Northeast Silviculture Institute – Acadian Spruce-fir Forests June 22, 2017 Orono, Maine

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Outline

- 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)

I. Silvics and Ecology of the "Acadian Forest"

- Northern New England USA
- Maritime provinces Canada (NB, NS, PEI)
- Signature species = red spruce (*Picea rubens*)

Red Spruce (*Picea rubens*)

"umbrella" red spruce (just released)

Old-growth red spruce (300+, Elephant Mtn)

Red Spruce (*Picea rubens*)

- Shade tolerance: very tolerant
- Longevity: 250-400+ years
- Persistence as advance regeneration: long (100+ yrs)
- Seeding, early establishment: infrequent, fragile
- Habitats: ubiquitous (except very wet) but not very responsive to gradients
- Pests: few, resistant

Balsam Fir (*Abies balsamea*)

- Shade tolerance: very tolerant
- Longevity: 70-150 (limited by pathological rotation)
- Persistence as advance regeneration: moderate (20-50 yrs)
- Seeding, early establishment: dependable (2-yrs), robust
- Habitats: fairly ubiquitous (except droughty sites), highly responsive to site gradients
- Pests: stem rots, spruce budworm, balsam woolly adelgid (latter is worsening rapidly)

Fir pathological rotation

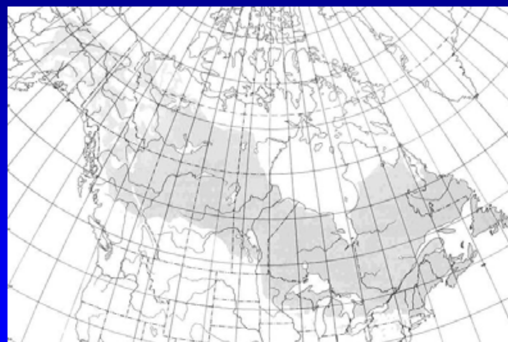
Budworm

Heart rot, windthrow

Black Spruce (*Picea mariana*)

- Shade tolerance: moderately tolerant
- Longevity: 150-250 years
- Persistence as advance regeneration: fairly long, as layered branches in open stands
- Seeding, early establishment: semi-serotinous, fire-dependent
- Habitats: organic soils (bogs)
- Pests: few, quite resistant

The natural range of black spruce



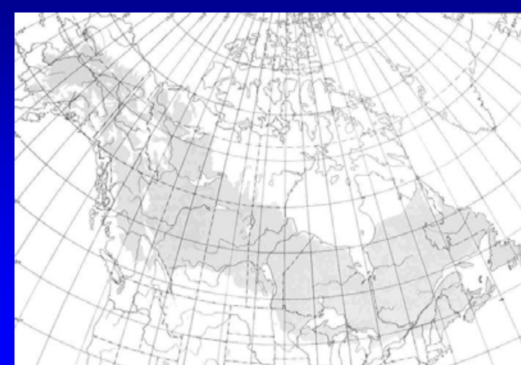
Natural stand

Planted black spruce

White Spruce (*Picea glauca*)

- Shade tolerance: tolerant
- Longevity: 100-250 years
- Persistence as advance regeneration: moderate (20-40 yrs)
- Seeding, early establishment: similar to fir
- Habitats: mesic, well-drained lowlands (associated with fir); abandoned fields
- Pests: budworm, other defoliators

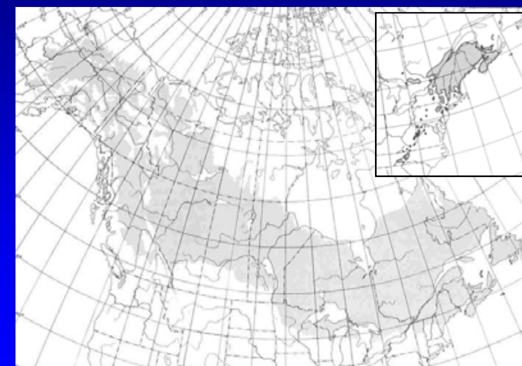
The natural range of white spruce



Old white spruce

White spruce stand in Black Hills, S.D.

Relative natural ranges: white vs. red



Fire-origin spruce stand

Miscellaneous comparisons

- Black and white spruces (boreal spruces):
  - more dependent on stand-replacing fire in boreal region, but not in Acadian
  - plantation species due more rapid juvenile growth than red spruce
    - White on fertile uplands
    - Black on wetter sites, low elevations
- Red spruce rarely planted, and only as an enrichment measure.

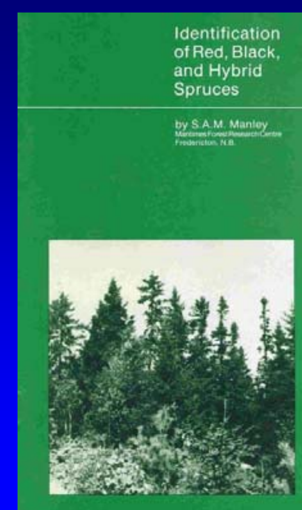
Black spruce plantation (age 12)

Miscellaneous comparisons

- All spruces and fir are notoriously NOT windfirm as individual, isolated trees.
  - Shallow rooting habits, poorly drained soils
- Creates important limitations on certain types of silvicultural treatments (e.g., heavy thinning) that work well for other forest types.

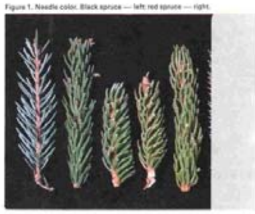
Shallow rooting

Spruce hybridization: red x black



Spruce hybridization: needles and twigs

Figure 1. Needle color. Black spruce — left; red spruce — right.



Needle Color (Figure 1) — The extent of the cuticular wax covering on needles of a 2-year-old twig contributes to the ultimate expression of this characteristic. The needles should be examined collectively at reading distance rather than individually.

Rating

0. Needles are covered on both sides with a glaucous bloom that produces an overall grayish-green appearance.
1. Needles are dull green on the upper sides, without a glaucous appearance (dull yellow-green under poor site conditions). The underside is still covered with a pronounced bloom.
2. Needles are shiny dark green (or yellow-green under poor conditions) with a glaucous bloom on the undersides.
3. Needles are shiny dark green, without any glaucous covering.
4. Needles are shiny yellow-green, without any glaucous covering.

Figure 2. Needle configuration. Black spruce — far left; red spruce — far right.

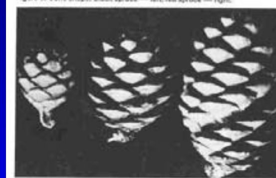
Needle Configuration (Figure 2) — A 2-year-old twig from trees 10 years old and older should be examined. Needles on developing shoots may be compressed and should be avoided.

Rating

0. Needles project radially from the pulvini (peglike projections on the twig surface bearing the needles). Individual needles are straight and often blunt.
1. Needles on the underside of the twig are curved toward its upper portion.
2. Needles on three sides of the twig are curved toward the upper side.
3. Needles on three sides appear compressed against the twig surface and curved upwards. The needles along the upper side are curved backward. Individual needles taper gradually to a sharp, pointed apex.

Spruce hybridization: cones, crowns

Figure 6. Cone shape. Black spruce — left; red spruce — right.



Cone Shape (Figure 6) — Cones should be mature and open.

Rating

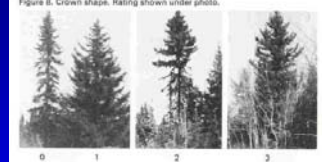
0. Cones are stubby and ovoid, and gradually taper to a long, incurved stalk.
1. Cones may be ovoid or ovoid-oblong but taper abruptly to a long, curved stalk.
2. Cones are ovoid-oblong and taper abruptly to a short, stublike stalk.

Cone Persistence

Rating

0. Cones are retained for more than 5 years.
1. Cones are retained up to 5 years.
2. Cones are retained up to 1 year and are usually deciduous by spring after maturity.

Figure 8. Crown shape. Rating shown under photo.



Crown Shape (Figure 8) — For mature, open-grown trees.

Rating

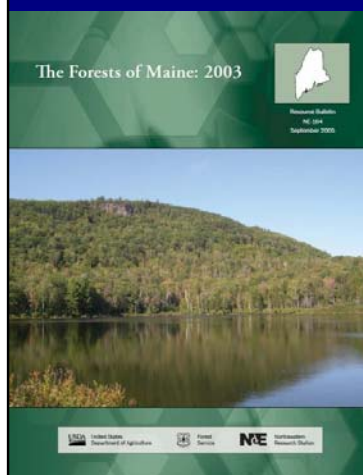
0. Crown is either tufted at the top or very fine-textured, narrow, and cylindrical. Branches extend less than 3 feet horizontally from the trunk and droop. Largest branches are generally less than 2 inches in diameter.
1. Crown is fine-textured, regular and broadly cylindrical in outline. Branches are less than 2 inches in diameter and extend more than 3 feet horizontally from the trunk but still droop.
2. Crown is irregular in outline. Branches are thick and stout (greater than 2 inches) and extend less than 8 feet horizontally from the trunk.
3. Crown is regular in outline, with stout branches (greater than 2 inches) extending 10 to 15 feet horizontally from the trunk and turning upwards at the tip. Branch angle with the trunk approaches 90 degrees.

Spruce hybridization: rating process

Characteristic	Maximum score	Tree number											
		1	2	3	4	5	6	7	8	9	10	11	12
Needle color	4	0	1	2	1	1	1	1	1	2	2	1	2
Needle configuration	3	1	2	2	1	2	1	1	1	1	2	1	2
Twig ridges	2	0	1	1	1	0	1	1	1	1	2	1	2
Twig-bark color	2	0	1	1	0	0	1	1	0	1	1	1	2
Vegetative-bud color	2	0	2	2	–	–	–	–	–	–	1	0	2
Twig-hair type	2	0	1	1	1	1	0	1	1	2	–	–	2
Cone shape	2	0	1	1	0	1	0	1	–	2	–	–	2
Cone persistence	2	0	1	1	1	1	0	1	–	1	–	–	1
Cone flexibility	4	0	2	2	0	0	0	2	–	2	–	–	4
Cone-scale edges	2	0	1	2	1	0	1	1	–	1	–	–	2
Crown shape	3	0	2	2	1	1	1	1	–	2	3	1	3
Total actual score		1	15	17	7	7	6	11	4	15	11	5	24
Maximum possible score		28	28	28	26	26	26	26	13	26	16	16	28
Hybrid index		.03	.54	.60	.27	.27	.23	.42	.31	.58	.69	.31	.86
Population index value							.43						

The population index value represents an overall average of the hybrid indices of sample trees and is valid only when representative of the composition of the population from which it was taken. For instance, equal proportions of red and black spruces in the sample would be described by a population index value of 0.50, whereas the sample actually represents a mixture of the two pure species, not a hybrid (intermediate) population. Association of the two pure species in populations in which hybridization has not occurred is not a common occurrence.

Maine Area by Forest Type (million acres, 2012)



Forest type group	Total
Total	17,008,761.904
White / red / jack pine group	1,049,042.612
Spruce / fir group	5,678,259.653
Loblolly / shortleaf pine group	5,452.591
Exotic softwoods group	33,547.031
Oak / pine group	345,302.906
Oak / hickory group	315,905.001
Elm / ash / cottonwood group	337,412.738
Maple / beech / birch group	7,065,188.264
Aspen / birch group	2,014,690.240
Other hardwoods group	123,603.552
Nonstocked	40,357.317

Sub-types of the Spruce-fir Group (thousand acres, 2012 FIA)

Balsam fir	2,107,980.797
White spruce	189,945.761
Red spruce	845,687.812
Red spruce / balsam fir	1,014,608.208
Black spruce	440,414.749
Tamarack	94,762.144
Northern white-cedar	984,860.182

Closely associated species: conifers

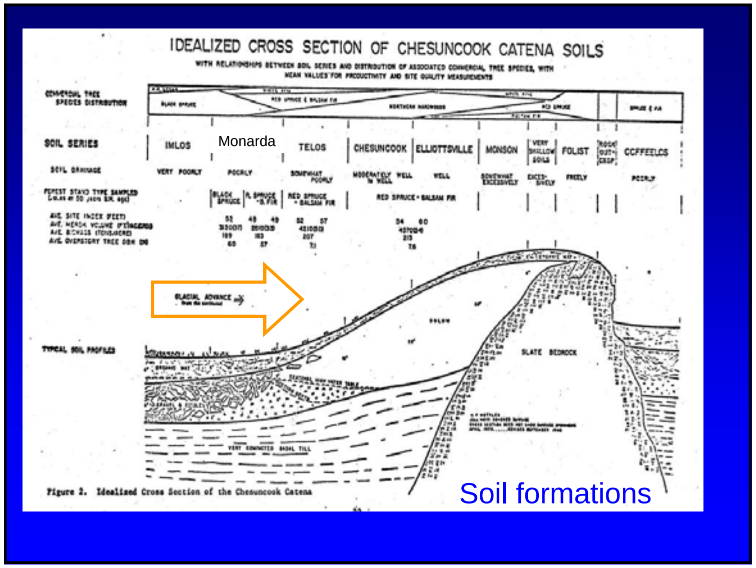
- White pine (*Pinus strobus*)
- Northern white-cedar (*Thuja occidentalis*)
- Eastern hemlock (*Tsuga canadensis*)
- Eastern larch (tamarack, "juniper"; *Larix laricina*)
- Red ("Norway") pine (*Pinus resinosa*)
- Norway spruce (*Picea abies*) – planted exotic

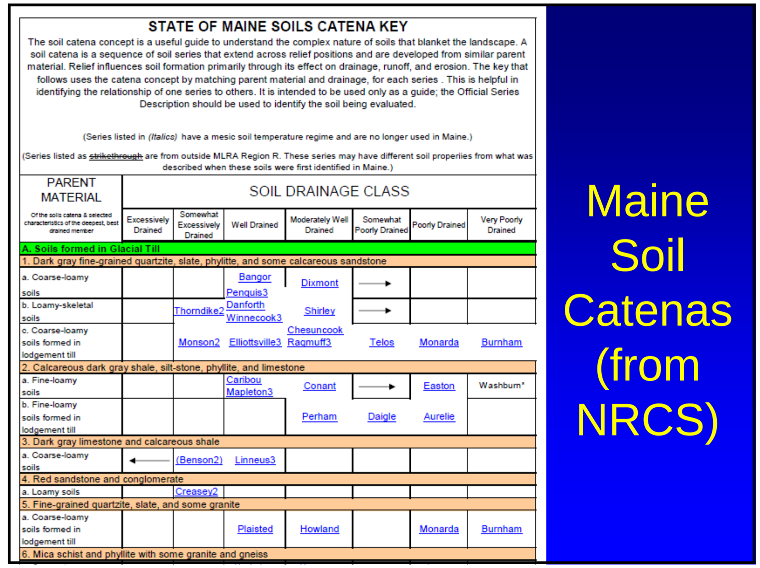
Closely associated species: hardwoods

- Red maple (*Acer rubrum*)
- Yellow birch (*Betula alleghaniensis*)
- Sugar maple (*Acer saccharum*)
- American beech (*Fagus grandifolia*)
- Paper birch (*Betula papyrifera*)
- Quaking and bigtooth aspen (*Populus spp.*)

Habitat Associations

- Northern Maine – Influence of glaciation
- Maine Soil Catenas
- Coastal Maine





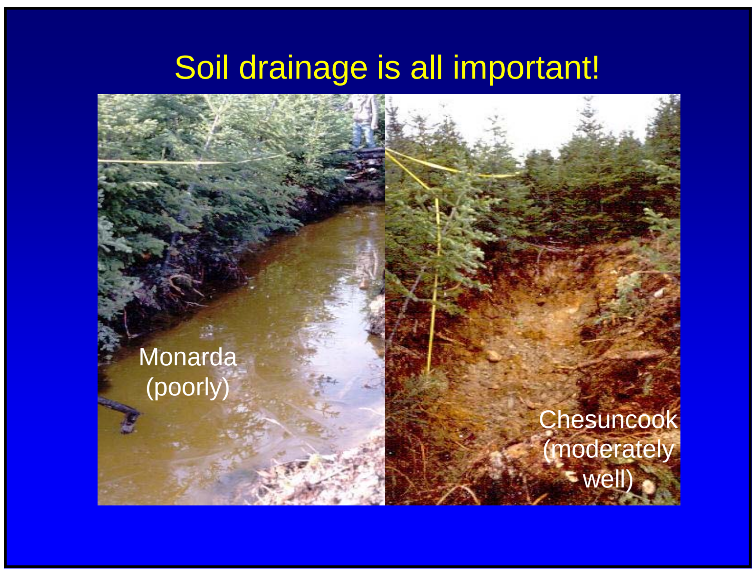
STATE OF MAINE SOILS CATENA KEY

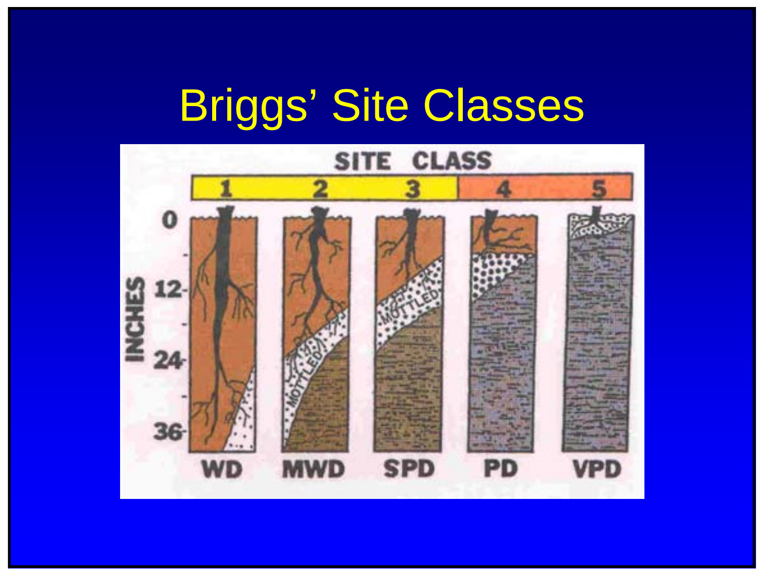
The soil catena concept is a useful guide to understand the complex nature of soils that blanket the landscape. A soil catena is a sequence of soil series that extend across relief positions and are developed from similar parent material. Relief influences soil formation primarily through its effect on drainage, runoff, and erosion. The key that follows uses the catena concept by matching parent material and drainage, for each series . This is helpful in identifying the relationship of one series to others. It is intended to be used only as a guide; the Official Series Description should be used to identify the soil being evaluated.

(Series listed in *(Italics)* have a mesic soil temperature regime and are no longer used in Maine.)

(Series listed as ~~strikethrough~~ are from outside MLRA Region R. These series may have different soil properiies from what was described when these soils were first identified in Maine.)

PARENT MATERIAL Of the soils catena & selected characteristics of the deepest, best drained member	SOIL DRAINAGE CLASS						
	Excessively Drained	Somewhat Excessively Drained	Well Drained	Moderately Well Drained	Somewhat Poorly Drained	Poorly Drained	Very Poorly Drained
A. Soils formed in Glacial Till							
1. Dark gray fine-grained quartzite, slate, phylitte, and some calcareous sandstone							
a. Coarse-loamy soils			Bangor Penquis3	Dixmont	→		
b. Loamy-skeletal soils		Thorndike2	Danforth Winnecook3	Shirley	→		
c. Coarse-loamy soils formed in lodgement till		Monson2	Elliottsville3	Chesuncook Ragmuff3	Telos	Monarda	Burnham
2. Calcareous dark gray shale, silt-stone, phyllite, and limestone							
a. Fine-loamy soils			Caribou Mapleton3	Conant	→	Easton	Washburn*
b. Fine-loamy soils formed in lodgement till				Perham	Daigle	Aurelie	
3. Dark gray limestone and calcareous shale							
a. Coarse-loamy soils	←	(Benson2)	Linneus3				
4. Red sandstone and conglomerate							
a. Loamy soils		Creasey2					
5. Fine-grained quartzite, slate, and some granite							
a. Coarse-loamy soils formed in lodgement till			Plaisted	Howland		Monarda	Burnham
6. Mica schist and phyllite with some granite and gneiss							





Landscape patterns

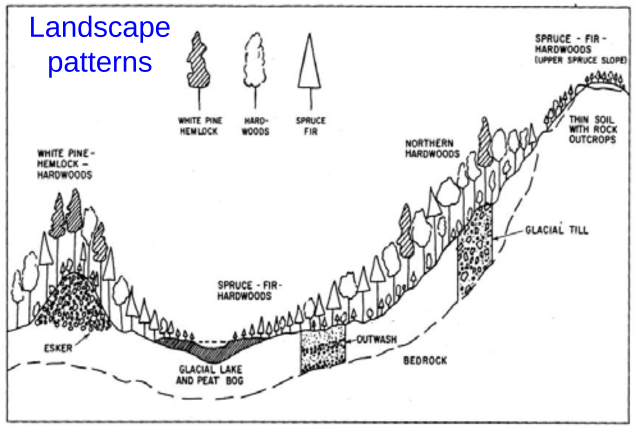


Figure 2-5. A diagrammatic transect of mountain terrain in the Northeast, with associated type groups.

Forest Types (after Westveld 1931, 1953)

- Dominant Softwood
  - Spruce swamp
  - Spruce flat
  - Spruce slope
- Secondary Softwood
  - Yellow birch-spruce (SH)
  - Sugar maple-spruce (HS)
  - Old-field spruce

Spruce “flat”

Pure fir

Mixed spruce-fir

Spruce “flat” (continued)

Paper birch

SH mixedwoods

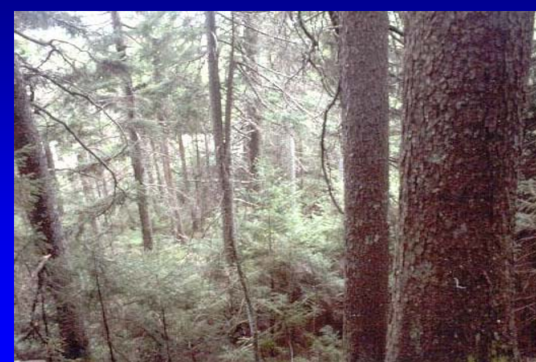
Red maple (hardwoods in background)

Yellow birch

Northern Hardwood-Spruce (HS mixedwood)

Northern Hardwood-Hemlock-Spruce (HS mixedwood)

Spruce slope



High-elevation spruce-fir

Coastal spruce forests (Davis 1966)

Less fir

Shallow, granitic soils

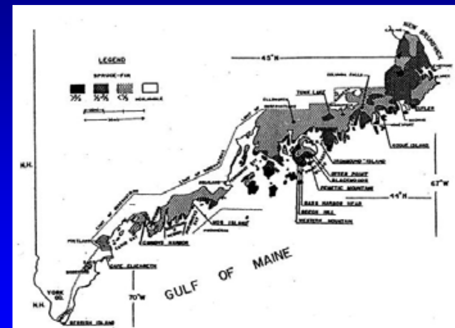


Fig. 2. Map of Maine coastal region, including locations referred to in the text. Study areas are underlined. Percentages of spruce and fir in the forests are discussed in text section entitled "Survey of Spruce-Fir Distribution."

Old-field spruce (red and white)

Soils naturally supported HS stands

Natural forest dynamics

II. Disturbance History – Natural vs. Humans

- Disturbance agents
- Historical development of the resource
- Hypothetical chronosequence
- Evidence of changes in forest composition and structure

Importance

- Has the spruce-fir forest changed since presettlement?
- What is the appropriate disturbance model?
- Have disturbance regimes changed?

My working hypothesis (ca. 1976)

- All stands were essentially even-aged
- Most originated after the spruce budworm outbreak of 1919
- Even-aged structures are thus "natural" and constitute an appropriate model for silviculture.
- (I no longer believe any of this..stay tuned.)

Disturbance Intensity

- *Stand-replacing* ("lethal") – most or all the overstory is killed
- *Partial* (incomplete) – only some of the overstory is killed; sufficient trees survive to prevent establishment of new cohorts in portions of the stand.

Stand-replacing disturbances

- *Complete* – all vegetation killed
- *Releasing* – only the overstory killed

wildfire

spruce budworm
(pure fir stands)

Partial disturbances
(gap dynamics)

windthrow

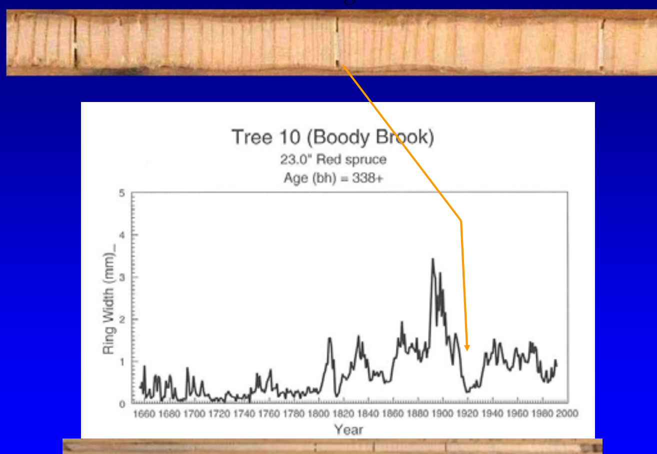
spruce budworm

Spruce budworm

Spruce budworm
(Choristoneura fumiferana)

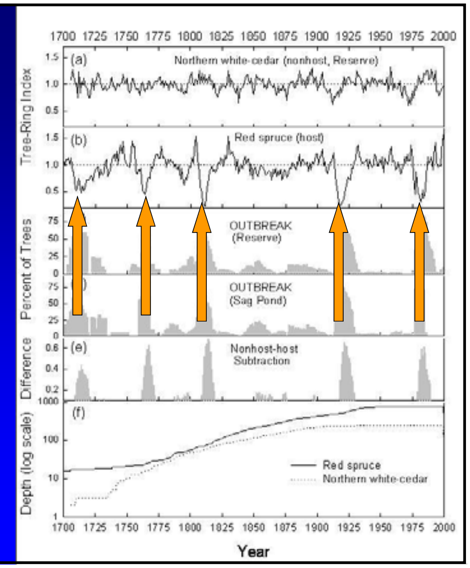
- Native insect
- Primary host = fir; also feeds on spruces
- Well documented outbreaks 1913-19 and 1972-84 (others by inference from tree rings)
- Partial or stand-replacing, depending on forest composition

Budworm "signature"



From Fraver, Seymour, Speer, and White (CJFR, 2007)

Two older outbreaks documented: 1708, 1760 !



Windstorms

Downburst in Telos area, 1981

Windstorms

- Usually a partial, releasing disturbance
- Rarely stand-replacing
- 1938 hurricane in W. Maine
- 1869 Saxby gale
- 1795 (?) Path over northern Maine

Wildfire (Very rare)

Post-fire succession

Spruce bark beetle

Spruce bark beetle

Dendroctonus rufipennis (formerly *D. piceaperda*)

- Pest of old-growth, thick-barked red and white spruces
- Studied by Hopkins in late 1800s
- Outbreaks in 1880s, coincident with peak of spruce sawlog cutting
- Recent problems in coastal Maine
- Now difficult to find in northern Maine
- Mostly partial; rarely stand-replacing

Beech bark disease

- Introduced disease complex of scale insect and *Nectria* fungus
- Chronic
- Partial, except in pure beech

Birch dieback – 1940s

- Killed 70% of birch (both yellow and paper) in Maine by early 1950s
- Cause never conclusively demonstrated
- Trees began to recover in 1950s
- Generally a partial or releasing agent.

Birch dieback – 1940s

(signature growth increase of spruce from increment cores, Reams and Huso CJFR paper)

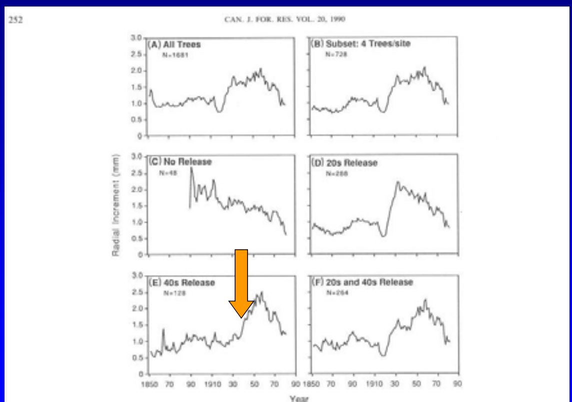
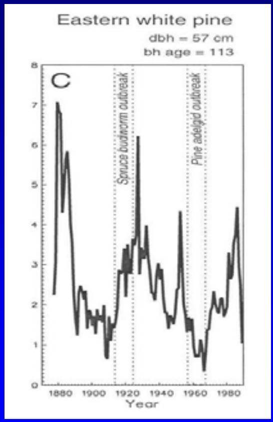


FIG. 2. Average chronologies. (A) Data are from all trees in the northern Maine data set from Hornbeck and Smith (1985). (B–F) Data are from trees in the subset of data used in this study (4 trees/site). 20s and 40s refer to the 1920s and 1940s, respectively.

Pine leaf adelgid

(Adelges pinifolea)

- Outbreak in downeast Maine during late 1950s
- Damages only white pine
- Alternate host is red spruce



Pine leaf adelgid (T6 R10, Baxter SFMA, Sept. 2012)
Photo by Allison Kanoti, MFS Entomologist

Hemlock looper

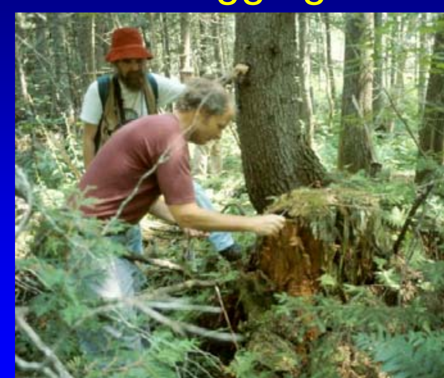
(Lambdina fiscellaria)

- Defoliator of hemlock and fir
- Outbreak ca. 1990
- Very abrupt onset and decline
- Earlier history not well known

Balsam woolly adelgid (aphid)

(Adelges piceae)

Logging



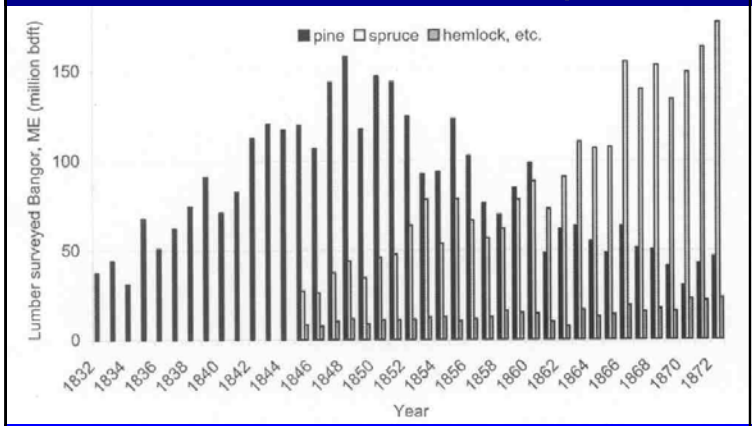
Historical Exploitation – 6 Periods

- Sawlog era (mid-late 1800s)
- Establishment of paper industry ca 1890s
- Spruce budworm aftermath (1925-1940)
- Maturation of second-growth forests (1950-1980)
- Harvest and regeneration of second-growth forests (1970-ongoing)
- The "New Forest" – third-growth stands with no precedent? (1980s-present)

Sawlog Era (mid 1800s)

- Repeated diameter-limit cuttings, each to smaller and smaller sizes
- First pine, then spruce and cedar
- Fir, hardwoods not merchantable
- Seasonal (winter) harvesting
- Came and went fairly quickly
- Regarded as fairly benign by Cary and Westveld

Penobscot Watershed (From J. Wilson, 2005, JF)



Pine Logging History T8R10, Pingree

Pine Logs, T8R10

Year	No.	Ft. (bf)	$/Mbf
1865-6	92	40160	3.00
1865-6 trespass	20	10360	4.00
1865-6 "down"	8	2240	2.00
1866-7	177	46340	3.50
1872-3	2210	388884	5.00
1872-3 "Dry"	33	3620	? "do"
1885-6	40	9040	4.00
1886-7	461	62100	4.00
1886-7 Public Lot	2	380	4.00
1887-8	28	4440	4.00
1889-90	3058	675570	4.00
1890-1 Chandler Brook	764	182680	4.00
1890-1 Chase & Munsungan Lakes	25	14090	4.00
1891-2	699	97430	4.00
1891-2 "Left on yards"	33	5280	-
1892-3	993	112680	4.00

437 BF per log (24" dib)

113 BF per log (13" dib)

Spruce Logging History T8R10, Pingree

Spruce Logs, T8R10

Year	No.	Ft. (bf)	$/Mbf
1872-3	43	9423	1.50
1885-6	422	53990	2.00
1886-7	9772	1255360	2.00
1886-7 Public Lot	63	8630	2.00
1887-8	830	91980	2.00
1889-90	9680	1282340	2.00
1890-1 Chandler Brook	7153	945550	2.00
1890-1 Chase & Munsungan Lakes	1207	171060	2.00
1891-2	9694	1054540	2.00
1891-2 "Left on yards"	650	75290	-
1892-3	14055	1427860	2.00

219 BF per log (17.5” dib)

101 BF per log (12” dib)

Pulp and Paper Industry Begins (ca. 1890s)

- Re-entries into previously cutover stands, now for trees down to 6” dbh.
- Much heavier cuttings; removals more or less complete for spruce
- Quotes from Cary (1896): “… *hardest cutting ever seen by this writer*…”

Post-budworm (1925-1940s)

- Growing stock much depleted
- Bark beetle, wind damage in surviving stands
- Harvesting operations cut very low volumes per acre, scattered stands
- Mountains and islands logged
- Great Depression “saved” the industry from a true wood shortage

Maturation of second-growth forests

- Unprecedented high growth rates
- Tremendous ingrowth of trees into merchantable size

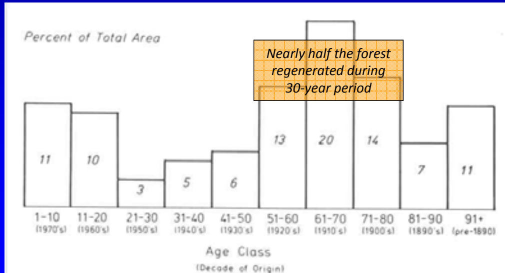


Figure 6. Age structure of Maine's spruce-fir forest, 1980.

Harvest and regeneration of second-growth forests

- Strong emphasis on even-aged silvicultural systems, in Maine and especially in the Maritimes
- Consistent with the national doctrine at the time
- Coincided with, and driven by, modern SBW outbreak ca. 1972-84 (in Maine)
- Regeneration response was very different from original exploitation…stands in stem exclusion, not old-growth

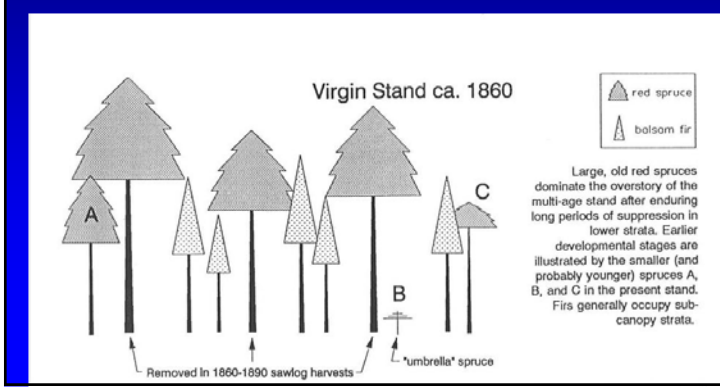
The "New Forest"

- Term coined in the early 1980s
- Applicable to third-generation stands originating after harvesting of the second-growth.

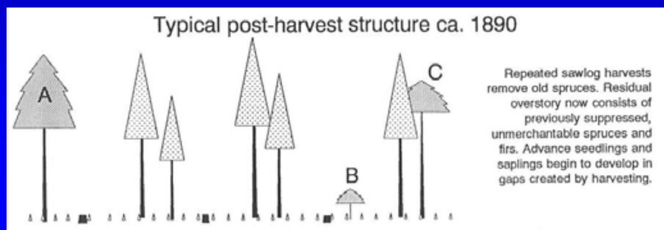
Effects on Forest Structure

- Reconstructed, hypothetical chronosequence
- Applies to spruce flats and lower slopes
- Mixedwood would be more complex

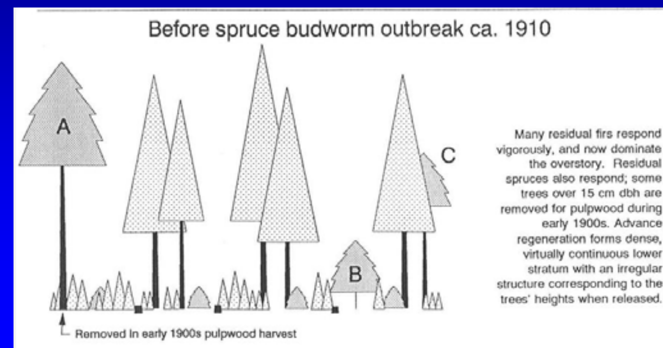
1860



1890

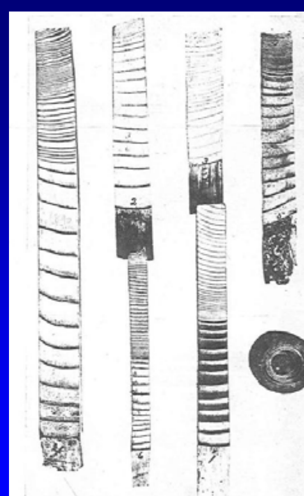


1910



Fir release?

- Evidence from Hopkins (1901) monograph



SECTIONS OF WOOD CUT FROM BALSAM FIR, SHOWING RAPID GROWTH AFTER THE OLD SPRUCES DIE OR ARE FELLED.

Fir release?

- Seymour (1980) dissertation, T4R10 WELS (now in BSP)

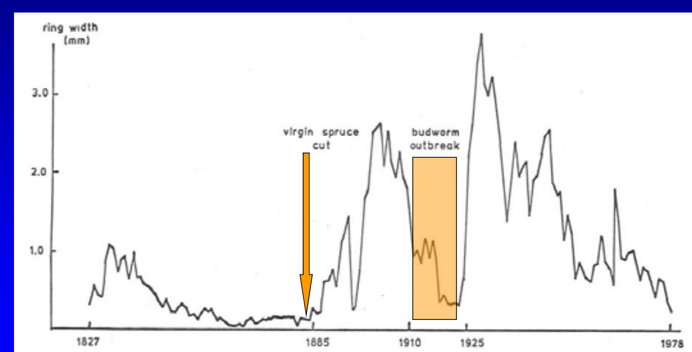
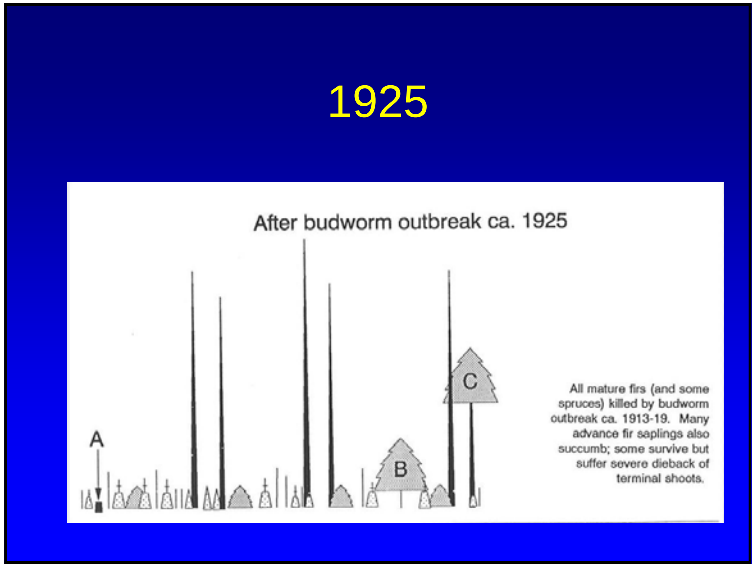
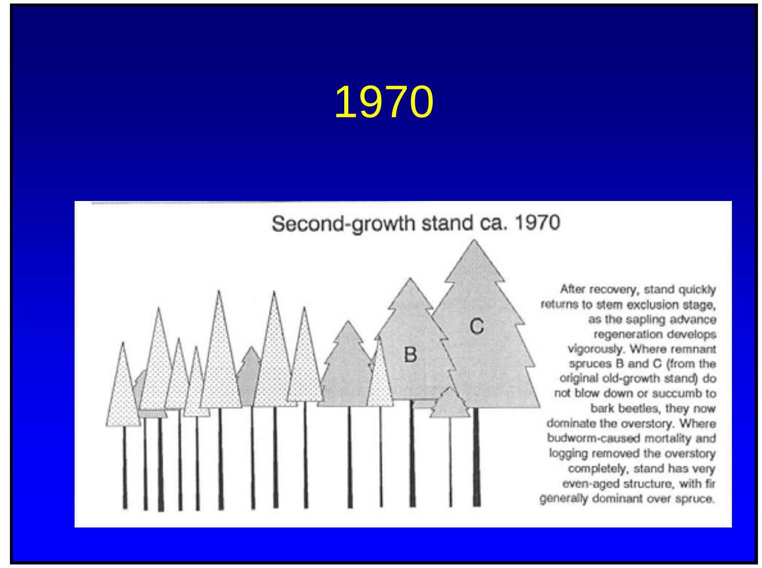
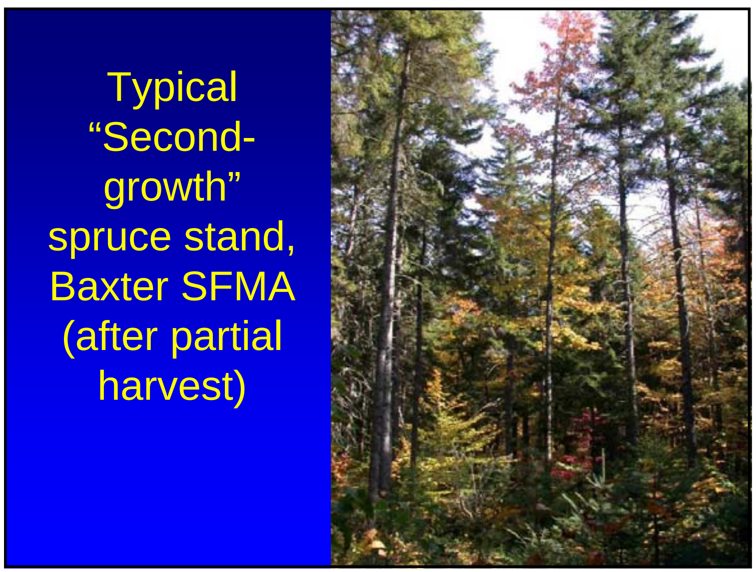
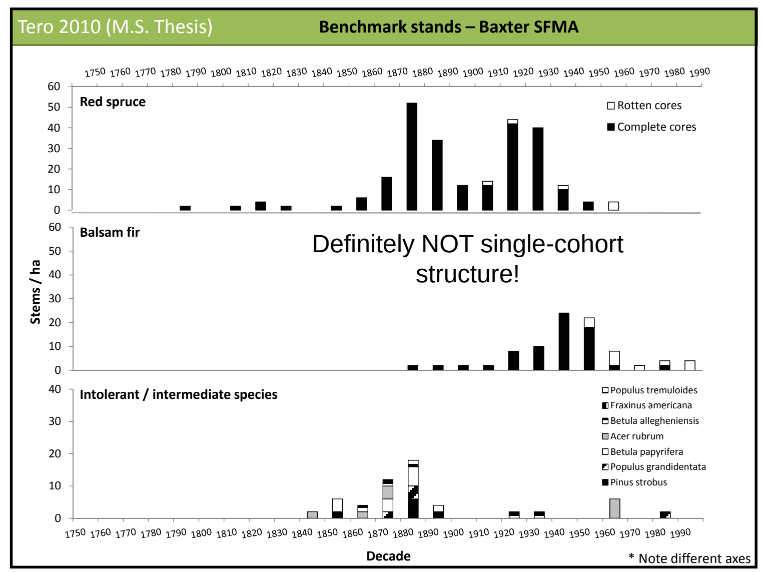


Figure 8. Growth of 150-year-old balsam fir between 1827 and 1978. Note severe suppression in old-growth stand, release after 1880's logging, reduction during the 1913-19 budworm outbreak, and response in the early 1920's after overstory mortality.


1925
After budworm outbreak ca. 1925
A
B
C
All mature firs (and some spruces) killed by budworm outbreak ca. 1913-19. Many advance fir saplings also succumb; some survive but suffer severe dieback of terminal shoots.


1970
Second-growth stand ca. 1970
B
C
After recovery, stand quickly returns to stem exclusion stage, as the sapling advance regeneration develops vigorously. Where remnant spruces B and C (from the original old-growth stand) do not blow down or succumb to bark beetles, they now dominate the overstory. Where budworm-caused mortality and logging removed the overstory completely, stand has very even-aged structure, with fir generally dominant over spruce.


Typical "Second-growth" spruce stand, Baxter SFMA (after partial harvest)


Tero 2010 (M.S. Thesis)
Benchmark stands – Baxter SFMA
Red spruce
Rotten cores
Complete cores
Balsam fir
Definitely NOT single-cohort structure!
Intolerant / intermediate species
Populus tremuloides
Fraxinus americana
Betula allegheniensis
Acer rubrum
Betula papyrifera
Populus grandidentata
Pinus strobus
Stems / ha
Decade
* Note different axes

1860

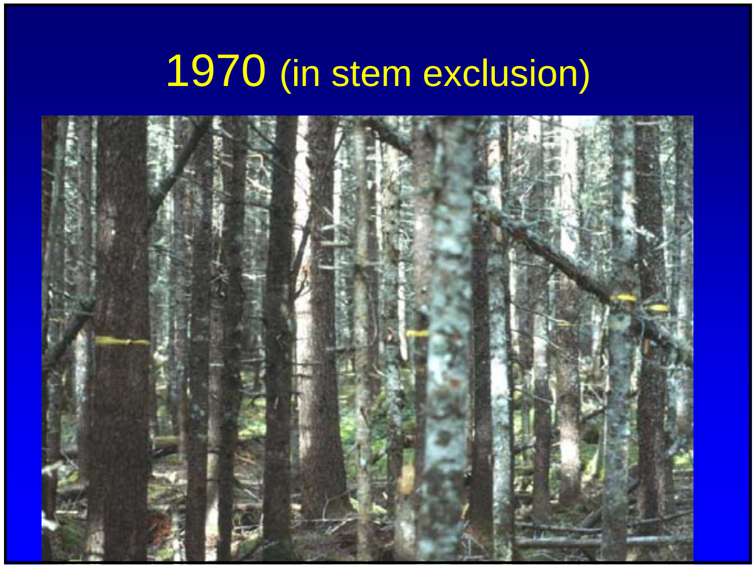
1910 (?)

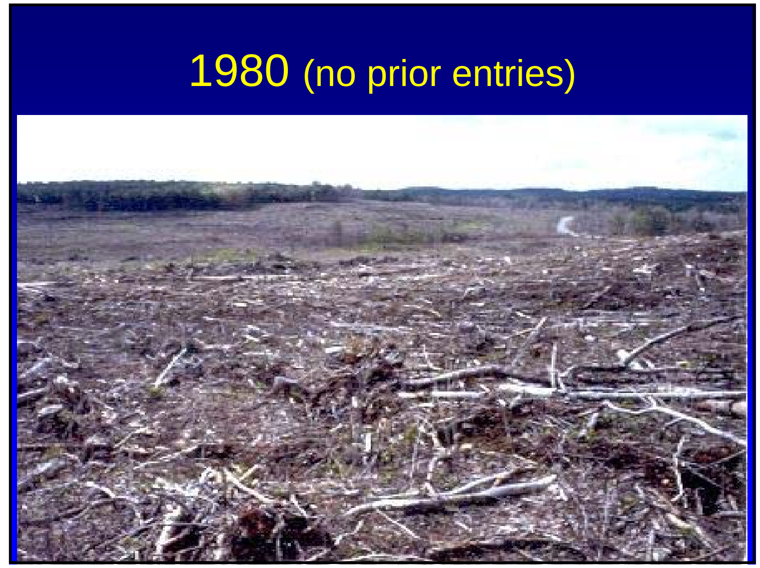
- But, there's something wrong with this picture…

1910 (?)

- 200-year old fir is missing!

1925?


1970 (in stem exclusion)


1980 (no prior entries)


1990 (managed regeneration, high fir)


2020 (ready for commercial
thinning and the next SBW outbreak!)

1860 (150 years before)

Spruce slope 1860

Spruce slope 1900 (Hosmer)

SPRUCE ON SPRUCE SLOPE
A dense stand of spruce, suitable for pulp. Subject to wind throw unless clean cut.

Spruce slope 1920 (Westveld)

FIGURE 2.—A virgin stand of spruce in spruce-slope type. Note the abundance o
young spruce and fir growing beneath the mature stand

Clearcut spruce slope (Westveld 1931)

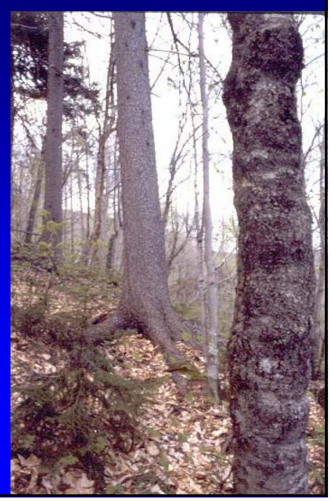
B, A recently cut-over area in spruce-slope type. With the exception of skid trails and haul roads prac tically the entire area is covered with slash. On steep slopes slash is a distinct aid in preventin excessive erosion

Former spruce slope - 1990

- Dominated by intolerant paper birch
- Spruce and fir in lower strata

Spruce-HW type 1860

- Scattered, very large red spruces
- Beech and sugar maple



Spruce-HW type (Westveld 1928)

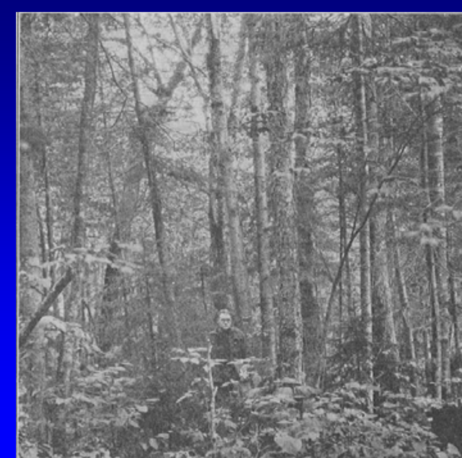
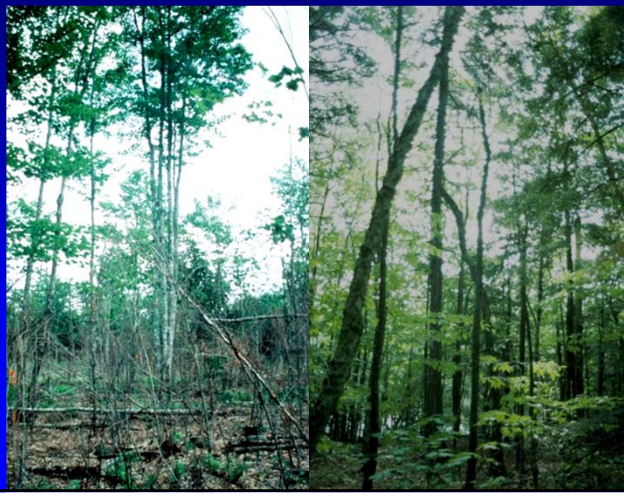


FIGURE 3.—A virgin stand of the spruce-hardwoods type, where spruce and fir commonly grow in mixture with beech, birch, and maple

Repeatedly high-graded H-S stands 1990



1970

1985 (no harvest)

- Gradual restoration of 2-aged, then multi-aged structure
- Many centuries until next stand replacement

Ecology of Northeastern Forests: *Gap Dynamics* rule

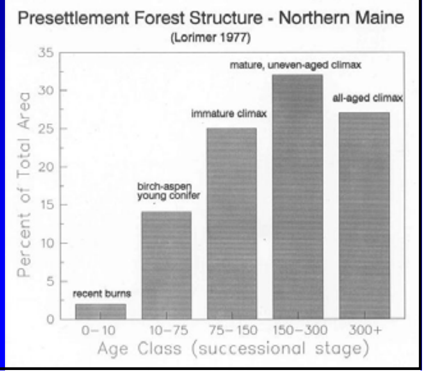
- Natural disturbance regimes dominated by partial disturbances (some minor exceptions), long-lived shade-tolerant species
- Stand-replacing disturbances were rare

Lorimer – inferred forest structure

- Stand replacements did occur, but were rare
- Most forest was multi-aged

Recurrence Interval of Natural Disturbances (Lorimer 1977)

	Disturbance Interval
Windthrow	1,150
Fire (all)	806
Fire (excl. 1803)	1,923
Insect	



Estimated return intervals (years) of stand-replacing disturbances in the northeastern US (Lorimer and White 2003)

Disturbance Agent	Northern Hardwoods	Spruce-Hardwoods	Spruce-dominated Flats	Fir-dominated Conifers
Fire	1000-3000	385-1200	800	-
Wind	1000-2500	575-1000	285	-
Spruce Budworm	NSR	NSR	NSR	80-100+
Combined	500-1364	230-545	210	?

Stand age structures, disturbance history of old-growth red spruce (Big Reed Preserve, Fraver and White 2005)

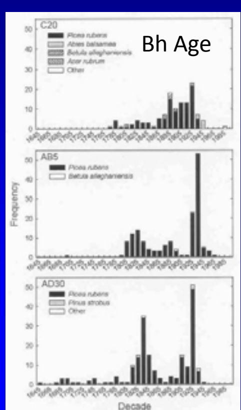
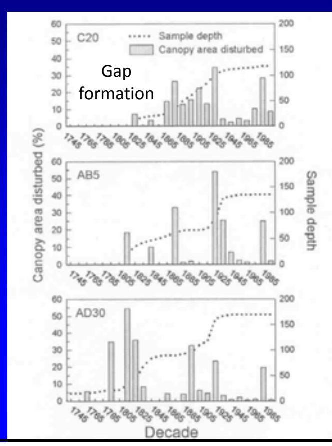


Fig. 2. Recruitment age-class distributions for three old-growth Picea rubens stands.



Pulsed gap formation, 1920-2000

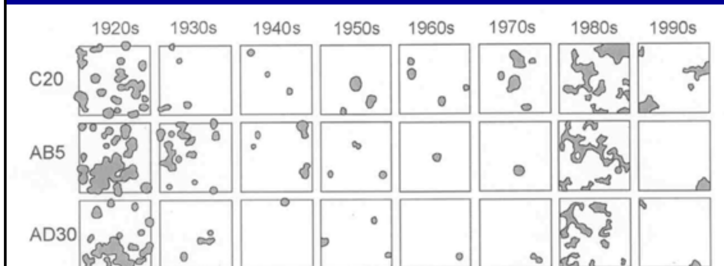


Fig. 4. Estimated size and dispersion of gaps formed in each decade (grey polygons) back to the spruce budworm outbreak of the 1920s. Gap areas prior to 1980 are likely underestimated (see Material and Methods). Gap areas were allowed to extend outside plot borders for earlier decades. Plot size is 50 m × 50 m; top of page is true north.

Fraver and White (2005)

What silvicultural systems do these dynamics imply?

- *Multi-aged* stand structures, with a significant component of “old” trees
- Regeneration in small gaps or patches *within irregular stands*
- Single-cohort (even-aged) silviculture –- where entire stands are regenerated in single cuttings -- would be the distinct exception
  (< 20% of the landscape under age 100)
  - Pure fir stands; shallow, poorly drained soils

Has the forest changed, relative to the presettlement benchmark period?

- ***Undeniably!***
- Conversion for multi- to even-aged structures
- Change in composition from spruce to fir
- Change in composition from mixedwood to hardwood

Have natural disturbance regimes been altered?

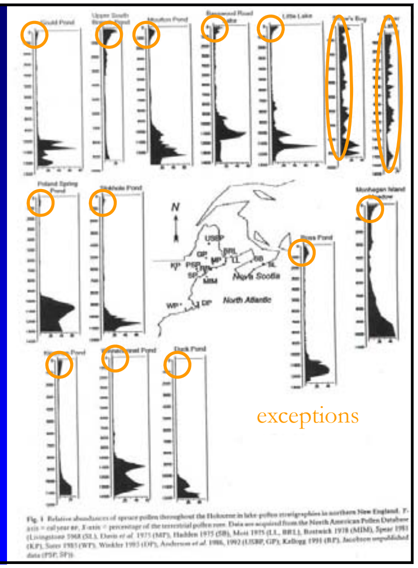
- Budworm is unclear (doubtful)
- Certainly true for bark beetles (less common)
- Fires likely now suppressed more than formerly
- Introduced pests have had huge impact

How stable was the *presettlement* red spruce forest?

- Trends in vegetation development through the Holocene
  - Schauffler and Jacobson (2002) paper using paleoecological reconstructions from pollen sediments
- 2 degrees C cooling during last 1000 years evidently promoted southward expansion of spruce into upland habitats throughout northern New England

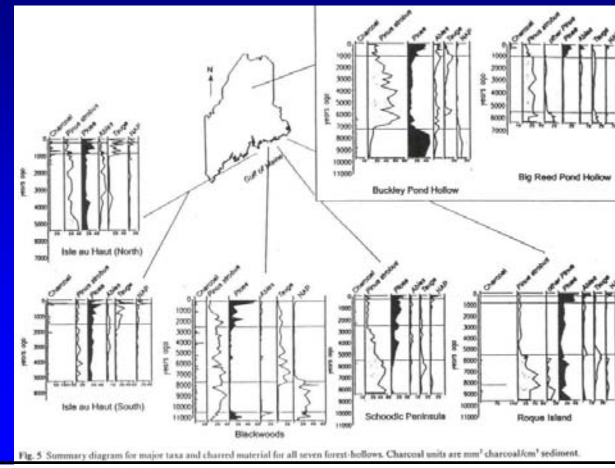
Regional patterns from *lake sediments*

- Relative abundance of *Picea* pollen, over 1000-year increments (on y-axis) since deglaciation



Coast vs. Inland Maine, *small "hollows"*

- *Picea* persistent on coast (cooler), but not inland



Managing Early Establishment and Competition

- *Tolerant conifers over earlier-successional hardwoods and shrubs*
  - Shelterwood method (variants)
- *Red spruce over fir*
  - Not so easy! Overstory manipulation not sufficient
  - PCT during sapling stage
  - Spruce on longer rotation than fir (two-aged shelterwood with reserves)

Regeneration and Early Stand Development

Factors that distinguish different regeneration methods

- Vegetative vs. Sexual Origin
- Microenvironment where seedlings become established
- Height of regeneration when overstory is removed

Vegetative Origin?

- Yes = ***coppice***
- No – seed origin (next)

Microenvironment where seedlings are established, and timing?

- In the open (*after* all or most of overstory is removed = *"new" seedlings*)
  - Source of seed?
    - Adjacent stands, buried seed, harvested trees = ***clearcutting***
    - Trees left standing on site = ***seed tree***
- In partial shade (*before* overstory is removed, using *advance regeneration*) = ***shelterwood***

Height of regeneration when overstory is removed? (length of *regeneration period*)

- Seedlings (< bh) = ***conventional* shelterwood** (1-5 years)
- Saplings (> bh) = ***extended* shelterwood** (10-20 years)
- Large saplings, poles **= *irregular* shelterwood**
  - regeneration period extends well into next rotation

Modifying adjectives:

- Variable spatial pattern of cuttings?
- Add: **"Uniform, group, strip, patch"** or whatever:
- e.g.: **Extended *group* shelterwood**

Clearcutting Terminology

- Unfortunately, there is great confusion about the use of the term "clearcutting" that results from the fact that "clearcutting" is both a ***logging practice*** and a **natural *regeneration method*** in silviculture.
- Unlike other regeneration methods, which describe the mode of seedling establishment, not the logging practice.

Logging Clearcuts…

As a logging practice, the focus is on how much of the overstory timber is harvested:

- Clearcutting = removal of most or all of the merchantable timber in a harvesting operation.

Logging Clearcuts

- “Complete" clearcut = thorough removal of all *overstory* trees, regardless of their economic value. [Sometimes called a "silvicultural" clearcut, but this is an incorrect use of this term.]
- "Commercial" clearcut = removal of only the more valuable trees, usually leaving many small-diameter or poor quality stems.

Silvicultural Clearcuts

- *As a regeneration method in silviculture,* the focus is on how the seedlings become established:
- Clearcutting = complete removal of all vegetation, with all growing space made available for establishment of new plants *after the harvest.*

Silvicultural Clearcuts

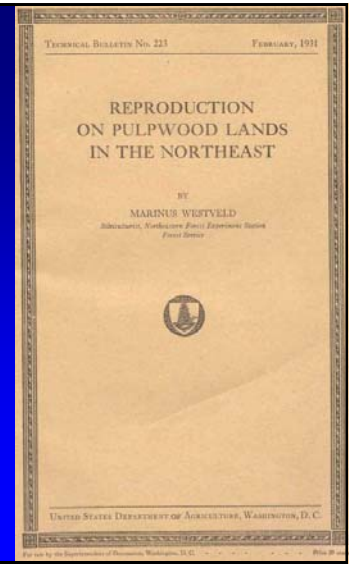
- Relies on new seedlings established by seeding from surrounding uncut stands, seed crops on harvested trees, dormant seed, or via artificial regeneration (planting or direct seeding).
- Sometimes we refer to the regeneration method as "true" clearcutting (suggesting that logging clearcuts often are not clearcuts in a silvicultural sense).

Where Logging clearcuts are not silvicultural clearcuts

- The most important case of confusion is where the overstory is "clearcut" (in a logging sense), releasing advance regeneration that became established in the understory of the previous stand.
- When the source of regeneration is *advance regeneration,* this is an example of the *shelterwood* method – "one-cut" shelterwood if no prior entries were conducted
- The correct silvicultural term in this important case is *(overstory) removal cutting (OSR).*

The "Bible" (Westveld 1931)

- Excellent descriptive account of how the mature forests of today came into being
- Extensive observations made during 1920s
- Crucial importance of advance regeneration

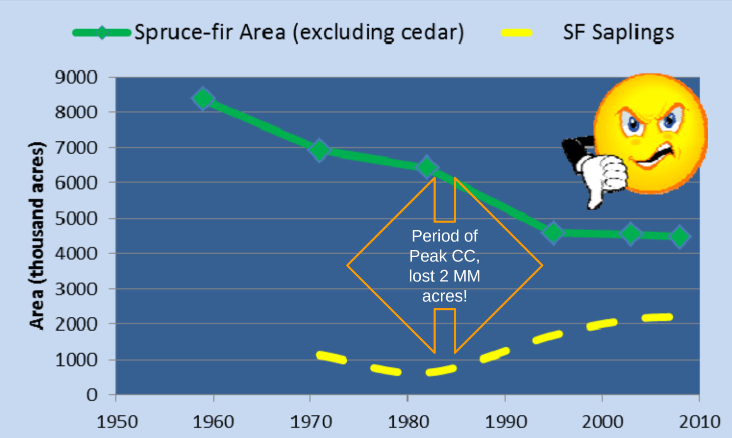


Advance regeneration is critical!

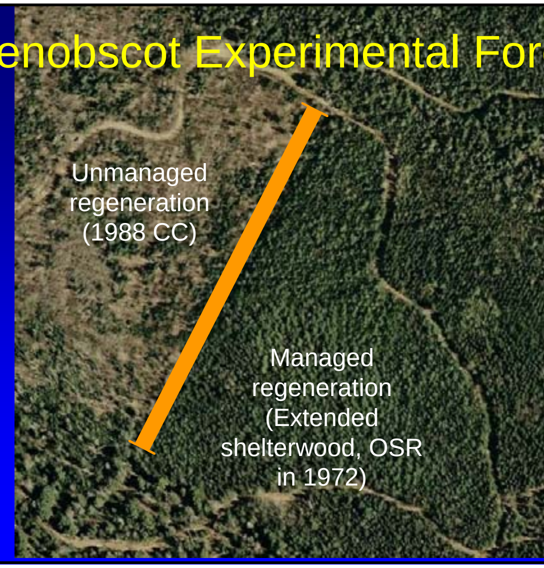
- Seedlings and saplings that are present in the understory *prior to* ("in advance of") the final removal harvest (or disturbance). ***SIZE DOES NOT MATTER!***
- Basically a SHELTERWOOD process.
  - Includes the "one-cut" variant, overstory removal to release advance growth
- Not Clearcutting or Seed Tree!

Contrasting spruce saplings
(Westveld 1931)

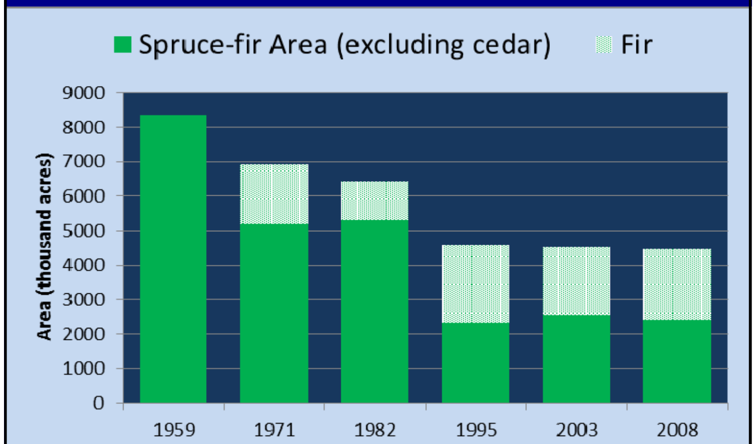
3.9 million acres (47%) of spruce-fir type lost since 1960



Penobscot Experimental Forest



Fir increasingly dominates SF Type



Possible Cause 1: Stands in Stem-Exclusion stage of stand development – exhibit poor stocking of advance regeneration before overstory removal

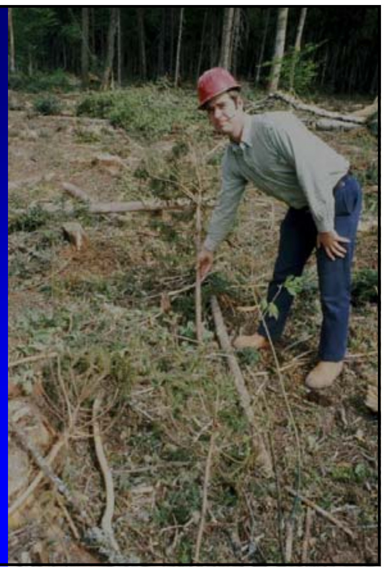
- Make a shelterwood establishment cutting, to move the stand from stem exclusion to understory re-inititation.
- Clearcut and plant.
  - Viable option for fir-dominated stands

Possible Cause 2: Destruction of advance regeneration through careless logging.

- Control skid trail layout; confine to no more than 20% of the harvest area
  - Feller-buncher + grapple skidder whole-tree systems
- Switch from whole-tree to cut-to-length systems

Careless destruction of advance regeneration ca. 1984

- Ideal Westveld-sized saplings all flattened
- Large (formerly suppressed) advance regeneration regarded as undesirable



Don't drive everywhere like this! Grossly excessive site disturbance

Perfect site preparation for raspberry, white birch, and red maple!

Possible Cause 3: Advance growth is present, but not well established (in mineral soil) – "burn off" phenomenon

- Wait (for stand to enter understory reinitation naturally)
- Shelterwood establishment cutting
- Leave harvest residues well-distributed over the site.
  - Importance of "dead shade" for early establishment

Not an established seedling

Nova Scotia guidelines – Good!

Table 2. Height class descriptions.

Height Class	Height Range (cm)	Description
1	less than 10	***PRE-ESTABLISHED:*** survival uncertain, with or without overstory removal.
2	10 to 29	***ESTABLISHED:*** capable of continued survival in understory, able to survive overstory removal
3	30 to 149	***ESTABLISHED:*** ideal stage for overstory removal
4	greater than 149	***TOO TALL:*** special care may be required during overstory removal to prevent damage.

- Caveat on height class 4 for good sites, hardwood-dominated stands.

Possible Cause 4: Subsequent suppression by competing vegetation.

- Delay overstory removal until advance regeneration has enough height advantage *("Extended Shelterwood Method")*
  - The better the site, the more "head start" is needed.
- Otherwise, timely herbicide release treatment to accelerate succession.

Umbrella spruce responding to natural canopy gap

Former Umbrella Spruce

Crown Base when released 80 years earlier

Recap: What went **wrong**?

1. Dense natural stands often in stem exclusion; advance regeneration absent or poorly established
2. Advance regeneration present, but destroyed in overstory removal harvest
3. Advance growth survived harvest, but died from exposure (not established in mineral soil)
4. Advance growth survived exposure, but died from suppression under weedy brush

Remedies?

Simple ***extended shelterwood method*** solves all of these problems!

1. Make the establishment cut (first step) as light as commercially possible (30-35%)
2. Remove overstory when advance growth reaches sapling size (>5 ft, 10-20 years)
3. Leave reserves if intent is to enhance structure and conserve immature growing stock

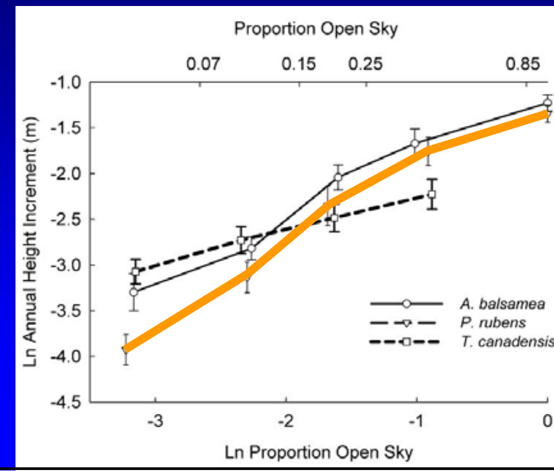
SIMPLE! (with right logging systems)

Can We Manage Light to Favor Spruce?

- ***Yes***, over intolerant competitors (extended shelterwood, as above)
- ***No***, over shade-tolerant conifer associates (fir, hemlock)

Managing Overwood Density (Moores, Seymour, and Kenefic 2007)

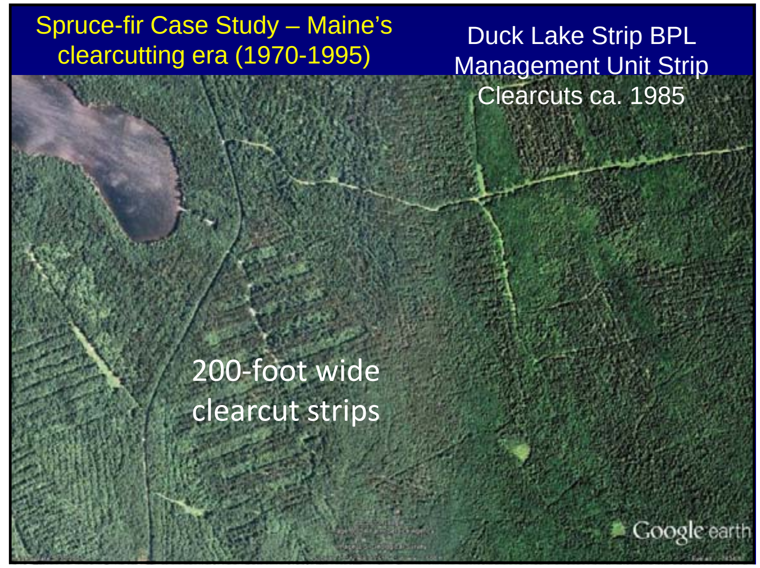
Response to increasing light (POS) – Spp. Comparisons

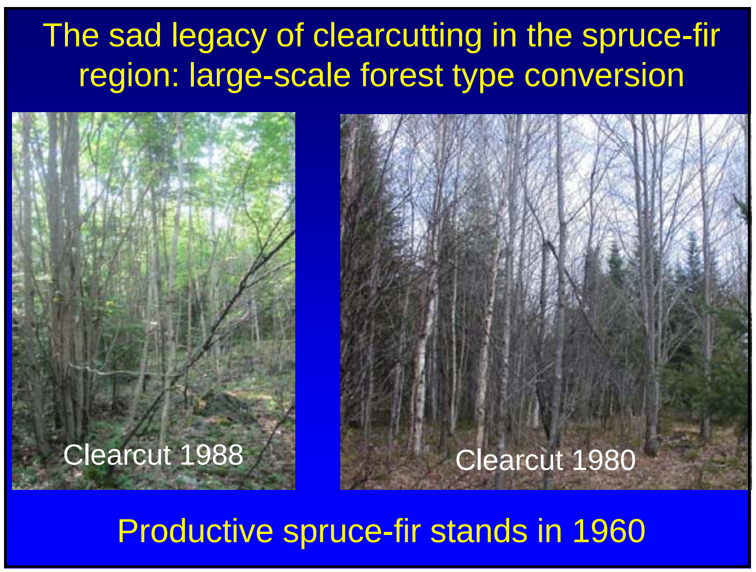


Dead red spruce sapling in hemlock thicket (PEF Selection treatment)

Contrasting spruce saplings


Irregular shelterwood reserve trees (pole-sized growing stock) after partial overstory removal
Trees may be 80+ years old, but they will respond and act like "tall regeneration"


Spruce-fir Case Study – Maine's clearcutting era (1970-1995)
Duck Lake Strip BPL Management Unit Strip Clearcuts ca. 1985
200-foot wide clearcut strips
Google earth


The sad legacy of clearcutting in the spruce-fir region: large-scale forest type conversion
Clearcut 1988
Clearcut 1980
Productive spruce-fir stands in 1960


Former whole-tree landing ca. 1985

Effect of light vs other factors

Effect of light vs other factors

Importance of nurse logs?

Spruce loves wood, fir doesn't care or avoids it (Weaver et al 2009)

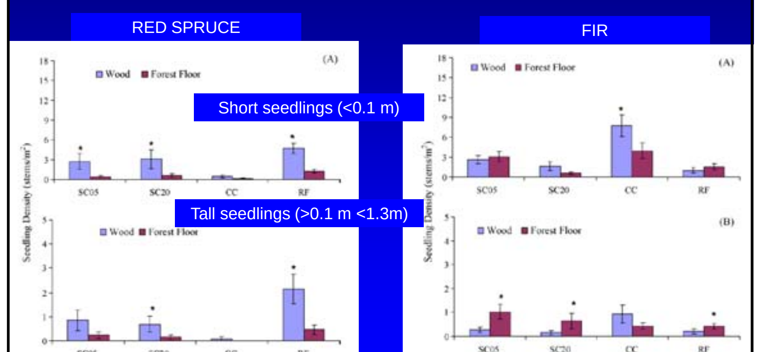
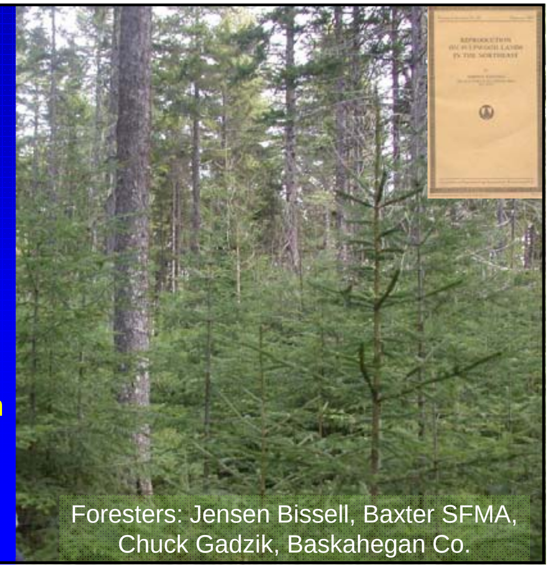


Fig. 3. Red spruce seedling densities on wood and paired forest floor plots in the 5- and 20-year selection (SC05 and SC20), commercial clearcut (CC) and reference (RF) treatments, for (A) seedlings ≤0.1 m in height and (B) seedlings >0.1 m but <1.3 m in height. Significant differences ($p < 0.1$) in seedling densities between paired microsites are shown with an (*).

Fig. 4. Balsam fir seedling densities on wood and paired forest floor plots in the 5- and 20-year selection (SC05 and SC20), commercial clearcut (CC) and reference (RF) treatments, for (A) seedlings ≤0.1 m in height and (B) seedlings >0.1 m but <1.3 m in height. Significant differences ($p < 0.1$) in seedling densities between paired microsites are shown with an (*).

Not all land was clearcut:

Baxter SFMA after shelterwood establishment cut (fir protected, then removed ca. 1990)



Take Home: Use Shelterwood!

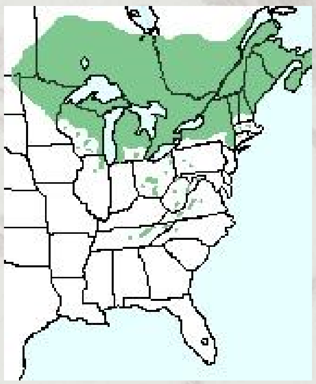
- Regenerate ***in the shade*** (shelterwood or selection, NOT in the open!
  – Small to medium gaps (< 0.5 acre) OK, with light overwood
- Conserve, protect, favor tall advance regeneration, including suppressed “umbrella” trees that have a height advantage over more aggressive species.
  - True (Silvicultural) clearcuttings will almost always ***FAIL***.

IV. Northern White-Cedar

Guidance for Forest Managers

Laura S. Kenefic
U.S. Department of Agriculture
Forest Service, Northern Research Station

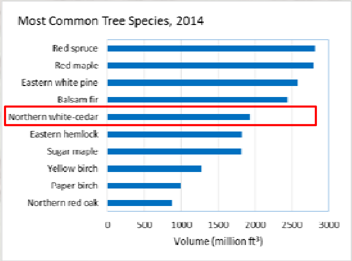
Natural Range of Northern White-Cedar



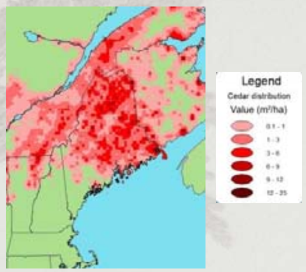
Source: Virginia Tech

Cedar in Maine

- One of the most abundant tree species



Forest Inventory and Analysis



Map: Eric Forget, Nova Sylva

Thuja occidentalis L.

Photo by Phil Hofmeyer

- northern white-cedar
- mid- to very shade tolerant
- long-lived, 400 years
- abundant seeds 2-5 years
- seedlings, or layering on wet sites
- weak and brittle, prone to decay when living
- extremely resistant to decay after death

Habitat Types

Lowland, swamp | Mid-slope, seepage | Upland

Photos courtesy of Phil Hofmeyer

Photo courtesy of Catherine Larouche

Damaging Agents

White-cedar

- Arborvitae leaf miner
- Browsing
- Decay
- Windthrow, uprooting
- Hydrologic changes
- Logging damage to roots, stems, and crown

https://www.ontario.ca/

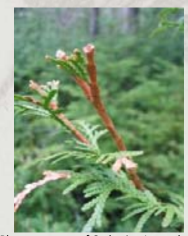


Photo courtesy of Catherine Larouche

Cultural Importance

Native Americans

Photo by Heather Perry

Commodity Production

White-Cedar

Photo from Maibec

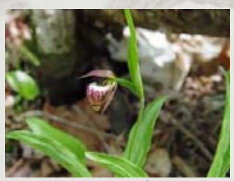
http://flwinternational.com/

Biodiversity Considerations

White-Cedar

Photo by KaDonna Randolph

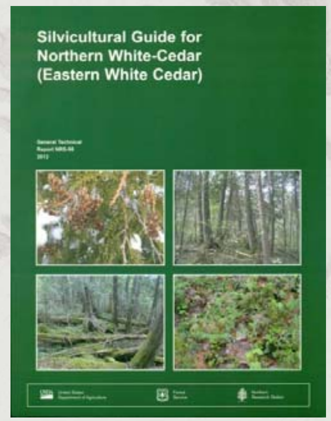
Photo by N.B. Hunter



Source: Maine Natural Areas Program

Photo by Rick Dionne

White-Cedar Silvicultural Guide



Photos courtesy of Catherine Larouche and Phil Hofmeyer

https://www.treesearch.fs.fed.us/pubs/41699

Stem Analysis: Observations

- 80% showed initial growth suppression followed by release
- Mean initial suppression > 60 years
- Some trees responded to release after 200 years

Hofmeyer et al. 2010

Number of Years to Reach a Given Size
from stump height (1 ft.)

Size		Mean (years)	Range (years)
1 in. DBH	Sapling	42.0	9 - 86
5 in. DBH	Poletimber	96.0	28 - 171
9 in. DBH	Sawtimber	139.9	54 - 238
15 in. DSH	Shingle Stock	170.1	81 - 317

DBH = diameter at breast height, DSH = diameter at stump height

Hofmeyer et al. 2010

Establishment and Early Growth

- Seepage and upland: mineral soil, decayed wood

Photo courtesy of Catherine Larouche

- Lowland, swamps: mounds (hummocks)

Silvicultural Experiment

120 ft^2ac^{-1}

Control

90 ft^2ac^{-1}

Selection (25% removal)

60 ft^2ac^{-1}

Shelterwood (50% removal)

90-ft. diameter gaps (0.15 acre)

Patch Cutting

Larouche et al. 2011

Observations

- Establishment
  - Best in selection and shelterwood cutting
  - Worst in patch cutting
- Growth of established seedlings
  - Positively correlated with light

Larouche et al. 2011

Influence of Herbivory

- Deer density: 0 versus 15 per mi^2
- At both densities, many seedlings < 6 inches
- At high density
  - Few seedlings 6 to 12 inches
  - Almost none > 1 foot

Larouche et al. 2010

Sapling Recruitment

- Penobscot Experimental Forest, partial harvesting
- ~ 15 deer per square mile
- >90% of white-cedar seedlings and small saplings browsed (2005)

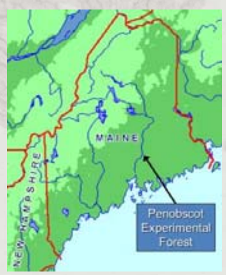


Photo courtesy of Catherine Larouche

Old-Growth White-Cedar

Photo credit: The Nature Conservancy

Photo courtesy of Catherine Larouche

Climate Change

Janowiak et al. in preparation

Key Points: Silvics White-Cedar

- Shade tolerant, slow growing
- Requires moisture-holding substrate
- Often originates beneath the canopy
- Seedlings or layers
- Withstands long periods of suppression
- Vulnerable to browsing
- Has increasing growth over time

Photo courtesy of Catherine Larouche,

Concerns

White-Cedar

- Vulnerable to damage and decay
- Loss of cedar from harvested mid-slope or upland stands
- Regeneration mechanism in managed lowland stands?
- Negative climate change impacts

Photo courtesy of Catherine Larouche

Recommendations: Regeneration

- Take advantage of what is already there
  - Establish
  - Protect
  - Release
- Control substrate and competition
- Consider browsing

Photo courtesy of Catherine Larouche

Recommendations: Tending

- Use intermediate treatments to improve growth of existing trees
- Protect stems and exposed roots during harvesting

Photo courtesy of Catherine Larouche

Irregular Shelterwood or Selection System

- Multiple treatment approach
  – Protect and release regeneration
  – Tend immature classes

- Treat patches (micro-stands) in mixed-species stands
- Retain seed trees for more than one rotation

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