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 sheltewood variants – Acadian Femelschlag (AFERP Study)

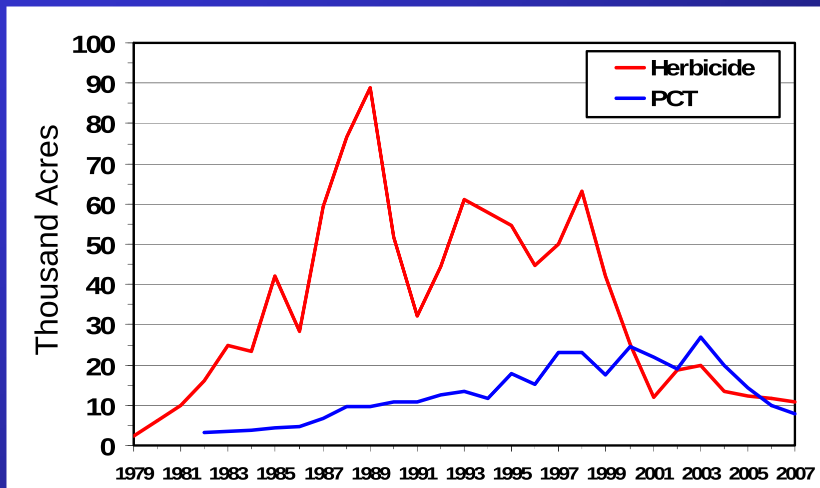
V: Even-aged silviculture for commodity production

- 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

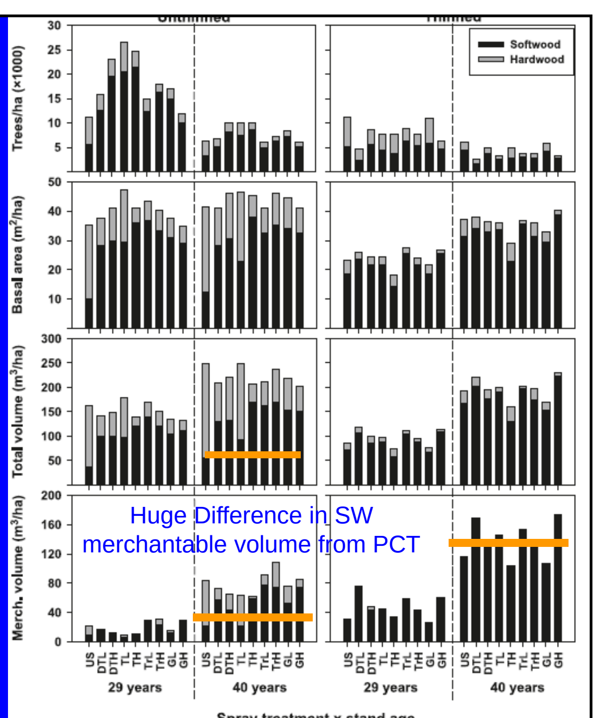


Derived from:
1979-1992: McCormack, M.L. 1994. Reductions in Herbicide Use for Forest Vegetation Management. Weed Technology 8:344-349.
1993-1999 Maine Board of Pesticide control, reflect permit requests and not actual sprayed acres
Wagner, R.G., E.H. Bowling, and R.S. Seymour. 2003. Forest and Agriculture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

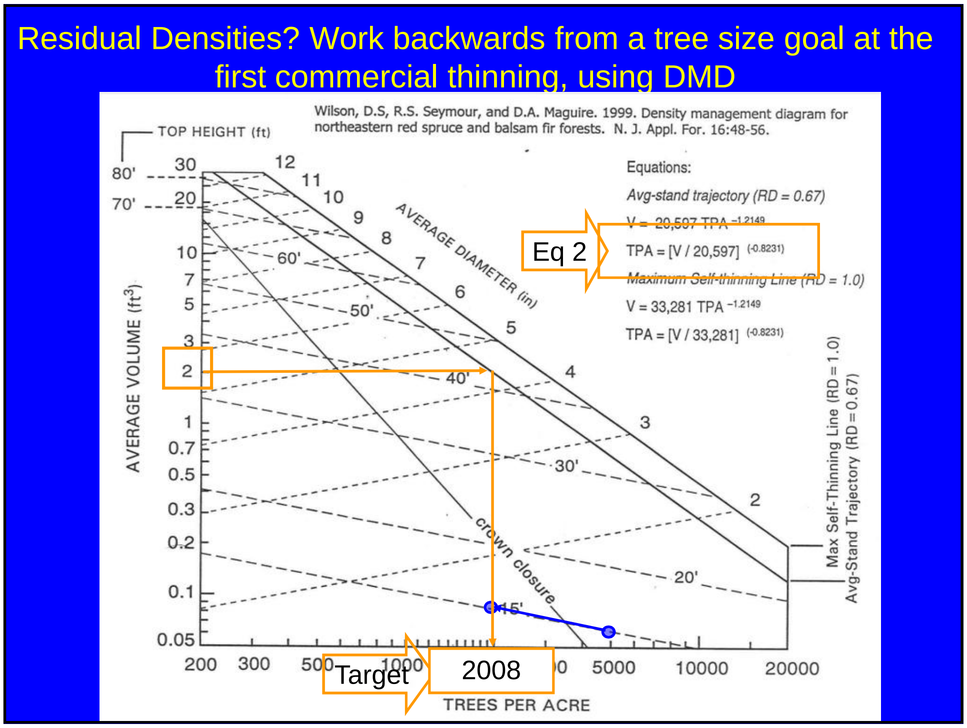
- Age 10-20 from overstory removal
  - Live crown lifted off ground, but…
  - Stump diameter < 4”
- Typically had history of herbicide release treatment 5-10-years earlier; now, most are from shelterwood removal cuts

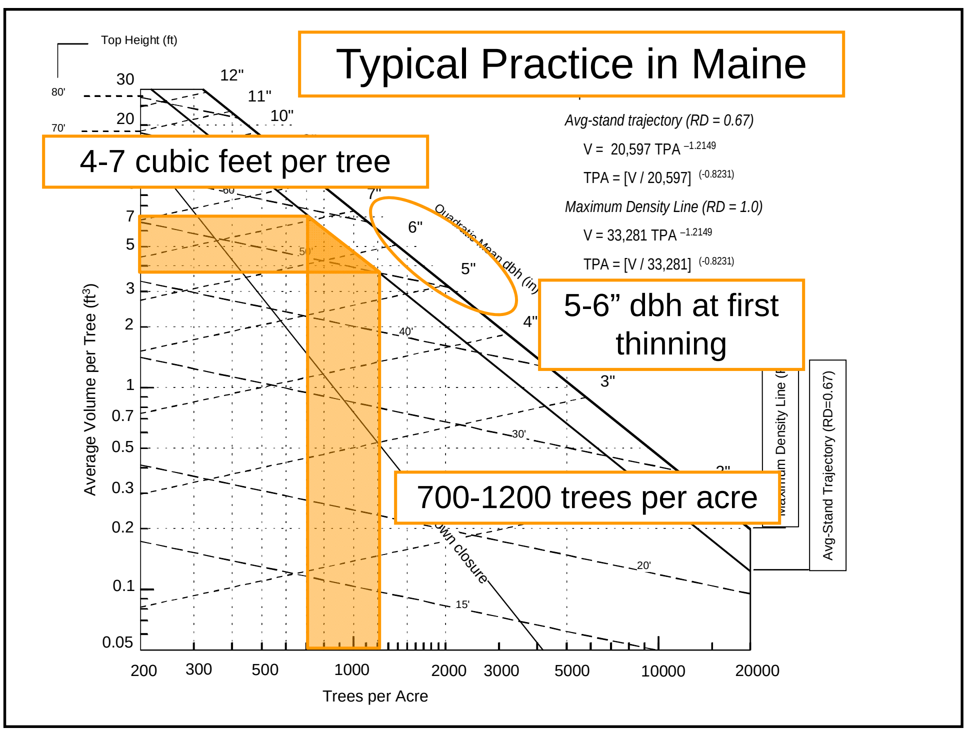
Rationale for Precommercial Thinning

- 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
Wilson, D.S, R.S. Seymour, and D.A. Maguire. 1999. Density management diagram for northeastern red spruce and balsam fir forests. N. J. Appl. For. 16:48-56.
TOP HEIGHT (ft)
AVERAGE VOLUME (ft³)
AVERAGE DIAMETER (in)
crown closure
Equations:
Avg-stand trajectory (RD = 0.67)
V = 20,597 TPA -1.2149
TPA = [V / 20,597] (-0.8231)
Maximum Self-thinning Line (RD = 1.0)
V = 33,281 TPA -1.2149
TPA = [V / 33,281] (-0.8231)
Eq 2
Max Self-Thinning Line (RD = 1.0)
Avg-Stand Trajectory (RD = 0.67)
Target
2008
TREES PER ACRE


Typical Practice in Maine
Top Height (ft)
4-7 cubic feet per tree
Avg-stand trajectory (RD = 0.67)
V = 20,597 TPA -1.2149
TPA = [V / 20,597] (-0.8231)
Maximum Density Line (RD = 1.0)
V = 33,281 TPA -1.2149
TPA = [V / 33,281] (-0.8231)
Quadratic Mean dbh (in)
5-6" dbh at first thinning
700-1200 trees per acre
Average Volume per Tree (ft³)
Avg-Stand Trajectory (RD=0.67)
Trees per Acre

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

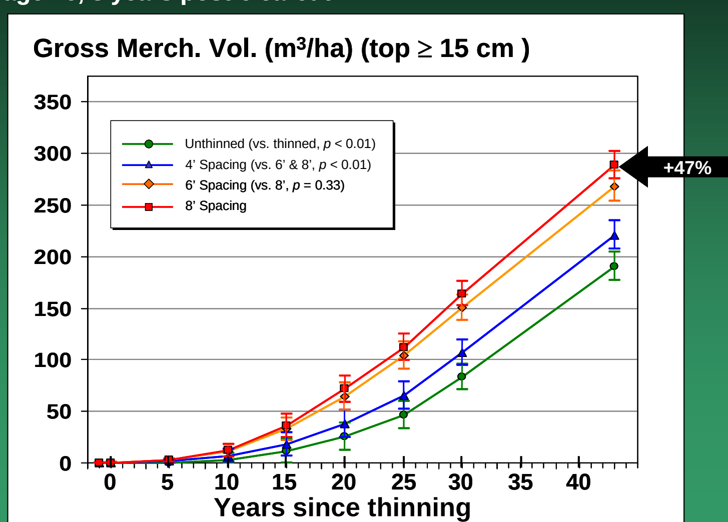
Stand Responses to PCT

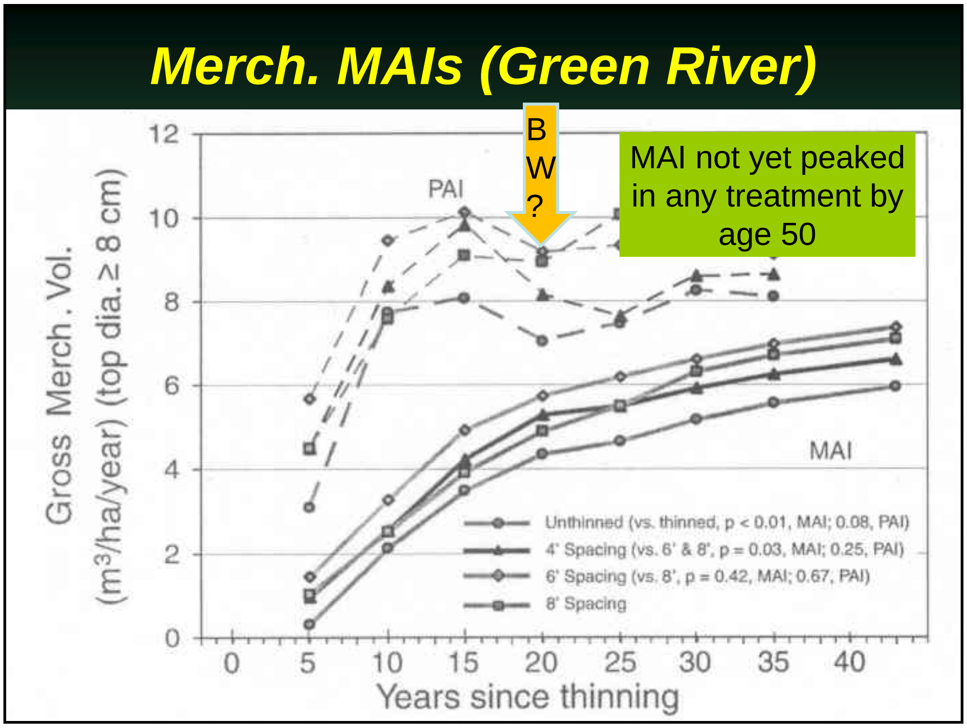
- PCT always increases merchantable yield
- Amount of yield increase depends on early tending, spacing, stand age, and merchantability thresholds

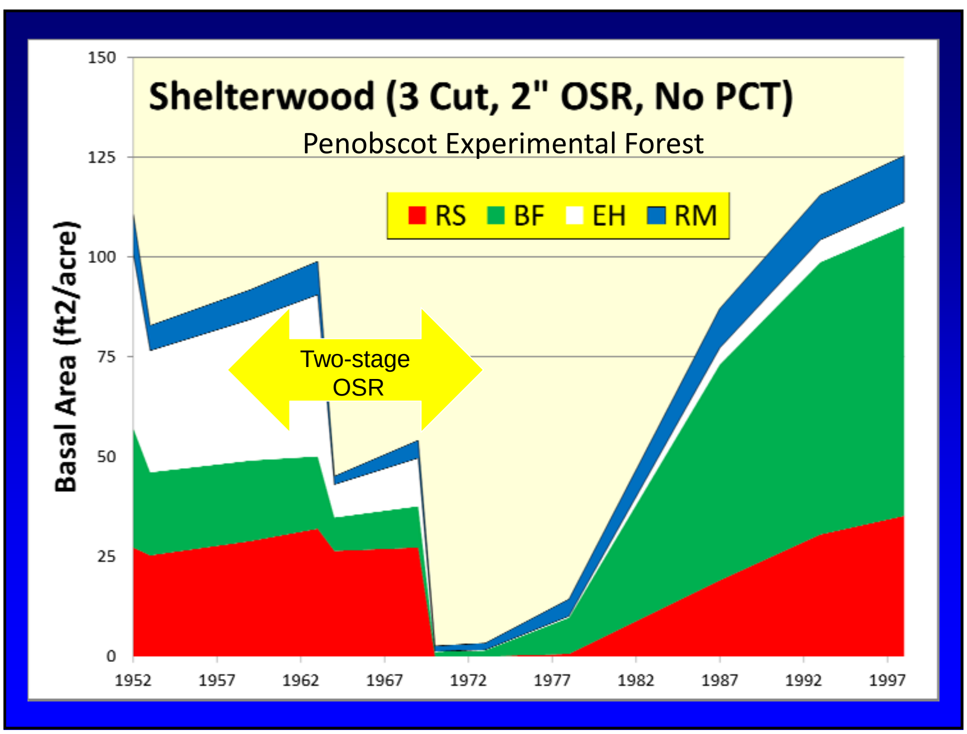
Green River Study (established ine early 1960s by G.L. Baskerville)

Green River Study *(Pitt and Lanteigne 2008)*

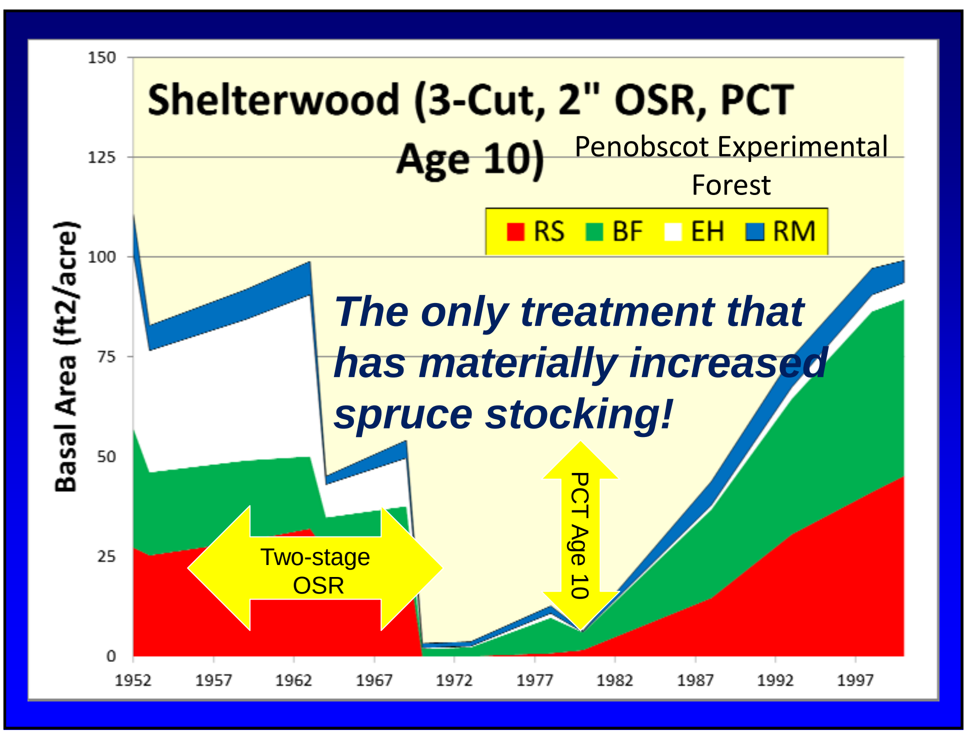
- **1959-61. G. Baskerville, NB study - Unthinned, 4', 6', 8', spacing in spruce-fir, installed age 16, 8 years post-clearcut**




Merch. MAIs (Green River)
B
W
?
MAI not yet peaked in any treatment by age 50
PAI
MAI
Gross Merch. Vol.
(m³/ha/year) (top dia. ≥ 8 cm)
Unthinned (vs. thinned, p < 0.01, MAI; 0.08, PAI)
4' Spacing (vs. 6' & 8', p = 0.03, MAI; 0.25, PAI)
6' Spacing (vs. 8', p = 0.42, MAI; 0.67, PAI)
8' Spacing
Years since thinning
0
2
4
6
8
10
12
0
5
10
15
20
25
30
35
40


Shelterwood (3 Cut, 2" OSR, No PCT)
Penobscot Experimental Forest
RS
BF
EH
RM
Two-stage OSR
Basal Area (ft2/acre)
0
25
50
75
100
125
150
1952
1957
1962
1967
1972
1977
1982
1987
1992
1997


No spacing– crop trees barely merchantable at age 40


Shelterwood (3-Cut, 2" OSR, PCT Age 10)
Penobscot Experimental Forest
RS BF EH RM
The only treatment that has materially increased spruce stocking!
Two-stage OSR
PCT Age 10
Basal Area (ft2/acre)
150
125
100
75
50
25
0
1952
1957
1962
1967
1972
1977
1982
1987
1992
1997

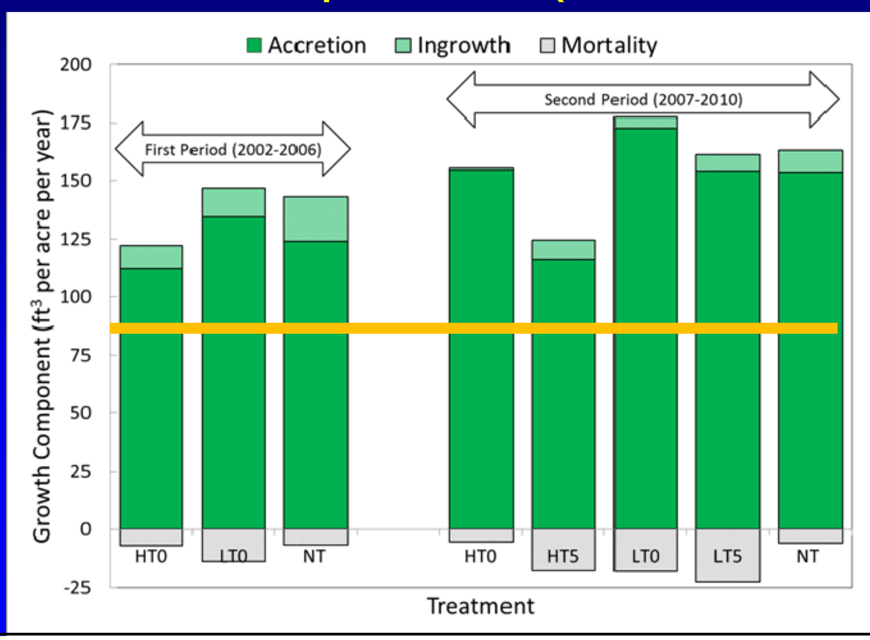

8-9 ft spacing (PCT) at Age 10 –
trees merchantable at age 30


12” RS Crop trees at age 40

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)



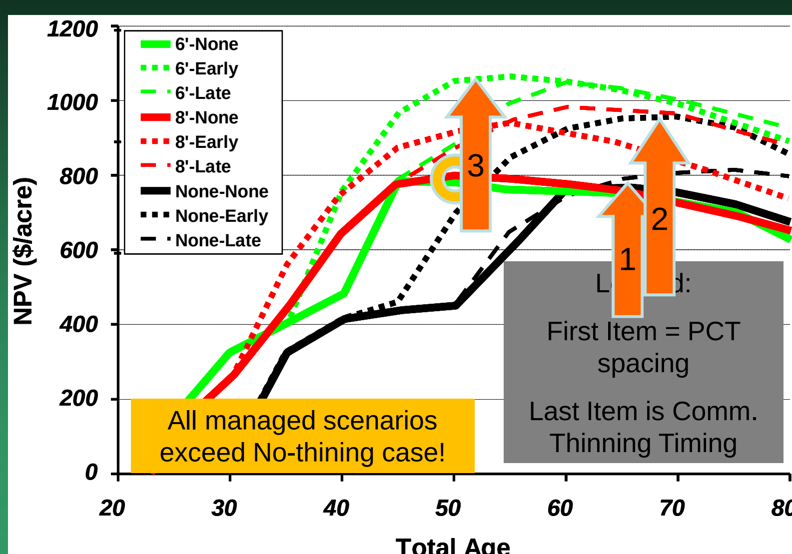
Optimum Combination PCT and Commercial Thinning – (*Saunders et al 2008)*

- 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

Uneven-aged Silviculture

- Uneven-aged silviculture
  - create and maintain stands with three or more distinct age classes
  - selection cuttings
- "Multi-aged" includes two-aged variants

Selection Cuttings

- Simultaneously
  - harvest
  - tend
  - regenerate
- Frequent, relatively equal harvest cuttings
  - Cutting cycle (no rotation)

Origins of Balanced Selection

- Normal yield tables
- Regulated forests
- Age classes occupy equal area
- Sustained yield

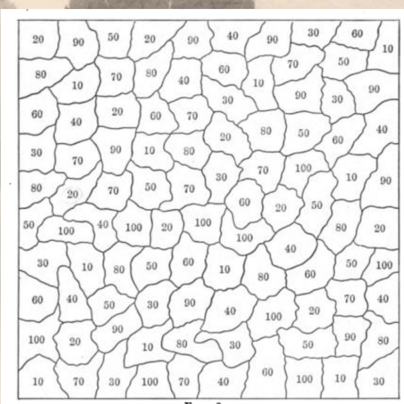


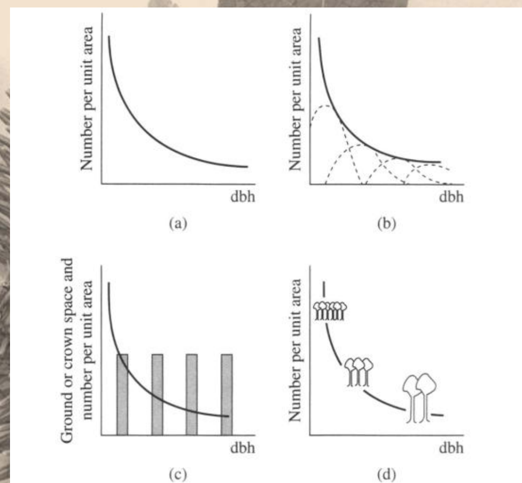
Fig. 28.

A portion (one acre) of an ideal single tree selection stand managed on a rotation of 100 years under a 10 year cutting cycle. Ten age classes are represented each occupying approximately one-tenth of the area. The numbers indicate the age of the trees.

Hawley 1921

Stand Structural Goal

- Balance
- Age – size correlation



Nyland 1987

Managing Selection Cuttings

- Target dbh distribution ("target structure")
- Compare actual to target; harvest accordingly

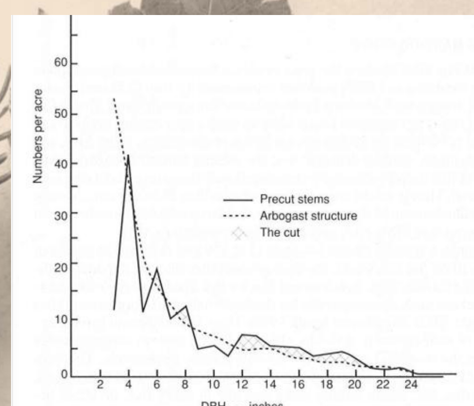
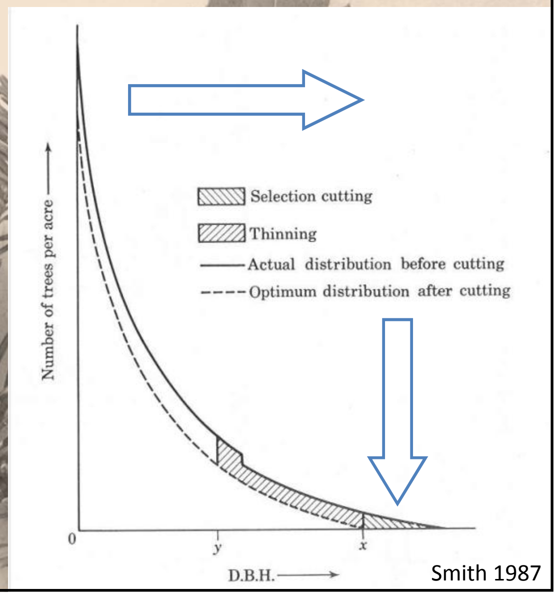


FIGURE 10-8
Comparison of precut stand structure with the residual diameter distribution recommended by Arbogast (1957) for the uneven-aged northern hardwood stand described in Table 10-3.

Nyland 2016

Dynamics of Balanced DBH Distributions

- Growth pushes distribution to the right
- Cutting pulls it down



Smith 1987

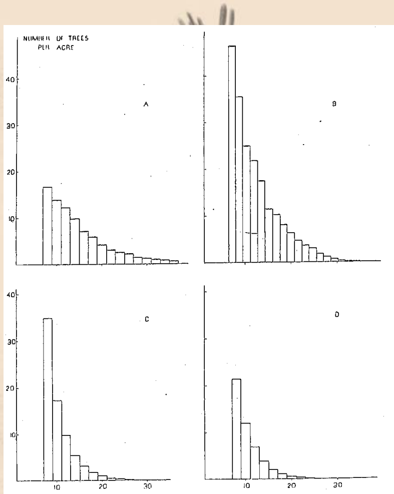
Why Practice Selection Cutting?

- Continuous forest cover
- Mature trees
- High vertical structural diversity
- Sustained yield from small parcels
- Emulates small-scale natural disturbance regimes

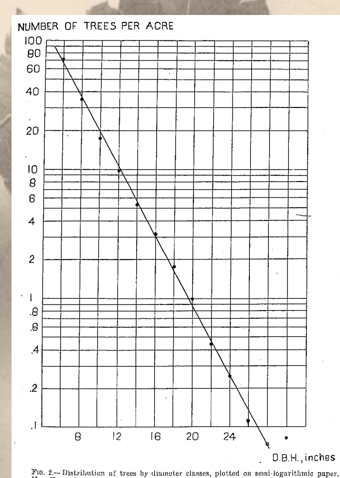
Challenges

- Prone to misapplication
  - Tendency to high-grade, diameter-limit cutting
  - Inattention to regeneration
- Potential for residual stand damage
- Windfirmness
- Cannot protect regeneration during spruce budworm outbreaks

q structure



Meyer 1952



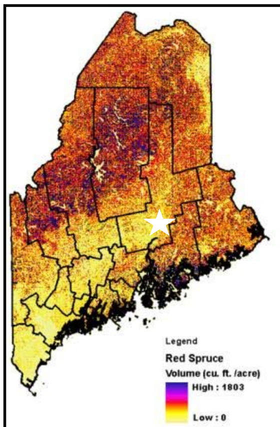
Based on de Liocourt 1898

Acadian Forest

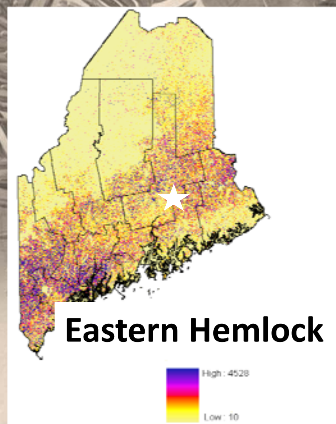
Penobscot Experimental Forest

- 3800-acre forest
- Located in central Maine
- U.S. Forest Service
  - Long-term silviculture experiment
  - 65+ years of research

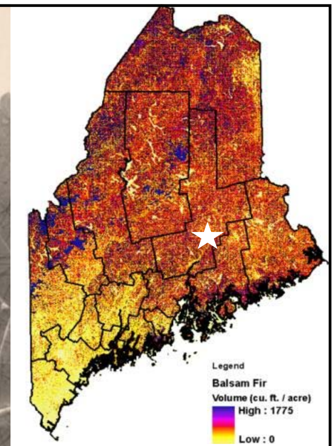
Acadian Conifers *FIA data*



Red Spruce



Eastern Hemlock



Balsam Fir

Selection System (1950-present)

- Single-tree selection
- BD*q* structural goal
- 19 stands
- 5-, 10-, 15-, 20-year cycles
- 100+ selection cuts

M. Westveld, A. Hart, W. Kidd, T. McLintock

Marking Guidelines

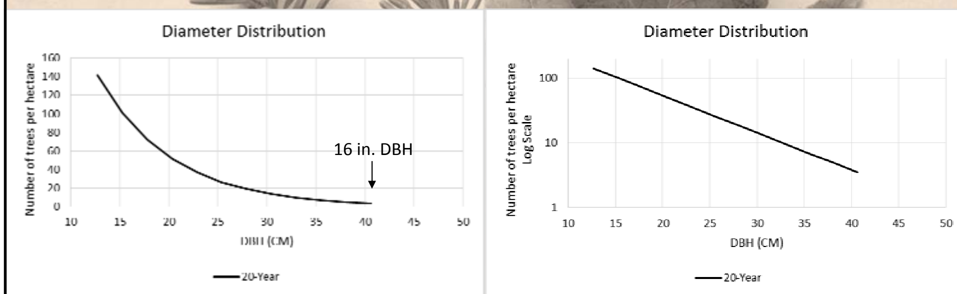
- BD*q* structural goal
- Control quality and vigor
  - Remove cull and high risk trees, undesirables species
- Control composition
  - Increase spruce, decrease hemlock and fir

Composition Goal (1950)

		Observed 1950
• Spruce spp.	35 – 55%	16%
• Balsam fir	15 – 25%	20%
• E. hemlock	15 – 25%	30%
• N. white-cedar	5 – 10%	12%
• Pine spp.	5 – 10 %	4%
• Birch spp.	5 – 10 %	4%
• Other	5 – 10%	14%

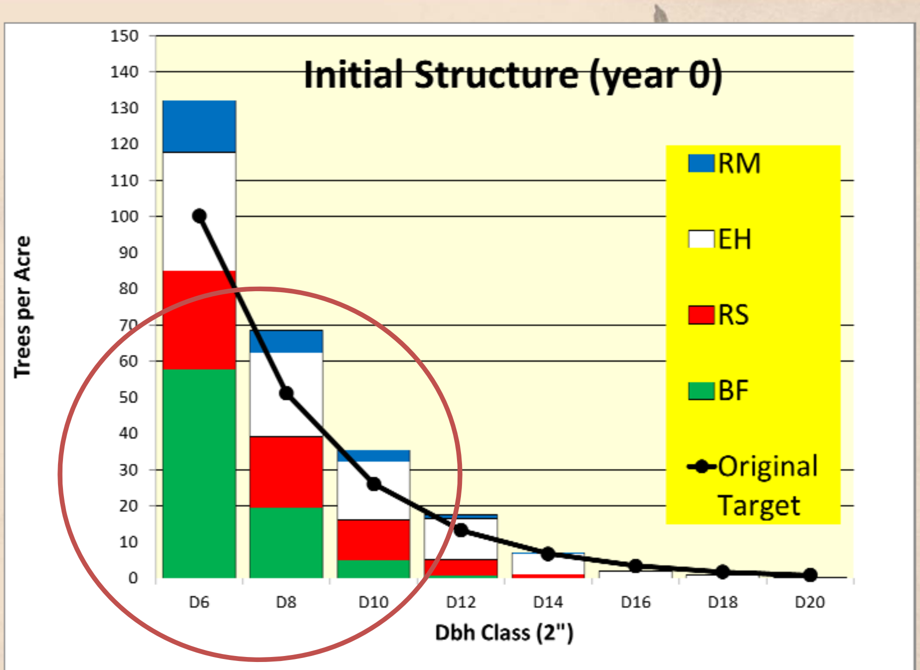
Structural Goal

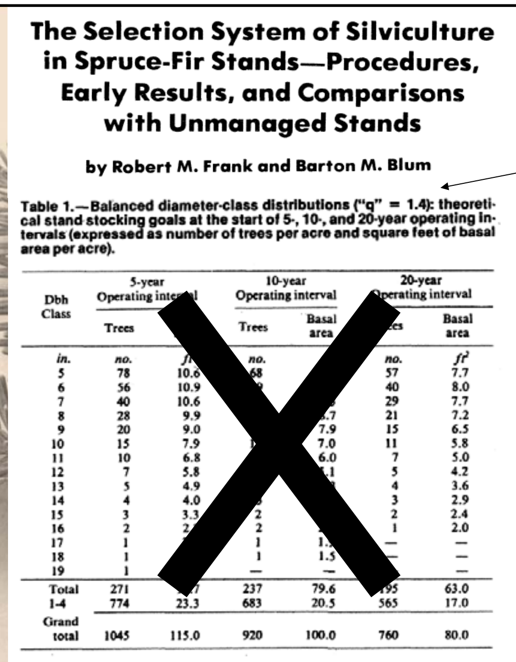
- Example: 20-year cycle



Note: metric units

- *q* factor = 1.96 on 2-inch DBH classes
- Merchantable-size BA = 60 to 90 ft^2/ac





The Selection System of Silviculture in Spruce-Fir Stands—Procedures, Early Results, and Comparisons with Unmanaged Stands

by Robert M. Frank and Barton M. Blum

Table 1.—Balanced diameter-class distributions ("q" = 1.4): theoretical stand stocking goals at the start of 5-, 10-, and 20-year operating intervals (expressed as number of trees per acre and square feet of basal area per acre).

Dbh Class	5-year Operating interval		10-year Operating interval		20-year Operating interval	
	Trees	Basal area	Trees	Basal area	Trees	Basal area
in.	*no.*	*ft²*	*no.*	*ft²*	*no.*	*ft²*
5	78	10.6	68	[illegible]	57	7.7
6	56	10.9	[illegible]	[illegible]	40	8.0
7	40	10.6	[illegible]	[illegible]	29	7.7
8	28	9.9	[illegible]	[illegible]	21	7.2
9	20	9.0	[illegible]	7.9	15	6.5
10	15	7.9	[illegible]	7.0	11	5.8
11	10	6.8	[illegible]	6.0	7	5.0
12	7	5.8	[illegible]	[illegible]	5	4.2
13	5	4.9	[illegible]	[illegible]	4	3.6
14	4	4.0	[illegible]	[illegible]	3	2.9
15	3	3.3	2	[illegible]	2	2.4
16	2	[illegible]	2	[illegible]	1	2.0
17	1	[illegible]	1	[illegible]	—	—
18	1	[illegible]	1	1.5	—	—
19	1	[illegible]	—	—	[illegible]	—
Total	271	[illegible]	237	79.6	[illegible]	63.0
1-4	774	23.3	683	20.5	565	17.0
Grand total	1045	115.0	920	100.0	760	80.0

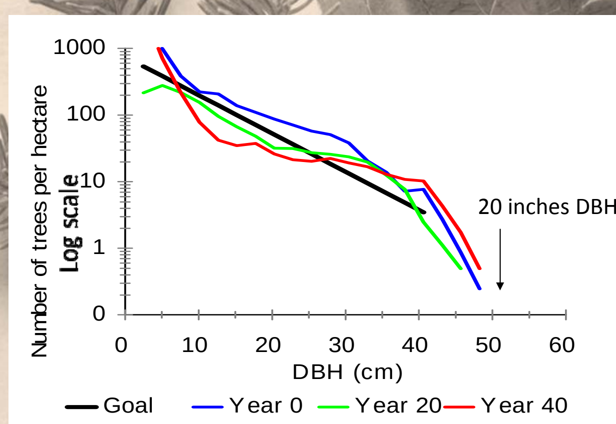
q= 1.96 on 2" classes

Forest Service Research Paper NE-425

Frank and Blum (1978)

Stand Structure: DBH Distribution

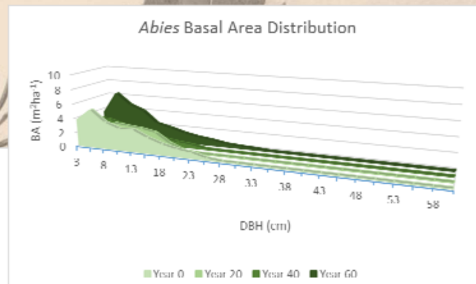
Example: 20-year cycle

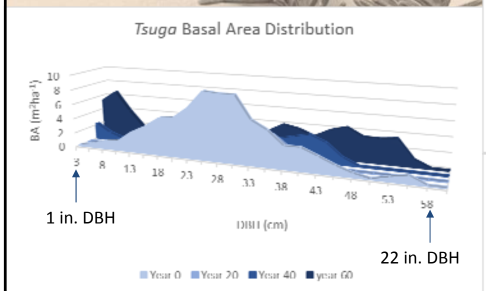


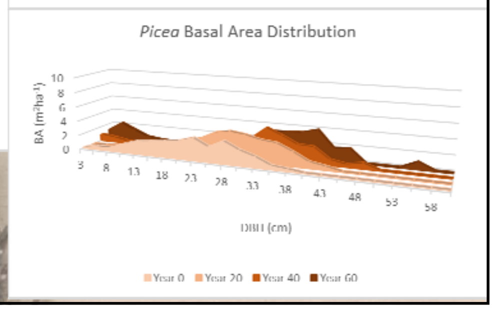
Note: metric units

Species Composition

Example: 20-year cycle



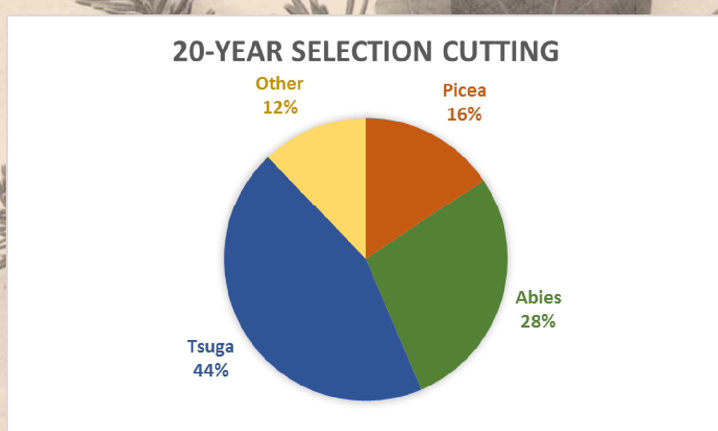




Note: metric units

Regeneration

Seedlings, year 60



~ 5,500 stems/ac

What Worked?

- Stands well stocked with vigorous trees
- Increased spruce basal area
- Continuous production of sawtimber
- Abundant regeneration

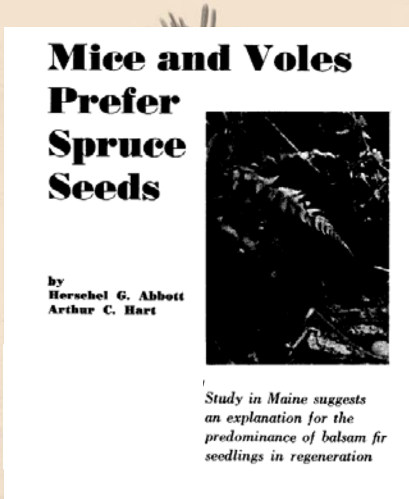

What didn't work

- Reverse-J diameter distribution
  - Bimodal structure
- Species composition
  - Little to no spruce recruitment

Why?



Seed Predation


Mice and Voles Prefer Spruce Seeds

by
Herschel G. Abbott
Arthur C. Hart

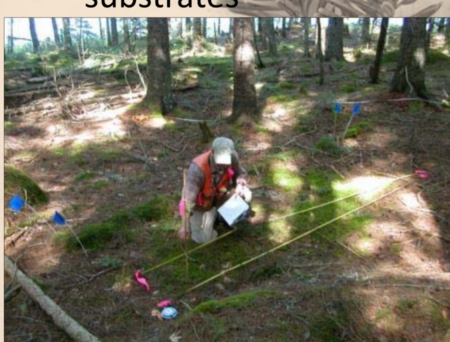
Study in Maine suggests an explanation for the predominance of balsam fir seedlings in regeneration


Red squirrel midden

Courtesy of Alessio Mortelliti, University of Maine

Regeneration Substrate

- Density of spruce and hemlock seedlings higher on decayed wood than adjacent forest floor
- Density of fir and red maple do not differ between substrates



58

Weaver et al. 2009

Herbivory

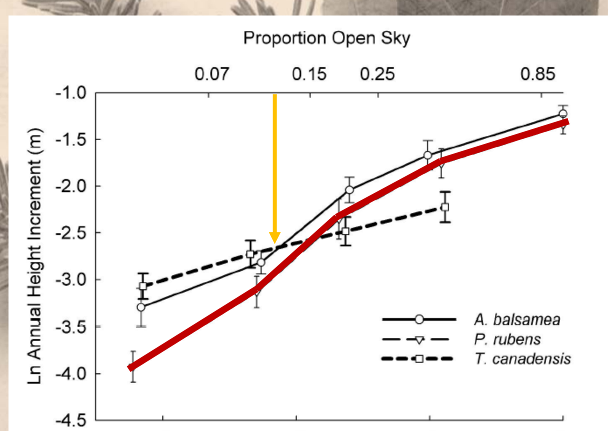
Species	Number of seedlings	Number browsed	Percent browsed
Balsam fir	1916	89	**5%**
Eastern hemlock	834	62	**7%**
Northern white-cedar	188	46	**25%**
Red spruce	388	145	**37%**
Red maple	2168	137	**6%**

Data shown for species with n>100 seedlings (216 plots)

Berven 2011

Competition

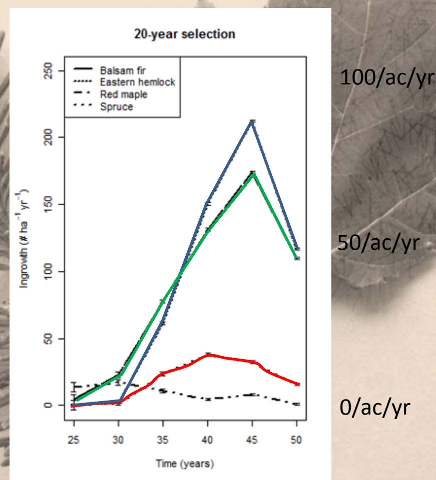
- Trees 1.5 to 20 feet tall



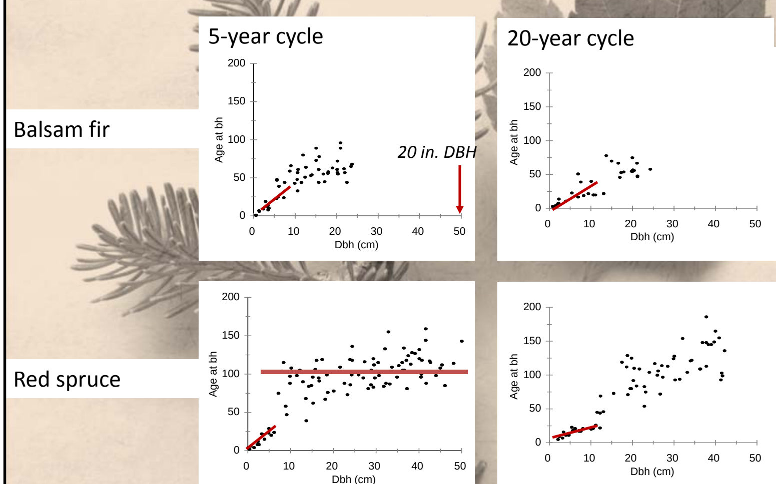
Note: metric units

Moores et al. 2007

Sapling Recruitment



Tree Age – Size Relationships



Note: metric units

Complexities of Mixed Species

- Balsam fir pathological longevity

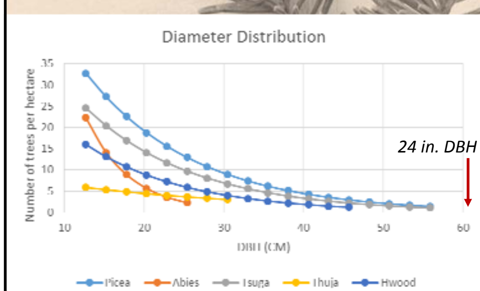
Alternative: Species-specific Goals

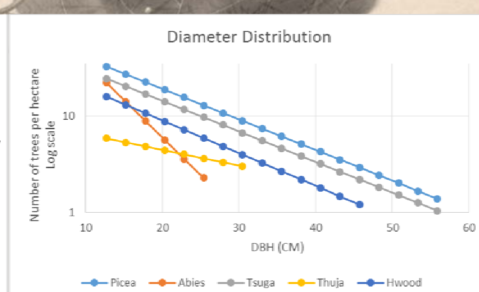
Example: 5-year cutting cycle treatment

5-year														
		EH		Spruce		BF		NWC		Hwoods		All species	
2 in q		1.45		1.45		2.50		1.20		1.50			
1 in q		1.20		1.20		1.58		1.10		1.22			
DBH in	TPA	BA squft/ac	TPA	BA squft/ac	TPA	BA squft/ac	TPA	BA squft/ac	TPA	BA squft/ac	TPA	BA squft/ac
1	20.93	0.11	27.90	0.15	56.17	0.31	3.47	0.02	14.33	0.08	122.81	0.67
2	17.38	0.38	23.17	0.51	35.55	0.78	3.16	0.07	11.75	0.26	91.01	1.99
3	14.43	0.71	19.24	0.94	22.50	1.10	2.87	0.14	9.63	0.47	68.68	3.37
4	11.99	1.05	15.98	1.39	14.24	1.24	2.61	0.23	7.89	0.69	52.71	4.60
5	9.95	1.36	13.27	1.81	9.01	1.23	2.37	0.32	6.47	0.88	41.08	5.60
6	8.27	1.62	11.02	2.16	5.70	1.12	2.16	0.42	5.30	1.04	32.45	6.37
7	6.86	1.83	9.15	2.45	3.61	0.96	1.96	0.52	4.35	1.16	25.93	6.93
8	5.70	1.99	7.60	2.65	2.29	0.80	1.78	0.62	3.56	1.24	20.93	7.31
9	4.73	2.09	6.31	2.79	1.45	0.64	1.62	0.72	2.92	1.29	17.03	7.52
10	3.93	2.14	5.24	2.86	0.92	0.50	1.47	0.80	2.39	1.31	13.96	7.61
11	3.27	2.15	4.35	2.87			1.34	0.88	1.96	1.29	10.92	7.21
12	2.71	2.13	3.62	2.84			1.22	0.96	1.61	1.26	9.15	7.19
13	2.25	2.08	3.00	2.77					1.32	1.21	6.57	6.06
14	1.87	2.00	2.49	2.67					1.08	1.15	5.44	5.82
15	1.55	1.91	2.07	2.54					0.89	1.09	4.51	5.53
16	1.29	1.80	1.72	2.40					0.73	1.01	3.74	5.21
17	1.07	1.69	1.43	2.25					0.59	0.94	3.09	4.88
18	0.89	1.57	1.19	2.10					0.49	0.86	2.56	4.53
19	0.74	1.45	0.98	1.94							1.72	3.39
20	0.61	1.34	0.82	1.78							1.43	3.12
21	0.51	1.23	0.68	1.63							1.19	2.86
22	0.42	1.12	0.56	1.49							0.99	2.61
Sum >4.5		31.50		42.00		5.25		5.25		15.75		99.75
											WP	5.25
											Sum > 4.5	105
											Sum > 0.5	115

Species-specific Goals

Example: 5-year cutting cycle treatment

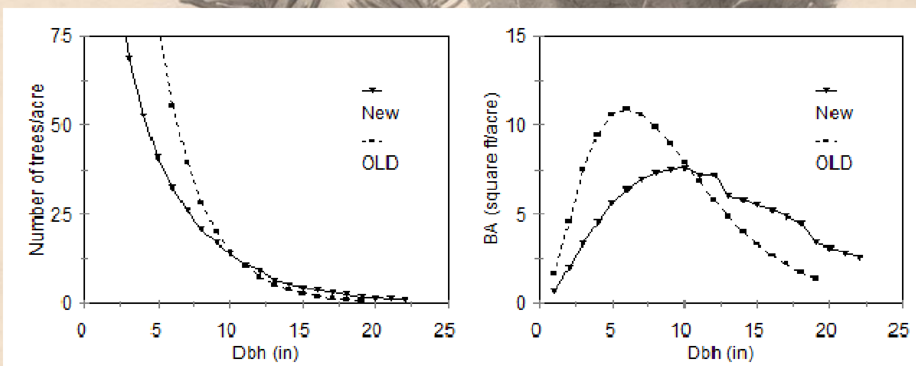




Note: metric units

Species-specific Goals

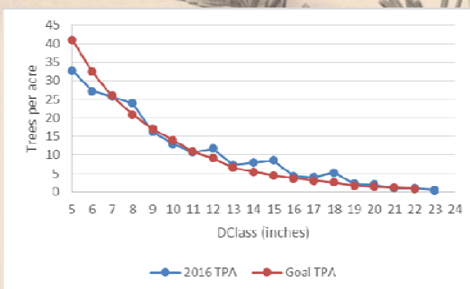
- Example: 5-year cutting cycle treatment



New Treatments

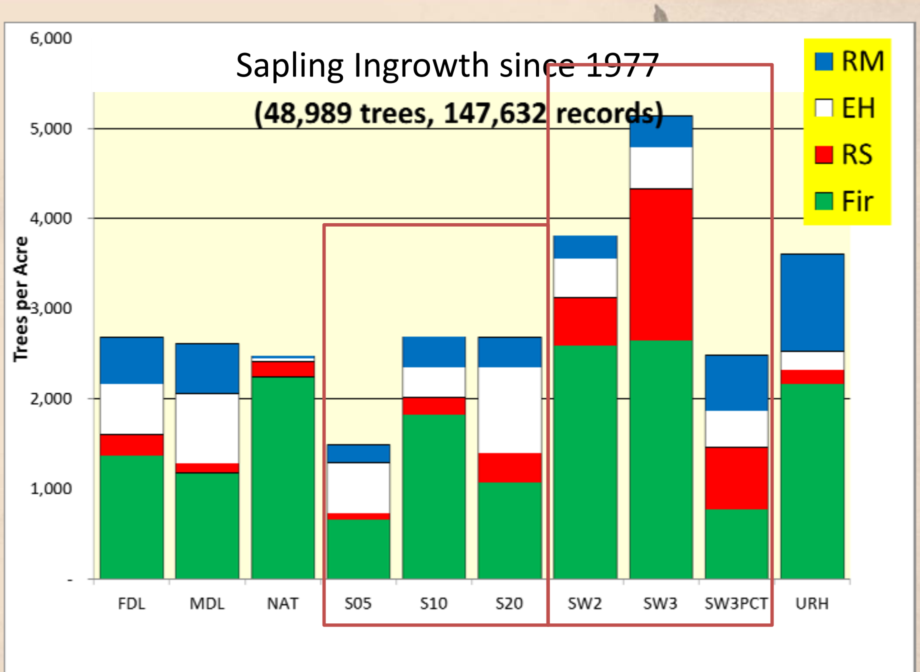
- Manage submerchantable trees

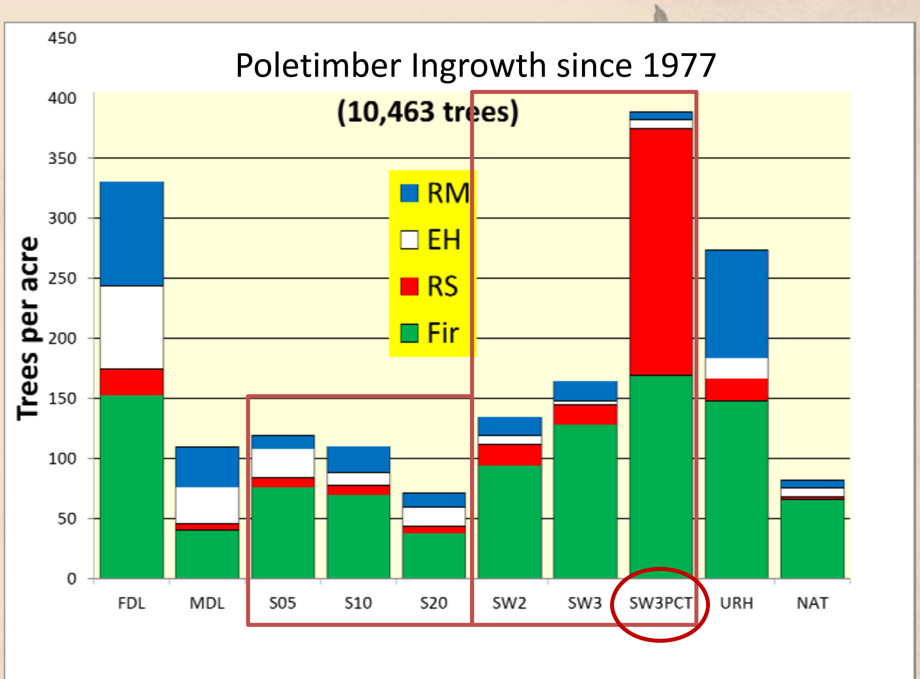
Outcomes



5-yr Selection, 2016

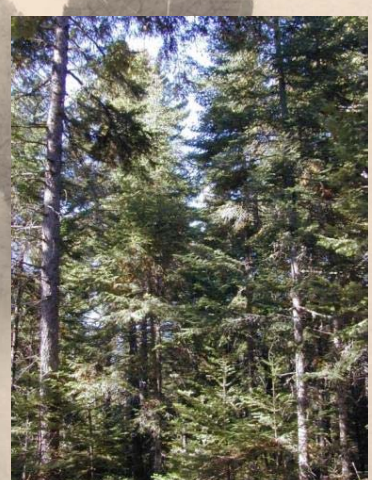
Sapling crop tree release





Review

- Why didn't we achieve our goals?
  - Poor age-size relationships
  - Slow sapling and pole ingrowth
  - Failure to account for species-specific dynamics
  - Problems were not evident
  - *Goals weren't realistic*



In Summary

- Single-tree selection maintains well-stocked, uneven-aged northern conifer stands
  - does not favor spruce; sapling growth rates are slow
- Reverse J structure difficult to achieve and maintain
  - attention to individual species and submerchantable trees needed to attain desired structure and composition

Alternatives for Uneven-aged Stands

- Area-based methods
  - Group selection
  - Irregular shelterwood

Acknowledgments

Robert Seymour and Aaron Weiskittel, University of Maine

Ralph Nyland, SUNY ESF (emeritus)

John Brissette, U.S. Forest Service (retired)

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

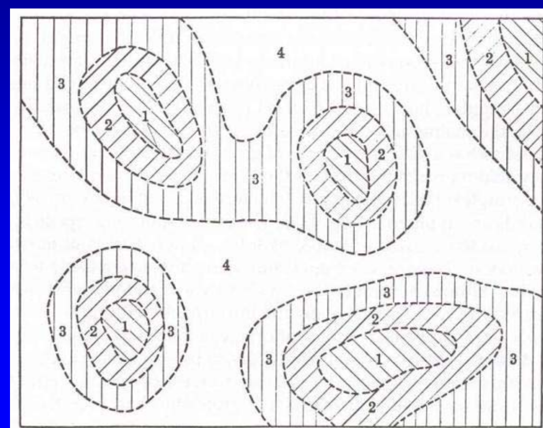
- Preparatory Cuttings (Optional!)
  - To prepare for regeneration by developing good seed-bearing trees and eliminating undesirable seed sources
- Establishment (= "seed") Cuttings
  - Goal is to *establish* advance regeneration
- [Overstory] Removal Cuttings (OSR)
  - Remove the overwood, *release* 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-succesional 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

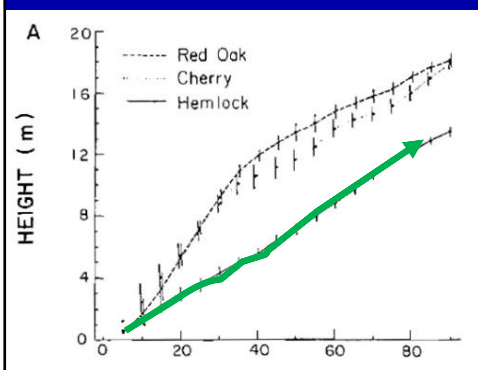


FIG. 4. (A) Average cumulative height growth and (B) basal area growth of trees growing in direct competition in the Great Mountain Forest stand. Results are based on six four-tree plots of overstory red oak ($n = 6$), overstory black cherry ($n = 6$), and understory hemlock ($n = 12$). Black cherry 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 ±1 SE.

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

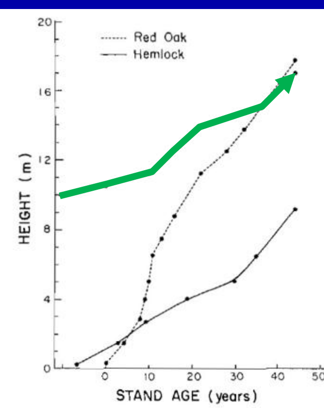
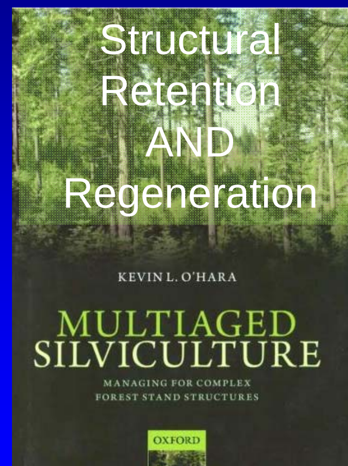


FIG. 6. Cumulative height growth of one three-tree plot from the Harvard Forest stand. A stand age of 0 denotes the year of overstory destruction by hurricane winds.

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

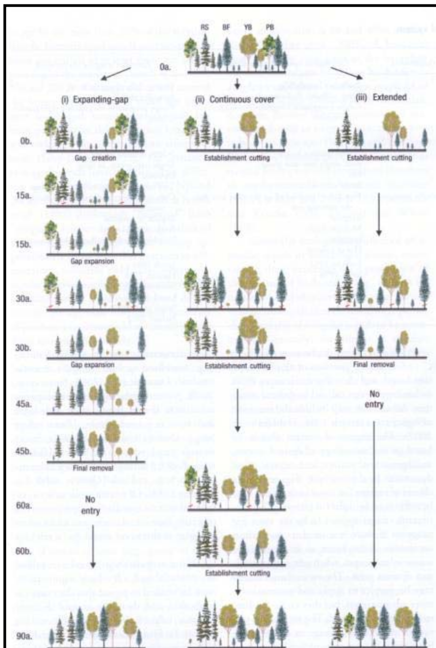


Figure 1. Example of silvicultural scenarios illustrating three variants of the irregular shelter-wood system in a fictive mixed balsam fir–yellow birch stand over a 90-year period. Red bars indicate marked trees. Numbers represent number of years since beginning. a = before cutting, b = after cutting, RS = red spruce, BF = balsam fir, YB = yellow birch, and PB = paper birch.

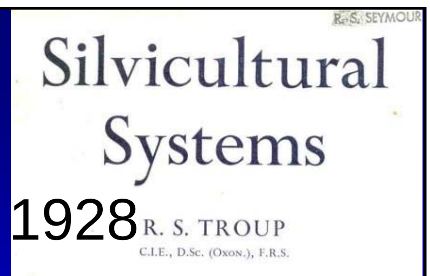
Variants

(Patricia Raymond et al 2009)

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

Europen Roots: ***Femelschlag***

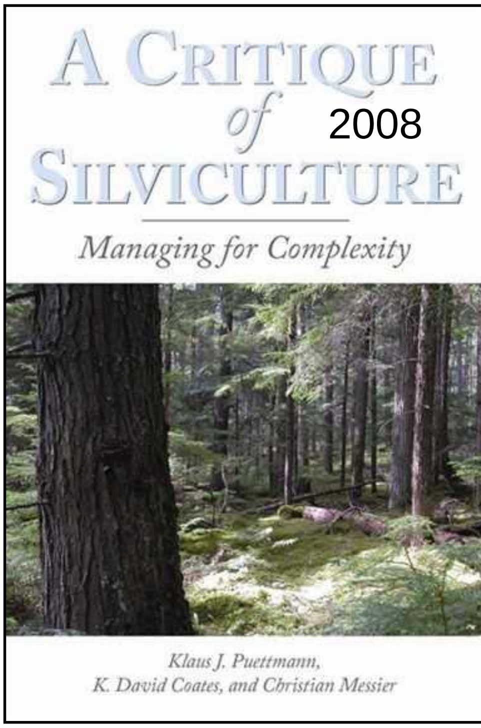
(Spurr 1956)

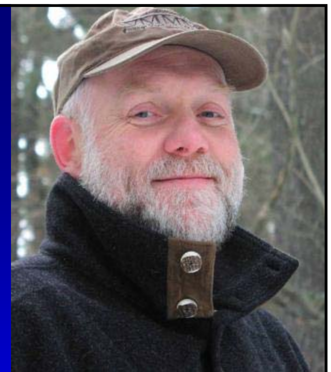


1928


Swiss Femelschlag (continuous cover)


Bavarian Femelschlag (expanding groups)





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

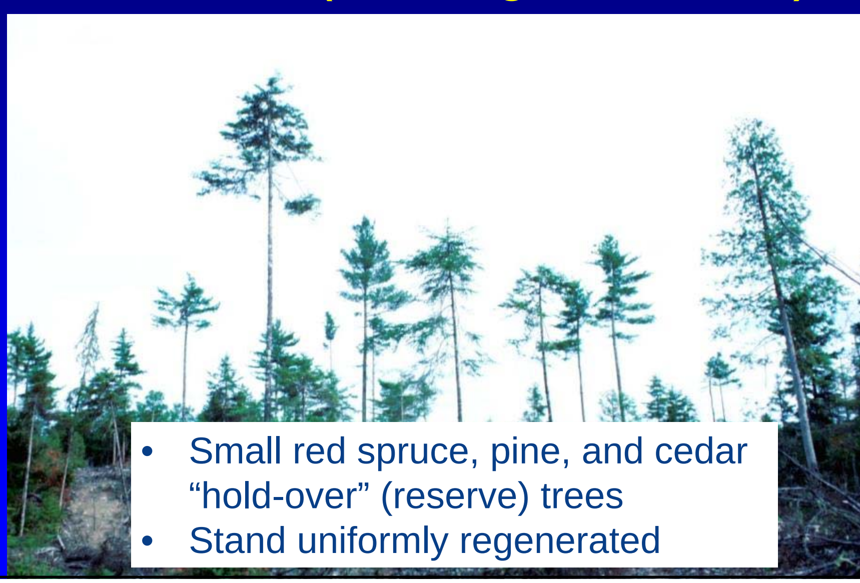
Contemporary North American Applications

- 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”)



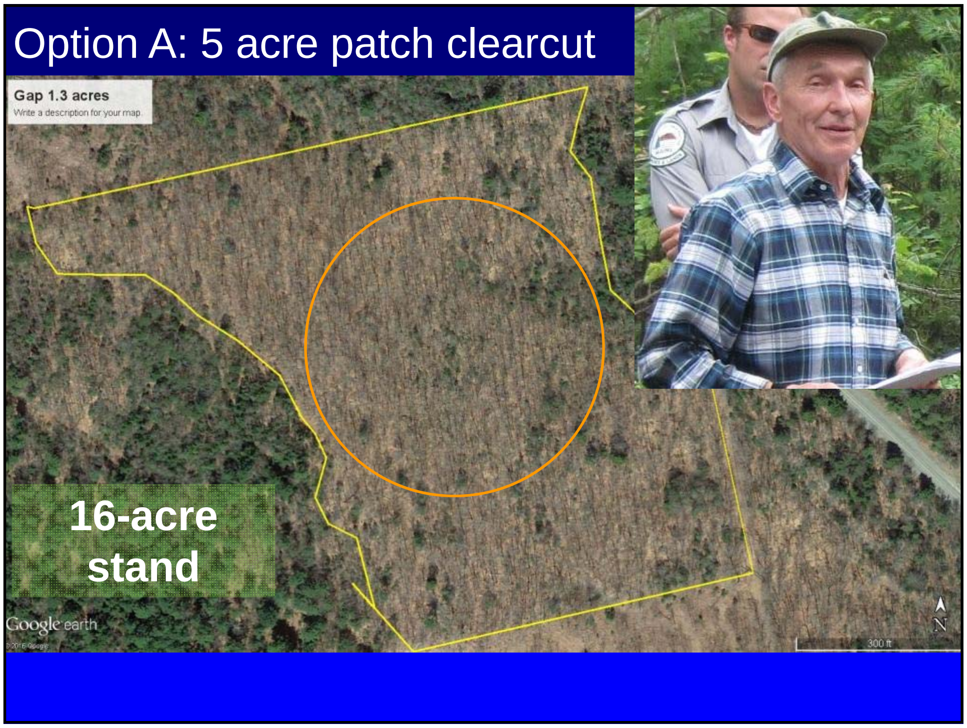
- Small red spruce, pine, and cedar “hold-over” (reserve) trees
- Stand uniformly regenerated

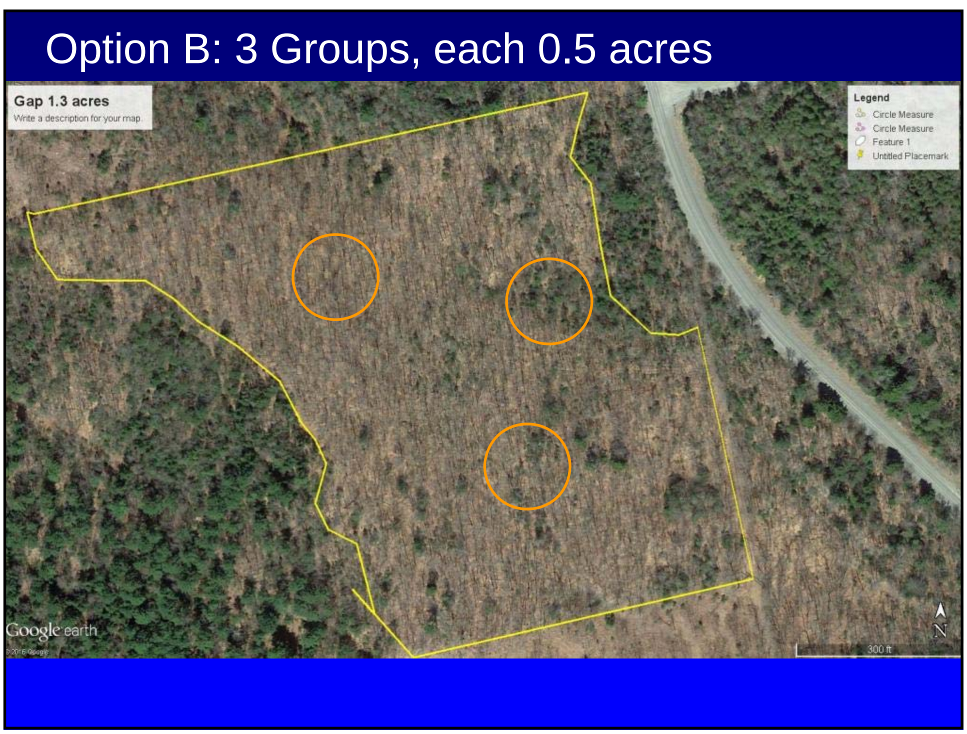
Emulating Natural Disturbance (Ecological Forestry)

- 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.

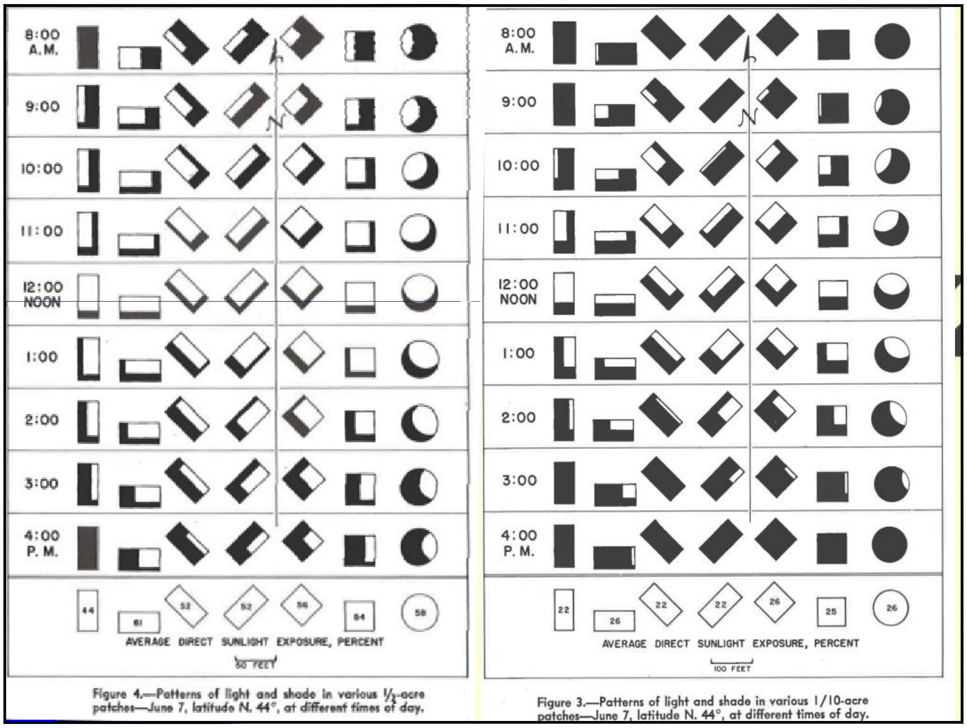

Option A: 5 acre patch clearcut
Gap 1.3 acres
Write a description for your map.
16-acre stand
Google earth
300 ft

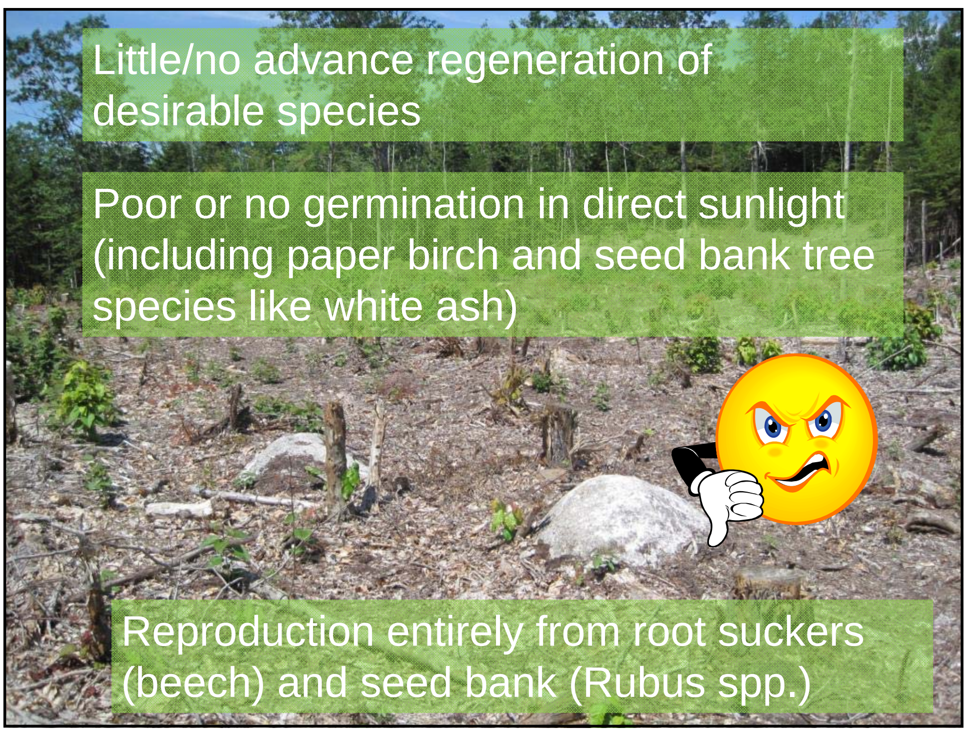

Option B: 3 Groups, each 0.5 acres
Gap 1.3 acres
Write a description for your map.
Legend
Circle Measure
Circle Measure
Feature 1
Untitled Placemark
Google earth
300 ft

Option C: 15 Groups, each 0.1 acre

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

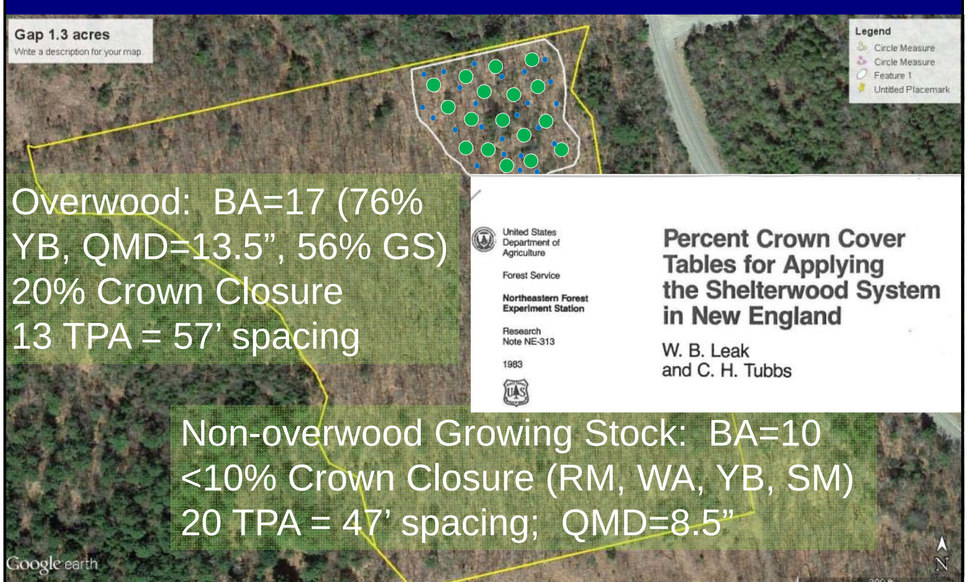

8:00 A.M.
9:00
10:00
11:00
12:00 NOON
1:00
2:00
3:00
4:00 P.M.
44 61 52 52 56 54 58
AVERAGE DIRECT SUNLIGHT EXPOSURE, PERCENT
50 FEET
Figure 4.—Patterns of light and shade in various 1/3-acre patches—June 7, latitude N. 44°, at different times of day.
8:00 A.M.
9:00
10:00
11:00
12:00 NOON
1:00
2:00
3:00
4:00 P.M.
22 26 22 22 26 25 26
AVERAGE DIRECT SUNLIGHT EXPOSURE, PERCENT
100 FEET
Figure 3.—Patterns of light and shade in various 1/10-acre patches—June 7, latitude N. 44°, at different times of day.


Little/no advance regeneration of desirable species
Poor or no germination in direct sunlight (including paper birch and seed bank tree species like white ash)
Reproduction entirely from root suckers (beech) and seed bank (Rubus spp.)

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

Mark low-density shelterwood overwood uniformly throughout the group, favoring yellow birch and white ash

Retention: *Overwood + Legacy + Growing Stock*



Overwood: BA=17 (76% YB, QMD=13.5", 56% GS)
20% Crown Closure
13 TPA = 57' spacing

Non-overwood Growing Stock: BA=10
<10% Crown Closure (RM, WA, YB, SM)
20 TPA = 47' spacing; QMD=8.5"

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

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

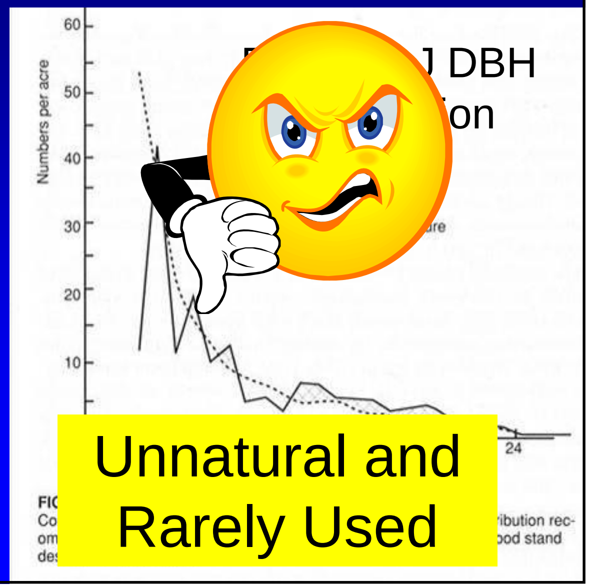
What silvicultural systems do these dynamics imply under an Ecological Forestry paradigm?

- *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

From Nyland (1996)

- Descriptive perhaps, but not informative



Ecological Forestry – What ***IS*** "Natural?"

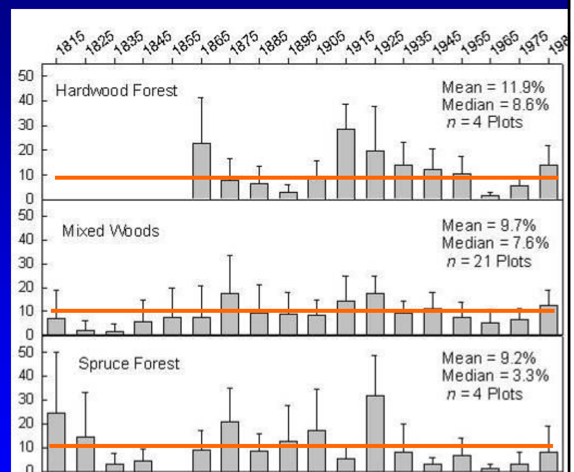
- Since ca.1990, significant studies in *disturbance ecology* have led to useful, quantitative working hypotheses for most common forest types
  - Disturbance rates
  - Patch sizes
  - Post-disturbance Legacies

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^2/ ac), focusing on larger trees of late-successional, long-lived species (arbitrary, hopeful)

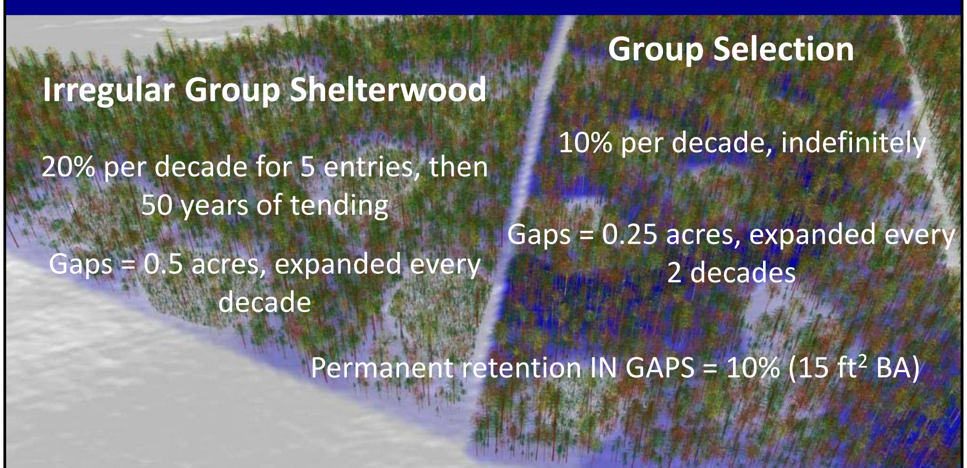
"What do we call this?"

- 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)

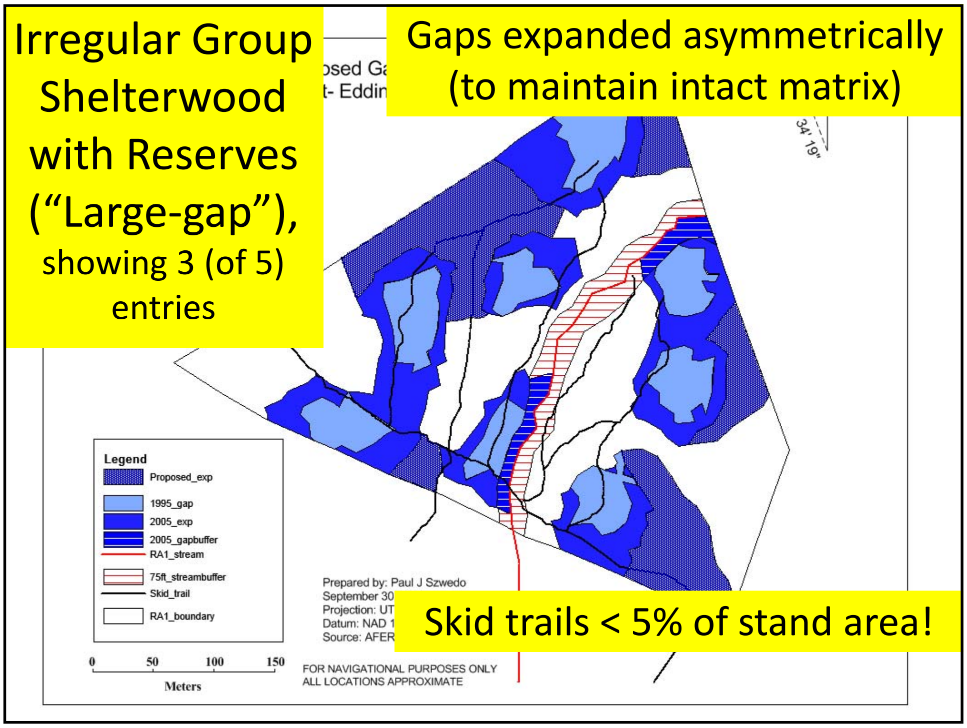
- Expanding gap system based entirely on *three ecological parameters* (not from established "cookbooks!"):
  - ✓ 1% annual disturbance frequency, over 100 years
  - ✓ Small, sub-stand regeneration patches (0.1 - 0.2 ha, expanded on 10 or 20-year cutting cycle)
  - ✓ 10% (arbitrary) permanent structural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

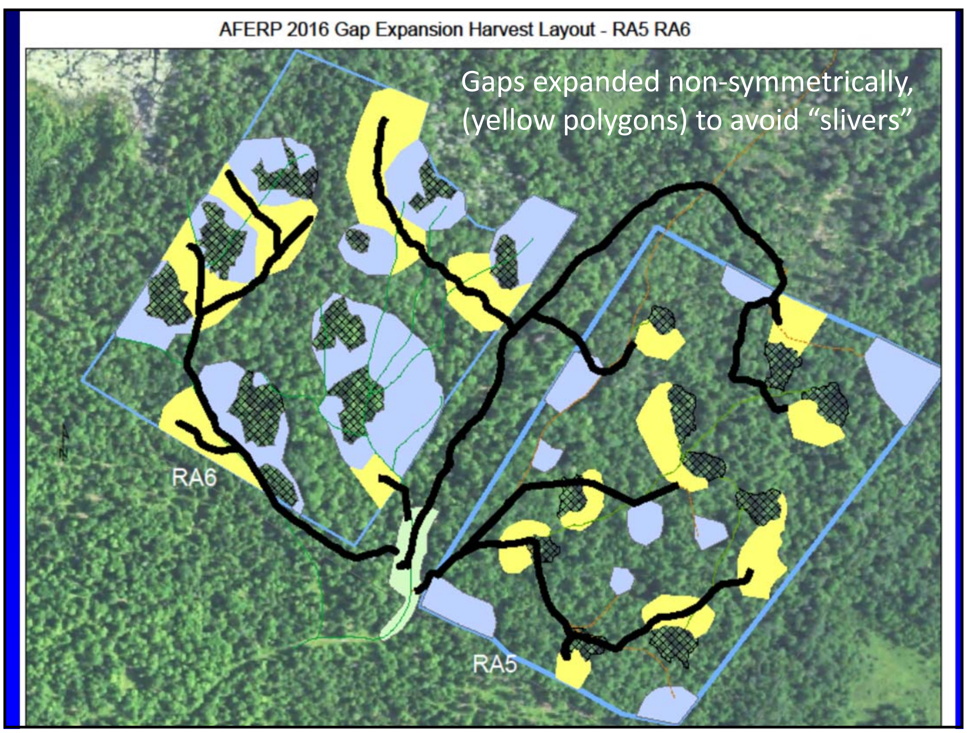
Small sub-stand patches (gaps) with retention



After second harvest (= first large-gap expansion)

EnVision USDA Forest Service Pacific Northwest Research Station BOTH: (531475.51, 4964389.38, 450.00)

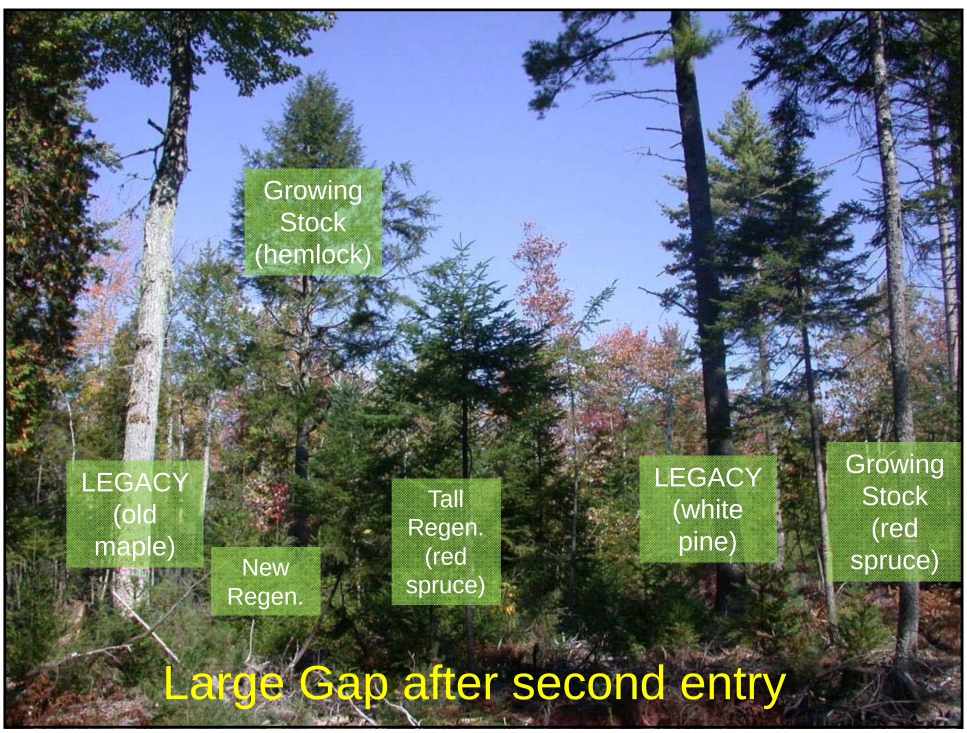

Irregular Group Shelterwood with Reserves ("Large-gap"), showing 3 (of 5) entries
Gaps expanded asymmetrically (to maintain intact matrix)
Skid trails < 5% of stand area!
Legend
Proposed_exp
1995_gap
2005_exp
2005_gapbuffer
RA1_stream
75ft_streambuffer
Skid_trail
RA1_boundary
Prepared by: Paul J Szwedo
0 50 100 150
Meters
FOR NAVIGATIONAL PURPOSES ONLY
ALL LOCATIONS APPROXIMATE


AFERP 2016 Gap Expansion Harvest Layout - RA5 RA6
Gaps expanded non-symmetrically, (yellow polygons) to avoid "slivers"
RA6
RA5

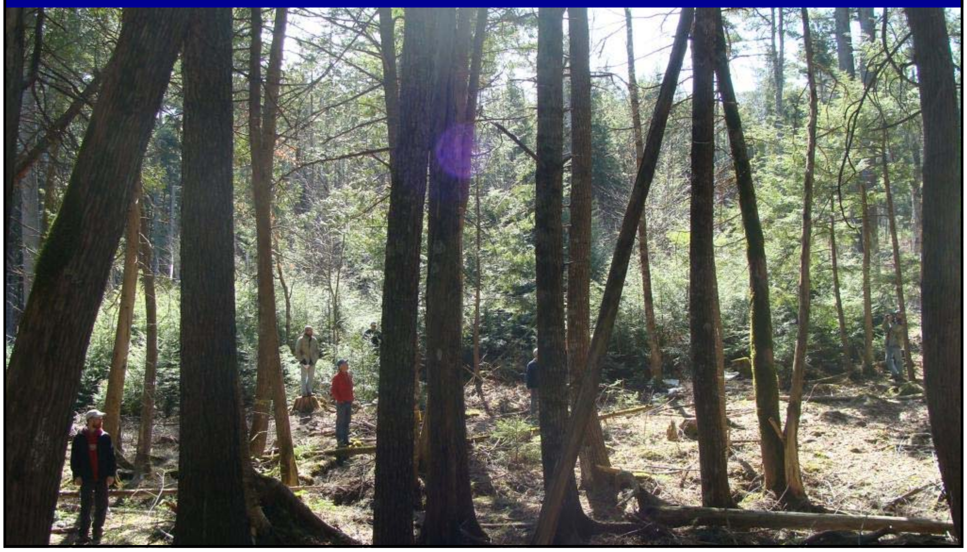
Irregular group shelterwood – AFERP Study

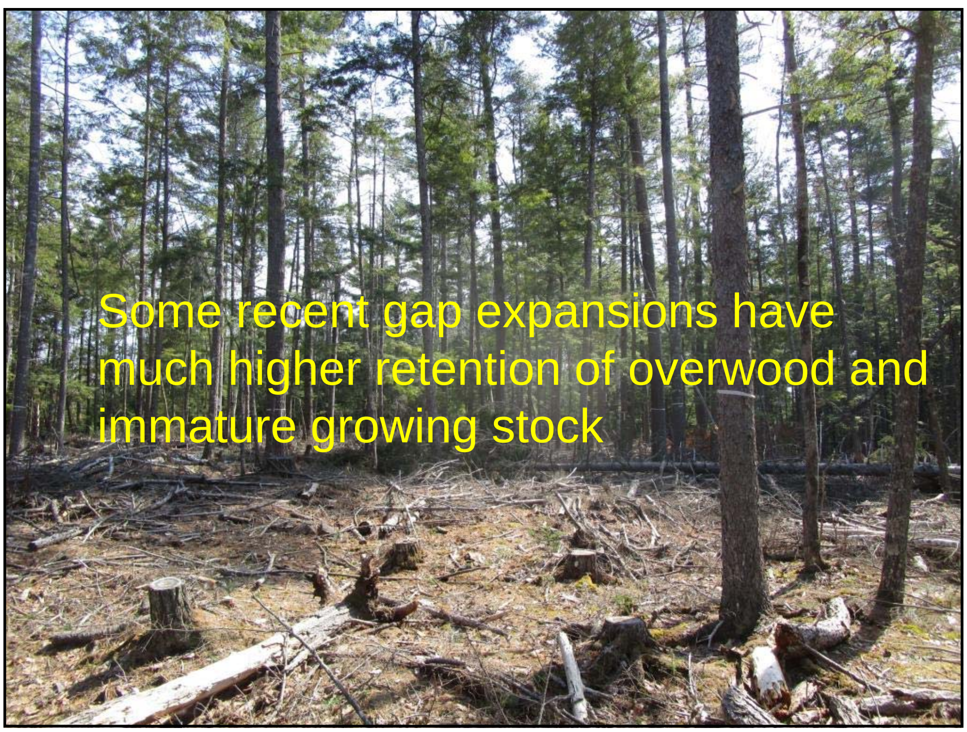
- *This could be continuous cover if entire stand were like this*

- 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)



Untreated Matrix, looking into 14-year-old gap and 4-year-old expansion





Advantages of Group-based Shelterwood Systems -- Ecological

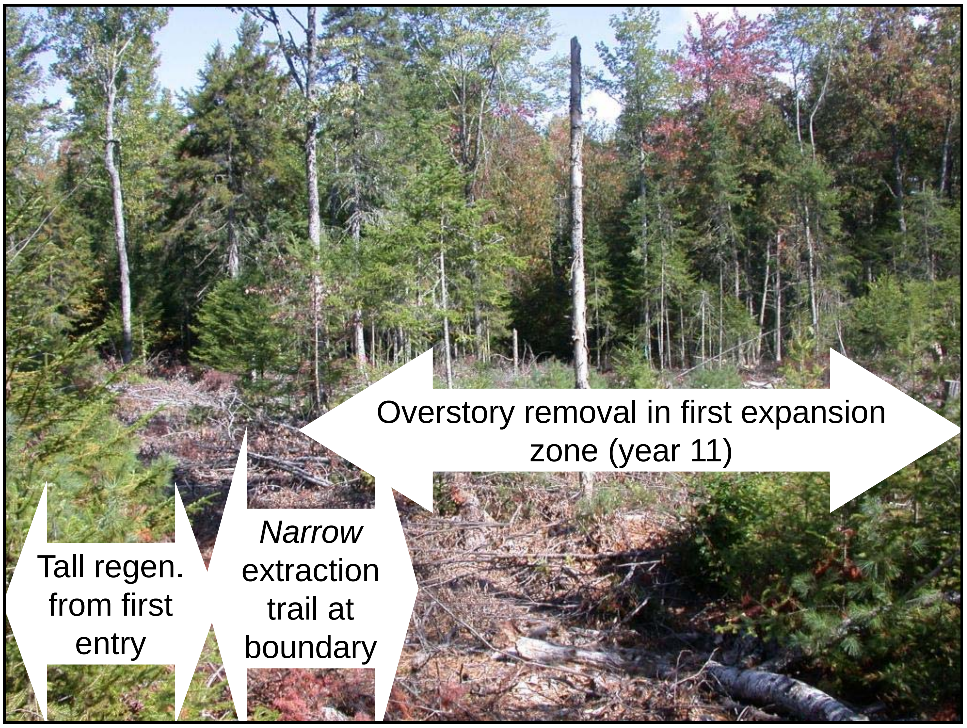
1. Manages regeneration deliberately, not by assumption (of future ingrowth)
   -- Gap size, overall regeneration rate
2. Ecological sustainability guaranteed (if cutting cycle is comparable to natural disturbance rates)
3. No need to assume a problematic linkage between age and size

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

Advantages of Group-based Shelterwood Systems -- Operational

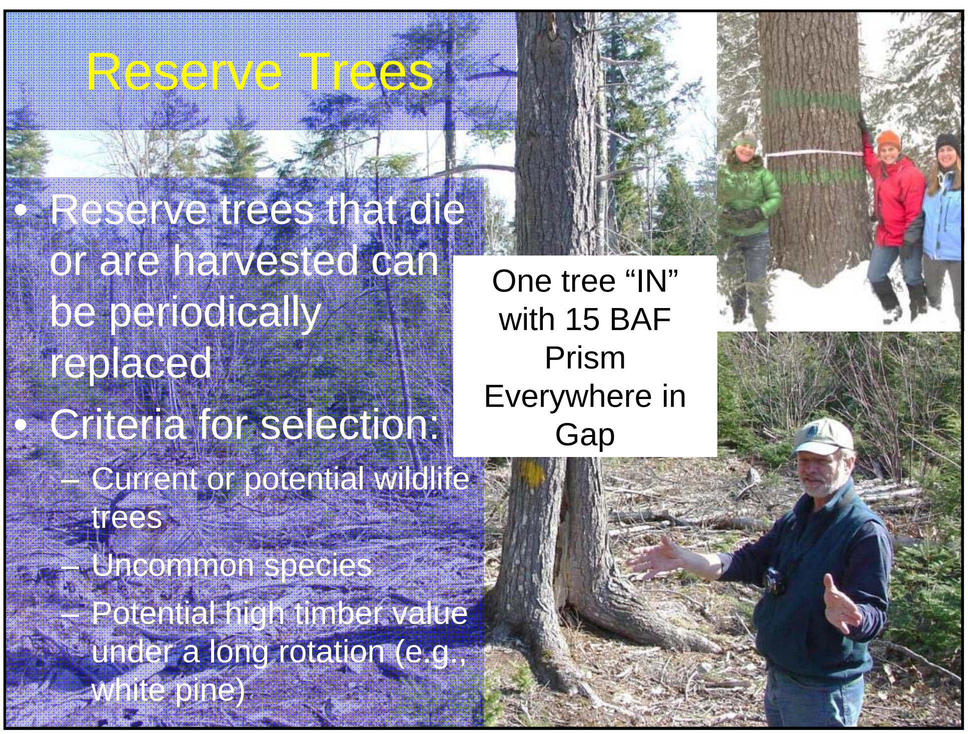
4. Pre-harvest layout, designation of reserve trees, logging, early tending are all concentrated on 10-30% of stand
   -- No need to work throughout entire stand (after first entry)
5. No need for pre-harvest dbh distribution information, or overall marking tally
6. Light harvests (<25%) are feasible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

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

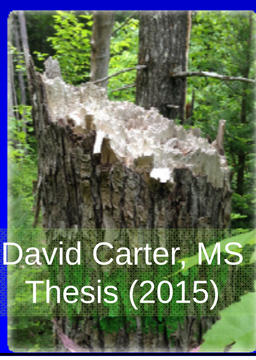


Regeneration somewhat predictable based on advance regeneration (fir, hemlock) and sprouting potential (red maple, aspen)


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!



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

"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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