeastern United States. Presentation at meeting of eastern wolf experts, Sherbrook, Quebec. October 23,1997.

Harrison, D.J. Advised biologists from Wrangels-St. Elias National Park regarding proposed research protocol for marten. December 1997.

Harrison, D.J. Attended meeting as advisor to The Nature Conservancy regarding landscape-level planning for wildlife habitat. January 21, 1998.

Harrison, D.J. Provided technical advice to U.S. Forest Service Rocky Mountain Research Station regarding lynx-habitat suitability issues at a regional scale. June 15, 1998.

Harrison, D.J. Provided technical advice to Newfoundland Wildlife Division regarding proposed buffer strip requirements near large lakes as potential movement corridors for marten. June 15, 1998.

Harrison, D.J. Habitat and population status of wolves, lynx, and cougar in Maine. Presentation at seminar series sponsored by Maine Audubon, Falmouth, Maine. April 29, 1998.

Harrison, D.J. Interviewed by Bangor Daily News on issues related to proposed listing of lynx as a threatened species by the U.S. Fish and Wildlife Service. September 15, 1998.

Harrison, D.J. Interviewed by Portland Press Herald for article on wolf recovery issues in Maine. September 13, 1998.

Harrison, D.J. Provided technical information to Maine Audubon regarding population and habitat information on lynx in Maine. September 4, 1998.

Harrison, D.J. Habitat ecology of American marten: specialist or generalist? Invited presentation in symposium titled *Mustelids in a Modern World,* Euro-American Mammal Congress, Santiago de Compostela, Spain. July 23, 1998.

Mann, L., and K.K. Carter. A provenance study of Norway spruce *(Picea abies* (L.) Karst.) in central Maine. Poster presentation to the New England SAF meeting, Manchester, New Hampshire. March 24-26, 1998.

McLaughlin, J.W. Hardwood classification of eastern Maine - update, and Lead Mountain nutrient dynamic studies. Presentations to CFRU field tour, Bradley, Maine. September 24,1997.

McLaughlin, J.W. Natural stand silviculture and site quality: a workshop and field tour with Champion International. Maine Region foresters. October 29-30, 1997.

McLaughlin, J.W. Changes in soil nutrient availability/mobility after harvest. Short and Long Term Effects of Forest Practices on Soil Nutrients. The Society of Soil Scientists of Northern New England, Bethel, Maine. December 5,1997.

McLaughlin, J.W. Current soil/forestry research. Maine Soil Survey Work Planning Conference, Orono, Maine. April 8, 1998.

McLaughlin, J.W. Forest practices and water quality in Maine: past work and future initiatives. Forest management and water: current policy developments. 1998 Maine Water Conference, Augusta, Maine. April 16, 1998.

McLaughlin. J.W. What is going on in soil and water? Fourth Munsungan Conference: Health of Maine's Forests—Status and Outlook. Orono, Maine. September 24-25, 1998.

Ostrofsky, W.D. USD A study: Log decomposition and nutrient dynamics of small forest gaps. Presentation to CFRU field tour, Bradley, Maine. September 24, 1997.

Ostrofsky, W.D. Methods for reducing logging injuries to residual trees. Presentation to the Georgia-Pacific Forest Management Assistance Program, Princeton, Maine. October 11, 1997.

Ostrofsky, W.D. Effects of overstory density and beech bark disease severity on height growth patterns of American beech and associated species. Presentation to Georgia-Pacific forestry staff, Princeton, Maine. November 18, 1997.

Ostrofsky, W.D. Ice damage to trees. Television interview, Channel 7, Orono, ME. January 12, 1998.

Ostrofsky, W.D. Recovering trees. The Weekly. February 28, 1998.

Ostrofsky, W.D. The ice storm of 1998: Predicting long-term consequences to tree and forest health. Seminar presentation, College of Natural Sciences, Forestry, and Agriculture. Orono, Maine. March 20, 1998.

Ostrofsky, W.D. Assessment and management of ice-damaged timber stands. Seminar presentation with Maine Forest Service ice storm recovery workshops. Calais, Machias, and Ellsworth, Maine. April 1-3, 1998.

Ostrofsky, W.D. Chair, 1998 annual meeting of the Northeastern Forest Pest Council, and panel presentation "Management recommendations for glaze-damaged forests," Fredericton, New Brunswick. March 9-11,1998.

Ostrofsky, W.D. Ice storm damage assessment. Presentation to Maine Society of American Foresters Spring meeting. Augusta, Maine. April 27,1998.

Payer, D.C., and D.J. Harrison. 1998. Effects of forest structure on spatial distribution of American marten. Final contract report submitted to National Council of the Paper Industry for Air and Stream Improvement (NCASI). 48pp.

Payer, B.C. Influence of microsite characteristics on patterns of habitat occupancy by American marten. Presentation at seminar series sponsored by the Department of Wildlife Ecology, University of Maine. November 3, 1997.

Payer, D.C. Structural differences between forests regenerating following spruce-budworm infestations and clearcutting, with implications for American marten. Presentation at seminar series sponsored by the Department of Wildlife Ecology, University of Maine. November 3, 1997.

Payer, D.C. Marten research and management in Maine. Talk presented to Aroostook Chapter of Maine Trapper's Association. April 14,1998.

Seymour, R., and D. McConville. Spruce-fir understory growth with white pine overstory. Presentation to CFRU field tour, Twp 39MD, Maine. September 24, 1997.

Seymour, R., and M. Greenwood. Spruce plantation with reserve trees, and group shelterwood with reserves, Forest Ecosystem Research Program. Presentations to CFRU field tour, Bradley, Maine. September 24, 1997.

Seymour, R. Ecological plantation forestry: a tour of the FERP research sites. Atlantic Nurseyman's Conference. Penobscot Experimental Forest, Bradley, Maine. October 8, 1997.

Seymour, R. Natural stand silviculture: a workshop and field tour with Champion International Maine region foresters. October 29-30,1997.

Seymour, R. Invited presentations before the Maine Legislature, Agriculture, Conservation and Forestry Committee on timber supply and forest certification. January 29, and February 26, 1998.

Seymour, R. Ecologically based uneven-aged silviculture. Seminar to the J. W. Jones Ecological Research Center, Ichauway, Georgia. March 19,1998.

Seymour, R. Certification of sustainable forestry: practical experience from Eastern North America. Plum Creek Distinguished Lecture, Univ. Montana. May 4, 1998.

Shepard, R.K. Juvenile periods and wood properties of commercially important conifers. Industry newsletters. April 1998.

Wagner, R.G. 1998. Herbicide resistance and tolerance: a problem for Christmas tree growers? Maine Christmas Tree Growers summer meeting, Bucksport, ME. 3 p.

Wagner, R.G. Co-Chair of Third International Conference on Forest Vegetation Management in Sault Ste. Marie, Ontario, August 24-28, 1998. 177 scientific papers presented from 28 countries.

Wagner, R. G. Radio and TV interviews - National Canadian Broadcasting Corporation (CBC), 12 live interviews from coast to coast regarding international advances in forest vegetation management, spoke as leader and organizer of Third International Conference on Forest Vegetation Management in Sault Ste. Marie, Ontario. Also MCTV live television interview about conference. (August)

Wagner, R.G. PEF tour host for Maine Forest Products Council/Maine Tree Foundation Teacher's Tour. (July)

Wagner, R.G. Public perceptions of risk and acceptability of vegetation management methods. Atlantic Vegetation Management Association, Fredericton, NB. (July)

Wagner, R.G. Effects of plant competition on tree growth and survival. Maine Christmas Tree Growers summer meeting, Bucksport, ME. (July)

Wagner, R.G. Advances in vegetation management research in Ontario. CFRU Advisory Committee meeting, University of Maine, Orono. (April)

Wagner, R.G. Critical period for herbaceous vegetation control in northern conifers. CFRU Advisory Committee meeting, University of Maine, Orono. (April)

Zschau, T.A., and W. D. Ostrofsky. Effects of beech bark disease and stand harvesting intensity on American beech regeneration. Poster presentation, Society of American Foresters National Convention, Memphis, Tennessee. October 4-8,1997.

COOPERATIVE FORESTRY RESEARCH UNIT ADVISORY COMMITTEE

1998 Membership

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Professor of Forest Resources Katherine K. Carter, Associate
Professor of Forest Resources Daniel J. Harrison, Associate
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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
Acerpensylvanicum L.	Striped maple
Acer rubrum L.	Red maple
Acer spicatum Lam.	Mountain maple
Alnus spp.	Alder
Fagus grandifolia Ehrh.	American beech
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
Piceaglauca (Moench) Voss	White spruce
Picea mariana (Mill.) B.S.P.	Black spruce
Picea rubens Sarg.	Red spruce
Picea spp.	Spruce
Pinus resinosa Ait.	Red pine
Populus spp.	Aspen
Rubus spp.	Raspberry
Salix spp.	Willow
Blarina (brevicauda) Say	(Shorttail) shrew
Castor canadensis Kuhl	Beaver
Clethrionomys gapperi Vigors	Red-backed vole
Lepus americanus Erxleben	Snowshoe hare
Martes americana Turton	American marten
Napaeozapus insignus	Jumping mouse
Peromyscus maniculatus Wagner	Deer mouse
Sorex (cinereus) Keer	(Masked) shrew
Tamiasciurus hudsonicus Erxleben	Red squirrel
Ursus americanus Pallas	Black bear
Choristoneura fumiferana Clemens	Spruce budworm
Pissodes strobi Peck	White pine weevil