

## Outline (Afternoon)

- Silvics and Ecology
- Natural disturbance dynamics; historical forest development
- Successful Natural Regeneration
- Northern white-cedar
- **Even-aged Silviculture - Production forestry**
- **Multi-aged Silviculture**
- **Ecological forestry using irregular shelterwood variants – Acadian Femelschlag (AFERP Study)**

## V: Even-aged silviculture for commodity production

- **REGENERATE** to full stocking, spruce well represented
- **THINNING** to precise target residual densities is the defining feature here
  - PCT
  - Commercial
  - Views have changed recently, owing to loss of markets for small-dbh SF pulpwood



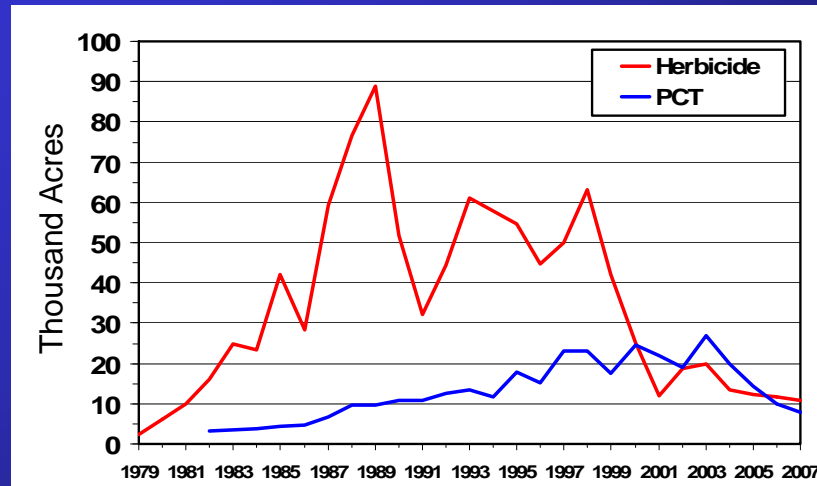
## Vegetation Management in Spruce-Fir Stands



### Application Details

- Timing, stand development: 2-5 years after overstory removal (varies by site quality) – don't wait for trees to become overtopped!
- Timing, season: late-Aug/early Sept. (as late as possible, phenological selectivity)
- Cost (aerial): \$50-80/acre (depending on guidance system used)
- Cost (ground): \$100-150

## Forestland Area Treated With Herbicides & PCT in Maine 1979-2007

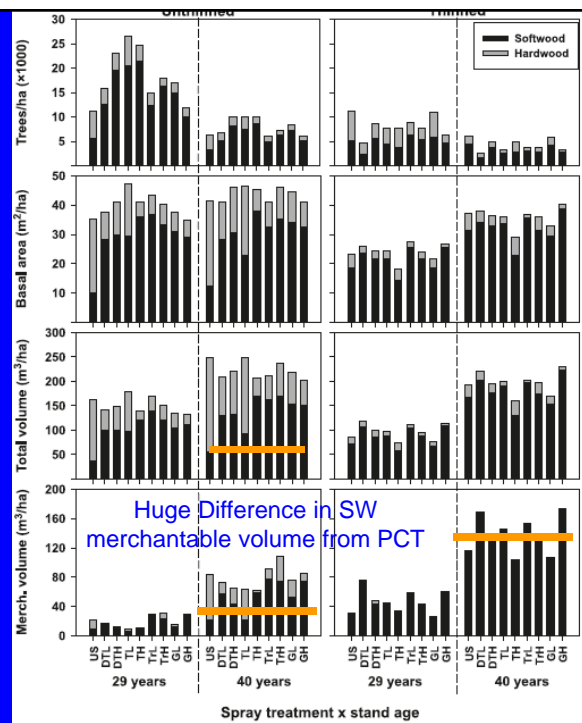


Derived from:  
 1979-1992: McCormack, M.L. 1994. Reductions in Herbicide Use for Forest Vegetation Management. *Weed Technology* 8:344-349.  
 1993-1999: Maine Board of Pesticide control, reflect permit requests and not actual sprayed acres  
 Wagner, R.G., E.H. Bowling, and R.S. Seymour. 2003. Forest and Agriculture Experiment Station Technical Bulletin 178.  
 Maine Forest Service, Silvicultural Activities Reports.

## Austin Pond Treatment Response (Olson et al. CJFR 2012)

- Tr = Triclopyr (garlon)
- G = Glyphosate (roundup)
- T = 2,4,5T
- D = 2,4 D
- US = UnSprayed Control Plots

Huge Difference in  
hardwood  
composition from  
herb. treatment



## Precommercial Thinning

- Definition, candidate stands
- Why do landowners do this?
- Prescription Issues

## Candidate Stands

- Age 10-20 from overstory removal
  - Live crown lifted off ground, but...
  - Stump diameter < 4"
- Typically had history of herbicide release treatment 5-10-years earlier; now, most are from shelterwood removal cuts





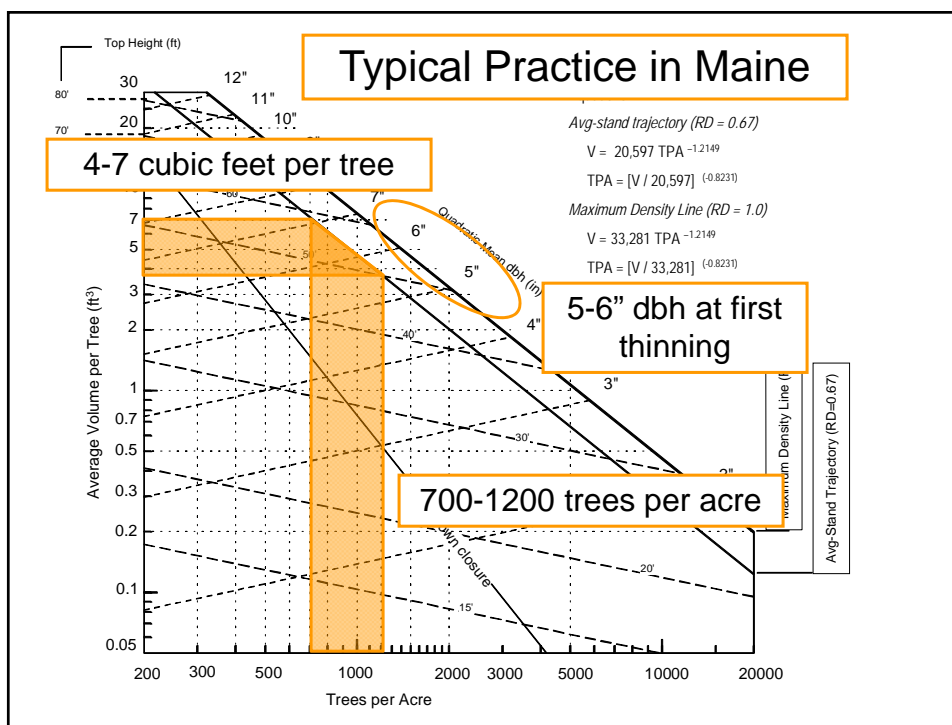
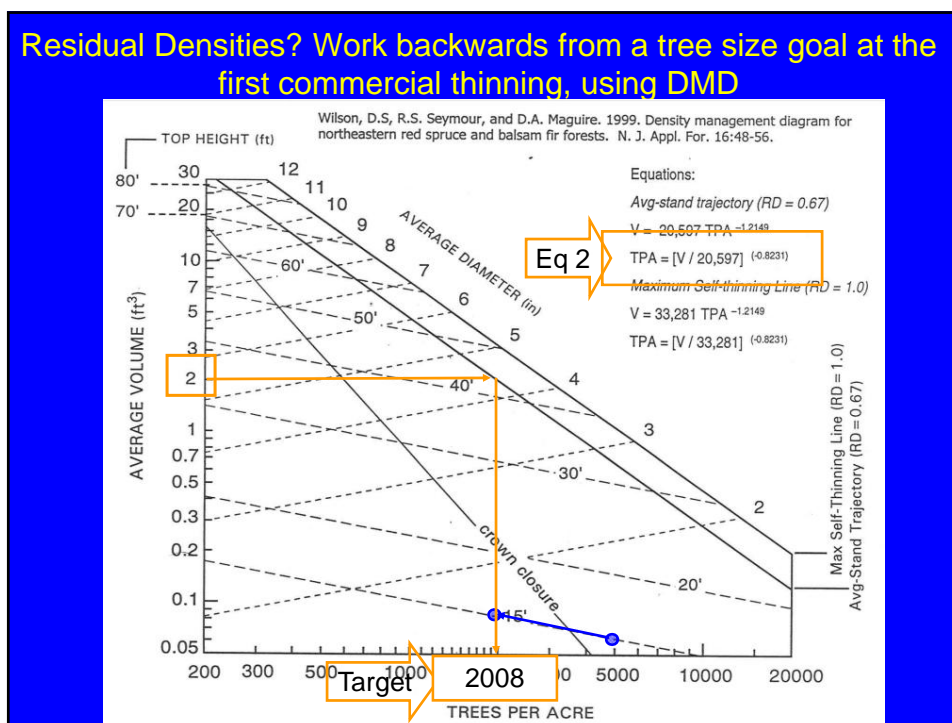
## Rationale for Precommercial Thinning

- Attempts to grow crop trees to merchantable size much sooner than would occur naturally.
  - 20-30-year reduction in time to merchantability
- Major opportunity to alter species composition away from fir (cleaning)
- Builds windfirmness for later partial entries

## Prescription Issues

- Residual Density (= spacing)
- Species
  - Spruce vs. Fir
  - Lower stratum species (cedar, hemlock)
  - Concept of “Invisible Species”
  - White Pine

## Residual Densities? Work backwards from a tree size goal at the first commercial thinning, using DMD



## Species Choices

- Favor spruce when tree is X times the height of the competing fir
- X has varied from zero to .3 or less
- Make spruce “invisible”



## Dealing with slow-growing lower strata

- Northern white-cedar, Hemlock
- If relatively rare or prescription would essentially eradicate them, treat as “invisible”
- Neither a crop tree, nor competition for crop trees.
  - Don't release
  - Don't cut to release crop tree.

## Species Choices

- White pine: wide range of approaches
  - Low on pecking order
  - Top choice
- Danger of attack by blister rust, white pine weevil if released



## White pine prescriptions

- Just say no (don't PCT). Pine will be better off without treatment.
- Leave very narrow spacing ( $< 4'$ )
  - Not practical unless pine density very high.
- Leave a clump of unthinned trees around 50-100 pines per acre.
  - Keep lower branches crowded





## ***Stand Responses to PCT***

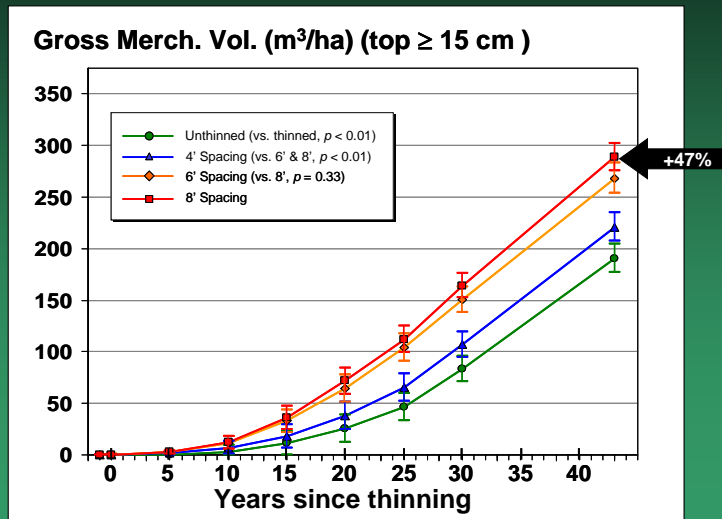
- **PCT always increases merchantable yield**
- **Amount of yield increase depends on early tending, spacing, stand age, and merchantability thresholds**

## Green River Study (established in the early 1960s by G.L. Baskerville)

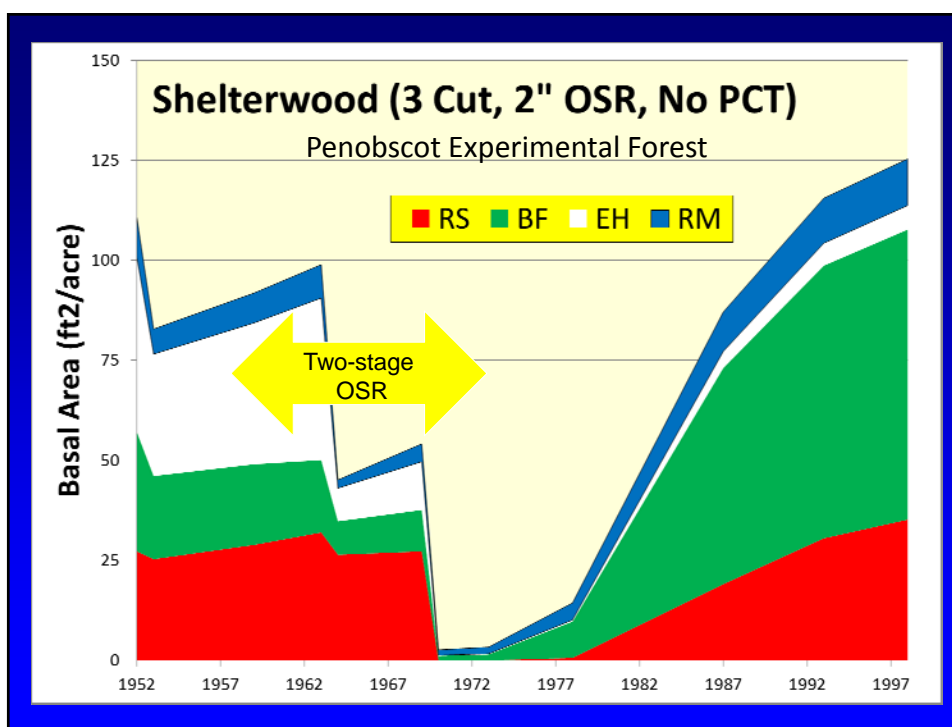
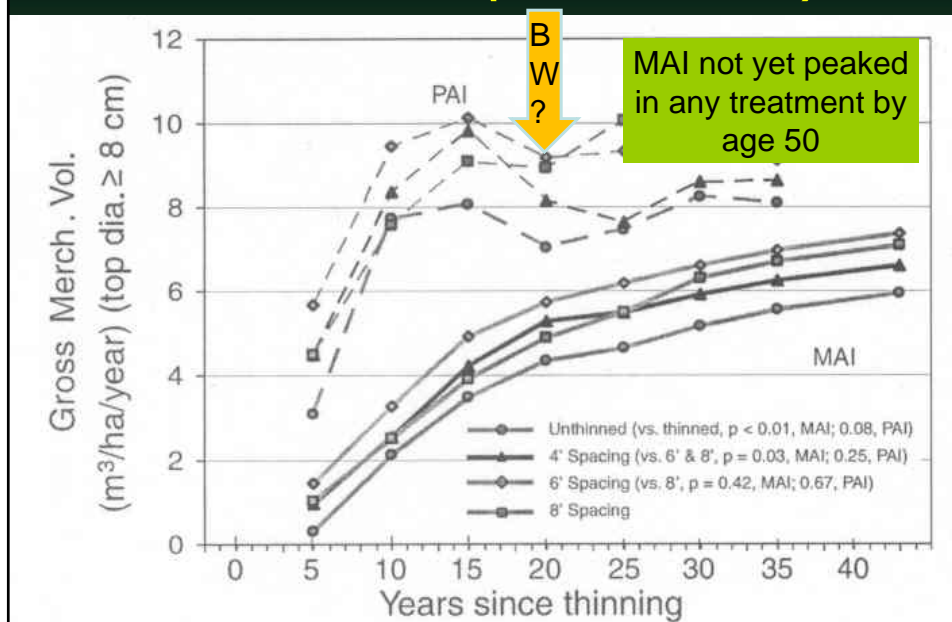


## Green River Study (Pitt and Lanteigne 2008)

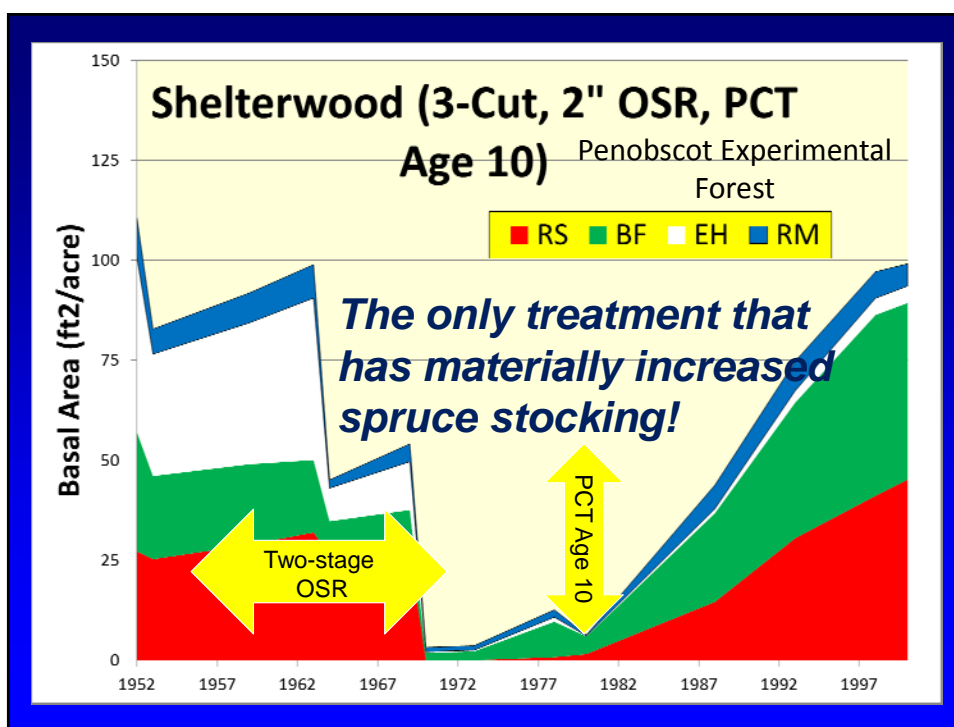
- 1959-61. G. Baskerville, NB study - Unthinned, 4', 6', 8', spacing in spruce-fir, installed age 16, 8 years post-clearcut



## Merch. MAIs (Green River)









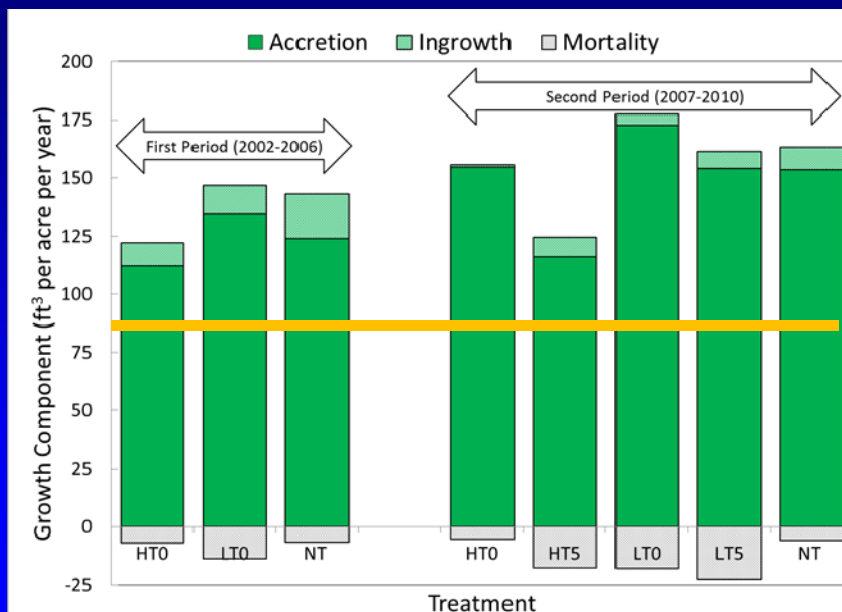


## Commercial Thinning



- Stands become “operable” (candidates for CT) when a commercial harvest is possible removing 40% of the stand
- Depends on history of PCT
- Harvesting done with Scandinavian cut-to-length systems (using forwarding)

## Growth Components (PCT Stands)







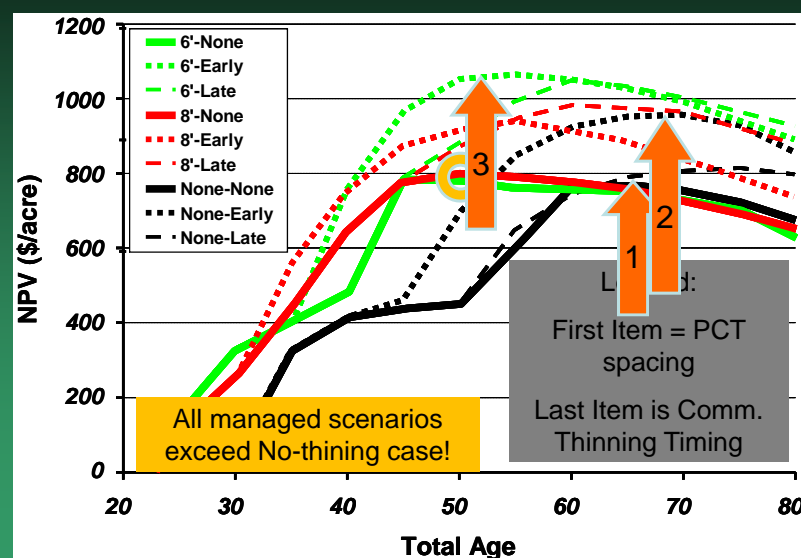
## Optimum Combination PCT and Commercial Thinning – (*Saunders et al 2008*)

- PCT spacing 6x6 and 8x8 feet
- Early and Late commercial thinning
- Used PPHarvest to simulate harvest cost based on piece size (volume per tree harvested)
- 4% discount rate
- Assumes good original stocking, as with shelterwood cutting or herbicide release

## Synthesis

- ✓ Not thinning (no PCT or CT) is the WORST strategy financially – Yay, we can't afford NOT to practice intensive silviculture!
- ✓ If no PCT, then early CT (ht = 45) is best and outperforms PCT with no CT....not bad. Final harvest at age 70, NPV = \$950/acre.
- ✓ If PCT, then leave high density (1200 tpa), CT early. Final harvest @ age 50, NPV = \$1050/acre. *(2016: Probably no longer true, owing to loss of small-tree markets?)*

## Saunders et al (2008)





## VI. Uneven-aged Silviculture

### *The Selection System in Acadian Mixed-Conifer Forests*

Laura S. Kenefic

*U.S. Forest Service, Northern Research Station*



## VII. Irregular Shelterwood Silviculture, inspired by natural disturbance dynamics



## Important Silvicultural Concepts

- Shelterwood Semantics
- Conservation of growing stock
- Two-rotation species – “tall regeneration”
- The 3 kinds of structural retention -- Permanent legacy, Growing stock, Temporary overwood
- Regeneration in partial shade



## Personal Reflection

- “This fits probably 95% of what we need to do....” Why?
- “New England forests are complicated! Deal with it!”
- Complexity

## Shelterwood Semantics

- Relies on the establishment of *advance regeneration* in partial shade before the overstory is removed
- *Conventionally*, all cuttings occur near the end of the rotation in an even- or two-aged silvicultural system (relaxed for irregular shelterwood)

## Shelterwood sequence

- **Preparatory** Cuttings (Optional!)
  - To prepare for regeneration by developing good seed-bearing trees and eliminating undesirable seed sources
- **Establishment** (= “seed”) Cuttings
  - Goal is to *establish* advance regeneration
- [Overstory] **Removal** Cuttings (OSR)
  - Remove the overwood, *release* advance regeneration
  - Can be more than one removal cutting
  - *complete* or *incomplete*

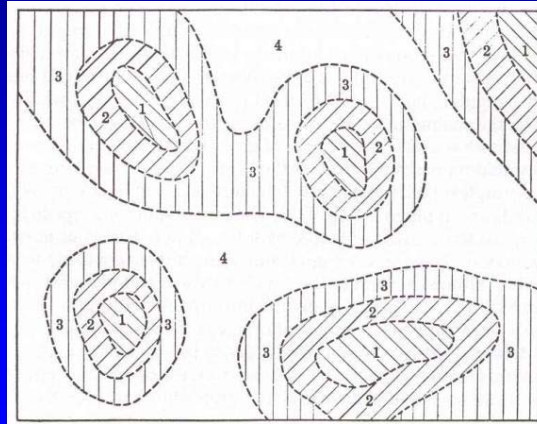
## Variants based on the *spatial pattern* of the cuttings

- Uniform
  - Regeneration is recruited uniformly throughout the stand by leaving uniformly stocked overwood in the estab. cutting
- Group
  - Separate patches within the stand are at different stages of the shelterwood sequence
- Strip (Narrow, < ½ tree in height)
  - Linear groups



## Group shelterwood

- Takes advantage of naturally established patches of advance regeneration
- One way to create horizontal diversity in originally uniform stand
- Cuttings expand outward from patches where overstory is removed in stage 1



## Modifying adjectives:

- Some mature trees (“**reserves**”) left *after regeneration is established* (to create or maintain a two-aged stand)?
  - Add “**with reserves**” (or with coppice method, “**with standards**”) to the above even-aged methods (e.g.: ***shelterwood with reserves, clearcut with reserves, seed tree with reserves, coppice with standards***)

## Variants based on the *timing* of removal cuttings (length of regeneration period)

- *Conventional* (3-5 years)
  - Overwood removed as soon as seedlings are established (intolerants)
- *Extended* (10-25 years)
  - Final removal cutting delayed until advance growth is sapling size (above bh)
- *Irregular* (no defined period)
  - some lower-stratum trees of the older cohort held over into the next rotation; regeneration period extended indefinitely

## What defines “*Irregular?*”

- Regeneration period extends for decades and has an uneven (=irregular) height structure (usually as a result of multiple partial cuttings or disturbances)
  - Relies on advance regeneration, thus is example of shelterwood method
- Eventually all old (large) trees are harvested (except designated permanent legacies), then the stand goes through several decades of stem exclusion (not a “balanced” system)

## Why use *Irregular* instead of simpler variants?

- Best system for growing all trees to financial or biological maturity in diverse, mixed-species stands – **“conservation of growing stock”**
  - Relies on ability of species to respond to release after growing in the lower strata for decades (shade-tolerant, late-successional)
  - Concept of “two-rotation” species, or “tall regeneration” that need a head start
- Restore ecological complexity in forests that have been simplified

## Key Concept: “Two-rotation” species, in stratified, mixed-species stands (Dave Smith concept)

- Some later-successional species require two rotations of their early-successional associates to reach the canopy and grow to financial maturity.
- Must maintain two-aged stratified mixed species stand structure to keep these species in the main canopy
- Use low thinning ONLY WITHIN A SPECIES or STRATUM

## Key Concept: "Two-rotation" species Examples

- Eastern hemlock and white pine with northern red oak (Kelty 1986)
- Northern hardwoods (maple, beech) in competition with black cherry (Marquis 1992) or paper birch/aspen
- Red spruce in competition with hardwoods and balsam fir (Davis 1991)
- Northern white cedar almost everywhere

Kelty (1986)

Single-cohort Stand with Rapid Divergent Crown Stratification: Oak and cherry form a pure B-stratum, hemlock relegated to the C stratum

Two-cohort Stand: Residual C-stratum hemlock maintains presence in B-stratum with oak

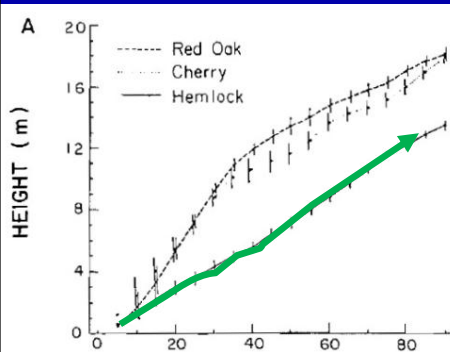


FIG. 4. (A) Average cumulative height growth and (B) basal area growth of trees growing in direct competition in the Great Mountain Forest stand. Results are based on six four-tree plots of overstory red oak ( $n = 6$ ), overstory black cherry ( $n = 6$ ), and understory hemlock ( $n = 12$ ). Black cherry is omitted from Fig. 4B because basal area growth could not be measured because of heartwood decay. A stand age of 0 denotes the year of overstory removal by logging. Vertical lines represent  $\pm 1$  SE.

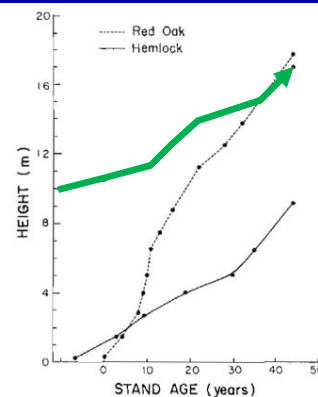
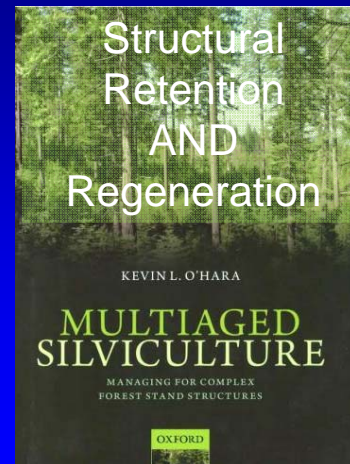


FIG. 6. Cumulative height growth of one three-tree plot from the Harvard Forest stand. A stand age of 0 denotes the year of overstory destruction by hurricane winds.



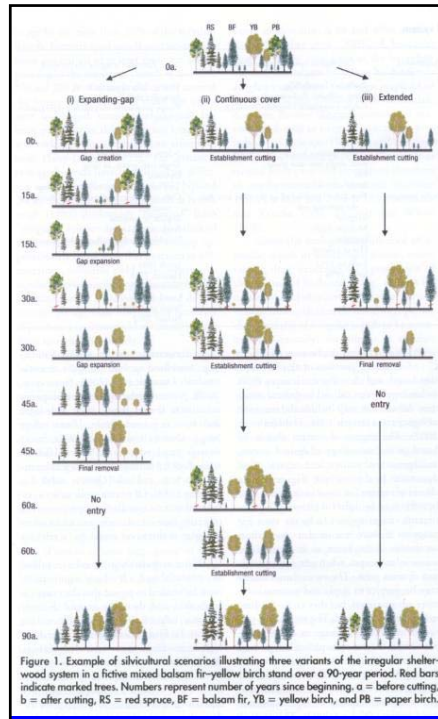
## Irregular shelterwood: any multi-aged system that:

- Relies primarily on advance regeneration
- Maintains a diverse vertical canopy structure (including merchantable trees that could be harvested)
- Does *not* use a dbh distribution as a target structure, but can instead use area-based goals (if group)



## Structural Retention – *Three Components*

- Permanent **Biological Legacies** – meet biodiversity goals
- (Temporary) **Overwood** – provide seed source and partial shade for regeneration establishment
- **Growing Stock** – trees with growth potential, not yet mature financially or biologically
- These may overlap



## Variants

(Patricia Raymond et al 2009)


- Group (“*expanding gap*”)
- “*Continuous cover*”
- Uniform extended with reserves (“*extended*”)

European Roots:  
***Femelschlag***  
(Spurr 1956)


Silvicultural  
Systems  
1928 R. S. TROUP  
C.I.E., D.Sc. (Oxon.), F.R.S.



**A CRITIQUE  
of 2008  
SILVICULTURE**  
*Managing for Complexity*



*Klaus J. Puettmann,  
K. David Coates, and Christian Messier*



- *Americans selectively imported German systems...somehow, we overlooked this one!*

## Contemporary North American Applications

- Extended, uniform shelterwood with large reserve trees
  - Distinctly two-storied structure
- Irregular shelterwood with old but short reserves (“hold-over” trees, “tall regen”)
- Irregular *group* shelterwood, with or without reserves
  - Includes expanding-gap Femelschlag systems

## Uniform shelterwood with reserves on Massachusetts Wildlife Lands



- Large oak and pine reserve trees
- Stand uniformly regenerated

## SF - Old but short residual structure (“tall regeneration”)



- Small red spruce, pine, and cedar “hold-over” (reserve) trees
- Stand uniformly regenerated

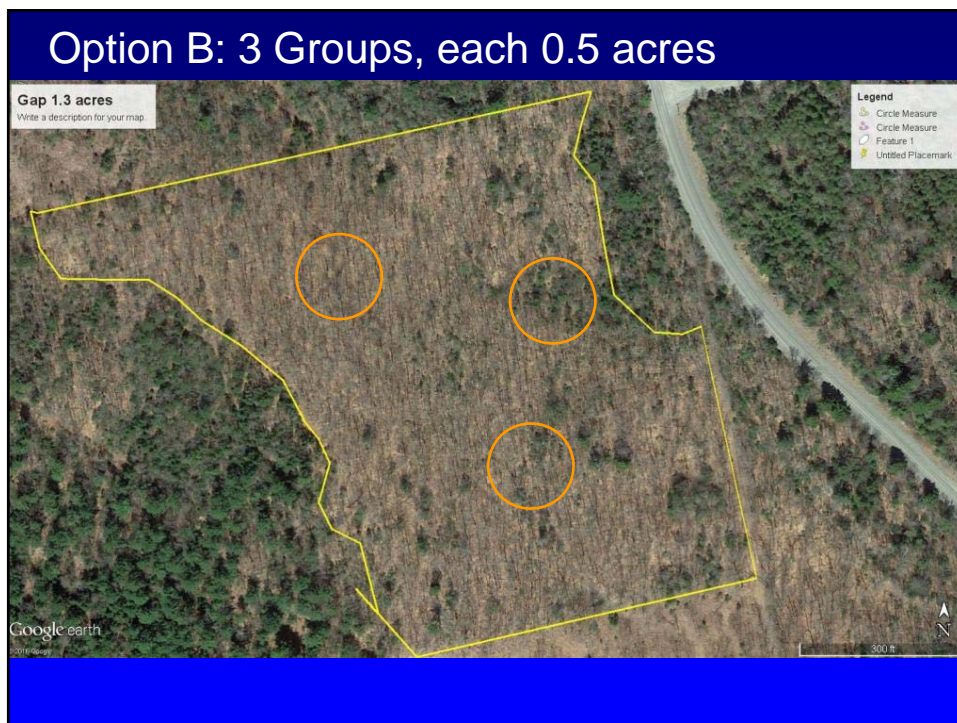
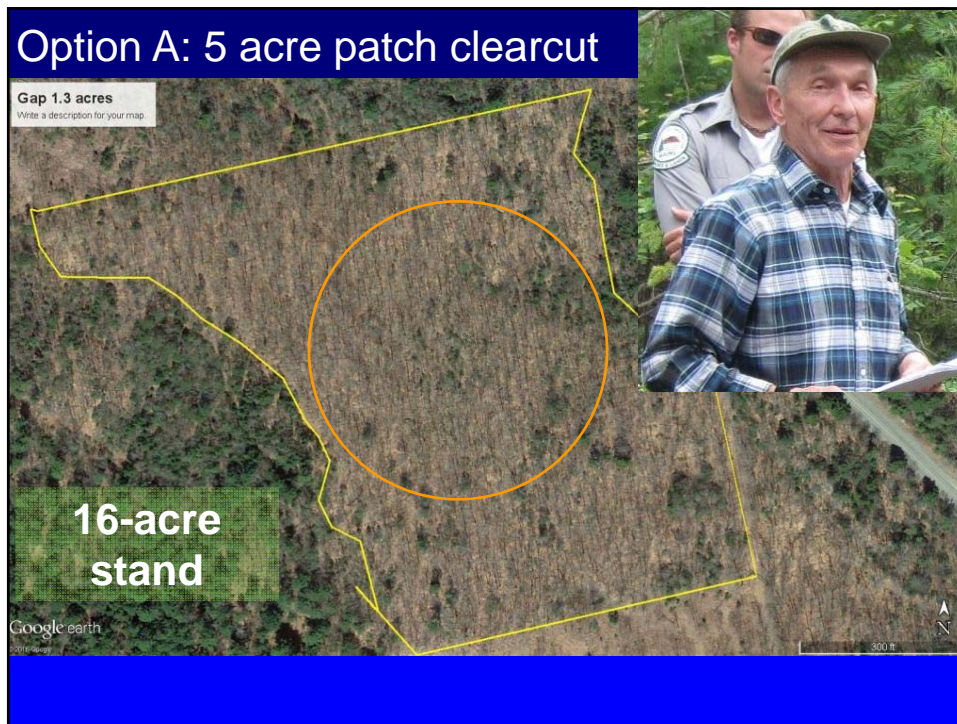


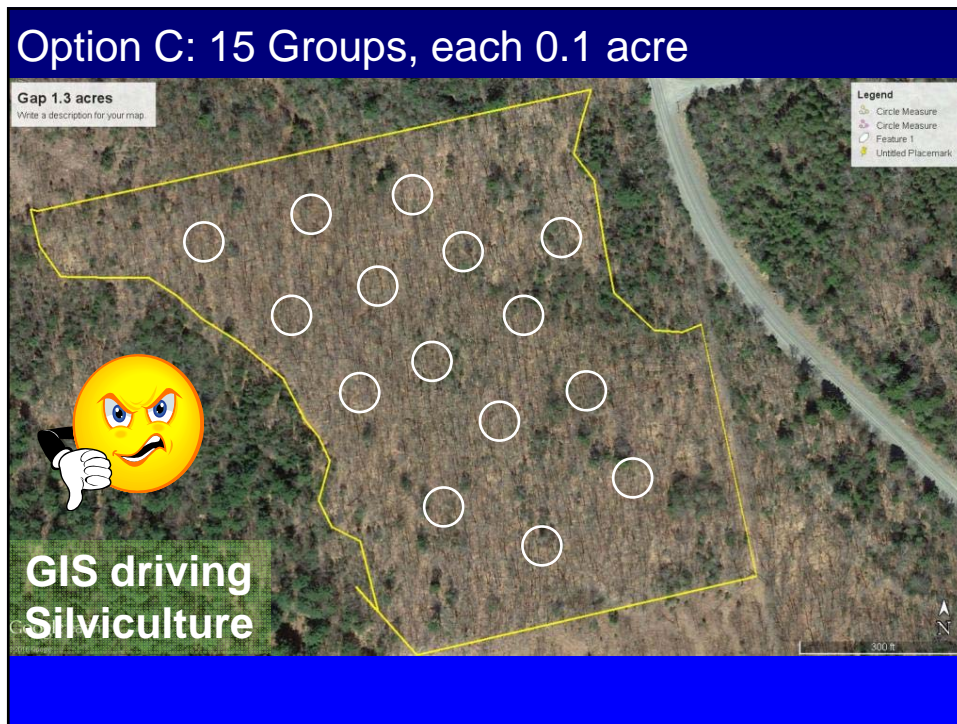
## Emulating Natural Disturbance (Ecological Forestry)

- Uniform systems arguably not adequate, even with reserves.
- “Group” approaches more in accord with natural gap dynamics

## A Digression about “groups” or “patches”

- Avoid geometric patterns and shapes, especially with no retention in the groups!
- Unlikely to intersect the real diversity of structure, spatial pattern of advance regeneration, and quality of growing stock.

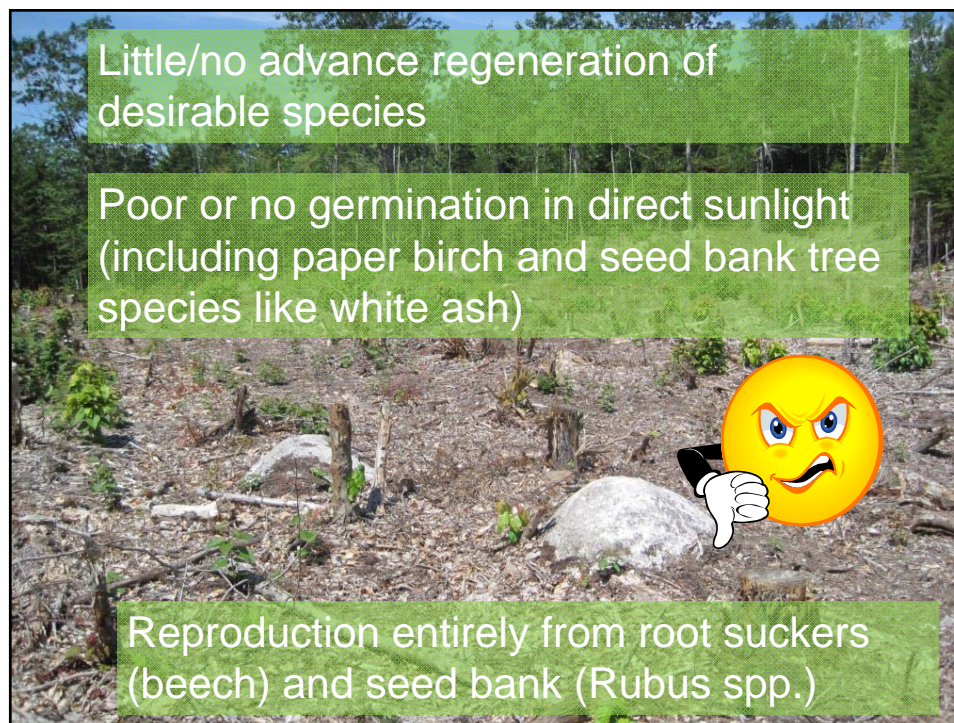
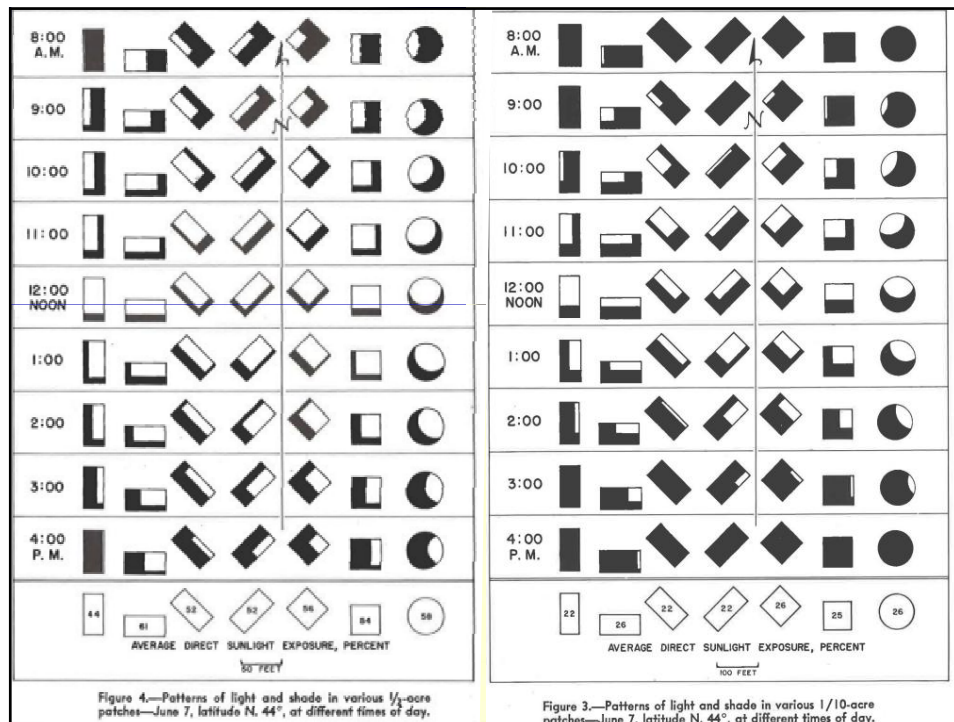




## Problems with gaps with no retention

- Too much area in direct sunlight (Marquis diagrams)
- Immature growing stock (tall regeneration) often needlessly sacrificed, owing to a false believe that such trees won't respond to release
  - Just the opposite is true; if you don't keep them, you'll lose these species



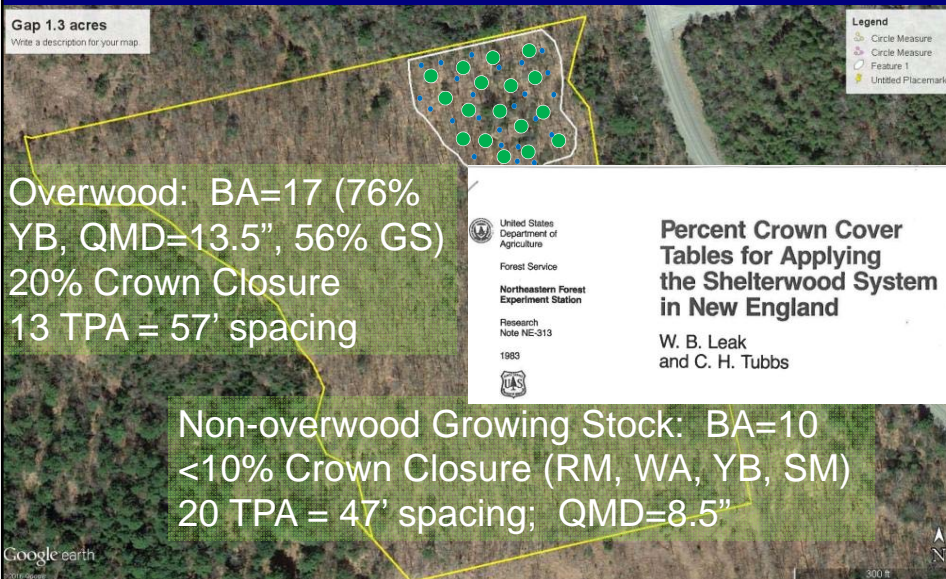




### Option D: Locate one 1.5-acre group with low overstory stocking



### Retention: Overwood + Legacy + Growing Stock



**Total Retention: BA=32, TPA=38, 30% CC**

## Added Prescription Element

- Uniform shelterwood (with reserves) within the gap for regeneration – this is the *ESTABLISHMENT CUT* step
- What makes this “irregular”?
  - Spatial context within the rest of the stand (which is largely still a thinned fully stocked matrix)
  - Retention of small poles as future growing stock (“Tall Regeneration”)

Retention flagged in yellow for emphasis





After harvesting, enrichment planting in Tubex



Disturbance Ecology of Acadian Forests: ***Gap Dynamics rule***



- Disturbance regimes dominated by partial disturbances (some minor exceptions), long-lived shade-tolerant species
- Stand-replacing disturbances and thus, even-aged stands, were very rare

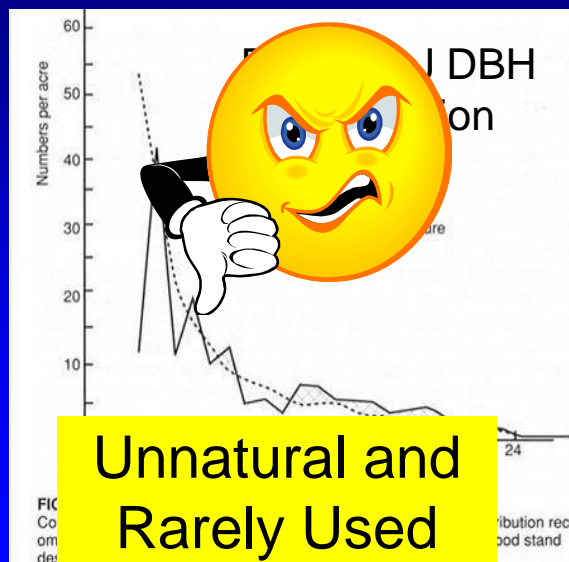
What silvicultural systems do these dynamics imply under an Ecological Forestry paradigm?

- *Multi-aged* stand structures, with a significant component of “old” trees
- Regeneration in small gaps or patches *within irregular stands*
- What is our **Target Stand Structure?**
  - Two options: DBH or AREA?

The “Target Structure” –  
Option 1:  
*A tree size (dbh) structure*

- Descriptive perhaps, but not informative

*From Nyland (1996)*





## Ecological Forestry – What *IS* “Natural?”

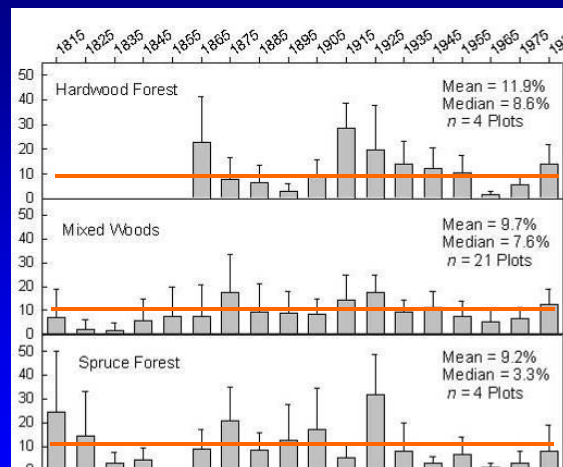
- Since ca.1990, significant studies in *disturbance ecology* have led to useful, quantitative working hypotheses for most common forest types
  - Disturbance rates
  - Patch sizes
  - Post-disturbance Legacies

The “Target Structure” –  
Option 2: an *area-based* structure

10% per decade for 180 years, or 1% per year !



### Disturbance Chronology (Fraver, White, Seymour 2009)



Area by Cohort  
(decade of initiation)

## Natural Disturbance Analogues in Silvicultural Prescriptions

- Disturbance rate: Cutting cycle, percent of stand regenerated per entry
- Patch size: Gap or group sizes; their orientation and proximity to each other
- Biological Legacies: Designation of permanent reserve trees *in gaps*

### Formulating ecologically based silvicultural systems: *regeneration rate*

1. The “1% rule”: *Within the stand, area regenerated at each harvest should fall within natural disturbance boundaries*
  - ✓ For a balanced system, portion of stand regenerated = cutting cycle (in percent)
  - ✓ Eg: 10% per decade, 20% every 20 years, etc.

### Formulating ecologically based silvicultural systems: **patch size**

2. Spatial arrangement of areas regenerated should also fall within natural limits
  - ✓ patch size = .01- 0.1 ha <<< stand size
  - ✓ Larger patches depart from the “natural” (but are still preferable to stand-wide uniform treatments)
  - ✓ Think in terms of fewer, larger stands with more within-stand diversity

### Formulating ecologically based silvicultural systems: **biological legacy**

3. Designate permanent reserve trees as a biological legacy *in gaps as they are treated*
  - ✓ Maintains and restores late-successional conditions as regenerating groups enter stem exclusion
  - ✓ 10% of original stand (15 ft<sup>2</sup>/ ac), focusing on larger trees of late-successional, long-lived species (arbitrary, hopeful)

## *“What do we call this?”*

- Apply ***shelterwood with reserves, but in patches within stands***
  - ✓ Entire stand contains examples of all stages of the regeneration process
  - ✓ Age structure within stands varies *spatially* across the stand, and *temporally* within gaps

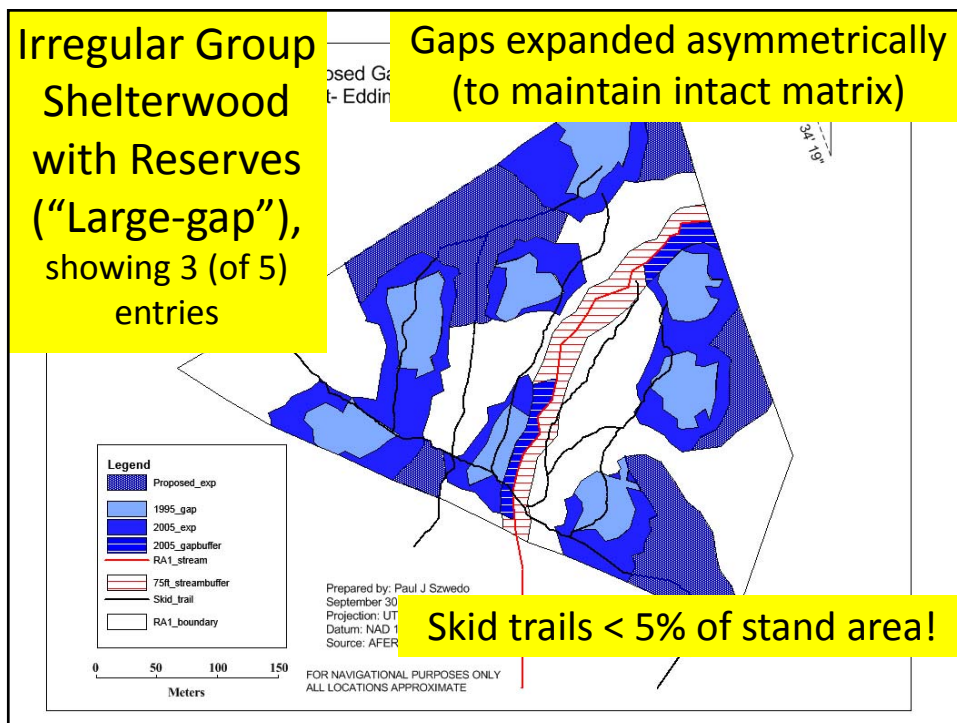
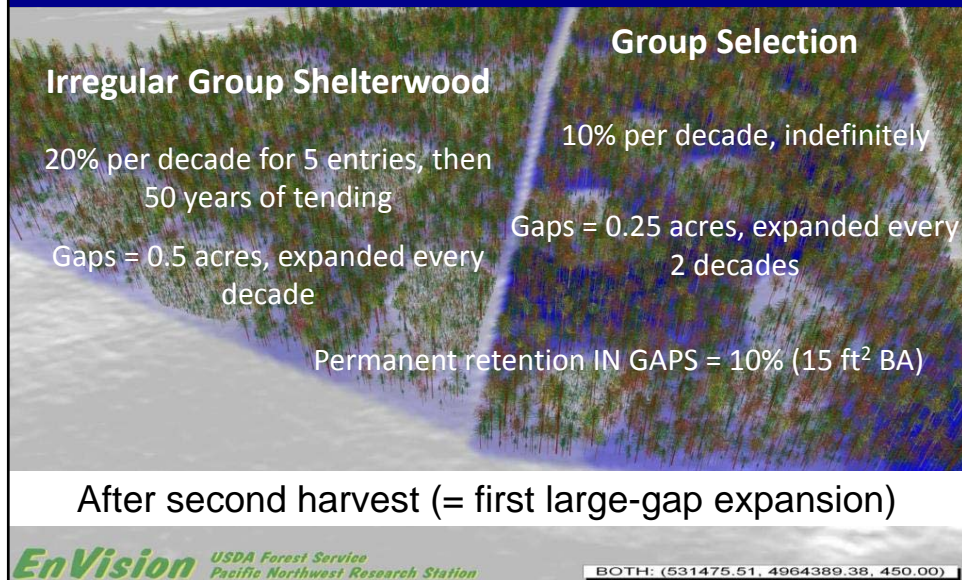
## The “Acadian Femelschlag” (AFERP Study, ca. 1994)

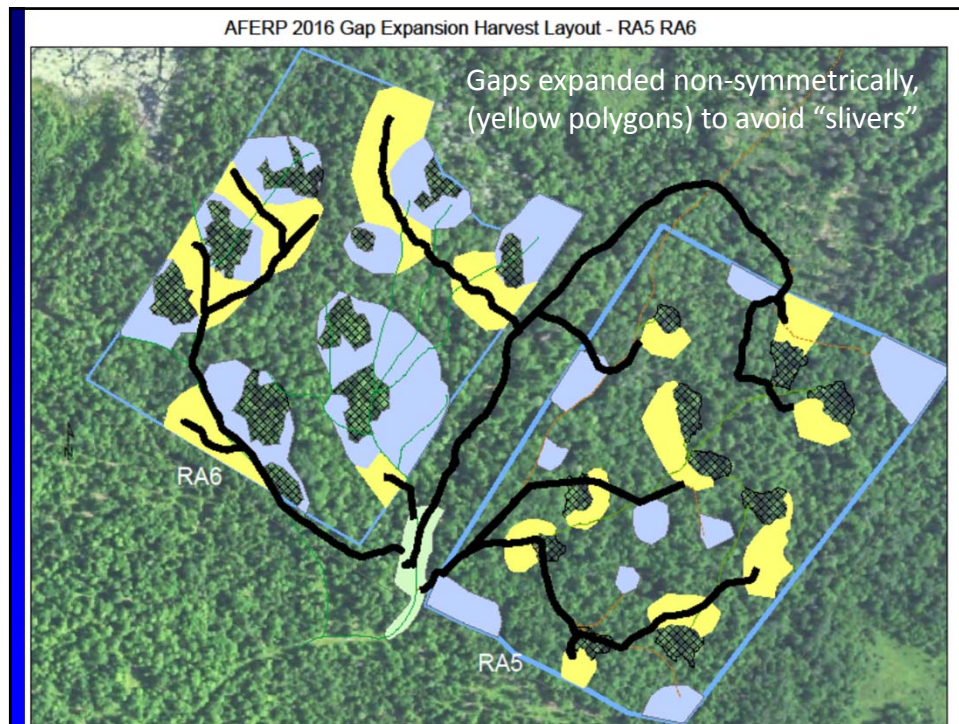


- Expanding gap system based entirely on *three ecological parameters* (not from established “cookbooks!”):
  - ✓ 1% annual disturbance frequency, over 100 years
  - ✓ Small, sub-stand regeneration patches (0.1 - 0.2 ha, expanded on 10 or 20-year cutting cycle)
  - ✓ 10% (arbitrary) permanent structural retention, dispersed throughout the entire stand
- *North American Translation:*
  - *Irregular group shelterwood with reserves (large gaps)*
  - *Group selection with reserves (small gaps)*



## Small sub-stand patches (gaps) with retention



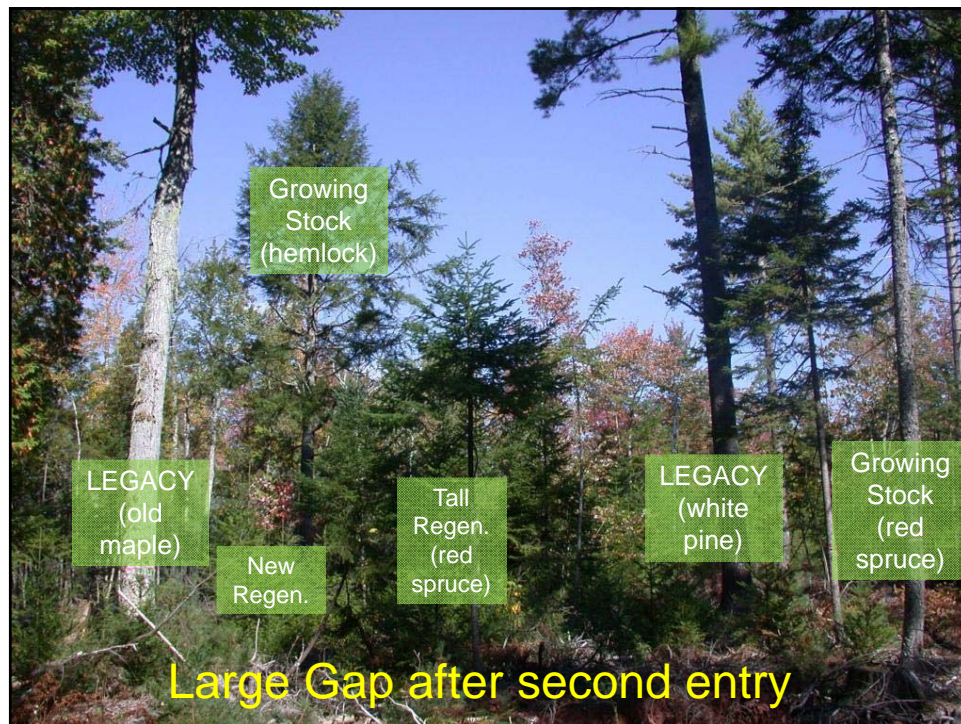


## Irregular group shelterwood – AFERP Study



- Large (0.5-1-acre) groups with 15% retention of legacy, plus growing stock if present, and overwood if necessary
- Matrix fully stocked, lightly thinned (not shown)











## Advantages of Group-based Shelterwood Systems -- Ecological

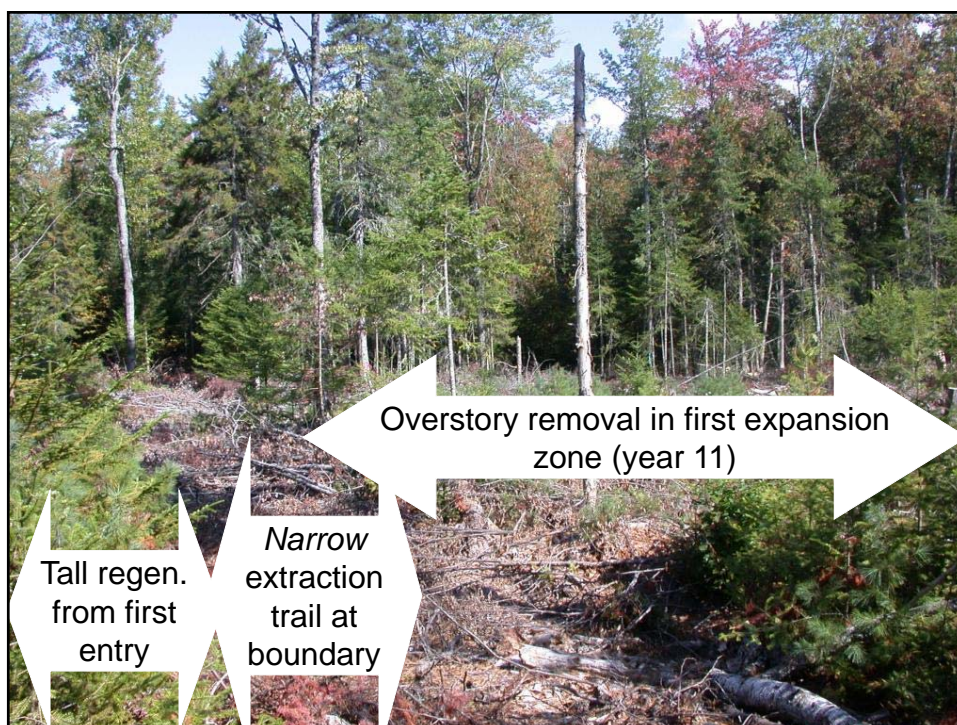
1. Manages regeneration deliberately, not by assumption (of future ingrowth)  
-- Gap size, overall regeneration rate
2. Ecological sustainability guaranteed (if cutting cycle is comparable to natural disturbance rates)
3. No need to assume a problematic linkage between age and size

All of these are demonstrated Achilles' Heels of B-d-q structural approach!

## Advantages of Group-based Shelterwood Systems -- Operational

4. Pre-harvest layout, designation of reserve trees, logging, early tending are all concentrated on 10-30% of stand  
-- No need to work throughout entire stand (after first entry)
5. No need for pre-harvest dbh distribution information, or overall marking tally
6. Light harvests (<25%) are feasible (volumes are concentrated, not dispersed)

Long-reach CTL systems are ideal for these gap expansion harvests – Ponsse Ergo





Regeneration somewhat predictable based on advance regeneration (fir, hemlock) and sprouting potential (red maple, aspen)



Red maple sprouts amidst dense fir and hemlock seedlings (under pine reserve trees)

Exception: white pine increased from 21% to 100% stocking!



Elaborate cleaning/PCT prescription just completed to improve composition and reduce density



## Reserve Trees

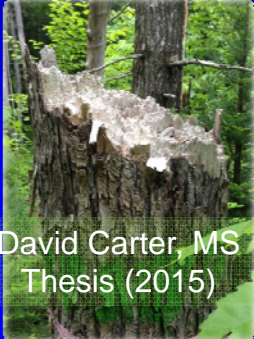
- Reserve trees that die or are harvested can be periodically replaced
- Criteria for selection:
  - Current or potential wildlife trees
  - Uncommon species
  - Potential high timber value under a long rotation (e.g., white pine)

One tree "IN"  
with 15 BAF  
Prism  
Everywhere in  
Gap



## Fate of AFERP Reserve Trees

MUCH better than studies in single-cohort stands!



David Carter, MS  
Thesis (2015)

Tree Species	Number	Survival
<i>Abies balsamea</i>	4	100
<i>Fraxinus americana</i>	22	100
<i>Fraxinus nigra</i>	1	100
<i>Ostrya virginiana</i>	2	100
<i>Picea glauca</i>	6	100
<i>Populus grandidentata</i>	12	100
<i>Quercus rubra</i>	20	100
<i>Tsuga canadensis</i>	150	97
<i>Acer saccharum</i>	32	97
<i>Acer rubrum</i>	120	97
<i>Betula alleghaniensis</i>	14	93
<i>Pinus resinosa</i>	14	93
<i>Pinus strobus</i>	127	91
<i>Fagus grandifolia</i>	17	88
<i>Picea rubens</i>	150	88
<i>Betula papyrifera</i>	25	84
<i>Thuja occidentalis</i>	85	82
<i>Populus tremuloides</i>	18	67
<b>Total</b>	<b>820</b>	<b>92</b>



## ***“What have we learned?”***

- These gap-based systems are clearly viable (*Saunders and Arsenault 2013*) and have been widely adopted by public lands' managers and family forest owners.
- The longer I follow and manage these experiments, the more encouraged and enthusiastic I become.
- But, this will not work everywhere! (there are no silvicultural panaceas)

## **Irregular Shelterwood is not just about managing structure!**

- Must also ensure suitable conditions for regeneration where overstory is not fully stocked
- Failure to do so can cause the composition to “drift” in the direction of low-value shade tolerant generalists – beech in NHw, fir in N Conifers
- Advantage of Group-based approaches

## Irregular shelterwood is not a panacea for everything

- Not applicable in: Uniform even-aged stands dominated by shade-intolerant, early-successional, short-lived species (pure aspen)
- Predicting stand development (with models like FVS) is problematic, owing to spatial irregularity

## Take-home:

- Apply group shelterwood when the stand is spatially diverse ("patchy")
- Avoid geometrical regeneration patches with no retention (except aspen) - put them where they need to be and leave overwood to create diffuse light in understory. ***When you do this, size of group becomes irrelevant.***
- Conserve small-dbh growing stock always (two-rotation species), but....
- Remove undesirable low shade from midstory competitors if needed.
- Leave permanent legacies to meet biodiversity objectives related to large, old trees

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