
# Long-Term, Multi-Disciplinary Research in the Acadian Forest of Maine

2008 ECANUSA Field Tour
October 18, 2008

# 2008 ECANUSA FIELD TOUR AGENDA

**12:00 – 12:15** **Pick-up box lunch & load vans for PEF tour**

**12:15 – 12:45** **Drive to STOP 1**

**12:45 – 1:25** **STOP 1: Intro to the PEF & USFS Study**

- History of PEF & USFS study – *Brissette/Kenefic*
- CC and Rehabilitation study – *Kenefic*
- 3-stage SW - *Brissette*

**1:25 – 1:35** **Walk to STOP 2**

**1:35 – 2:15** **STOP 2: PCT & Commercial Thinning**

- 3-stage SW w/ PCT – *Brissette*
- CFRU commercial thinning – *Seymour/Meyer*

**2:15 – 2:20** **Drive to STOP 3**

**2:20 – 3:00** **STOP 3: Uneven-aged Silviculture**

- U26 – Selection system – *Kenefic*

**3:00 – 3:20** **Drive to STOP 4**

**3:20 – 4:00** **STOP 4: AFERP Expanding-gap Experiment**

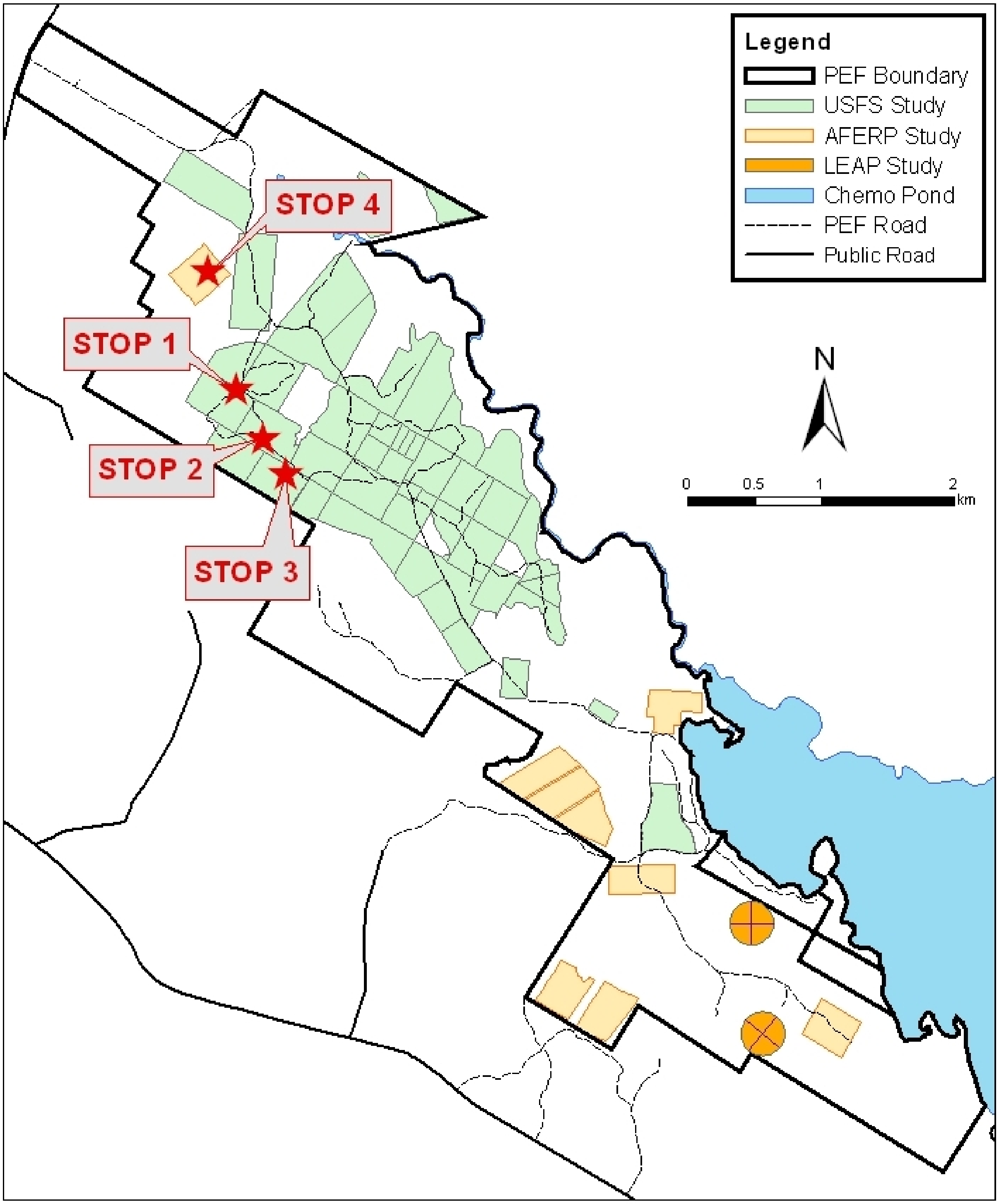
- RA 9 – Intro of AFERP – *Wagner/Seymour/Olson*
- Multi-disciplinary research findings – *Wagner/Olson*

**4:00 – 4:30** **Drive to STOP 5**

**4:30 – 5:10** **STOP 5: LEAP Study**

- LEAP study – *Popescu*

**5:10 – 5:30** **Travel back to UMaine campus**




**Map for 2008 ECANUSA field tour of the Penobscot Experimental Forest (PEF)**

# STOP 1: INTRODUCTION TO THE PEF

## *Background*

Land for the Penobscot Experimental Forest (PEF) was purchased in 1950 by the nine pulp, paper, and land holding companies listed below. It was leased to the Northern Research Station of the USDA Forest Service as a site for long-term forest management research in the northeastern spruce-fir forest. In 1994, the industrial owners of the PEF donated the land to the University of Maine Foundation. The University of Maine and the Northern Research Station jointly manage the PEF under a long-term Memorandum of Agreement.

| 1950 | 1994 |
|---|---|
| Dead River Company | Boise Cascade Corporation |
| Eastern Corporation | Champion International Corporation |
| Great Northern Paper Company | Great Northern Paper, Inc. |
| Hollingsworth and Whitney Company | J.M. Huber Corporation |
| International Paper Company | International Paper Company |
| Oxford Paper Company | J.D. Irving, Ltd. |
| Penobscot Development Company | James River Timber Corporation |
| S.D. Warren Company | Prentiss and Carlisle Company |
| St. Regis Paper Company | Scott Paper Company |
| | Seven Islands Land Company |
| | J.W. Sewall Company |

When the PEF was donated to the University of Maine Foundation, the industrial owners stated that:

> *"The mission of the PEF is to afford a setting for long-term research conducted cooperatively among USDA Forest Service scientists, university researchers and professional forest managers in Maine; to enhance forestry education of students and the public; and to demonstrate how the timber needs of society are met from a working forest."*

## *Location*


Figure 1. Scientists of the Northern Research Station of the U.S. Forest Service, in cooperation with a number of universities, state agencies, and other collaborators, conduct research at numerous experimental forests across the region. The Penobscot Experimental Forest is one of four in northern New England.

## *History*

1938: Hurricane destroyed the Northeastern Forest Experiment Station's spruce-fir research at the Gale River Experimental Forest on the White Mountain National Forest in New Hampshire.

1940: Louis Freedman of Penobscot Chemical Fiber Company and Marinus Westveld of the Northeastern Station discussed need for a spruce-fir experimental forest in Maine.

1942: Northeastern Forest Experiment Station closed for World War II.

1944: Station reopened; spruce budworm research initiated under leadership of Tom McLintock from an office in Bangor, Maine.

1947: A number industrial land owners and related companies in Maine endorsed the concept of providing the Northeastern Station with land for an experimental forest.

1948: Land in southern Penobscot County suggested by Forest Commissioner Al Nutting was selected among more than 15 tracts examined and Louis Freedman was authorized to negotiate the purchase.

1950: A 100-year lease was signed between the owners and the Northeastern Forest Experiment Station "…for the purpose of conducting experiments in forestry." The 3,800 acre tract "…hereafter will be known as the Penobscot Experimental Forest."

1952-1957: The long-term silvicultural experiment, or Compartment Management Study, was installed with a focus on timber production and economics.

1964: Regeneration added to periodic inventories in long-term experiment.

1975: Instituted monitoring individual trees in the long-term experiment.

1994: Industrial owners donated the PEF to the University of Maine Foundation.

1995: The University of Maine and the Northeastern Station signed a 50-year Memorandum of Agreement "…to foster cooperation between said parties in conducting research, development, and demonstrations on the Penobscot Experimental Forest for the economic and ecological benefit of the spruce-fir-hardwood region of Maine…." This memorandum replaced the 1950 lease and established USDA Forest Service control over its ongoing research program on the PEF.

## *Forest Characteristics*

About 10 miles north of Bangor, Maine, the PEF is in the Acadian Forest, a region covering much of Atlantic Canada and adjacent Maine. The region, dominated by mixed conifers, is an ecotone between boreal and broadleaf biomes. Red spruce is the signature species of the Acadian forest, distinguishing it from similar forests around the Great Lakes where white spruce is common and red spruce is absent. Balsam fir, a boreal species, is at its southern limit, while others trees, including eastern hemlock and eastern white pine, are at their northern limit. Stand-replacing fires are less frequent than in the boreal forest or other temperate forests. Natural disturbances are insect epidemics (notably spruce budworm) and windstorms, causing sporadic mortality. Most of the forest around Bangor has been periodically cut for high value products since the 1790s. However, little of the PEF was ever cleared and cutting for 20-40 years before it became an experimental forest was light.

The climate is cool and humid. Average annual temperature is 43.9 °F, with February the coldest (19.3 °F) and July the warmest (68.0 °F). Normal precipitation is 41.7 in., with 48% falling during the growing season, which averages 156 days.

Soils are complex and variable because of glacial influences. Till derived from fine grained, sedimentary rock is the principal parent material. Low till "ridges" are well drained loams, stony loams, and sandy loams. Flat till areas between ridges are poorly and very poorly drained loams and silt loams. Low areas along watercourses and in depressions have lake and marine fine sediments that are poorly drained silt and silty clay loams.

Forest types are typically more diverse than the industrial spruce-fir forest farther north. The canopy is dominated by conifers, including hemlock, spruce—red , white, and black, balsam fir, northern white-cedar, white pine, and an occasional tamarack or red pine. Common hardwoods include red maple, paper and gray birch, and trembling and bigtooth aspen.

# U.S. FOREST SERVICE LONG-TERM SILVICULTURE EXPERIMENT

*Silviculture is "the art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands to meet the diverse needs and values of landowners and society on a sustainable basis." (SAF 1998)*

## *Background*

The core silvicultural experiment on the PEF was established between 1952 and 1957 on about 600 acres of the most conifer-dominated part of the experimental forest. Originally a timber management study, current objectives are:

1. Quantify tree and stand response to silvicultural treatment.
2. Provide a variety of forest structures at one location to be used as the framework for short-term experiments in ecology and silviculture.

Results are used to generate fundamental scientific knowledge about forest ecosystems and management guidelines for northern conifers and associated species. Additionally, the experiment is used extensively for teaching and technology transfer.

## *Treatments*

Treatments were applied to compartments averaging 25 acres with each treatment replicated twice in a completely random design. The following treatments are included:

| System | Treatment | | Compartment |
|---|---|---|---|
| | Code | Description | |
| Even-aged silviculture | SW2 | Uniform shelterwood, 2-stage overstory removal | 21, 30 |
| | SW3 | Uniform shelterwood, 3-stage overstory removal; without precommercial thinning | 23b, 29b |
| | SW3 PCT | Uniform shelterwood, 3-stage overstory removal; with precommercial thinning; commercial thinning | 23a, 29a |
| Uneven-aged silviculture | S05 | Single tree and group selection, 5-year cutting cycle | 9, 16 |
| | S10 | Single tree and group selection, 10-year cutting cycle | 12, 20 |
| | S20 | Single tree and group selection, 20-year cutting cycle | 17, 27 |
| Exploitive cutting | URH | Unregulated harvest/commercial clearcutting | 8, 22 |
| | FDL | Fixed diameter-limit cutting | 4, 15 |
| | MDL | Modified diameter-limit cutting | 24, 28 |
| Control | NAT | Unmanaged natural area | 32a, 32b |

## Response Variables

Response variables are measured on a series of permanent sample plots established at the beginning of the study. Nested, fixed-radius plots have a common center point and plot size varies depending on the size of tree or variable measured. Within these plots are three permanent circular milacre plots for inventorying regeneration. Response variables have been measured before and after harvests, and at 5-year intervals between harvests.

Variables include: Tree Regeneration, Understory vegetation (by taxa or group), Diameter Breast Height (dbh), Spatial Distribution, Total Height, Height to Base of Live Crown, Crown Projection, Tree Condition, and Dead Wood.

## History of Activities

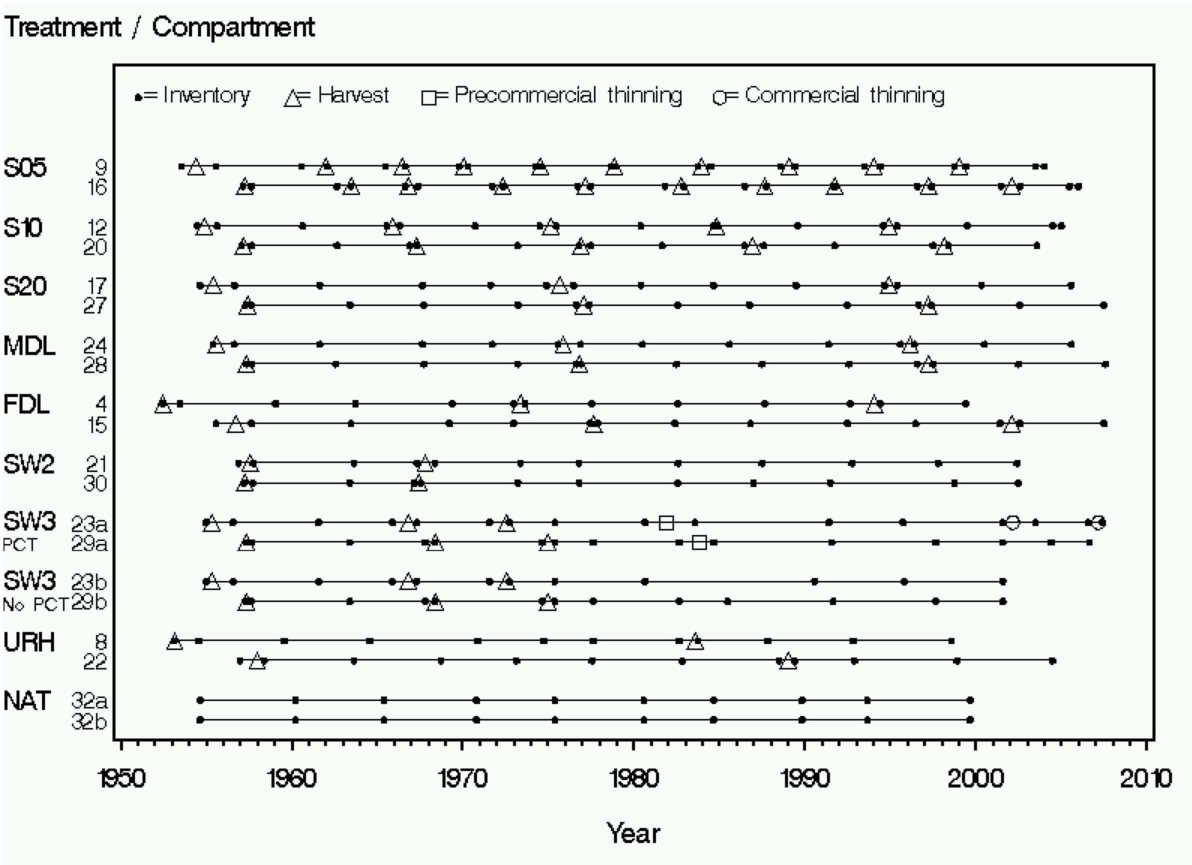



Figure 1. Timeline through 2008 of inventories, harvests, and thinnings in the USDA Forest Service long-term silvicultural experiment at the Penobscot Experimental Forest.

All aspects of conducting this study, including detailed treatment descriptions, inventory procedures and scheduling, training for field crew members, job hazards, equipment calibration, statistical analyses, and data management are documented in a peer reviewed study plan.

# COMMERCIAL CLEARCUT

Not a silvicultural clearcut. Merchantable trees harvested twice, once in the 1950s and again in the 1980s. No protection of advance regeneration and no planning for new regeneration. No investments following either harvest.

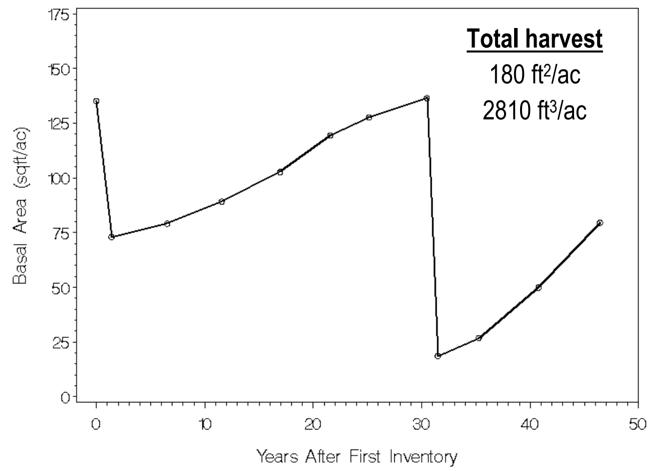



Figure 1. Growth and removals from the commercial clearcut treatment in the long-term silvicultural experiment at the Penobscot Experimental Forest.

The repeated removal of all merchantable trees with retention of cull and inattention to regeneration has substantially and negatively impacted stand composition and quality. The effect of the treatment has been to convert softwood stands to mixedwoods with large components of cull trees, shade-intolerant hardwoods, and shrubs.

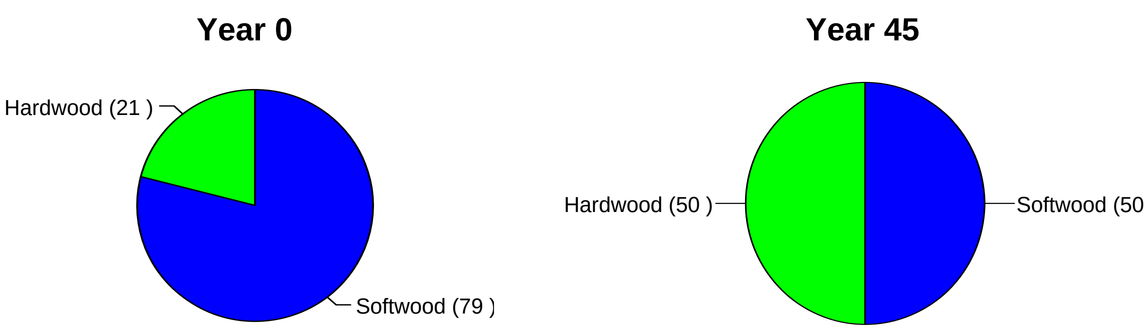



Figure 2. Species composition (percentage of BA ≥ 0.5 inches dbh) in years 0 and 45 in the PEF commercial clearcuts.

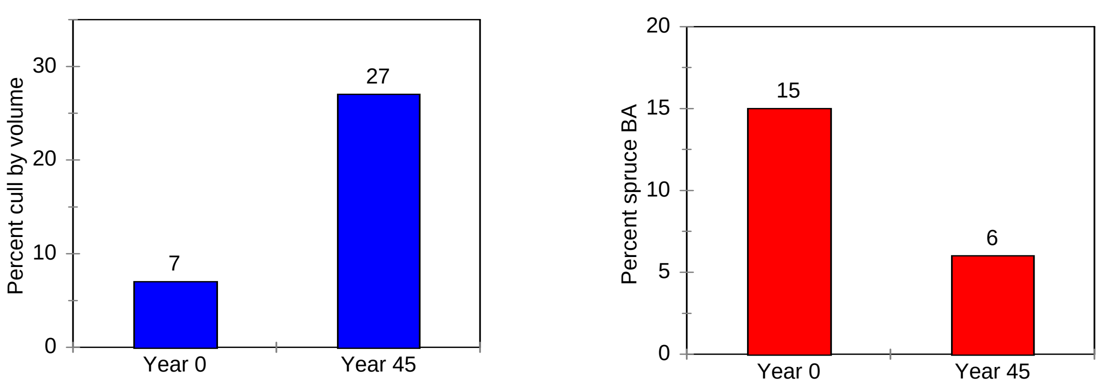



Figure 3. Percentage of unmerchantable volume (left) and spruce BA (right) in commercial clearcuts.

# REHABILITATION OF CUTOVER MIXEDWOODS

*A Silvicultural and Economic Assessment of Alternatives*

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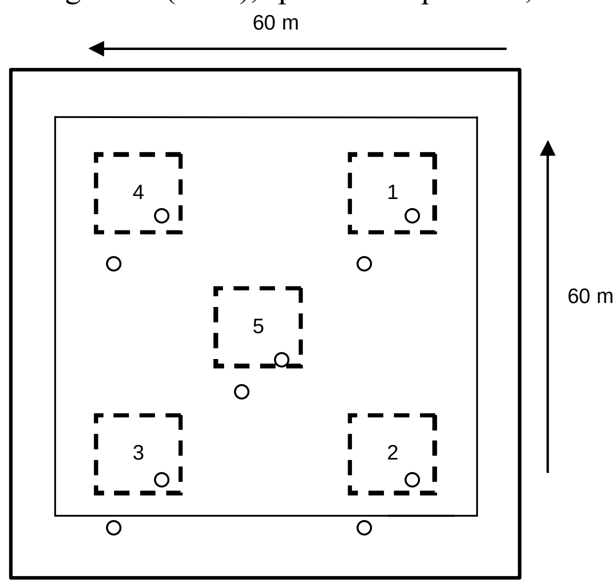
**Summary**
We are evaluating rehabilitation options in stands treated with commercial clearcutting (defined here as removal of all merchantable trees) within the U.S. Forest Service's long-term silvicultural experiment on the Penobscot Experimental Forest. Prior to rehabilitation, the stands were dominated by sapling-sized trees, poor quality residuals and clumps and voids of vegetation. Red maple, aspen species, pin cherry and paper birch were common.

Four replicates of three rehabilitation options are being investigated in two areas with different lapse times since commercial clearcutting (20 years in block 1 (C22) and 25 years in block 2 (C8)). Treatments are as follows (described on next page):

- Control: no rehabilitation
- Moderate rehabilitation: crop tree release
- Intensive rehabilitation: crop tree release, removal of unacceptable growing stock (UGS) and non-commercial species (timber stand improvement, TSI), and fill planting

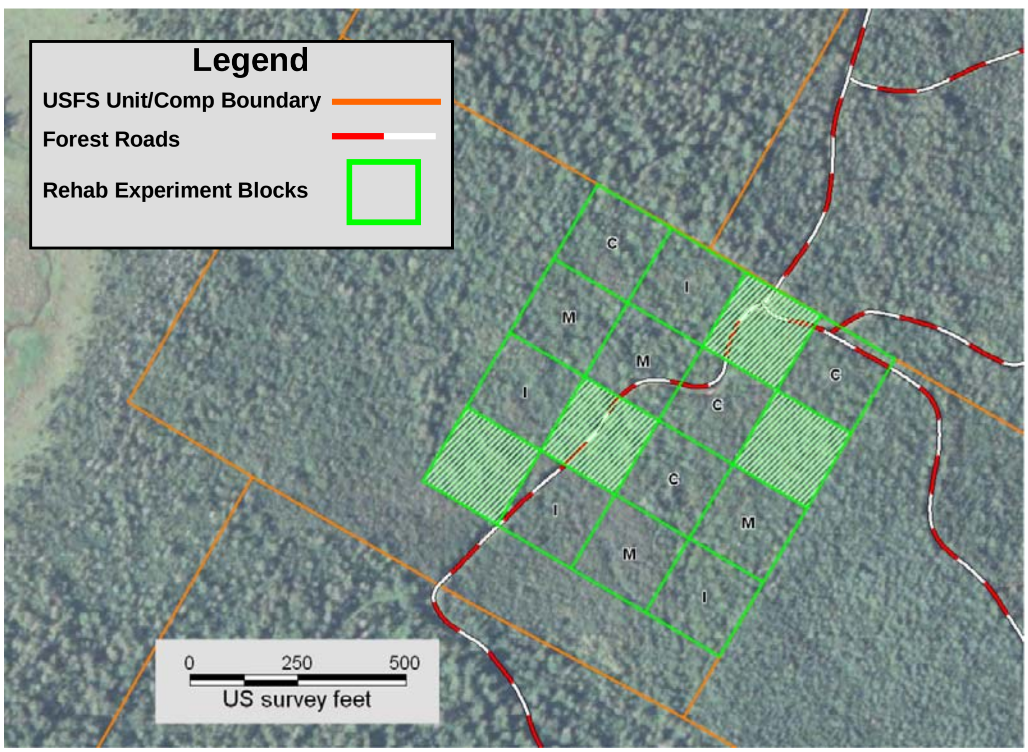
Treatment blocks are 0.4 ha and contain nested overstory, sapling, and regeneration measurement plots. Hardwood and softwood trees were selected for release at about 7.5- and 5-m intervals, respectively; all crop trees were > 1.3 m. On average, we selected 195 crop trees/ha (range 110 to 249) of spruce, aspen, hemlock, red maple, and eastern white pine (there are a few northern red oak, white ash, red pine and larch). Release and TSI were accomplished with a combination of mechanical and chemical treatments; fill planting is scheduled for 2009.

Pre- and post-treatment data will be used to assess future outcomes via the Forest Vegetation Simulator, calibrated with historic data for our study area. Outcomes will be evaluated based on changes in volume and percent acceptable growing stock (AGS), species composition, crop tree growth, uniformity of stocking, and economic costs/benefits.




**Data Collection**

A 100% inventory of trees ≥ 11.5 cm dbh was made by dbh class and species in all blocks, excluding a within-block 7.5-m buffer. In addition, five 0.006-ha plots were established in each sample block to measure trees 1.3 to 11.4 cm dbh; two 0.0004-ha ha regeneration plots are located within each sapling plot to measure trees < 1.3 m. All crop trees are spatially located and measurements included height, height to crown base, crown radii, and canopy position.




Map of PEF C22 with rehabilitation treatments (4 replicates of control, moderate, and intensive).

**Treatment Instructions**

The following instructions were given to student field workers:

Moderate Rehabilitation

*"Crop tree release only"*

Kill (brush saw, chain saw, or herbicide) all trees that are:

- within 2.5 to 3 meters of a crop tree, with crowns within the same level or above the crown of the crop tree
- overtopping a crop tree
- crown-touching or abrading a crop tree

Do not kill any trees that are:

- crop trees
- within 2.5 to 3 meters of a crop tree, with a crown below the level of the crop tree
- not affecting the crown of a crop tree
- spruce, pine, or oak, if the crop tree is already released on three sides
- large (sawtimber-sized) overstory residuals (also called legacies: old trees from the previous stand) unless aspen or fir

Intensive Rehabilitation

*"Crop tree release, TSI, and fill planting"*

See instructions re: crop tree release above. Aside from crop tree release, also kill (brush saw, chain saw, or herbicide) all trees that are:

- UGS (unacceptable growing stock, i.e. a tree that will not increase in value due to decay or form. This includes most of the red maple clumps.)
- Poor vigor trees (trees that look like they are going to die)
- Cull (trees that are unmerchantable due to decay or form)
- Non-commercial tree species: grey birch, pin cherry – *Fill planting is planned for 2009*

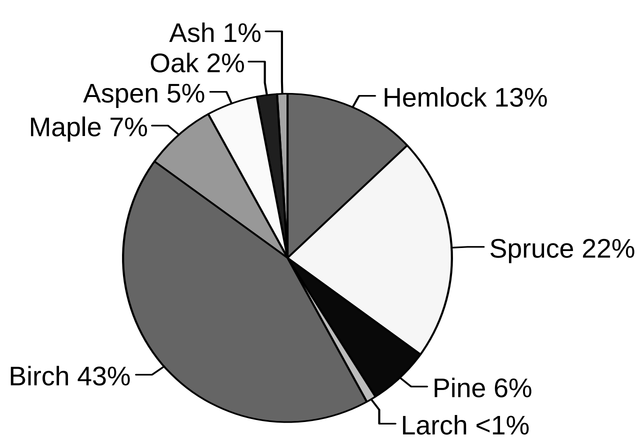
**Preliminary Results**

Pre-treatment number of trees per hectare, by species:

| Species | TPH < 11.4 cm | TPH ≥ 11.4 cm | Total Stems/ha |
|---|---|---|---|
| Balsam fir | 2526 | 80.6 | 2606.5 |
| Red maple[1] | 2032 | 45.9 | 2078 |
| Paper birch | 1760 | 6.8 | 1766.3 |
| Pin cherry | 1174 | 0 | 1173.9 |
| Trembling aspen | 677.4 | 22 | 471.5 |
| Grey birch | 272.7 | 4 | 276.7 |
| Bigtooth aspen | 215.3 | 14 | 229.2 |
| Red maple[2] | 209.5 | 7.2 | 216.7 |
| Eastern hemlock | 140.6 | 9.2 | 149.8 |
| Red spruce | 77.5 | 12 | 89.5 |
| Eastern white pine | 51.7 | 8 | 59.6 |
| White ash | 34.4 | 3.6 | 38 |
| American beech | 14.4 | 2.4 | 16.7 |
| N. red oak | 11.5 | 0.4 | 11.9 |
| N. white-cedar | 0 | 10.8 | 10.8 |
| White spruce | 2.9 | 3.2 | 6.1 |
| Tamarack | 2.9 | 1.6 | 4.5 |
| Balsam poplar | 0 | 0.8 | 0.8 |
| Total | 9202 | 232.5 | 9206.5 |

[1]clump (stump-sprout origin); [2]single-stem (seedling origin)

Species composition of crop trees



Mean student worker hours per hectare by task

| Work Type | Control | Moderate | Intensive |
|---|---|---|---|
| Brushsaw | 0.0 | 24.8 | 37.8 |
| Chainsaw | 0.0 | 25.4 | 61.7 |
| Herb. App. | 0.0 | 3.0 | 3.1 |
| Hipchain | 0.0 | 1.5 | 2.0 |
| Saw Maint. | 0.0 | 2.2 | 0.0 |
| Slashing | 0.0 | 3.3 | 0.6 |
| Tree-marking | 0.0 | 1.2 | 1.9 |

Abundance of pole size and poor quality residual trees necessitated use of chain saws, increasing the time associated with treatment application.

# THREE-STAGE SHELTERWOOD

Overstory removed in three harvests over a 17-year period. Spruce favored for retention during first and second harvests. All residual trees ≥ 2 in. DBH were cut after the final overstory removal.

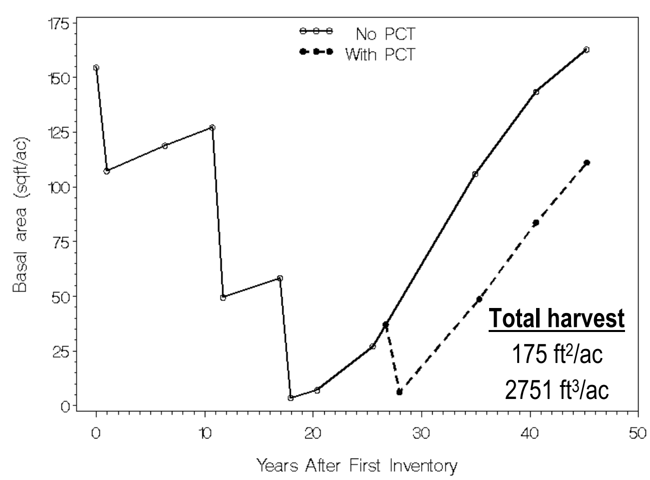



Figure 1. Growth and removals from the 3-stage shelterwood treatment in the long-term silvicultural experiment at the Penobscot Experimental Forest.

## *Regeneration Performance of Shelterwood vs. Commercial Clearcut*

**Seedling Abundance:** Natural regeneration after disturbance is prolific in the Acadian Forest Region. Seedlings of shade tolerant species continue to establish and persist for 30 years or longer after a stand-initiating disturbance. As more competitive seedlings grow into saplings and saplings grow into poles, the number of seedlings declines.

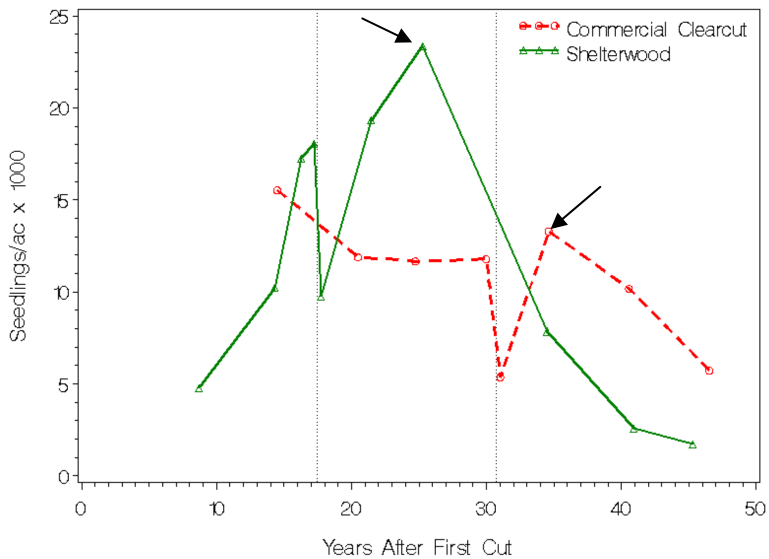



Figure 2. Seedling (>0.5 ft. tall < 0.5 in. DBH) density following stand-initiating harvests in commercial clearcut and shelterwood treatments. Vertical lines indicate most recent harvests, arrows indicate inventories with peak seedling density in each treatment.

**Seedling Stocking:** Stocking is the percentage of milacre sample plots that have seedlings of a particular species or species group.

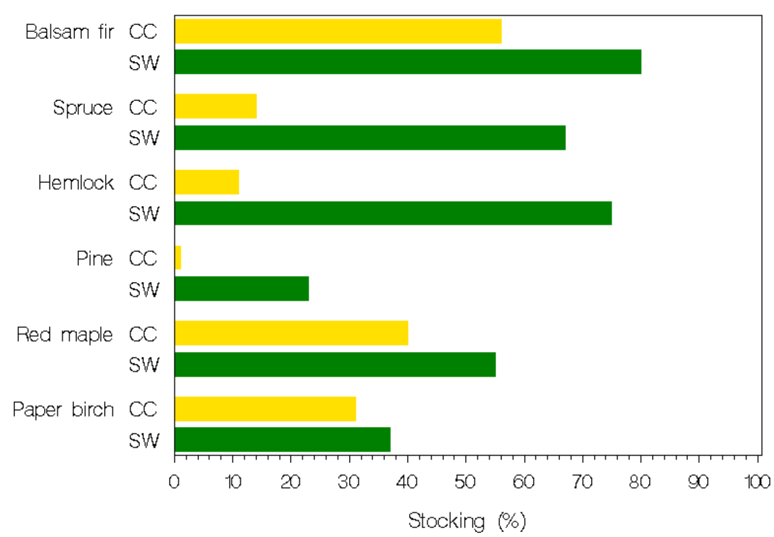



Figure 3. Seedling (>0.5 ft. tall & < 0.5 in. DBH) stocking by species in the commercial clearcut (CC) and shelterwood (SW) treatments at the inventory of greatest abundance (see arrows in Figure 5 above).

# STOP 2: PCT & COMMERCIALTHINNING

Growth and yield of **crop** trees 18 years after treatment. From: *Brissette, J.C.; Frank, R.M.; Stone, T.L.; Skratt, T.A. 1999. Precommercial thinning in a northern conifer stand: 18-year results. For. Chron. 75(6):967-972.*

| Response Variable | Control | 8 x 8 Spacing | MSD ($p \leq 0.05$) |
|---|---|---|---|
| Survival (%) | 77.2 | 97.2 | 8.2 |
| Diameter Growth (inches) | 1.9 | 4.4 | 0.4 |
| Height Growth (feet) | 16.4 | 22.3 | 1.6 |
| Crown Width (feet) | 5.9 | 9.8 | 0.7 |
| Live Crown (%) | 43.8 | 67.6 | 5.1 |
| Basal Area ($ft^2/ac$) | 23 | 89 | 11 |
| Fir + Spruce volume ($ft^3/ac$) | 362 | 1,366 | 220 |

Growth and yield of **crop** trees 25 years after treatment. From: *Phillips, L.M. 2002. Crop tree growth and quality twenty-five years after precommercial thinning in a northern conifer stand. M.S. Thesis, University of Maine. 87 p.*

| Response Variable | Control | 8 x 8 Spacing | Significance |
|---|---|---|---|
| DBH (inches) | 4.9 | 6.3 | p<0.0001 |
| Total Height (feet) | 39 | 39 | NS |
| Live Crown (%) | 44.5 | 57.3 | p<0.0001 |
| Branches (#/m at 1 to 2 m above DBH) | 12.2 | 16.9 | p<0.0001 |
| Branch Size (inches) | 0.4 | 0.6 | p<0.0001 |
| Knot Volume (%) | 0.2 | 0.5 | p<0.0001 |
| Ht:DBH (m:cm) | 98 | 75 | p<0.0001 |
| Form Factor | 0.78 | 0.74 | p=0.0006 |

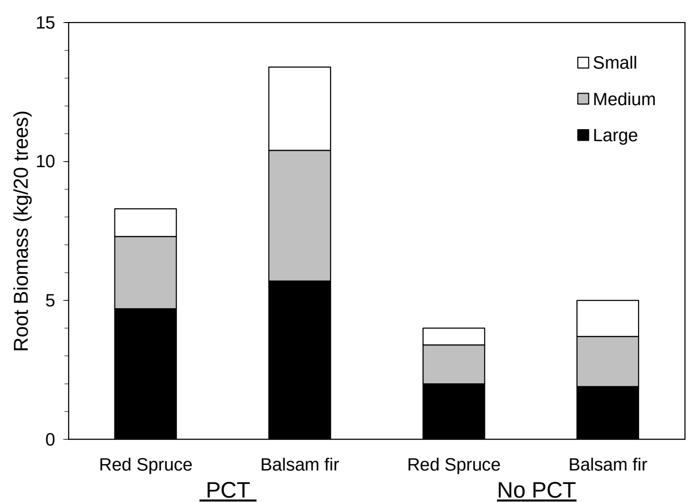



Figure 1. Root development 16 years after precommercial thinning. From: *Tian, S. 2002. Effect of precommercial thinning on root development and root and butt decay incidence in red spruce and balsam fir. Ph.D. Dissertation, University of Maine. 265 p.*

# CFRU: Commercial Thinning

Robert Seymour, Spencer Meyer and Robert Wagner

## What is the CFRU?

The **Cooperative Forestry Research Unit** (CFRU) is a partnership between forest landowners and managers in the state of Maine and the University of Maine. The purpose of the CFRU is to help member organizations advance forest management practices in the state of Maine through applied scientific research. Member organizations contribute annual dues to support research projects that are guided by an Advisory Committee. The CFRU currently has 26 members (representing approximately 8 million acres), including private industrial, private non-industrial, and public forest landowners, wood processors, and other private contributors.

## What is the Commercial Thinning Research Network?

The Commercial Thinning Research Network (CTRN) is a statewide system of study sites created to study questions surrounding commercial thinning of Maine's spruce-fir resource. The Network was installed in 2000-2001 consists of two experiments, each replicated at six sites (Figure 1). The research questions for the two experiments are:

1. For natural spruce-fir stands that **have never received** precommercial thinning (PCT), what is the influence of (a) method of commercial thinning and (b) residual density on subsequent stand response?

2. For natural spruce-fir stands that **have received** PCT, what is the influence of (a) timing of first commercial thinning entry and (b) residual density on subsequent stand response?

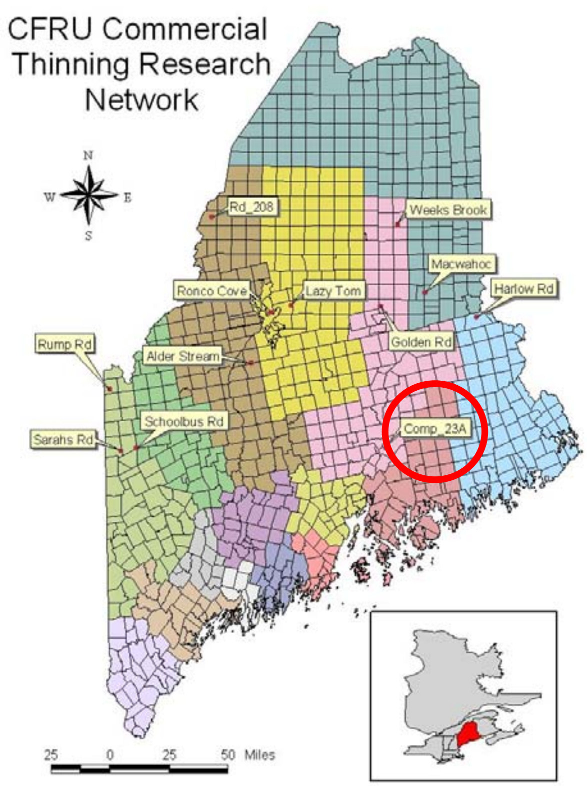



Figure 1. Location of twelve CFRU Commercial Thinning Research Network study sites.

The Penobscot Experimental Forest (PEF) study site has an installation of the second experiment type. PEF includes study treatments designed to answer the questions associated with timing and intensity of commercial thinning entry:

## *Treatment Descriptions (for Objective 2):*

| Timing | Relative Density (RD) Reduction: 33% | Relative Density (RD) Reduction: 50% |
|---|---|---|
| Now | Evenly-space residual stand & reduce RD by 33% in 2001-2002 | Evenly-space residual stand & reduce RD by 50% in 2001-2002 |
| Wait 5 years | Evenly-space residual stand & reduce RD by 33% in 2006-2007 | Evenly-space residual stand & reduce RD by 50% in 2006-2007 |
| Wait 10 years | Evenly-space residual stand & reduce RD by 33% in 2011-2012 | Evenly-space residual stand & reduce RD by 50% in 2011-2012 |
| Never | Untreated check | |

Relative density is the ratio of the current density (trees per acre) to the maximum number of trees possible based on the current average tree volume. Treatments were 33% and 50% removal based on the original relative density [calculated from the diagram of Wilson et al. (1999)]; marking generally favored the largest, most vigorous crop trees while attempting to maintain fairly uniform spacing of residuals; the exception was that firs over 9” dbh were generally removed, based on their typical silvics and biology.

Treatment plots are nominally 1.0 acres with a 0.2 acre measurement plot in the center. (Figure 2). Forwarder trails are spaced 100 feet apart with only one forwarder trail running through the sample plot. Small, single-grip processors used ghost trails spaced between forwarder trails to conduct thinnings.

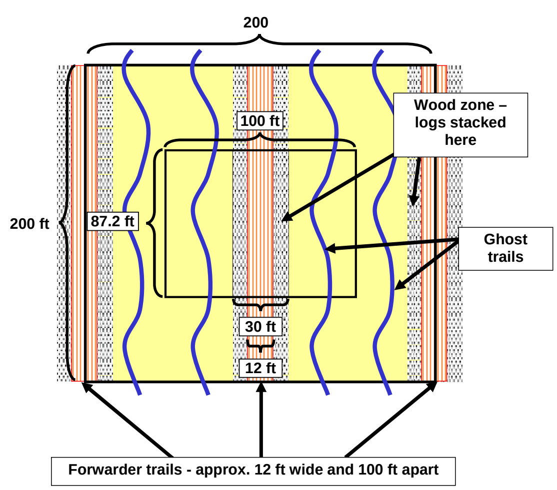
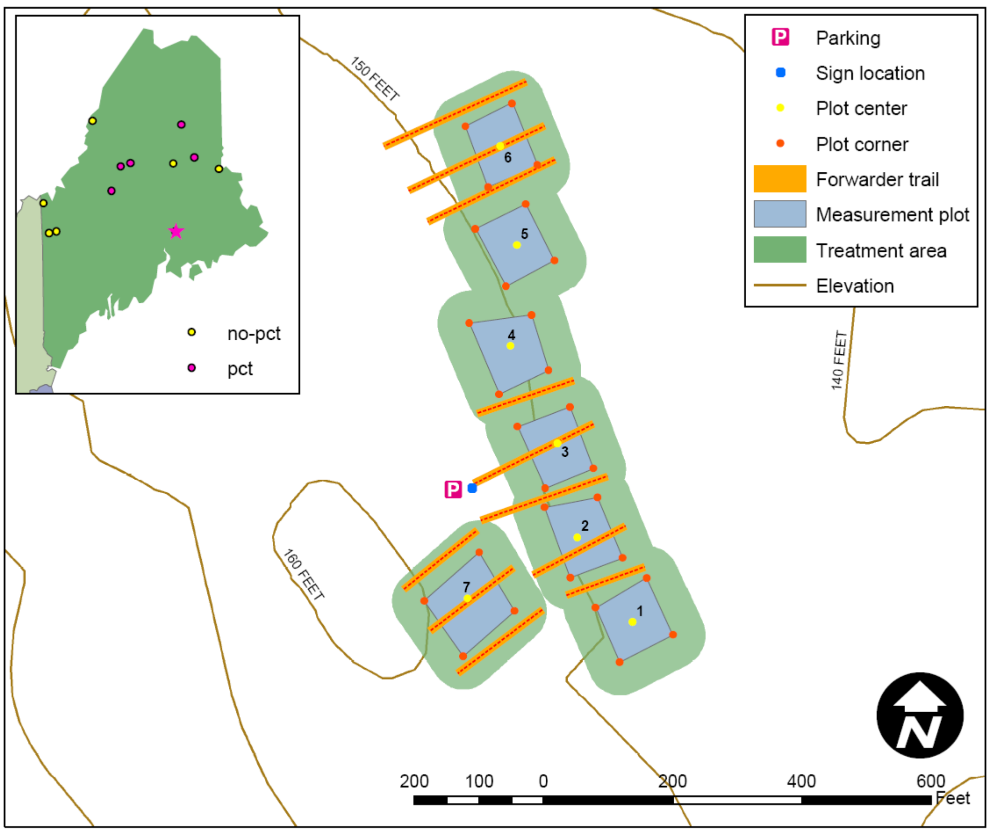



Figure 2. Treatment and sample plot design for CFRU Commercial Thinning Research Network study sites.

## *PEF Study Site Description:*

This stand originated from a shelterwood removal cutting in 1972. Spacing was done in 1981 to 2x3 m (slightly lower density than 8x8 ft) by the USFS as part of the long-term silvicultural methods comparison study. In 2001, before commercial thinning, this stand had 600 trees/A with an average dbh of 4.3 inches and the site index was 67 ft at age 29. The stand had a basal area of 73 $ft^2$/A and a relative density of 0.29. We estimated that it had a volume of about 22 cords/A (1,870 $ft^3$/A). First commercial thinnings done in the winter of 2001-02; the second treatments were just completed in the winter of 2006-07. The study treatments were randomly applied across seven plots (Figure 3).




| Penobscot Exp. For. Site Information | | Plot Information | | |
|---|---|---|---|---|
| Site name | PEF, Penobscot Exp. For., Compartment 23A Site | Plot | TrtmntDate | Treatment |
| Township | Bradley | 1 | | Control |
| County | Penobscot | 2 | 2001-2002 | 33% |
| Landowner | University of Maine | 3 | 2001-2002 | 50% |
| History | PCT - 1983 | 4 | 2011-2012 | 33% |
| Plots established | August 2001 | 5 | 2011-2012 | 50% |
| Commercial Thinning(s) | February 2002, February 2007 | 6 | 2006-2007 | 50% |
| Location | 45-51'-17" N, 68-38'-07" W | 7 | 2006-2007 | 33% |
| For more information contact the Cooperative Forestry Research Unit at (207) 581-2893 | | | | |

CFRU

Cartographer: Benjamin Gannon
Date: August 16, 2007
Projection: UTM Zone 19 North
Datum: NAD 1983

Figure 3. Treatment map for PEF Commercial Thinning Study

## *Measurement Protocol*

We are monitoring the growth of all trees in seven 0.20-acre (87.2 x 100 ft) plots that are centered within a 0.92-acre (200 x 200 ft) treatment plots.

## *Initial Effect of Commercial Thinning on Previous PCT Sites*

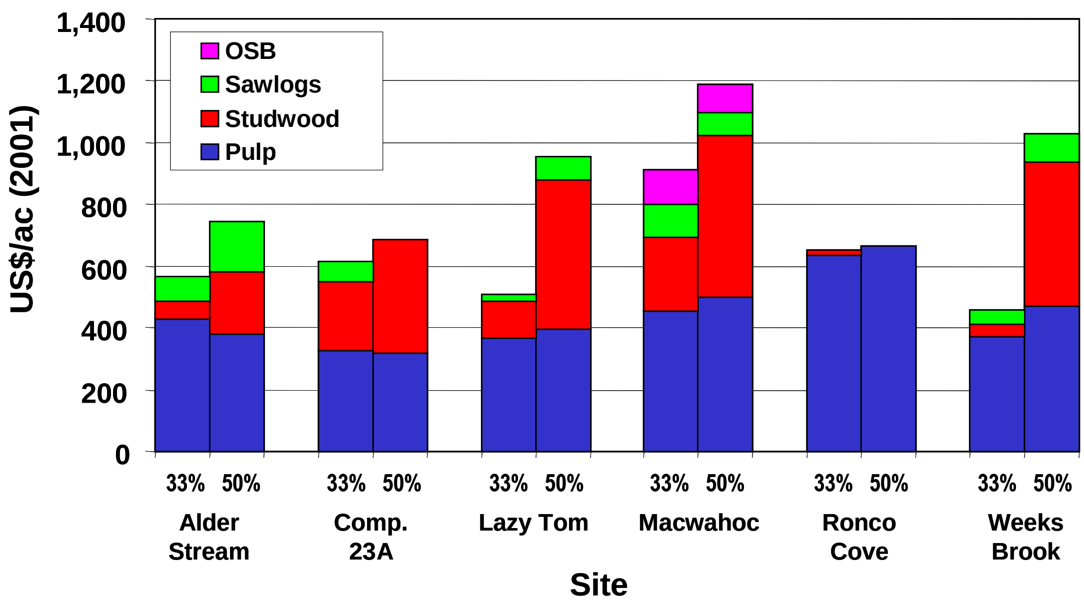



Figure 4. Mill-delivered value by product class from thinning each of the six sites at 33% and 50% relative density reductions from first thinning (2001).

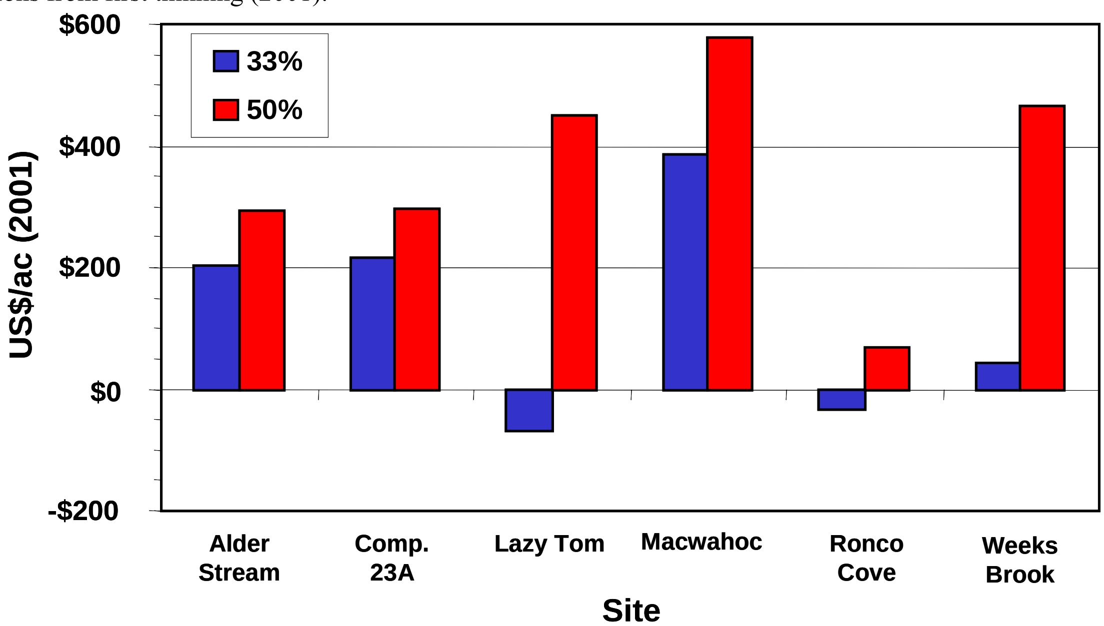


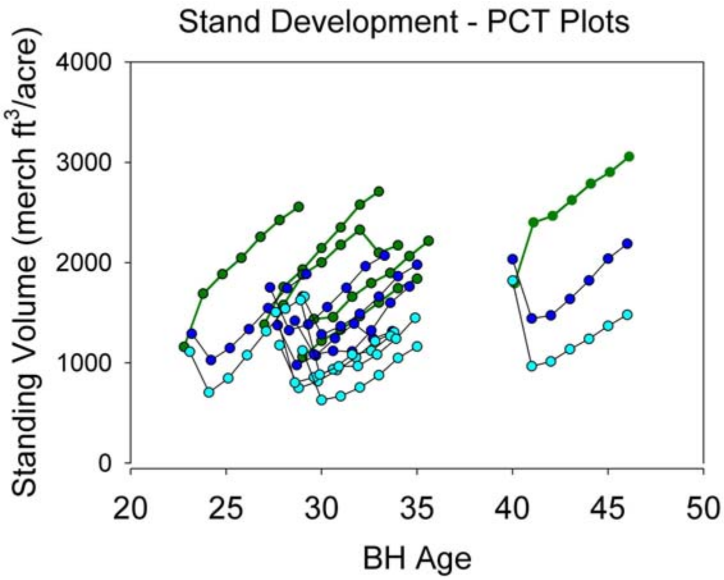

Figure 5. Stumpage (net revenue) from thinning each of the six sites at 33% and 50% RD reductions during first thinning (2001).

## *6-Year Results from PCT Study Sites (PEF plus 4 other sites)*

All stands were originally precommercially thinned to approximately 8x8 feet (600-800 trees per acre). Stand age at the time of the first commercial thinning ranged from 22-40; site index is high, ranging from 60 to 81 (height in feet at a bh age of 50).

Results pertain to net merchantable volume increment (trees 4.6” dbh and larger, accretion plus ingrowth). Mortality was negligible, even on the unthinned control plots, except at one site (Lazy Tom) which suffered severe top breakage from a fall snowstorm and was excluded from these analyses. Volumes calculated from Honer’s equations and include all conifer species (mostly balsam fir).

Figure 6. Volume of most plots has essentially doubled in six years.



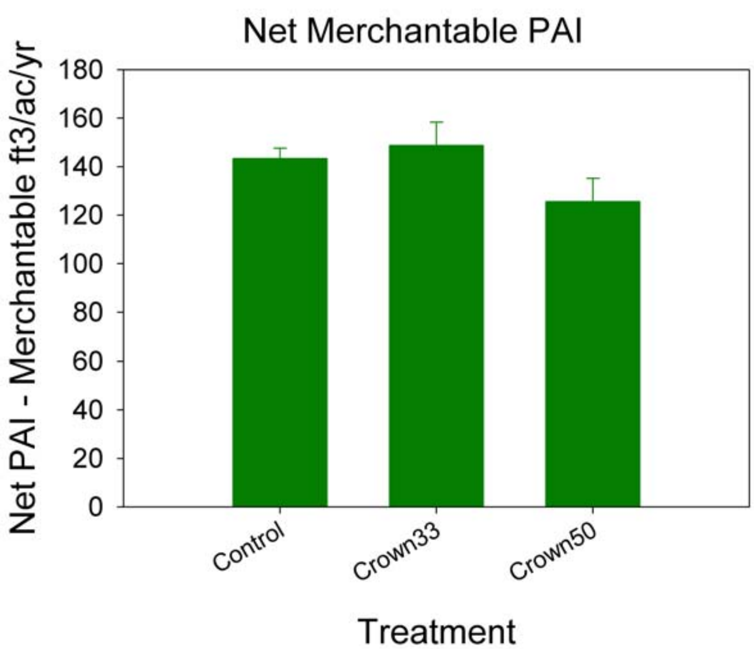




Figure 7. Remarkably, neither commercial thinning treatment differed from the Untreated Controls (p=.19) although the 50% removal mean is highly influenced by one plot at the Ronco Cove site.

Figure 8. Both relative density and site index were highly significant predictors of gross merchantable PAI (overall $R^2$ = .76). Note the remarkable, very high PAI of one 50% removal plot (Ronco Cove). On the left figure, note the very strong, linear relationship between gross PAI and site index (using the unthinned plots only); rarely have we found Site Index to be so highly predictive in the spruce-fir region.

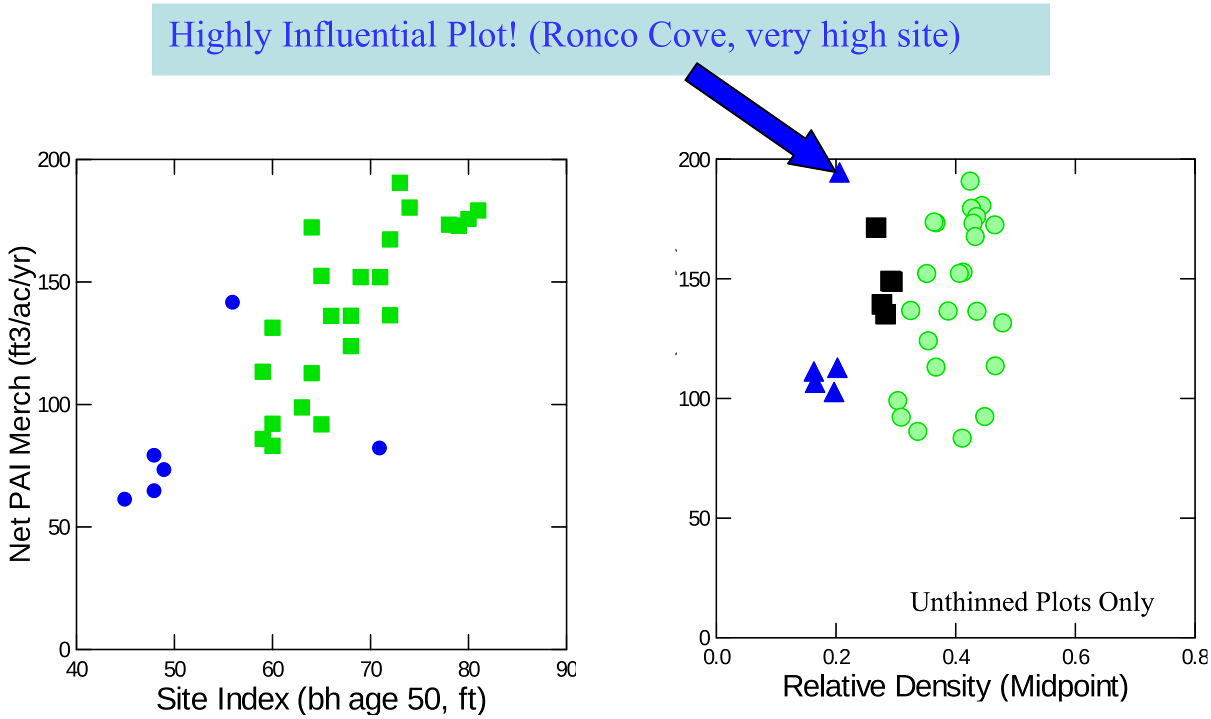



Figure 9. The density management diagram (DMD) for the PEF shows the thinned plots have higher average tree volume with a lower density. The thinnings have kept the stands below the 40% relative density line.

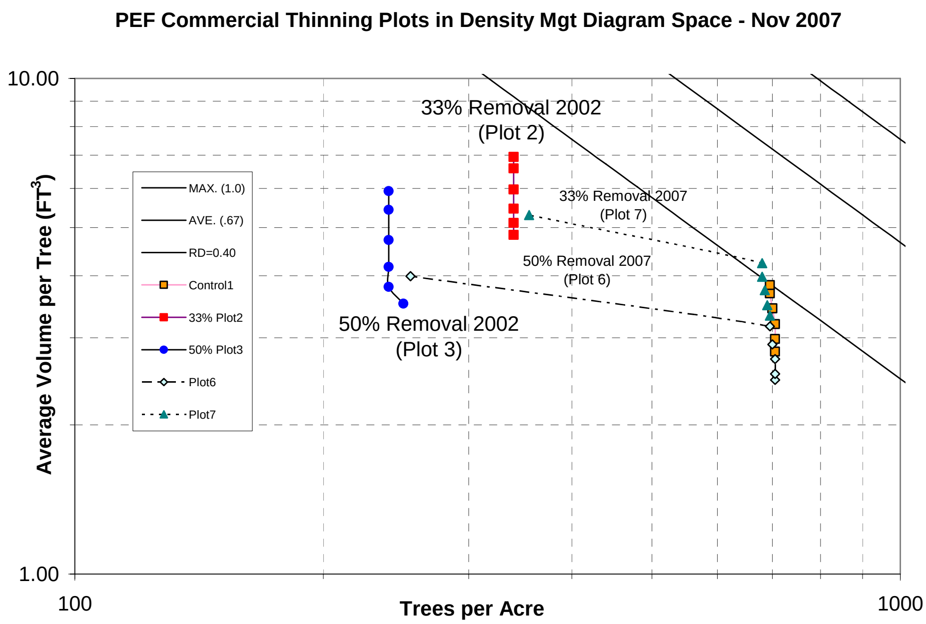


Figure 10. Stocking guide for PEF plots. First and Second thinnings are shown. Plots 1 is the control and plots 4 and 5 will be thinned in 2012.

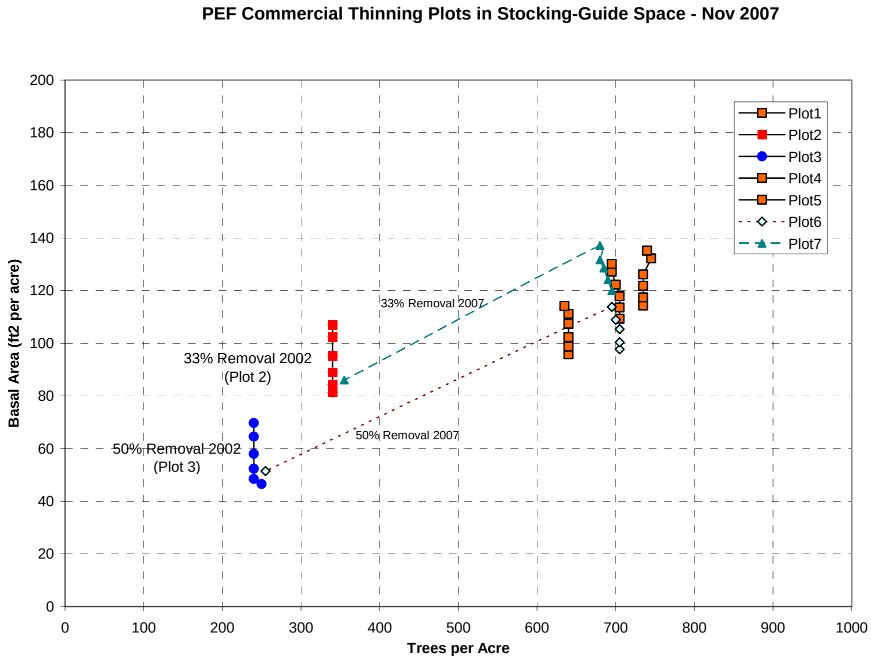
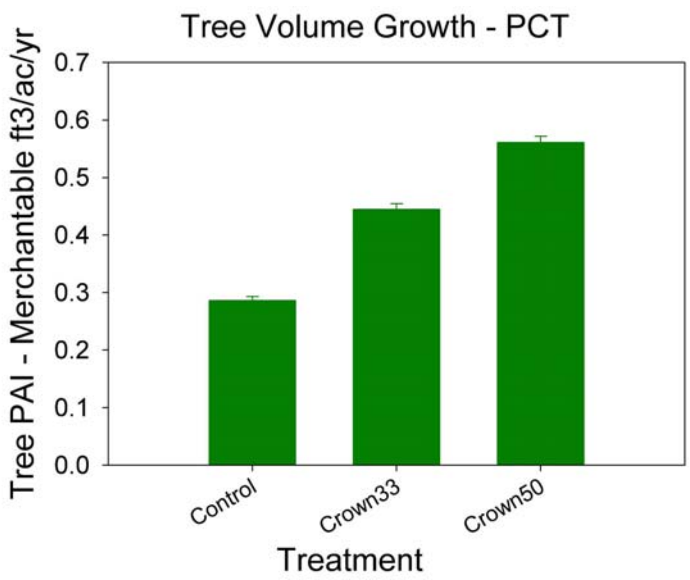



Figure 11. 6-year volume growth across PCT study sites (Except Lazy Tom). Growth is for upper crown classes only, spruce and fir, corrected for initial tree basal area and site index. All contrasts are highly significant.



### *Improving Current Regional G&Y Models:*

A primary value of these state-wide CTRN plots is testing and refining current stand simulators used to predict long-term stand responses and financial gains associated with commercial thinning.

Figure 12. Total standing volume of site index 60 stands of pure balsam fir for the nine PCT/CT thinning scenarios.

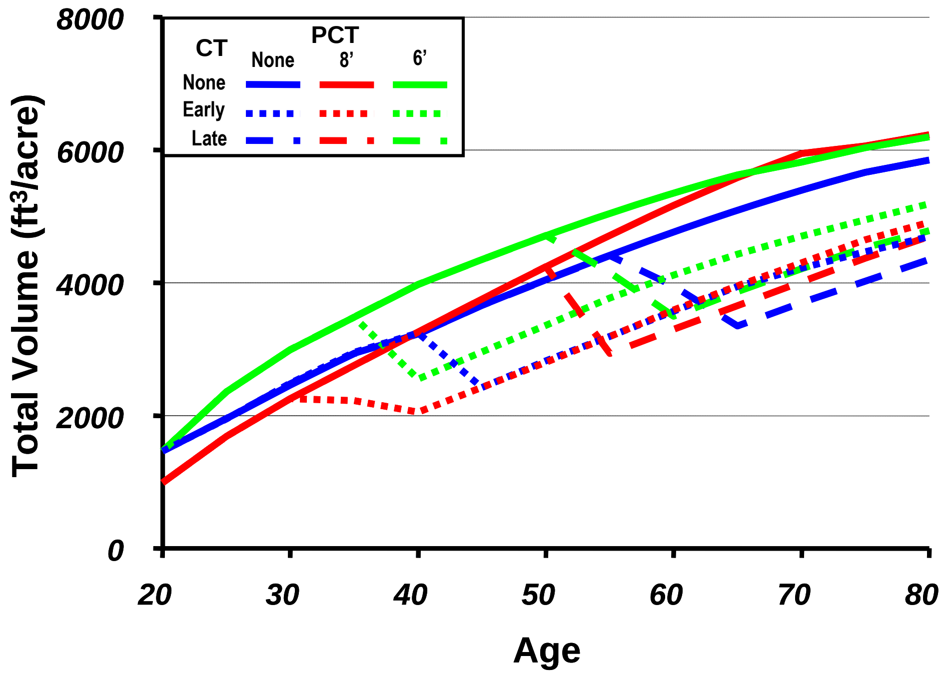
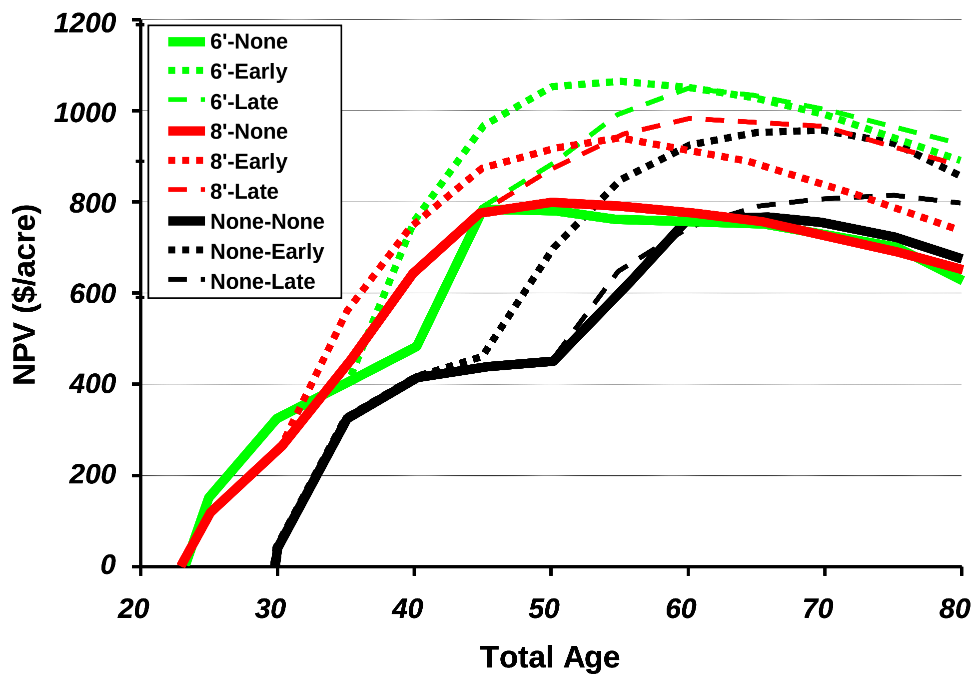



Figure 13. Net present value (NPV) in year 2000 dollars of site index 60 stands of pure balsam fir for the nine PCT/CT thinning scenarios.



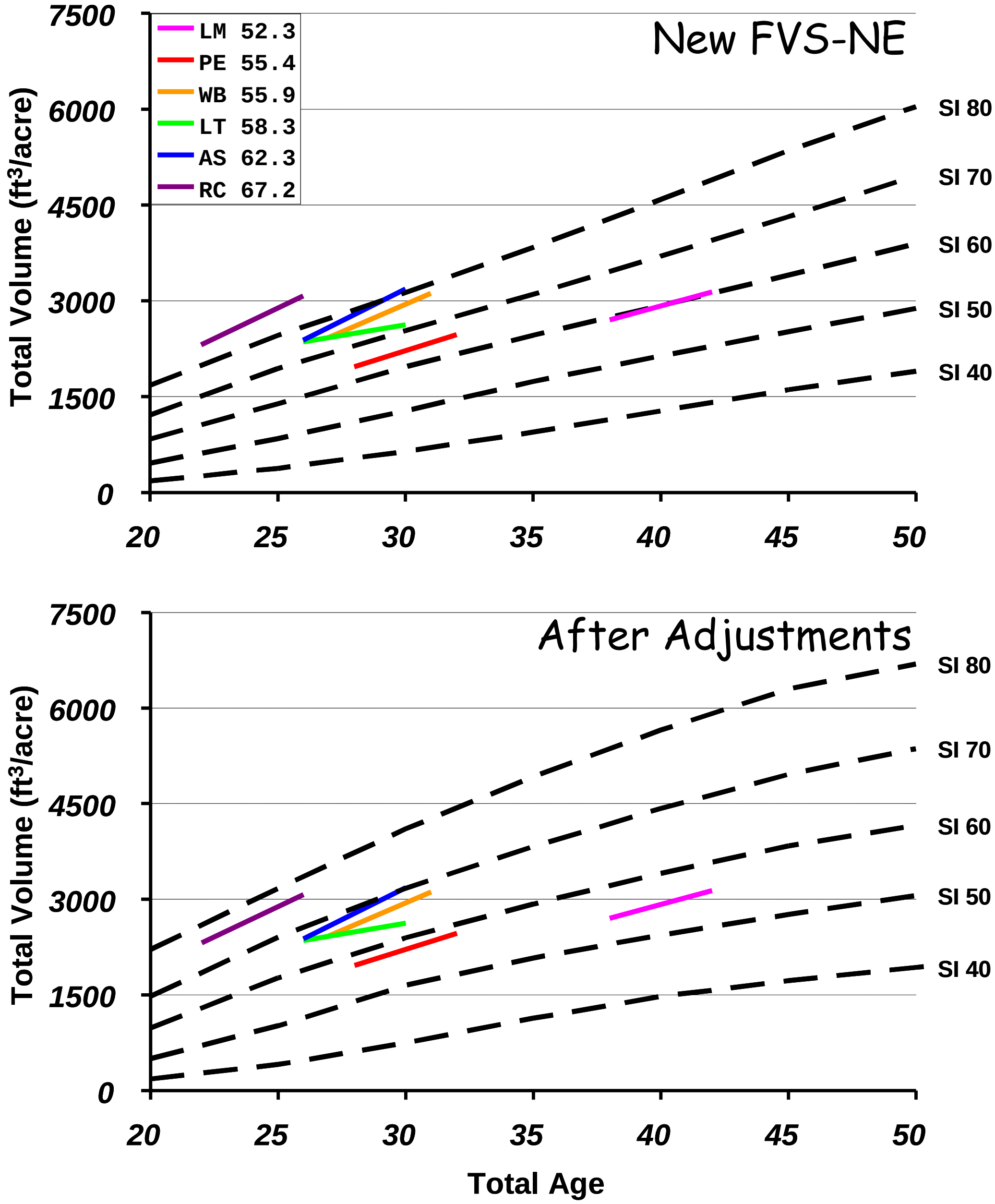



Figure 14. FVS can be calibrated with data from PCTd stands to improve the volume growth predictions.

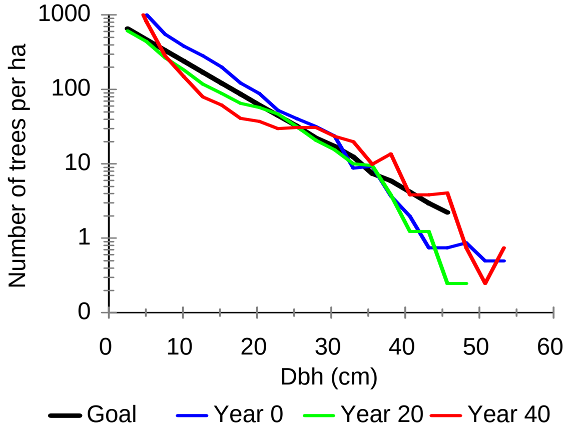
For more information about the CFRU, go to our website:

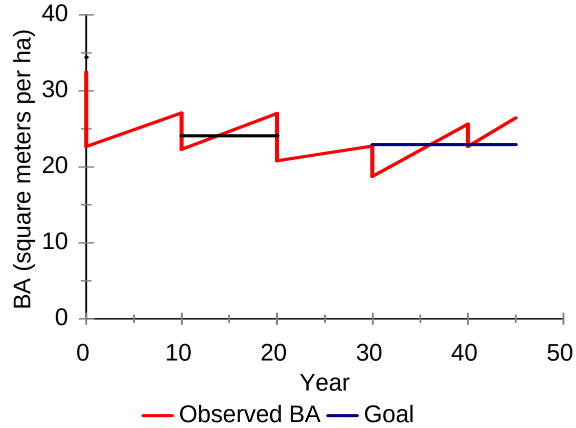
**www.umaine.edu/cfru**

# STOP 3: UNEVEN-AGED SILVICULTURE

Selection cutting is applied to 18 stands in the Forest Service experiment; the earliest treatments were started in the 1950s. We use a mathematically determined (BD*q*) reverse-J structural goal. Target maximum diameter and residual BA vary by cutting cycle (5, 10, 15, or 20 years), and all treatments are replicated at least twice. Allowable harvest at each entry is determined by target residual BA and is distributed among size classes per the diameter distribution goal. Marking guidelines and species composition goals guide removals.

Examples of structural change over time:
10-year cutting cycle




The stand we will visit today is Unit 26. This approx. 13-ha stand was recently marked for harvest. This stand was on a 5-year cutting cycle from 1957 until 1972, a 10-year cutting cycle from 1972 until 1992, and is now on a 15-year cutting cycle. This is the 7th selection cutting. The marking guidelines follow (data are in English units).

---

**Marking Guidelines**
U26, 15-year selection cutting
(Prepared by Laura Kenefic on August 22, 2008)

<u>Trees ≥ 5 in. dbh</u>

| | | |
|---|---|---|
| 1. | Target BA (trees ≥ 4.5 in. dbh) | 80 $ft^2$/ac |
| 2. | Observed BA | 113.6 $ft^2$/ac |
| 3. | Prescribed BA removal | 33.6 $ft^2$/ac |
| 4. | Estimated Volume removal | about 6.5 cd-eq/ac |

5. Species Composition (percent of BA ≥ 4.5 in. dbh)

| Species | Target | Observed | |
|---|---|---|---|
| E. hemlock | 30 | 34 | * |
| Spruce | 40 | 29 | |
| B. fir | 5 | 8 | * |
| N. white-cedar | 5 | 6 | * |
| Hardwoods | 15 | 20 | * |
| Eastern white pine | 5 | 3 | |

6. Maximum dbh (in.)

| Species | Target | Observed | |
|---|---|---|---|
| E. hemlock | 19 | 22 | * |
| Spruce | 19 | 19 | |
| B. fir | 7 | 10 | * |
| N. white-cedar | 11 | 19 | * |
| Hardwoods | 15 | 18 | * |
| E. white pine | na | 24 | |

Note: because cedar is close to the BA goal, ability to reduce MaxD is limited by the small allowable cut of cedar.

7. Diameter distribution (See next page)

Trees < 5 in. dbh

No data

**Instructions for marking:**

Harvest: 33.6 $ft^2$/ac (approximately 30% of BA ≥ 5 in dbh).

Priorities:

1. Remove cull trees (< 50% merchantable by volume, except northern white-cedar unless negatively impacting growth or regeneration of more desirable tree), regardless of size. Note: < 1% of current stand volume is cull.
2. Remove high-risk trees (expected to die within next 15 years) and unacceptable growing stock (UGS: trees without potential for volume and value increase), regardless of size.
3. Reduce proportion of fir, hardwood, and hemlock BA. Fir and hardwood removals may come from all classes. Hemlock removals should come from small and large sawtimber classes (see diameter distribution).
4. Remove trees beyond maximum dbh, especially fir, hardwood and hemlock.
5. Release or thin potential crop trees in saplings, poles, and small sawtimber.

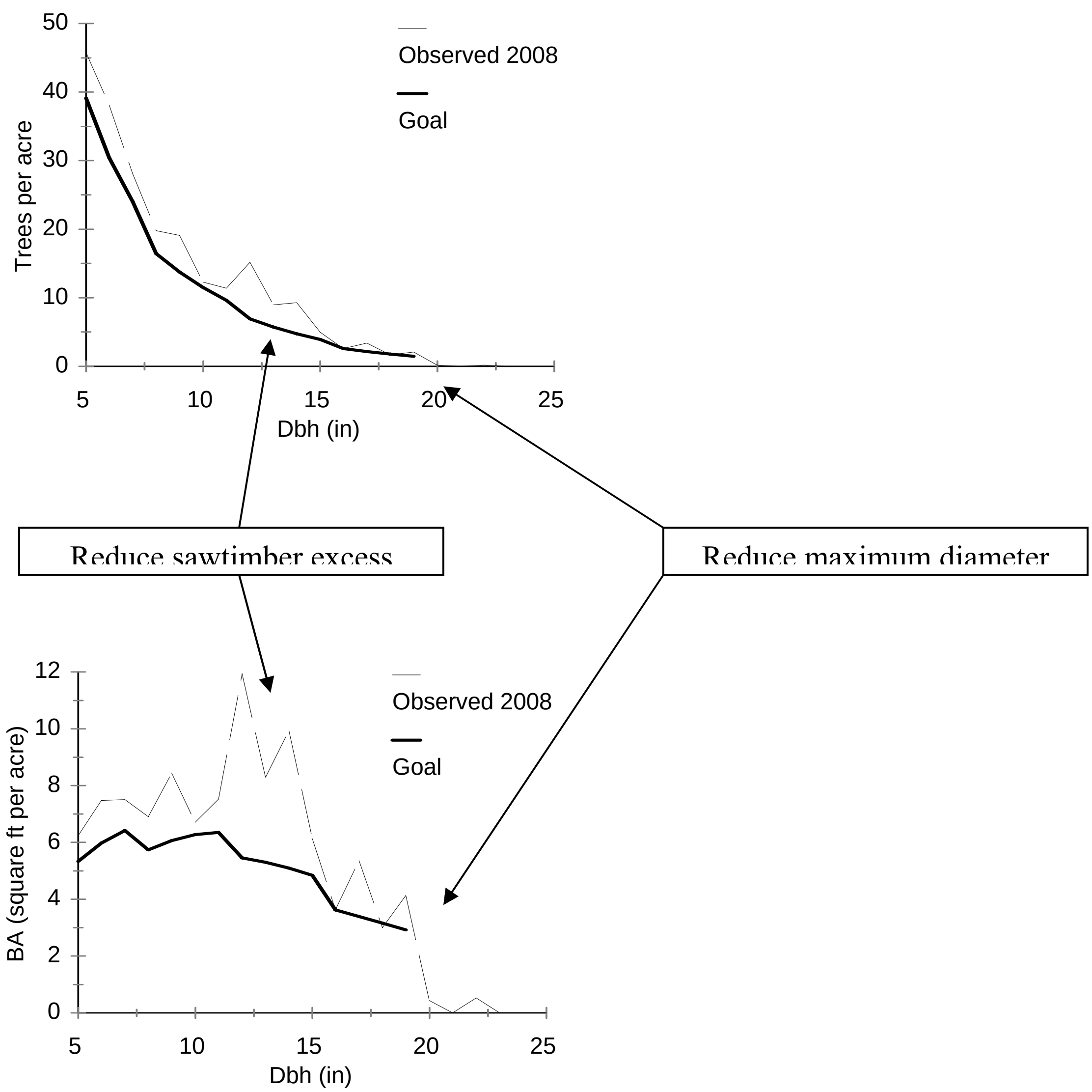
Note: No spruce or are to be harvested, unless cull or high risk.

Note: Up to 5 trees > maximum diameter may be retained per unit if of exceptional size and quality for their species.

Note: Dead trees (snags) and trees with active cavities or nests (wildlife trees) should not be harvested.

Summary: Mark 33.6 $ft^2$/ac. After cull (which should be rare), high-risk trees, and UGS, the top priorities for removal are fir > 7 inches, hardwoods > 15 inches, and hemlock > 19 inches (most trees in those classes should be cut unless exceptional). The remainder of the cut should consist almost entirely of fir and hardwoods (any size), hemlock (small and large sawtimber), and cedar (medium to large sawtimber). Removals should be made within the constraints of the allowable cut and target diameter distribution.

Unit 26: Diameter and Basal Area Distributions (2008)



# STOP 4: AFERP – EXPANDING-GAP STUDY

Bob Wagner, Bob Seymour, & Matt Olson

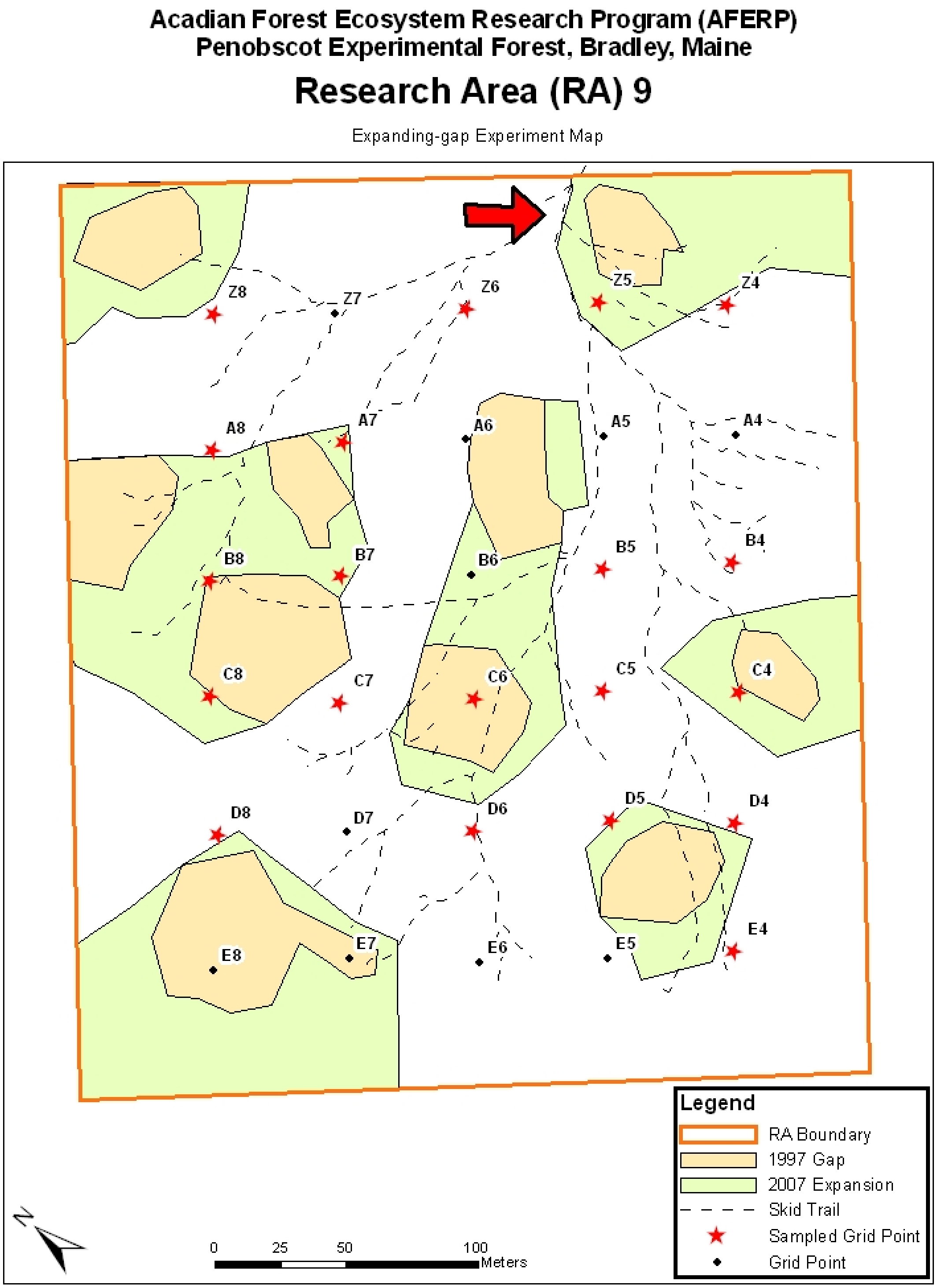
**What is AFERP?**

The Acadian Forest Ecosystem Research Program (AFERP) was established in 1995 with the objective of documenting the effects of alternative silvicultural systems on stand-level ecosystem patterns and processes. For more information about AFERP check us out online at:

www.forest.umaine.edu/facstaff/facstaff_pages/wagner/FERP/default.html

**Objectives:**

1) Enhance understanding of managed forest ecosystems in the Acadian ecoregion;
2) Assess the ecological effects of alternative silvicultural systems; and
3) Evaluate the practical feasibility of silvicultural systems designed after regional patterns of natural disturbance.


Acadian Forest Ecosystem Research Program (AFERP)
Penobscot Experimental Forest, Bradley, Maine
Research Area (RA) 9
Expanding-gap Experiment Map
Z8
Z7
Z6
Z5
Z4
A8
A7
A6
A5
A4
B8
B7
B6
B5
B4
C8
C7
C6
C5
C4
D8
D7
D6
D5
D4
E8
E7
E6
E5
E4
Legend
RA Boundary
1997 Gap
2007 Expansion
Skid Trail
Sampled Grid Point
Grid Point
N
0 25 50 100
Meters

## Expanding-gap Harvest Treatments

Two expanding-gap silviculture regeneration methods were designed to emulate the 1% annual disturbance intensity and disturbance pattern common to the Acadian ecoregion (Table 1). Gaps are created and then systematically expanded in all directions after the previous gap area has been regenerated (Figures 1 and 2). Both systems are applied using a 10-year cutting cycle.

***20:10 treatment*** – Harvests 20% of the area using 0.2 ha expanding gaps and with a 10-year regeneration period between expansions. The 20:10 system is designed to encourage natural regeneration of tree species of intermediate shade tolerance and to maintain stands of mid-successional status.

***10:20 treatment*** – The second system is spatially and temporally half of the 20:10. This 10:20 system harvests 10% of the area using 0.1 ha expanding gaps with a 20-year regeneration period between gap expansions. The 10:20 system is designed to encourage shade-tolerant species and accelerate development of late-successional stands.

***Unharvested control*** **–** No harvesting will be used in the control, thus providing a background comparison for natural disturbance patterns.

Table 1 – Break down of AFERP treatments.

| **Treatment** | **Area Treated During Cutting Cycle** | **Gap Regeneration Period** | **Disturbance Frequency ($yr^{-1}$)** | **Compositional Goal** | **Research Area #** |
|---|---|---|---|---|---|
| 20:10 | 20% | 10 yr | 1% (2% for 1st 50 yrs, then rest for 50 yrs ) | Mid-successional | 1, 6, 9 |
| 10:20 | 10% | 20 yr | 1% | Late successional | 2, 5, 7 |
| Control | 0% | Natural | Natural only | Natural succession | 3, 4, 8 |

**20:10 Treatment**
(20% of area harvested/cutting cycle,
10 year regeneration period in a gap)

**10:20 Treatment**
(10% of area harvested/cutting cycle,
20 year regeneration period in a gap)

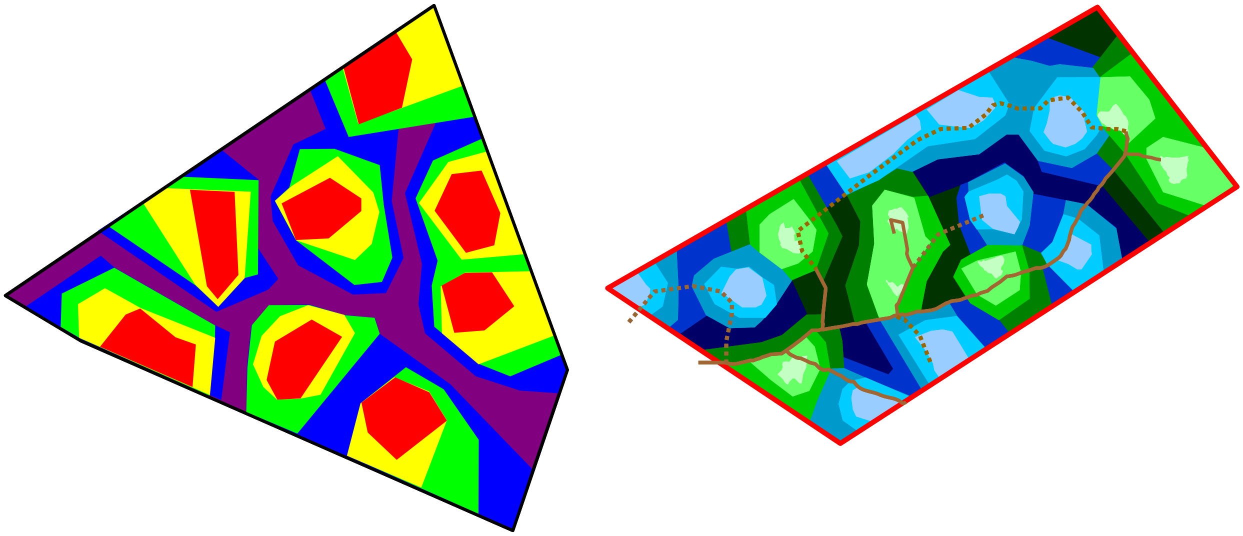


Figure 1 – Example of AFERP expanding-gap harvest system design for two treatments.

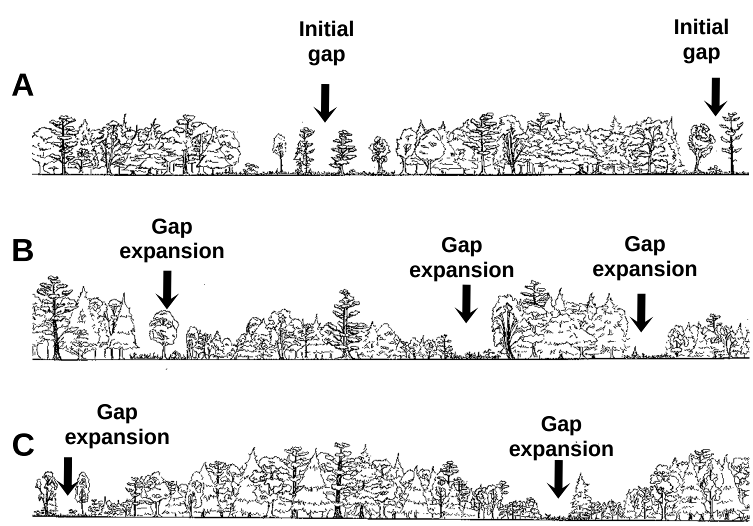



Figure 2 - Hypothetical canopy profiles after harvest entries 1 (A), 3 (B) and 5 (C) for the 20:10 treatment.

**Retention Trees**

Overstory trees also are retained to facilitate natural regeneration (seed and shade), provide wildlife habitat (i.e., cavity trees), and maintain long-term structural diversity. 10% of the initial overstory basal area (~4 $m^2$/ha) is permanently retained with both systems. An additional 20% of the basal area (~8 $m^2$/ha) may be retained in harvest gaps (for 10 or 20 years depending on treatment) to encourage natural regeneration when it is not present at the time of harvest.

**Experimental Design**

- Randomized complete block with 3 replicates of the 2 treatments and a control (9 experimental units in total). Blocks replicated in time.
- Units range from 8.7 – 11.3 ha in size.
- First harvest gaps for both treatments created from 1996-98. First gap expansions began January 2006 on the first block and will be completed on the remaining two blocks by 2008.
- Fifteen to twenty 0.05 ha fixed area plots, randomly selected from a 50 x 50 m grid lain across each RA, to measure overstory. Nested plots within to measure understory vegetation, saplings, and light availability.
- Growth of all short-term (overwood) and permanent reserve trees tracked within each gap. Additionally, a population of potential research trees (150-200/RA) tracked in 20-10 treatment.
- Downed wood tracked on a series of 100 m transects centered on each gridpoint (2.5 – 3.5 km total transect/RA).
- Measurement of core variables occurs on a 5-year cycle for each block. All measurements are made the same number of years before and after each gap harvest. Measurements have been conducted for 10 of 12 field seasons since the inception of AFERP in 1995.

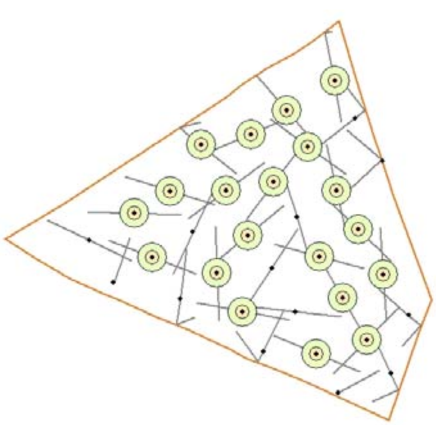


Figure 3 – Map of RA 1 with actual locations of deadwood transects (lines) and sapling (nested tan circle) & overstory (green) plots.

## Multi-disciplinary Research

A key mission of AFERP has not only been the monitoring of long-term stand dynamics resulting from these new silvicultural systems, but to provide a laboratory for multi-disciplinary investigations. Since its inception, AFERP plots have been used to address a number of ecological questions (Table 2). Extramural funding has been secured from a variety of sources to complete these studies.

Table 2 – AFERP ecosystem components studied and key findings.

| Ecosystem Component | Key Findings |
|---|---|
| **Downed woody material (DWM)** | Harvesting increased volume and biomass of non-decayed, small-diameter DWM. U-shaped temporal trend in DWM volume and biomass seen in even-aged stands may not apply to these uneven-aged stands due to their more complex, small-scale natural disturbance regime and repeated silvicultural entries (Fraver). |
| **Stand structure** | Regeneration events, whether induced through natural processes or by harvesting, increased aggregation in spatial pattern and reduced species mingling. The pattern was heightened when silvicultural treatments shifted species composition more towards hardwood species (Saunders). |
| **Understory vegetation and tree regeneration** | Plant species diversity was higher in harvested gaps than under a closed canopy. Species evenness in harvest gaps was higher than in natural gaps and under a closed canopy. Plant community composition in harvest gaps was different from natural gap and under a closed canopy (Schofield). |
| **Tree ecophysiology** | Examination of age-related trends in red spruce needle morphology and gas exchange in a multi-cohort stand indicated that: (1) foliage of red spruce exhibits age-related trends in both morphology and physiology; (2) age-related decreases in photosynthetic rates contribute to declining productivity in old red spruce; (3) declines in photosynthetic rates result from nonstomatal limitations; and (4) age-related changes in morphology and physiology are inherent in meristems and persist for at least 3 years in scions grafted to juvenile rootstock (Day). |
| **Songbirds** | No significant changes in community composition, species richness, or density of songbirds were detected from initial harvest gaps (Hartley). |
| **Amphibians** | Numbers of juvenile and adult spotted salamanders were reduced in harvest gaps compared to under a closed canopy. Salamanders were influenced by the presence of larger diameter DWM in gaps, but not under the closed forest canopy (Strojny). |
| **Click beetles** | Abundance and composition of click beetles were affected by gap harvesting and DWM characteristics (Thomas). |
| **Epiphytes and arthropods** | Arthropod and epiphyte assemblages dwelling on the bark of red maple varied with height. Gap harvesting reduced the abundance of bryophytes, Collembola, Araneae, and total arthropods on the bark of red maple (Miller). A positive correlation among bryophytes, Collembola, and Araneae indicated a trophic interaction. This relationship appeared to be sensitive to gap harvesting (Miller). |

## Current Research

### Spatial pattern of forest regeneration (Olson and Wagner)

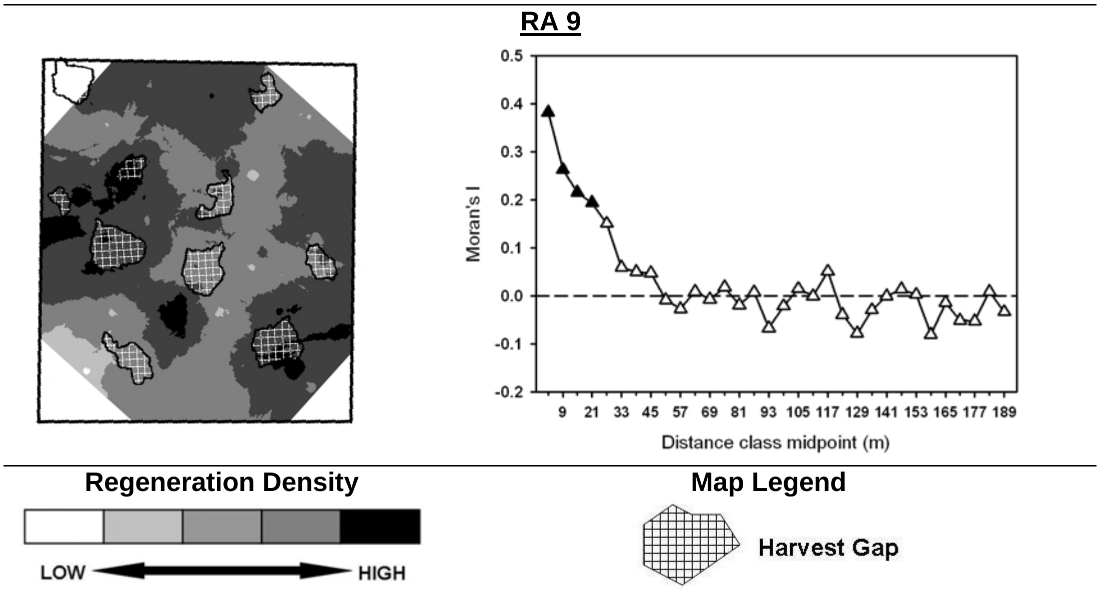



Figure 4. Interpolated maps of tree regeneration density generated by Ordinary Kriging (left) and corresponding spatial correlograms (right; significant Moran's I are represented by black triangles, P ≤ 0.0016).

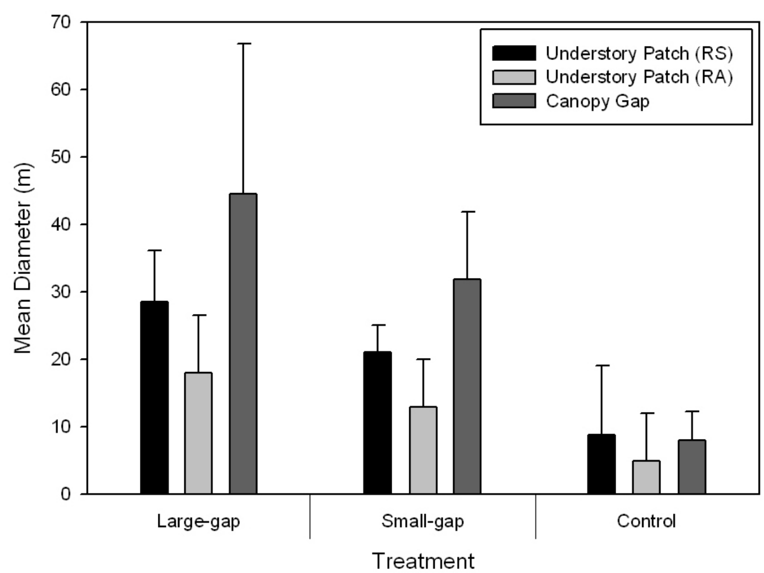



Figure 5 – Comparison of two estimates of mean patch diameter (semivariance & autocorrelation) of understory tree regeneration and mean gap diameter by gap-harvest treatment for the AFERP expanding-gap experiment.

**Future Research Directions**

**Sub-Stand Spatial Analyses**

Results from the above interdisciplinary research (see Table 2) suggest that significant advances in understanding the ecological effects of expanding-gap harvest systems will require methods that quantify spatial variability at the sub-stand scale.

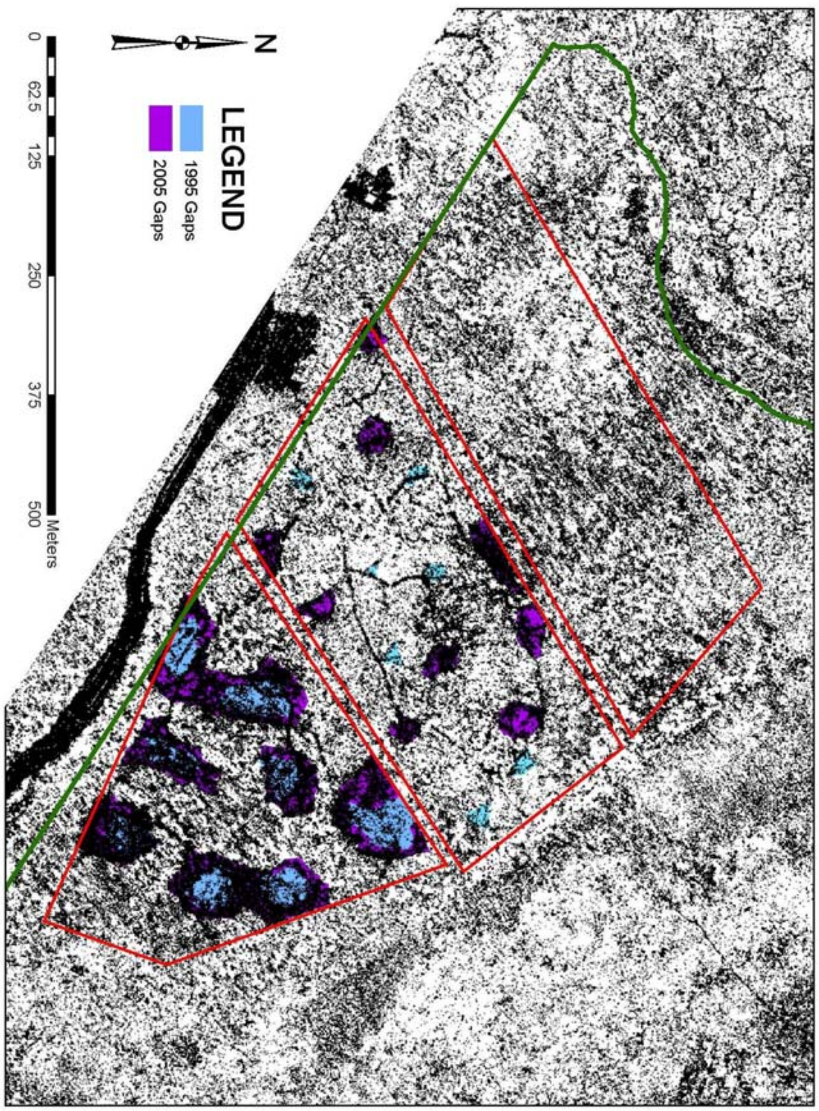



Figure 6 – Map of LiDAR ground returns for AFERP RAs 1, 2, & 3 (Red polygons arranged left to right) and adjacent PEF lands (Green polygon).

# STOP 5: LAND USE EFFECTS ON AMPHIBIAN POPULATIONS

Department of Wildlife Ecology, University of Maine
http://www.wle.umaine.edu/MaineLeap/index.html

Principal Investigator: Dr. Malcolm L. Hunter
Previous students: Dr. David Patrick, Dr. Sean Blomquist
Current students: Viorel D. Popescu

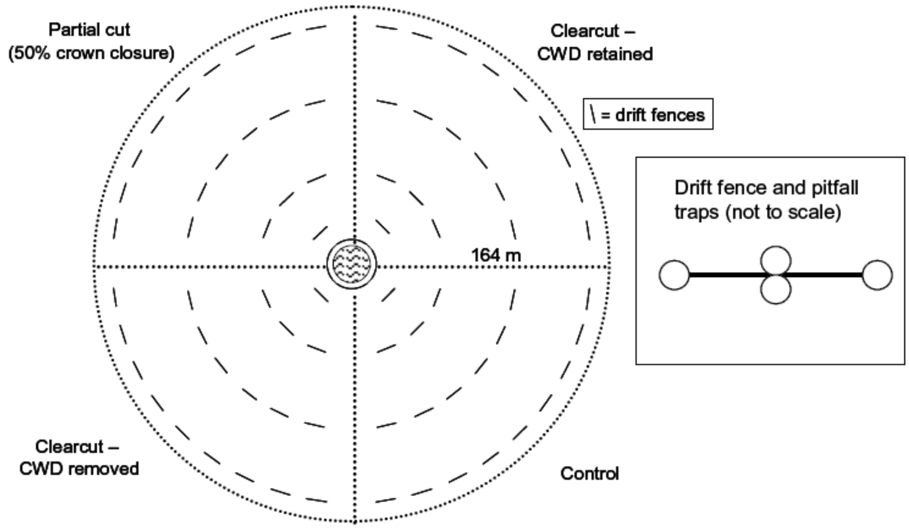
The major ecological objective of this research is to understand how amphibian populations persist in natural landscapes that are inherently heterogeneous both spatially and temporally. The same experiment is being conducted in 3 regions: Maine, South Carolina, and Missouri (collaborative NSF grant).

The research focuses on field experiments and model simulations that measure responses associated with three processes:

1. **Local population dynamics** - the ecological and demographic processes related to larval metamorphosis and recruitment of juveniles into the breeding population, and therefore local population size and those available for dispersal among ponds
2. **Dispersal and migration** - the behavioral process of individual movement through terrestrial habitats for reproduction at home ponds or for dispersal to nearby ponds
3. **Connectivity and recolonization** - the landscape-level process by which individuals disperse, and rescue or recolonize nearby ponds thereby maintaining metapopulation structure

In Maine, this study is conducted at the four experimental sites located on the Dwight B. Demerrit and Penobscot Experimental Forests. Each site is composed of four treatments representing four different forest management practices: 1) thinned forest (partial cut), 2) clearcut with CWD removed, 3) clearcut with CDW retained, 4) and control, unharvested forest.

The treatments are centered on an artificially excavated vernal pool and extend up to 164 m radius (see Figure). Harvesting was executed during the winter of 2003-2004 and arrays of drift fences were set up in spring-summer 2004 at distances of 16.6, 50, 100, and 150 m from the edge of the breeding pools. A total of 19 fences per treatment per site (1, 3, 6, and 9 fences located at 16.6, 50, 100, and 150 m distance, respectively) allow sampling 38% of the circumference of each concentric fence arrays. The drift fences are made of 3-foot wide black silt fencing, with up to 1/3 buried in the ground. Four pitfall traps are associated with each drift fence, resulting in a total of 1216 traps across all treatments and all sites.




The study is aimed at the entire forest-dwelling amphibian community in Maine, but focuses on two vernal pool-breeding amphibians: woods frogs (*Rana sylvatica*) and spotted salamanders (*Ambystoma maculatum*).

**Preliminary findings:**

- Juvenile wood frogs and spotted salamanders leaving experimental ponds were found to select for forested treatments in preference to clearcut treatments, but for those individuals that did enter a treatment, no difference was seen in the movement behavior over distance from the source pond
- Spotted salamanders appeared to be more sensitive to partial harvesting than did the wood frogs
- The data on the entire amphibian community revealed that species differed in their responses to habitat heterogeneity and that juveniles of all species preferred forested habitat
- There was no difference between the partial cut and control treatments, and between CWD retained and CWD removed treatments with respect to habitat selection by juvenile and adult amphibians.

Ongoing research specifically aims at the effects of regeneration on the habitat use of juvenile wood frogs and spotted salamanders, the specific habitat resistance to juvenile amphibian movements (rates and timing of movements) at various spatial scales, and the orientation of juveniles leaving experimental ponds.