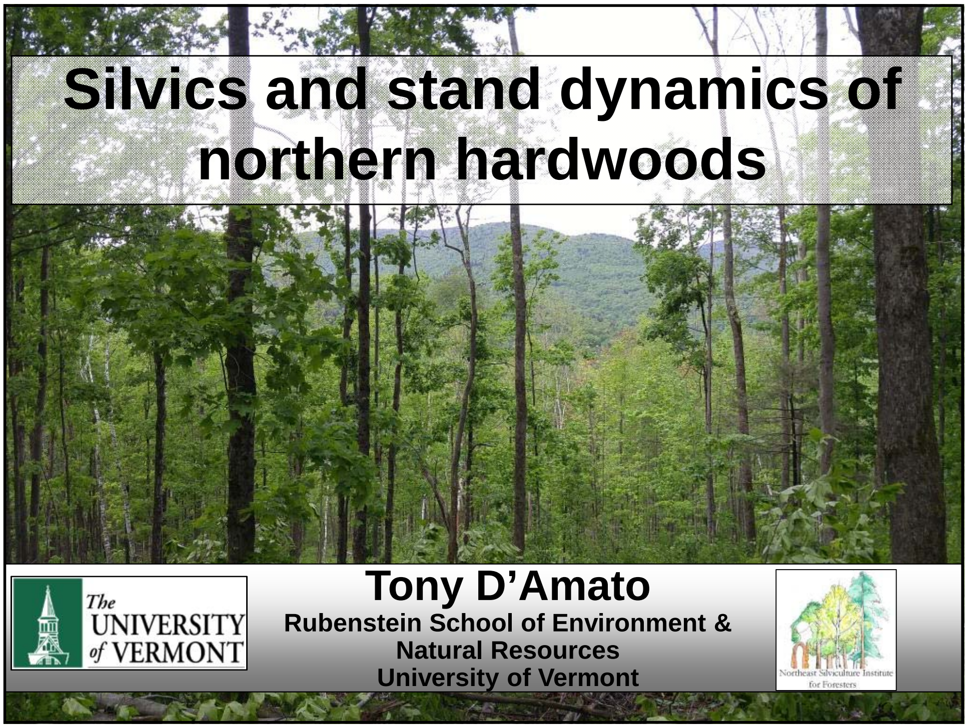

Silvics and stand dynamics of northern hardwoods

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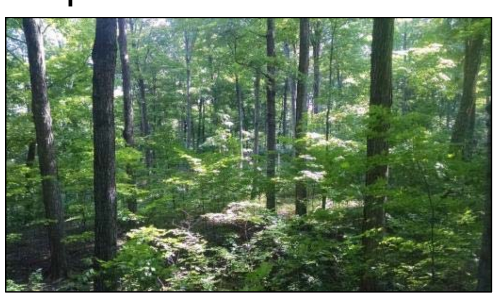
Outline

- Silvics review for primary species in northern hardwood systems
- Historical forest dynamics and structure
- Evolution of contemporary forests and associated challenges
- General adaptation considerations



Silvics of primary species

Silvics of primary species

Species	Shade tolerance	Early relative height growth	Relative site requirements
Sugar maple	Tolerant	Slow to moderate	High
American beech	Very tolerant	Slow	Low
Yellow birch	Intermediate	Moderate	Medium to high
Paper birch	Intolerant	Fast	Low
White ash	Intermediate	Moderate	Very high
Red maple	Intermediate	Moderate	Low
Aspen	Intolerant	Very fast	Low
N. red oak	Intermediate	Moderate	Medium
Black cherry	Intermediate	Fast	Low
Red spruce	Tolerant	Very slow	Low
Hemlock	Very tolerant	Very slow	Low
White pine	Intermediate	Moderate	Low

From Leak et al. (2014)

Stand age 22

Stand age 81

Silvics of primary species

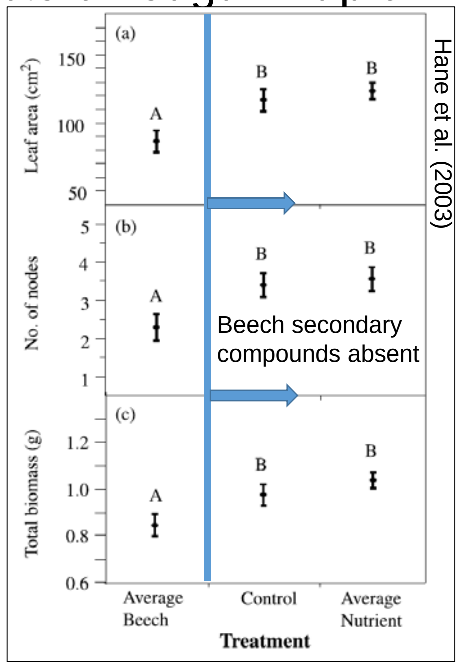
Species	Preferred seedbed	Gap size
Sugar maple	Litter	0.1 ac
American beech	Litter	0.1 ac
Yellow birch	Humus mix	0.25 ac
Paper birch	Humus mix	> 1 ac
White ash	Litter	0.2 ac
Red maple	Litter	0.2 ac
Aspen	Moist mineral	> 1 ac
N. red oak	Litter	0.5 ac
Black cherry	Litter	> 1 ac
Red spruce	Litter, moist mineral	0.1 ac
Hemlock	Humus mix	0.1 ac
White pine	Moist mineral	0.25 ac

From Anderson et al. (2001)

Litter quality impacts on sugar maple

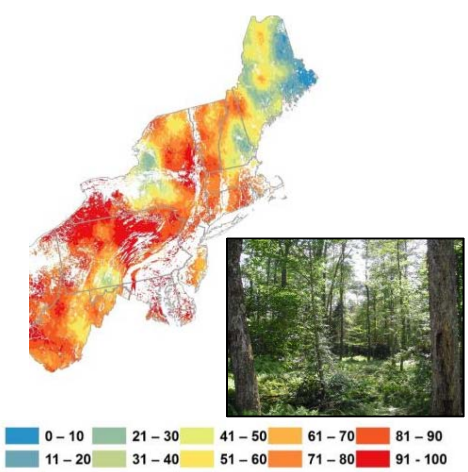
32-year-old shelterwood

57-year-old patch



Browse sensitivity

Probability of medium/high ungulate herbivory risk, 2015. McWilliams et al. (in review)

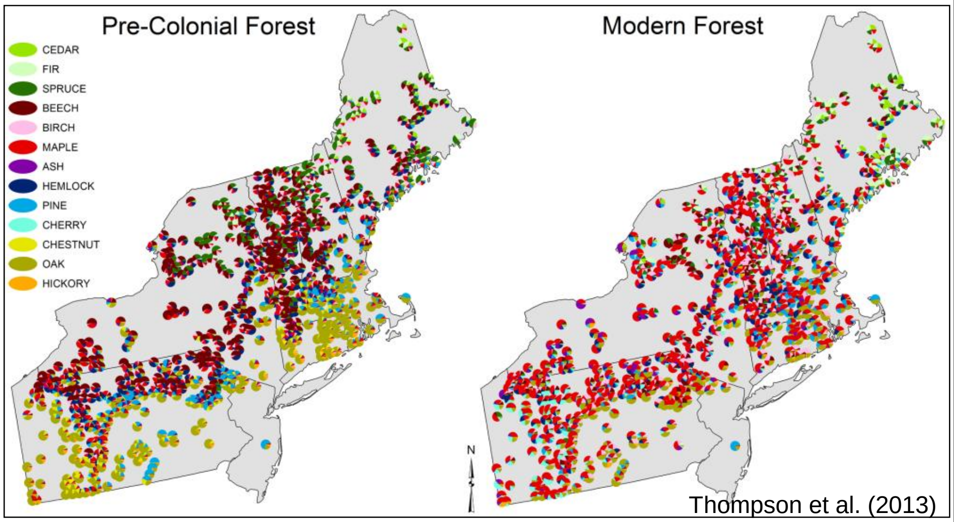


Pair up with your neighbor and spend a few moments discussing whether or not the following species are browse sensitive:

- American beech No
- Black cherry No
- Pin cherry Yes
- Striped maple No
- Sugar maple Yes
- White ash Yes
- Yellow birch Yes

Site types and communities

Site types and communities



Thompson et al. (2013)

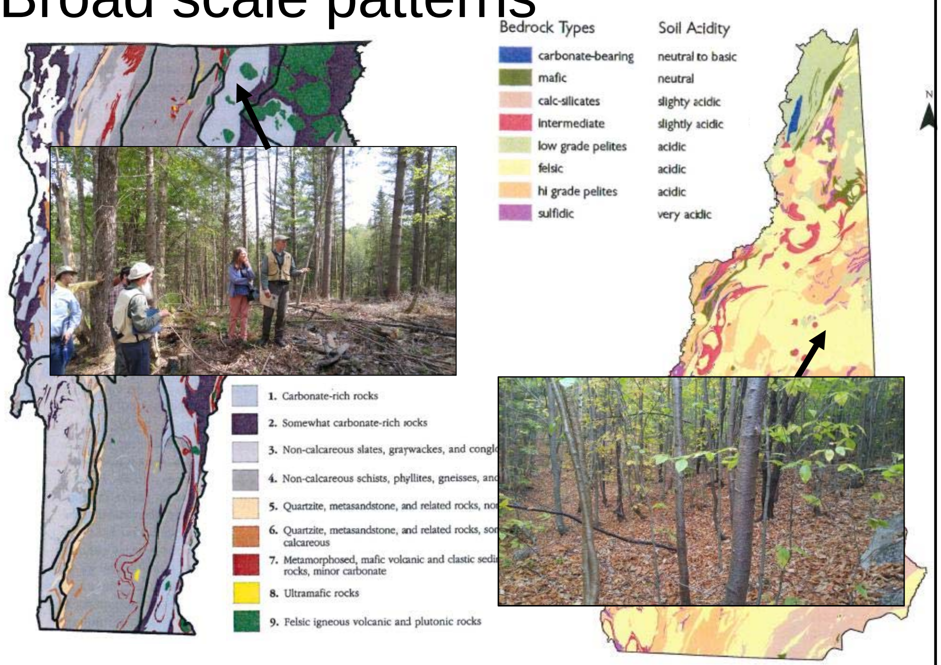
- Just because there is sugar maple in the overstory doesn't mean a site will support a sugar maple-dominated site over time

Site types and communities

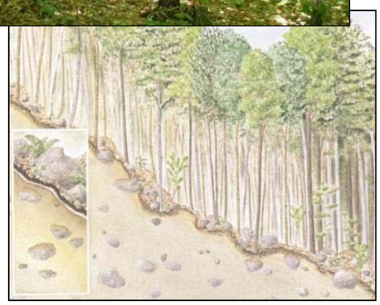
Forest type	Characteristic species	Bedrock type	Soils
Sugar maple-ash[a]	Sugar maple, white ash, basswood	Calcareous	Well- or moderately well-drained tills
	Sugar maple, white ash	Granite, schist	Enriched
Northern hardwood[b]	Beech, sugar maple, yellow birch	Granite, schist	Well-to moderately well-drained tills

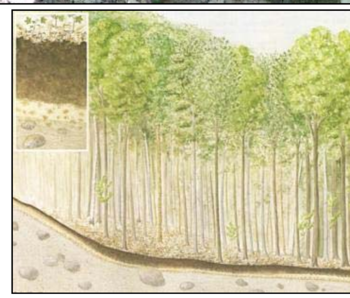
NH and VT Natural Communities:
[a]NH=Rich mesic forest; VT=Rich northern hardwood forest
[b]NH=semi-rich mesic sugar maple forest; VT=Northern hardwood forest

Broad scale patterns



Fine scale patterns





Leak and Riddle (1979)

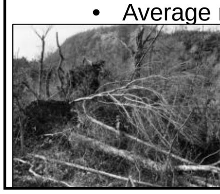
Northern hardwood dynamics

Northern hardwood dynamics

Expected % of landscape occupied by different age classes based on average, historic disturbance rates (Lorimer and White 2003)

Age class	500-year Rotation (Fire 1000 yrs, Wind 1000 yrs)	1364-year Rotation (Fire 3000 yrs, Wind 2500 yrs)
Seedling-sapling (1-15 yrs)	3.0	1.1
Small pole (15-30 yrs)	3.0	1.1
Large pole (30-60 yrs)	6.0	2.2
Mature even-aged (60-100 yrs)	8.0	2.9
Old even-aged (100-150 yrs)	10.0	3.7
Transitional uneven (150-300 yrs)	30.0	11.0
Old uneven-aged (300+ yrs)	40.0	78.0

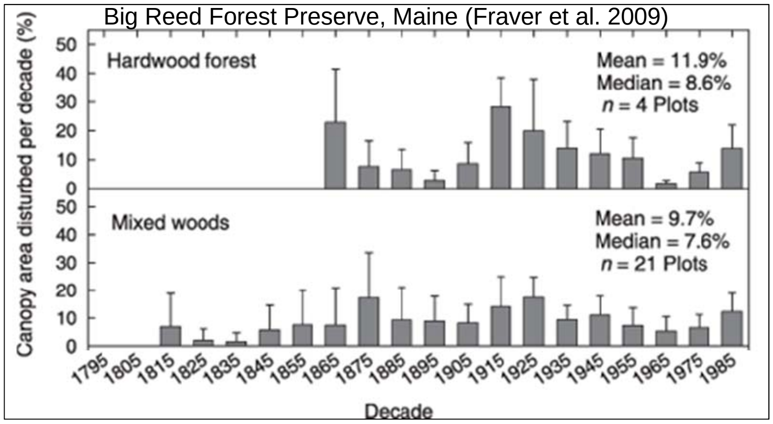
- Lowest frequency of stand-replacing disturbance of any northeast forest type
  - Average rotation periods of 1000-3000 yrs for stand-replacing wind and fire



Northern hardwood dynamics

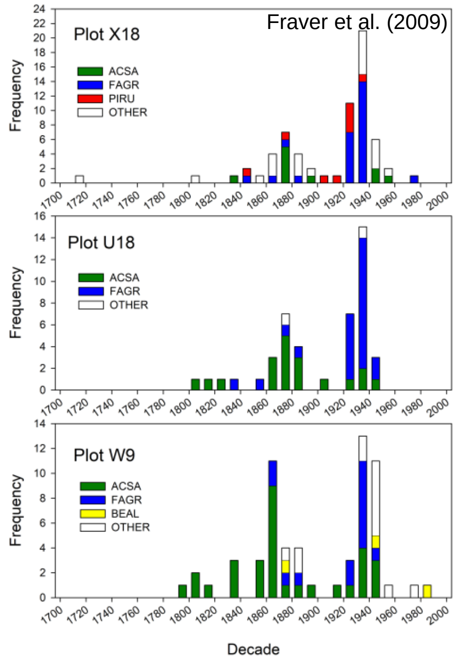
Gap dynamics (0.5-2.0% of canopy disturbed per year) represent general pattern across northern hardwood forests

Big Reed Forest Preserve, Maine (Fraver et al. 2009)





Northern hardwood dynamics

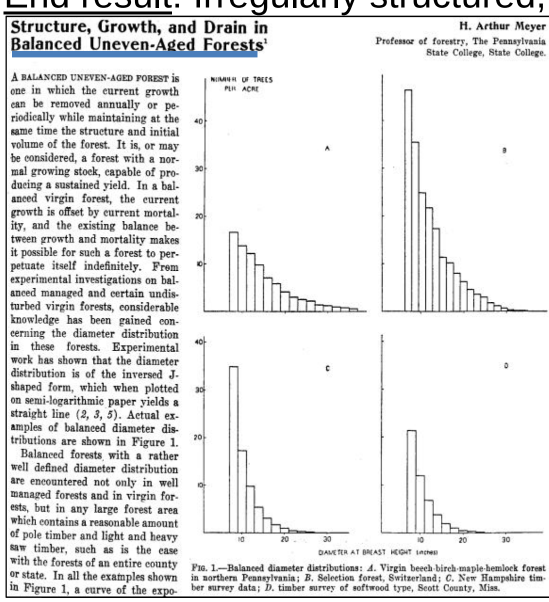


Natural age structures

- Uneven-aged, but often dominated by 2-3 cohorts
  - Reflective of moderate disturbance (30-60% canopy removal) every 60-400 yrs
  - Moderate severity events (microbursts, ice) critical for recruiting intolerant and mid-tolerant species

Northern hardwood dynamics

- End result: Irregularly structured, multi-cohort forests



Structure, Growth, and Drain in Balanced Uneven-Aged Forests[1]

H. Arthur Meyer
Professor of forestry, The Pennsylvania State College, State College.

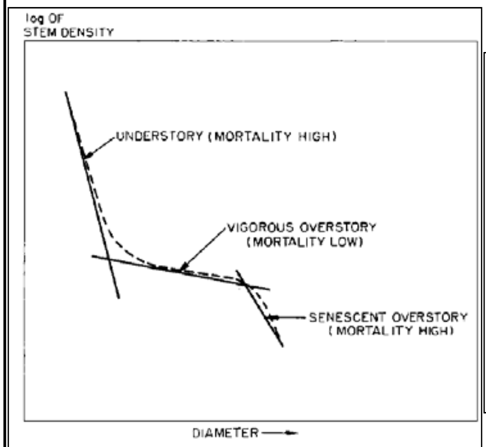
A BALANCED UNEVEN-AGED FOREST is one in which the current growth can be removed annually or periodically while maintaining at the same time the structure and initial volume of the forest. It is, or may be considered, a forest with a normal growing stock, capable of producing a sustained yield. In a balanced virgin forest, the current growth is offset by current mortality, and the existing balance between growth and mortality makes it possible for such a forest to perpetuate itself indefinitely. From experimental investigations on balanced managed and certain undisturbed virgin forests, considerable knowledge has been gained concerning the diameter distribution in these forests. Experimental work has shown that the diameter distribution is of the inversed J-shaped form, which when plotted on semi-logarithmic paper yields a straight line (2, 3, 5). Actual examples of balanced diameter distributions are shown in Figure 1.

Balanced forests with a rather well defined diameter distribution are encountered not only in well managed forests and in virgin forests, but in any large forest area which contains a reasonable amount of pole timber and light and heavy saw timber, such as is the case with the forests of an entire county or state. In all the examples shown in Figure 1, a curve of the expo-

FIG. 1.—Balanced diameter distributions: *A.* Virgin beech-birch-maple-hemlock forest in northern Pennsylvania; *B.* Selection forest, Switzerland; *C.* New Hampshire timber survey data; *D.* timber survey of softwood type, Scott County, Miss.

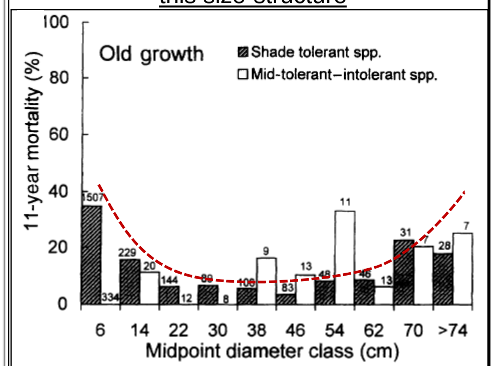
Northern hardwood dynamics

- Live-tree diameter distributions
  - Rotated sigmoid distribution is most commonly observed distribution in old-growth stands



Goff and West (1975)

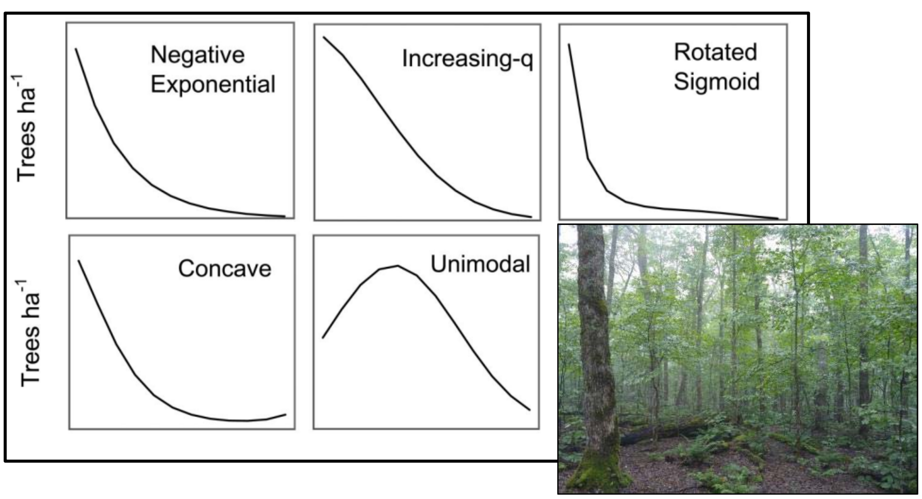
U-shaped mortality trend reinforces this size-structure



Lorimer et al. (2001)

Natural dynamics and development

- Live-tree diameter distributions
  - Range of natural distributions documented and recognized (Leak 1964, 1996; Janowiak et al. 2008)

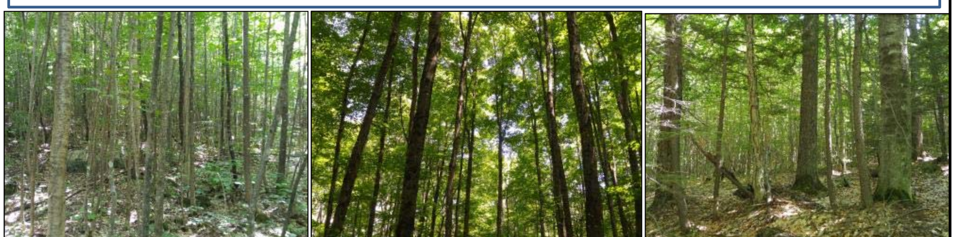


Overstory species dominance over time at gap and stand and scales

General pattern for "matrix" northern hardwoods (semi-rich)

Early succession	Mid succession	Late succession
Yellow birch, white ash, aspen, sugar maple, pin cherry, paper birch, beech	Sugar maple, beech, yellow birch (understory spruce and hemlock)	Beech, sugar maple, yellow birch (some hemlock or spruce)
Rich: Bigtooth aspen, little to no beech	Rich: Basswood, bitternut hickory, white ash	Rich: Basswood, little to no conifer or beech

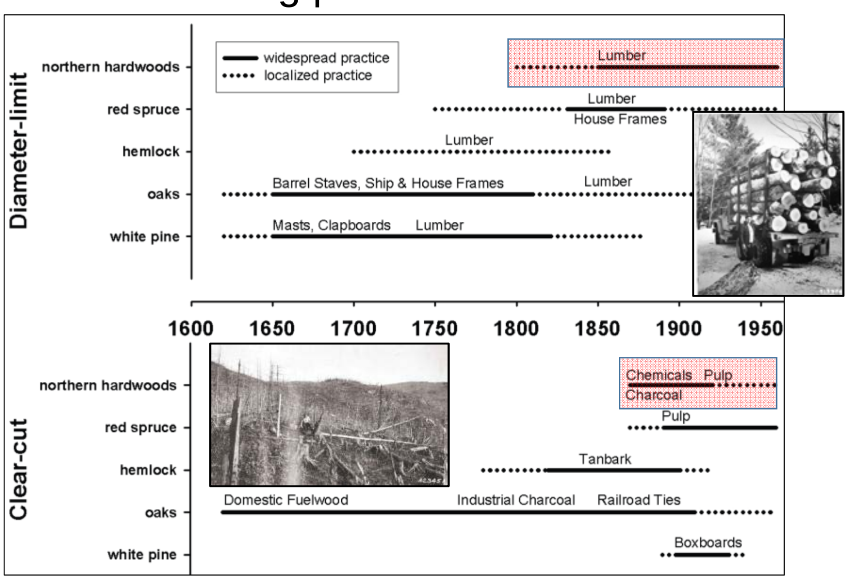
From Thompson and Sorenson (2005)



True stand replacement is rare due to resilience of advance regeneration


Land-use history and contemporary conditions

Past harvesting practices in northeast US



Kelty and D'Amato 2006

Early silviculture (vs. harvesting) in northeast US

Increasing demand and transport ability for northern hardwood species in 1900s

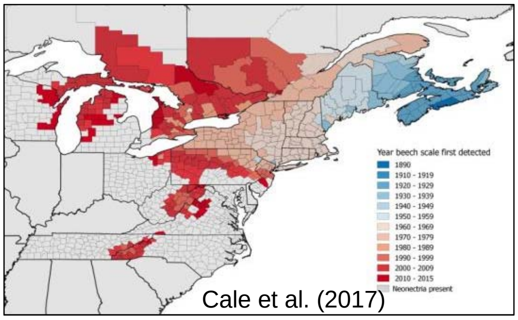
- 1920-1930s: Establishment of USFS Experimental Forests in northeastern US (Bartlett Experimental Forest in 1932)
- Silvicultural research focused on addressing prevailing conditions left from history of land-use
  - "Old growth"
  - Even-aged

General forest conditions

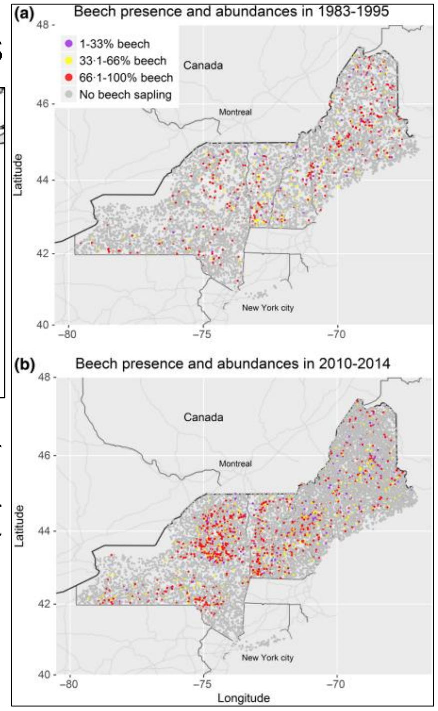
"Old growth", WMNF (Gilbert and Jensen 1958)

Improvement cutting 60-year-old stand, GMNF 1939 (post-charcoaling)

Changing beech dynamics

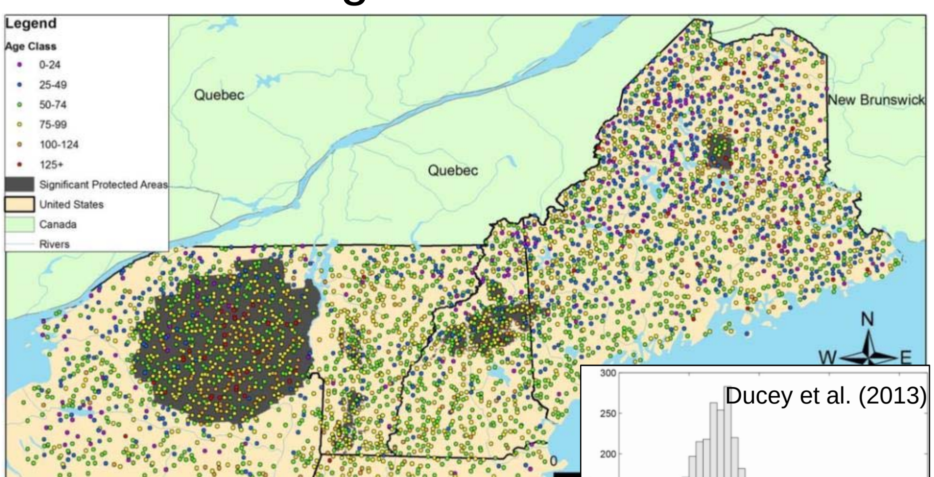


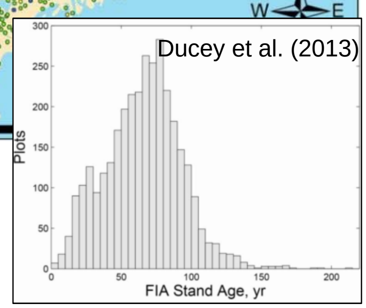
Cale et al. (2017)



Bose et al. (*In press*)

Forest age-class conditions



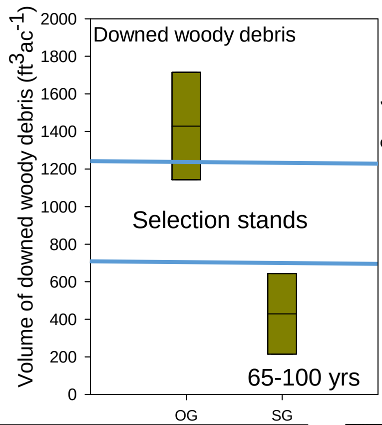


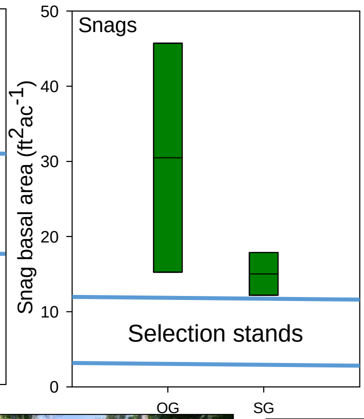
Ducey et al. (2013)

Much of northern hardwood resource is in 61-100 year class

- Rarely even-aged due to past selective cutting but anything but the "balanced condition" early guides were based on

Deadwood abundance in current forests

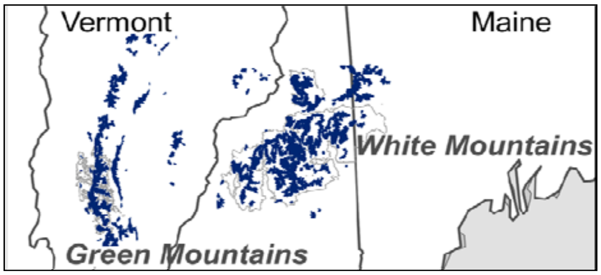


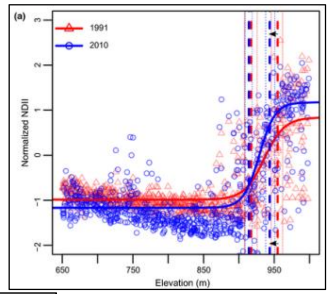


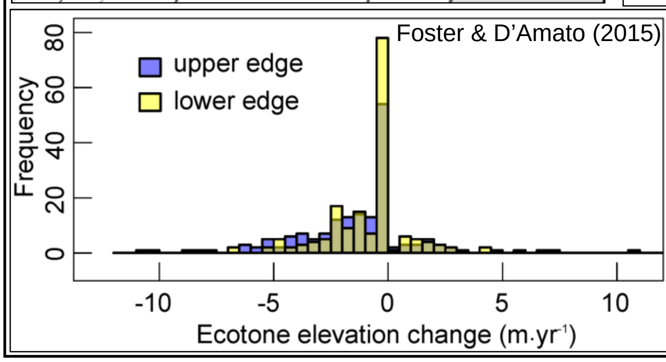
Based on: McGee (2003); Gore and Patterson (1986); Tritton (1980); Kenefic and Nyland (2007); Goodburn and Lorimer (1998)

Recent mixedwood dynamics

Recent mixedwood dynamics







Foster & D'Amato (2015)

Upper ecotone elevation generally shifted **downslope** 4-5 ft yr^{-1} from 1991-2010 across 15,000 mi^2 area

Recent mixedwood dynamics

- Many areas are still recovering from history of selective red spruce harvesting (artificially pushed spruce upslope and out of mixed northern hardwood stands)
- Importance of retaining red spruce on mixedwood sites to provide seed source given slow rates of development
- Prevalence of mixedwood condition often underestimated given current stand conditions on moderate quality sites

Adaptation considerations



Adaptation considerations

Vulnerability determination for selected forest types in New England and New York (Janowiak et al. *in press*)

Forest type	Potential impacts	Adaptive capacity	Vulnerability
Central hardwoods	Moderate-positive	Moderate-high	Low
Lowland conifer	Moderate-negative	Moderate	Moderate-high
Montane spruce-fir	Moderate-negative	Low-Moderate	Moderate-high
Northern hardwoods	Moderate	Moderate-high	Low-Moderate
Pitch pine-scrub oak	Moderate-positive	Moderate	Low

Adaptive capacity of NHW

- **Positives:** many tree species representing broad mix of tolerances and reproductive strategies; occur across wide range of soils and landforms (some less vulnerable than others)
- **Negatives:** many species affected or threatened by non-native insects and diseases, deer herbivory



Adaptation considerations

Revisiting two of several principles guiding previous "new trend" in silvicultural thinking

1. **Continuity** - provision for continuity in forest structure, function, and biota between pre- and post-harvest (legacies)
2. **Complexity** - create and maintain structural and compositional complexity and biological diversity through silvicultural treatments



(From Seymour and Hunter 1999, Franklin et al. 2007)

Adaptation considerations

Value in retention during regeneration harvests

Principle	Linkages with Uncertainty and Adaptation

Continuity	• Long-term options for regeneration and structure in face of uncertainty
	• Amelioration of harsh environmental conditions
	    • Regeneration safe sites (shaded understory, well-decomposed dead wood)
	    • Micro-refugia for sensitive taxa
	• Conservation of genetic diversity




Adaptation considerations

Look to silvicultural systems that increase within stand and landscape-level complexity

Principle	Linkages with Uncertainty and Adaptation

Complexity	• Reduced vulnerability to disturbance
	  • Heterogeneity in: 1) wind/ice risk, 2) potential host species abundance, 3) within-species stress tolerance (tree size/age), 4) resource availability
	• Multiple recovery/developmental pathways
	  • Diversity of seed sources and reproductive mechanisms
	  • Heterogeneity in microsites for new species

Adaptation considerations

Projected changes in suitable habitat by 2100 Northern Forest region under high emissions scenarios (Janowiak et al. *in press*)

Decreasing	No change	Increasing
American beech	White ash*	Basswood
Quaking aspen	Big-tooth aspen	N. red oak
Paper birch	Eastern white pine	Black birch
Yellow birch	Red maple	Bitternut hickory
Red spruce		Black cherry
Sugar maple		
Eastern hemlock*		

Primarily intolerant and intermediate species

Do we consider artificial regeneration or deliberate tending to increase range of species on these sites?

Conclusions

- Site and associated natural communities represent most important filter for determining appropriate long-term silviculture regime for northern hardwoods (i.e., listen to Bill)
- Current condition of resource and potential future changes speak to need for applying diversity of regeneration methods that retain and enhance structural and compositional complexity on site
    - Group/patch selection, irregular shelterwoods, two-aged variants