Productivity, Regeneration Patterns, and Pre-Commercial Treatment Options of Two Ecologically-Based Silvicultural Systems: 20-Year Results from the AFERP Study

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- Completed all plot remeasurements for overstory, sapling, understory vegetation, and reserve trees for 9 10-ha treatment replicates.
- Established an intensive sample of regeneration plots within harvest gaps to document 20-year regeneration patterns, and inform the prescription of precommerical composition and density control treatments.
- Hosted numerous, influential field tours, webinars and intensive training based on AFERP accomplishments..

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http://www.nsrcforest.org

Project Summary

The Acadian Forest Ecosystem Research Project (AFERP, established on the Penobscot Experimental Forest, Maine) represents a 25-year ongoing effort to test an ecologically based silvicultural system in a mixed-species forest type representative of much of the Northern Forest. We evaluated two variants of natural disturbance-based expanding gap silviculture, and implemented the second decadal gap-expansion harvests from 2015-17. Permanent overstory and understory vegetation plots were remeasured on all 9 replicates. M.S. student David Carter remeasured 787 retention trees and found only 8.4% had died over 20 years. M.S. student Maggie Mansfield found significant increases in understory species richness in both treatments. Precommercial thinning treatments were implemented in the large-gap treatment, following a protocol developed by M.F. student Michael Pounch in 2017. The AFERP study sites have been featured in countless, influential field tours targeted at professionals, two iterations of the Northeast Silviculture Institute (2017, 2018), multiple webinars given by the Principal Investigator, several University of Maine forestry classes and field exercises, and other public outreach events focused on the Penobscot Experimental Forest.

Background and Justification

- Over the past two decades, forestry has seen increasing emphasis on managing forests for both commodities and biodiversity, giving rise to a number of ecologically based silvicultural systems, or ways to grow and harvest trees that mimic natural disturbances in a forest.
- Although several large-scale, long-term experiments have been established throughout North America aimed at studying such alternatives to traditional production forestry, astonishingly few have documented basic regeneration, stemwood productivity, and carbon stocks in a currency familiar to forest managers.
- The Acadian Forest Ecosystem Research Project (AFERP), established on the Penobscot Experimental Forest in Maine, represents a 25-year ongoing effort to test an ecologically based silvicultural system in a mixed-species forest type representative of much of the Northern Forest.

Background and Justification

- Funding for this project made it possible to:
  - Complete the scheduled 5-year plot remeasurements of overstory and sapling tree vegetation,
  - Lay out, implement, and monitor the second (20-year) gap-expansion harvest treatments,
  - Re-inventory 787permanent reserve trees to assess long-term survival and growth,
  - Install tree regeneration plots in the harvest gaps,
  - Apply stand tending treatments to the large-gap treatments, and
  - Remeasure understory vegetation quadrats.

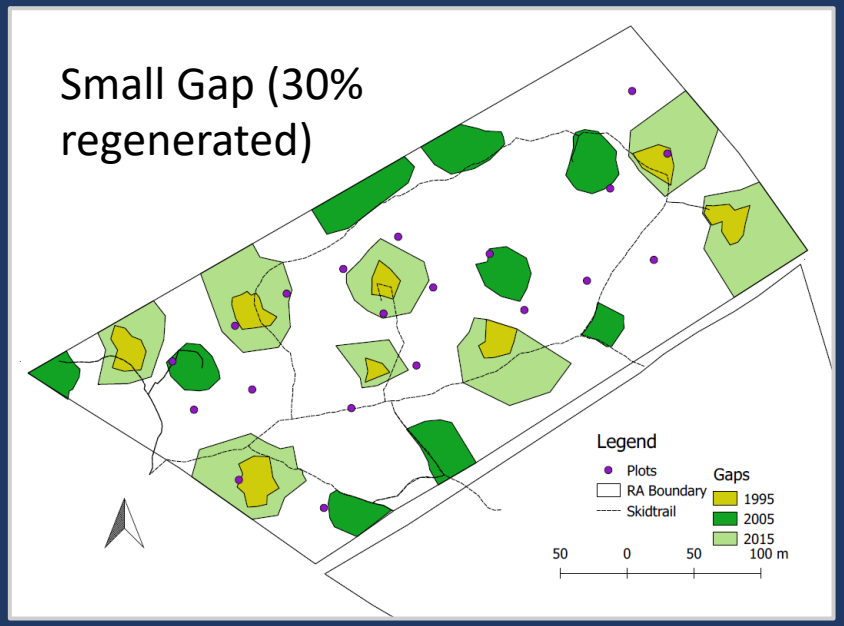
Objectives

1. Extend the short-term (10-year) results from earlier work (NSRC 2007; Arsenault and Saunders 2011) by quantifying 20-year stand development patterns (regeneration, growth, and mortality) in terms of conventional stemwood volumes and carbon stocks, focusing on the productivity tradeoffs among matrix forests, regeneration, and permanent reserve trees
2. Examine within-gap understory and regeneration patterns to isolate the effects of harvest timing, location within gap, and proximity to reserve trees
3. Compare understory and regeneration patterns by silvicultural treatment (large gap, small gap, unharvested matrix, unharvested control) and quantify statistically significant differences
4. Install a new study of stand-tending intermediate treatment options for the regenerating gaps.

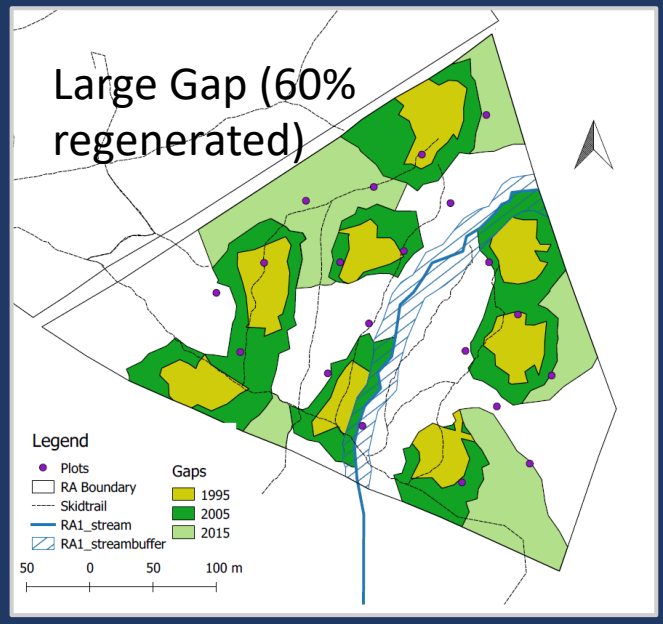
Methods

- To characterize general long-term growth and composition trends and provide baseline comparisons between treatment types and control areas, a permanent plot network of nested, fixed-area overstory, sapling, and regeneration plots have been measured every five years since 1995 (Saunders et al. 2012).
- Trees >9.5 cm dbh are stem-mapped on 20 0.05-ha plots per research area; saplings are measured on nested 0.01-ha plots. We have been working to remeasure these plots prior to harvest entries, and again after completion, to complete a 20-year record. Data include species, dbh, status, height (total and crown base), crown stratum, and Bechtold's (2003) light exposure class.

Treatments (after 3 harvest entries)



- Harvests every 10 years
  - 0.1 ha gaps
  - Gaps expanded every 20 years
  - 10% area harvested
- 100% area treated in 100 years



- Harvests every 10 years
  - 0.2 ha gaps
  - Gaps expanded every 10 years
  - 20% area harvested
- 100% area treated in 50 years
- No harvesting for 50 years

Methods

- Establish an intensive sample of regeneration plots within harvest gaps, and use these data to (1) document 20-year regeneration patterns, and (2) inform the prescription of precommerical composition and density control treatments (Objective 4).
- Use the data from objectives (1) and (2) to further stratify results by silvicultural treatment to determine the effect of harvest prescription on stand dynamics and development. This will be accomplished by assessing the significance of gap size, position within gap, time since harvest, and proximity to retention trees.

AFERP permanent plot overstory tree marked with vertical tree tag. Breast height marked with bark scribe and tree paint.

Photo Credit: Paul J Szwedo

Methods

- Use the results of the vegetation clustering from Objective (2) to create specific crop-tree release and precommercial thinning prescriptions.
  - Treatments focus on shifting species composition to higher-value, longer-lived, and locally uncommon species where possible.
  - Treatments applied by trained workers to the sapling regeneration to each large-gap research area, using motor-manual cutting. The treatments applied during the first growing season following the third harvest entry (2017-2019).
  - Remeasured the vegetation quadrats (4 per overstory plot) in 2017/2018.

Results/Project outcomes

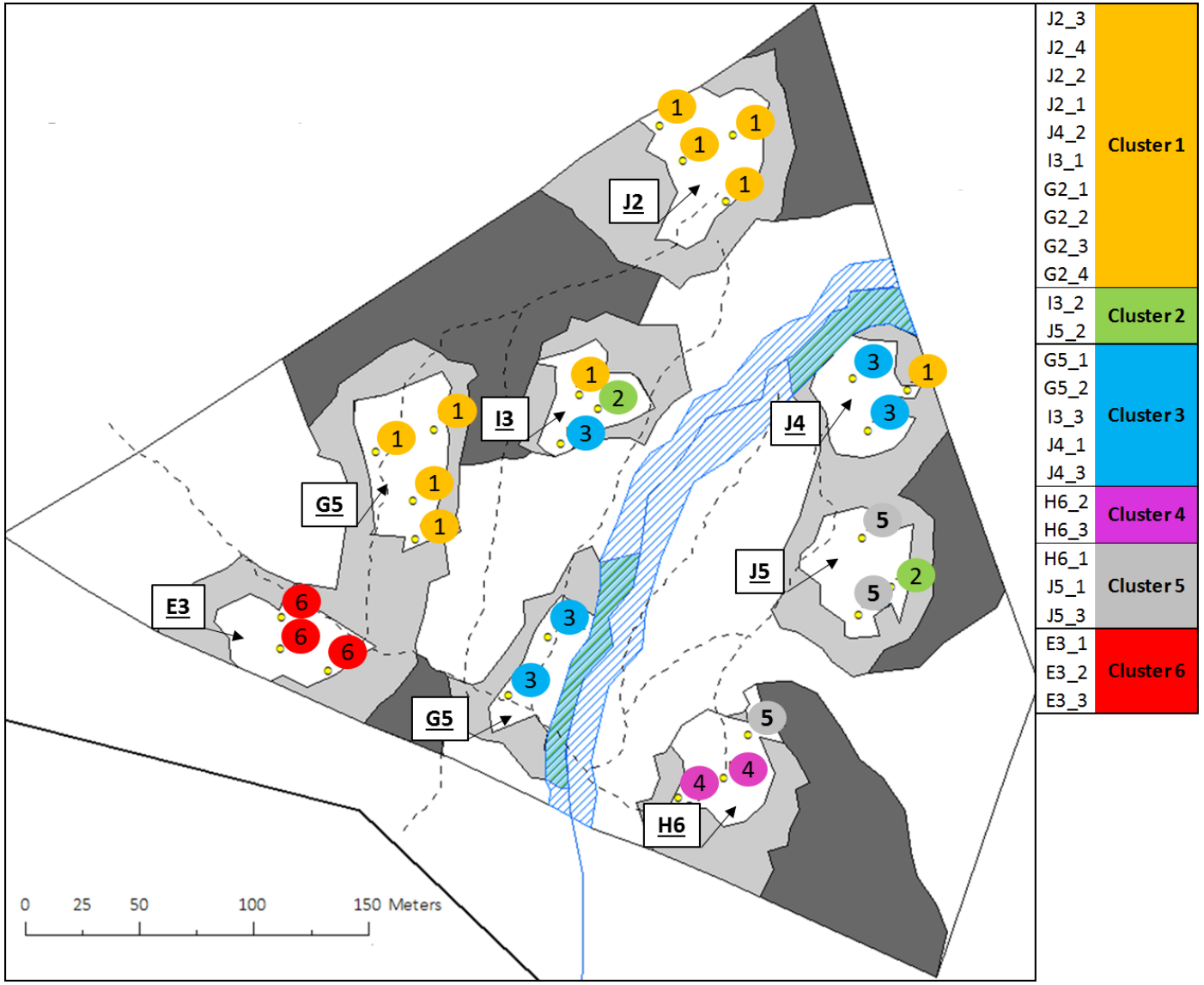
- Laid out and completed gap-expansion harvests 2015-17.
- Established an intensive sample of regeneration plots within harvest gaps to (1) document 20-year regeneration patterns, and (2) inform the prescription of precommerical composition and density control treatments.
- Used the results of the vegetation clustering to create specific crop-tree release and precommercial thinning prescriptions. See slides 12-13 for details.
- Research Area (RA) 1 was so treated during winter/spring of 2017; treatment of other RAs completed during summer 2019.

Expanded gap (left), harvester trail, and untreated matrix (right) – Feb 2015 treatment application

Pine and spruce legacy trees marked for retention post-harvest March 2016.
Photo Credit: Joshua Puhlick

Advance pine regeneration in research area 6 (large expanding-gap) post-harvest March 2016.
Photo Credit: Joshua Puhlick

AFERP Gaps showing distinct vegetation clusters warranting different treatments



AFERP Precommercial Thinning Prescription for mixed-species Acadian sapling stands

- The purposes of this treatment are to upgrade the quality and future timber value of this gap vegetation without simplifying the species composition unduly. We are not spending all this money to grow better pulpwood! Therefore, any tree of any species that will never make a sawlog (8 foot butt log for hardwoods, 12 feet for white pine) owing to crooks, forks or other serious defects, should be cut. If the trees are relatively large (5" inches dbh) it is easier and less damaging to residual trees simply to girdle them with the chainsaw, causing them to die standing.
- Species can be characterized by 3 distinct vertical strata which are useful for treatment designations, as follows:
- A. The uppermost stratum is any paper birch and aspen that have emerged above the largely conifer matrix.
- B. The middle (or upper if no birch and aspen) stratum of white pine and red maple and perhaps other more rare hardwoods like red oak and yellow birch.
- C. The lower stratum of shade-tolerant conifers, fir, hemlock and spruce. (Cedar would also be here if encountered but it is very rare.)
- The upper stratum of ***paper birch*** and ***aspen*** should be retained on a wide spacing 20-50 feet and cut if they are overtopping high-quality stems of trees from lower strata, particularly white pine.

AFERP PCT Prescription for mixed-species Acadian sapling stands (continued)

- ***White pine*** in the middle stratum should generally be retained, or treated as invisible, unless it qualifies for cutting based on Principle 1 above. The eventual stocking goal for white pine is similar to paper birch, about 100 trees per acre or 20 foot spacing, but it is too early in stand development to release pines at this density because they will likely lose stem quality from excessive branchiness and weevil attacks. However, there is also no point in retaining pines closer than 6-8 feet apart (700-1200 trees per acre), so when dense pine is encountered, space them out favoring the tallest, straightest trees no closer than 6 feet.
- ***Red maple*** mostly occurs as clumps of stump sprouts which usually interfere with development of better, more valuable nearby conifers. Hence, most of these should be eliminated completely, unless maple is uncommon. In such cases, leave a single straight, low-origin stem. The spacing of these residual maples should be at least 30-50 feet apart or even farther, to the point where you can't see back to the last one. On our walk-through inspection, I saw way too many red maple clumps retained that should have been eliminated, especially when the tree retained was defective. Non-sprout-origin red maple should be favored unless overly abundant, but not necessarily released heavily if doing so will degrade stem quality.
- ***Red oak*** is uncommon but valuable and will generally be competing with pine and maple. Treat oak as invisible (don't cut) and release from any maple competition and also from white pine if pine is generally well represented. Leave trainers nearby (see next section).

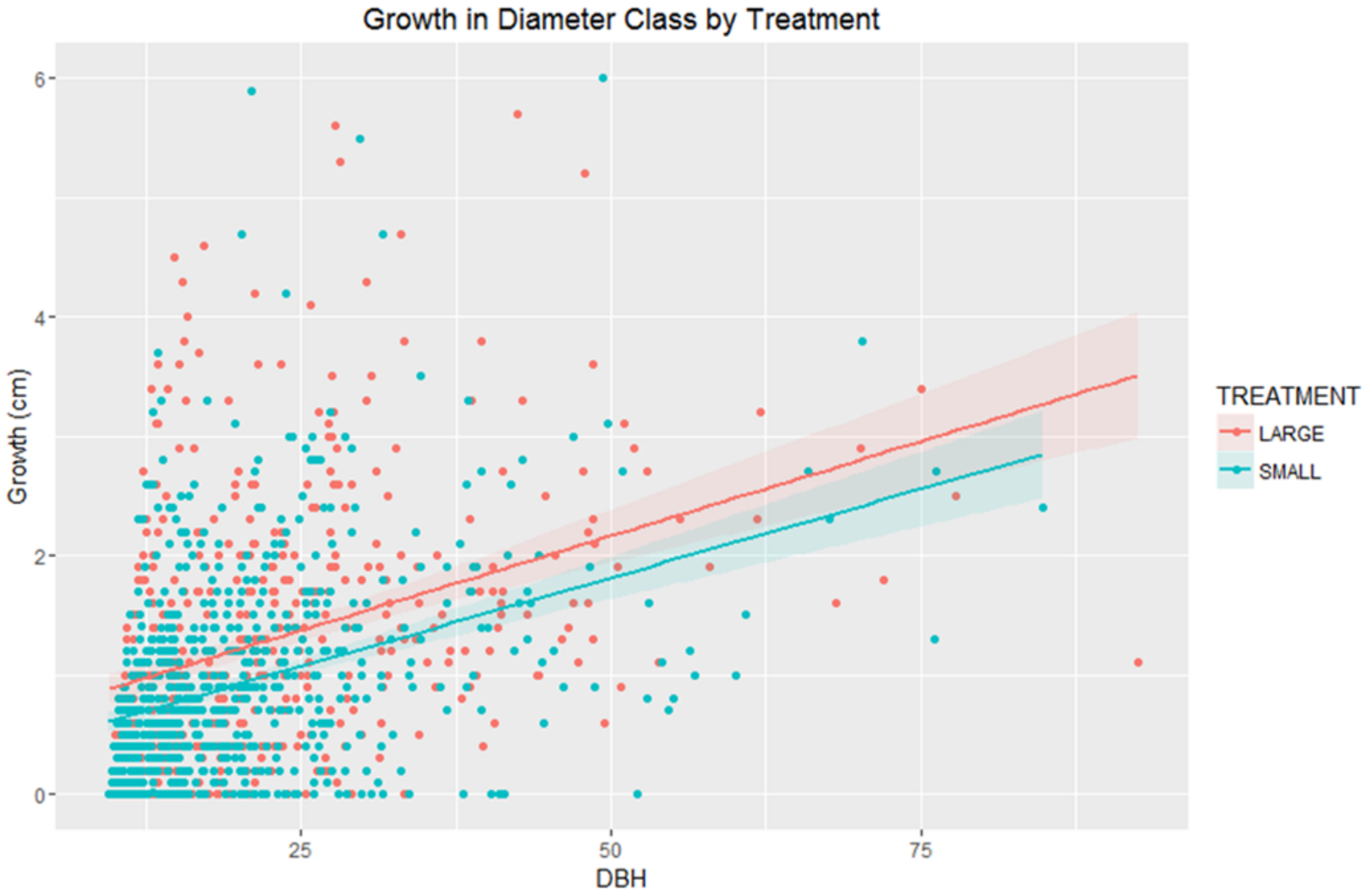
AFERP PCT Prescription for mixed-species Acadian sapling stands (continued)

- ***Balsam fir*** and ***eastern hemlock*** often occur as a dense matrix of 1-4" dbh stems and form the lower-most vegetation stratum. Most of the effort in this treatment will be directed at reducing the density of this stand component. The goal here is to shift the species composition away from fir as much as possible, without understocking the stand and leaving "holes." Hence, hemlock should generally be favored over fir here, given that it is usually rarer than the fir and other associates. Also, like the white pine, there is no point whatsoever in leaving these species closer than 8 feet apart, so treat accordingly.
- ***Spruce*** (mostly red) is generally rare but valuable, so it should always be left (treated as "invisible"), or often, released from fir and hemlock using the "inverted cone" concept. If the cone intersects valuable mid-stratum trees (white pine, red oak) do not cut these but do release the spruce heavily from other lower-stratum competition.
- ***Trainers*** are trees from the lower stratum species that should be left close to crop trees from the mid-stratum in order to shade their lower boles and facilitate branch shedding, and for hardwoods, prevent epicormics branching. Trainers of fir, hemlock and spruce should be treated as lower-stratum crop trees as a part of the spaced matrix following Principle 6. Hemlock is especially valuable as a trainer because it maintains long, deep crowns but grows much more slowly in height than the mid-stratum species.
- ***Beech*** if found will likely be in the lower stratum like fir and hemlock and should generally but cut unless it is the only species present (unlikely in these blocks). Beech can be valuable as a trainer, however, so it's OK to leave them in this role.
- Other ***rarer hardwoods*** (ash, yellow birch, sugar maple) should be treated similarly to red oak, i.e., as invisible unless the stem is defective.

Residual crop trees (spruce, hemlock, white pine) after PCT removing mostly fir

Mean diameter growth by dbh under two variants of natural disturbance based silvicultural systems over the last re-measurement cycle.

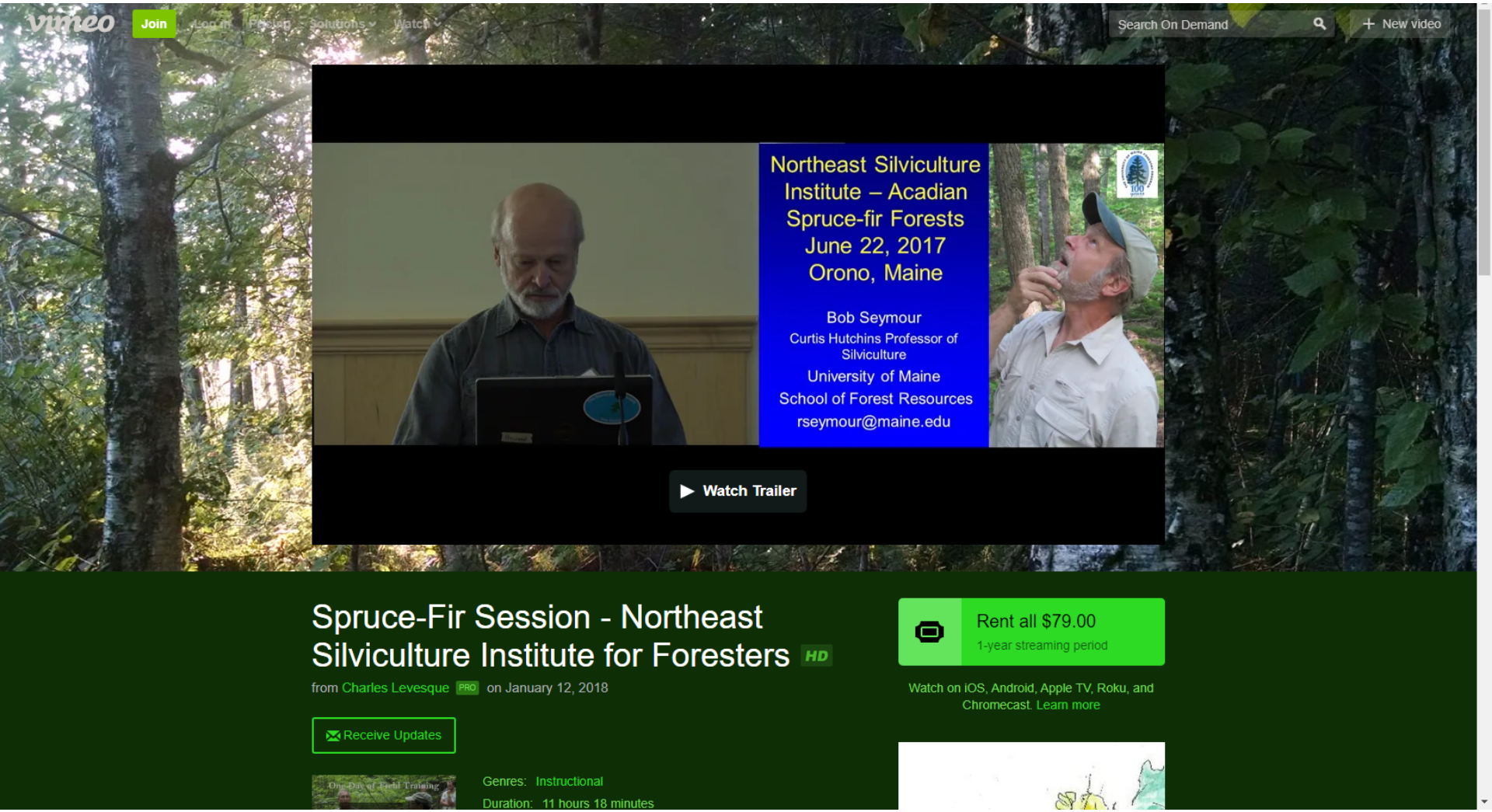
Figure created by Paul J. Szwedo



Implications and applications in the Northern Forest region

- Execution of the novel expanding-gap treatments, coupled with intensive monitoring made possible by this project funding, has made the irregular shelterwood silvicultural systems pioneered by this study of growing interest to foresters and landowners throughout the Acadian Forest.
- The AFERP study sites have been featured in countless, influential field tours targeted at professionals, two iterations of the Northeast Silviculture Institute (2017, 2018), multiple webinars given by the Principal Investigator, several University of Maine forestry classes and field exercises, and other public outreach events focused on the Penobscot Experimental Forest.

AFERP Research Featured in Northeast Silviculture Institute – Spruce-fir Module



Implications and applications in the Northern Forest region (continued)

- Carter's research demonstrated that reserve trees in gaps survive at much higher levels than reported in any other retention study in the world-wide literature; after 20 years, over 90% of the original trees were still alive.
- Mansfield's research found that species richness increased significantly in both treatments relative to unmanaged controls, without losing any species originally present.

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Only 8.4% of 787 trees died over a 20-year period

Reserve tree mortality in two expanding-gap silvicultural systems 20 years after establishment in the Acadian forest of Maine, USA

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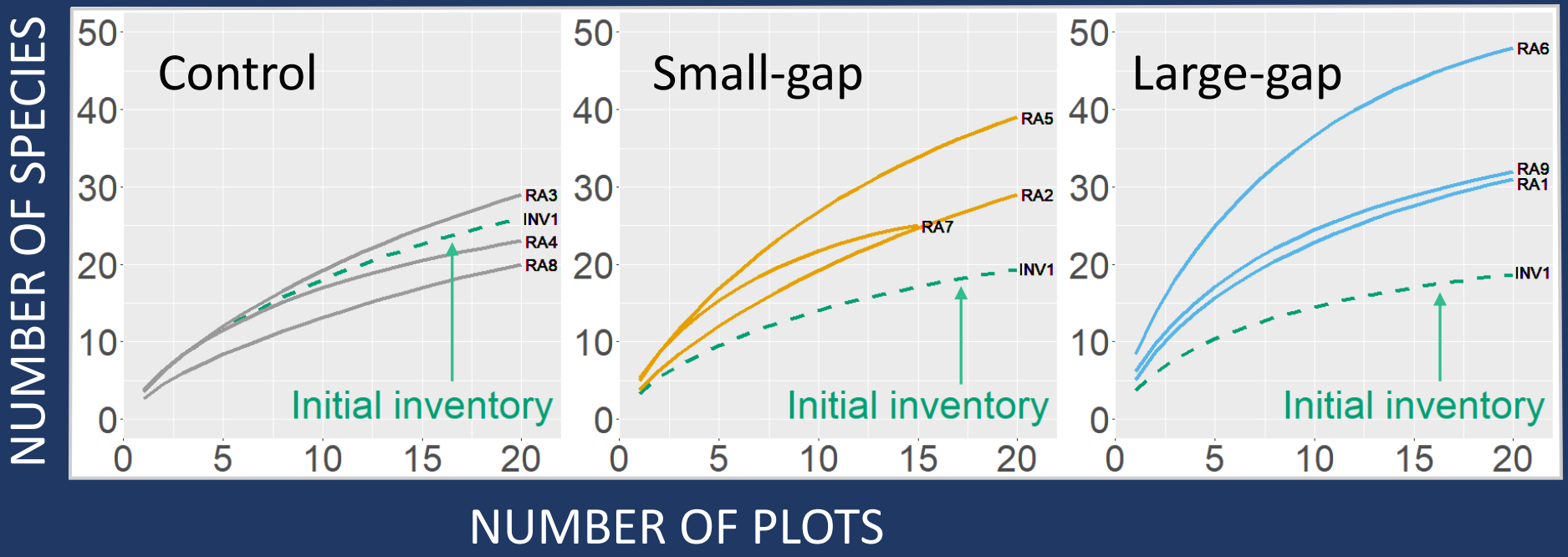
Number of reserve trees in harvested RAs and mortality data for different species covering the duration of the study.

Tree species	Trees that died during the study						
	No.	Mortality (%)	Brash	Died standing	Trunk broken	Uprooted	Wind-related deaths (%)
Softwoods							
Abies balsamea	4	0	0	0	0	0	0
Picea rubens	153	11.1	4	1	6	6	70.6
Pinus resinosa	12	8.3	0	0	0	1	100
Pinus strobus	112	8.9	3	2	4	1	50
Thuja occidentalis	84	19	1	2	6	7	81.3
Tsuga canadensis	146	2.1	0	2	0	1	33.3
Hardwoods							
Acer rubrum	119	3.4	2	0	2	0	50
Acer saccharum	33	3	0	0	0	1	100
Amelanchier canadensis	1	100	0	1	0	0	0
Betula alleghaniensis	12	8.3	0	1	0	0	0
Betula papyrifera	24	16.7	3	1	0	0	0
Fagus grandifolia	17	11.8	1	0	1	0	50
Fraxinus americana	22	0	0	0	0	0	0
Fraxinus nigra	1	0	0	0	0	0	0
Ostrya virginiana	2	0	0	0	0	0	0
Populus grandidentata	9	0	0	0	0	0	0
Populus tremuloides	18	33.3	1	2	3	0	50
Quercus rubra	18	0	0	0	0	0	0
Total	787	8.4	15	12	22	17	59.1

Post-Treatment Richness (species area curves) more than doubled in large gaps after 20 years



Future directions

- Publish Maggie Mansfield's thesis work in a peer-reviewed journal (target: *Canadian Journal of Forest Research*).
- Quantify 20-year stand development patterns (regeneration, growth, and mortality) in terms of conventional stemwood volumes and carbon stocks, focusing on the productivity tradeoffs among matrix forests, regeneration, and permanent reserve trees.
- Analyze and stratify results of all permanent plots by silvicultural treatment to determine the effect of harvest prescription on stand dynamics and development. This will be accomplished by assessing the significance of gap size, social position within gap, time since harvest, and proximity to retention trees.

List of products

Refereed Journal Publications

Carter, D.R., R.S. Seymour, S. Fraver, and A. Weiskittel. 2017. Mortality of reserves trees in two expanding-gap silvicultural systems 20 years after establishment in the Acadian Forest of Maine, USA. *Forest Ecology and Management* 389: 149-157.

Carter, D.R., R.S. Seymour, S. Fraver, and A. Weiskittel. 2017. Effects of multi-aged expanding-gap silvicultural systems on mature, within-gap reserve tree growth 20 years after establishment in the Acadian Forest of Maine, USA. *Canadian Journal of Forest Research*. 47: 1314–1324.

Mansfield, M., S. Fraver, R.S. Seymour. Understory vegetation response to expanding-gap silvicultural treatments. *In preparation, Forest Ecology and Management.*

List of products

Theses

Carter, David. 2015. Survival and growth of reserve trees in an expanding-gap silvicultural system 20 years after establishment. M.S. Thesis, University of Maine.

Anderson, Emily. 2016. Environmental features influencing *Myotis* bat presence in the Penobscot Experimental Forest in central Maine, USA. Honors Thesis, University of Maine.

Mansfield, Margaret. 2019. Understory response to gap-based, multi-aged silviculture. M.S. Thesis, University of Maine.

List of products

Presentations / Workshops / Meetings / Field Tours

Seymour, R.S. March 2017. Irregular Shelterwood Silviculture. Invited Webinar, Univ. Vermont (host). Attendance = 80. Views now over 1,200.

Seymour, R.S., L. Kenefic, and others. 2017. Northeast Silviculture Institute – Spruce-fir forests. June 2017. This study (AFERP) was a key feature.

Seymour, R.S., L. Kenefic, and others. 2018. Northeast Silviculture Institute – Spruce-fir forests. June 2018. This study (AFERP) was a key feature.

Carter, D.R. 2016. Growth and survival dynamics of reserve trees in an expanding gap silvicultural system 20 years after establishment. Oral Presentation at the University of Minnesota, Twin Cities, November.

List of products

Presentations / Workshops / Meetings / Field Tours

Carter, D.R., R.S. Seymour. 2014. Growth and survival dynamics of reserve trees in an expanding gap silvicultural system 20 years after establishment. Contributed a Poster at the Society of American Foresters Convention, Salt Lake City, Utah, October.

Seymour, R.S., D.R. Carter, M.R. Saunders. 2014. Natural disturbance-based multiage silviculture in the Acadian Forest of Northeastern North America. Oral Presentation at the Society of American Foresters Convention, Salt Lake City, Utah, October.

Seymour, R.S. and D.R. Carter. 2014. Are we regenerating the forests we want? Northern Conifers. Contributed Oral Presentation at the New England Society of American Foresters Annual Winter Meeting, Nashua, New Hampshire, March.

List of products

Presentations / Workshops / Meetings / Field Tours cont.

Carter, D.R. 2014. Acadian Forest Ecosystem Research Project. Contributed Oral Presentation at the USFS Collaborations with School of Forest Resources meeting, Orono, Maine, March.

Mansfield, M., Seymour, R.S., Fraver, S., Gill, J. Understory response to gap-based multi-aged silviculture. New England Society of American Foresters Winter Meeting. Nashua NH, March 2018.

Mansfield, M., Seymour, R.S., Fraver, S., Gill, J. Understory response to gap-based multi-aged silviculture. New England Society of American Foresters Winter Meeting. Burlington, VT. March 2019.

Seymour, R.S. Ecological forestry in the Acadian region. Multiple field tours to Canadian foresters and scientists May-June, 2019.