An Economic and Ecological Assessment of Pre-Commercial and Commercial Thinning

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Outline

- **Part I:** *Introduction*
- **Part II:** *Assessing Timber Quality and Financial Return Following Pre-commercial and Commercial Thinning in Northern Hardwood Forests*
- **Part III:** *Ecological Outcomes of Pre-commercial and Commercial Thinning in Northern Hardwood Forests*
- **Part IV:** *Management Applications*
- **Part V:** *Current Research*

Part I: *Introduction*

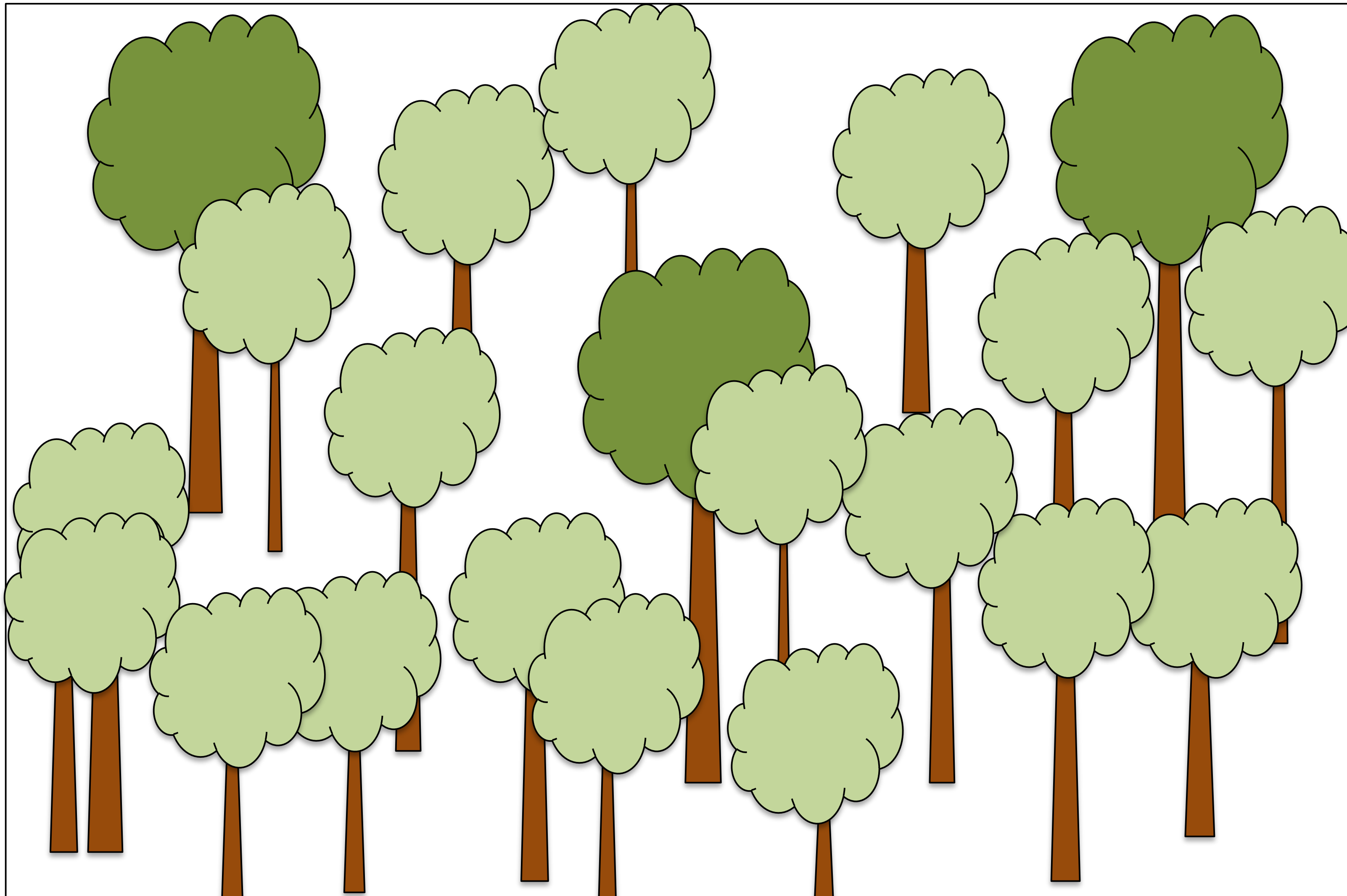
Research Agenda

- Economics of silviculture in Northern New England
  - Timber economics and finance
  - Ecosystem services
- Past, Present and Future Projects
  - Whole-tree and conventional harvesting (Roxby, 2012)
  - Martelscope: forest stand analytics (Kilham, 2013)
  - Single-tree versus group selection (Sinacore, 2013)
  - Managing stands invaded by glossy buckthorn (Kozikowski, 2016)
  - <u>***Pre-commercial thinning in northern hardwoods (Thornton, 2017)***</u>
  - TSI: economics and ecosystem services (Kalp, 2020)

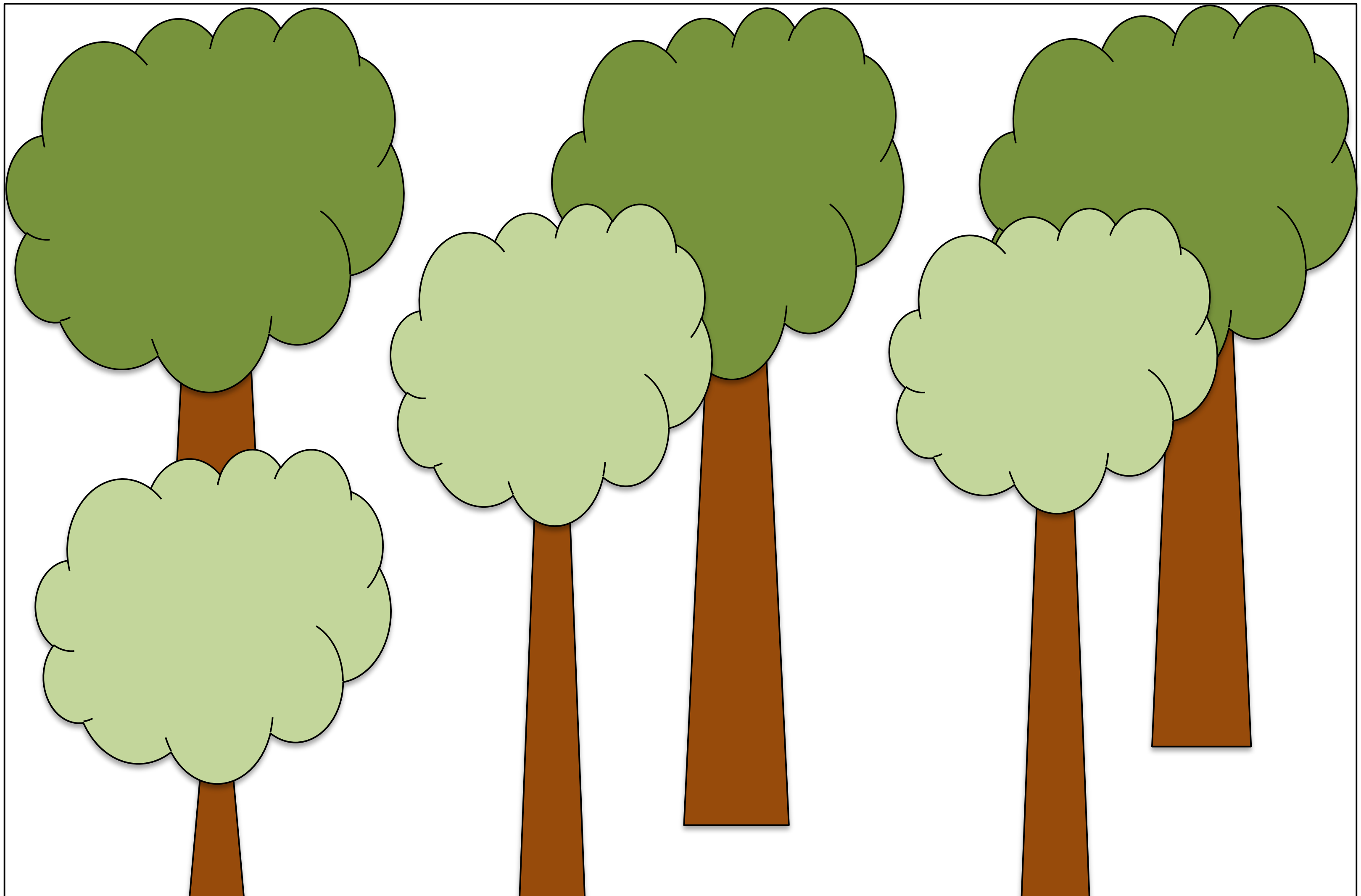
Northern Hardwood Forests

- 8 million hectares across New England states and New York (Leak et al. 2014)
- American beech, yellow birch, sugar maple, red maple, white ash, paper birch, aspen
- Timber products from veneer to biomass
- Recreation, wildlife habitat for over 200 vertebrate species, watershed protection, and other ecosystem services

What is pre-commercial thinning?

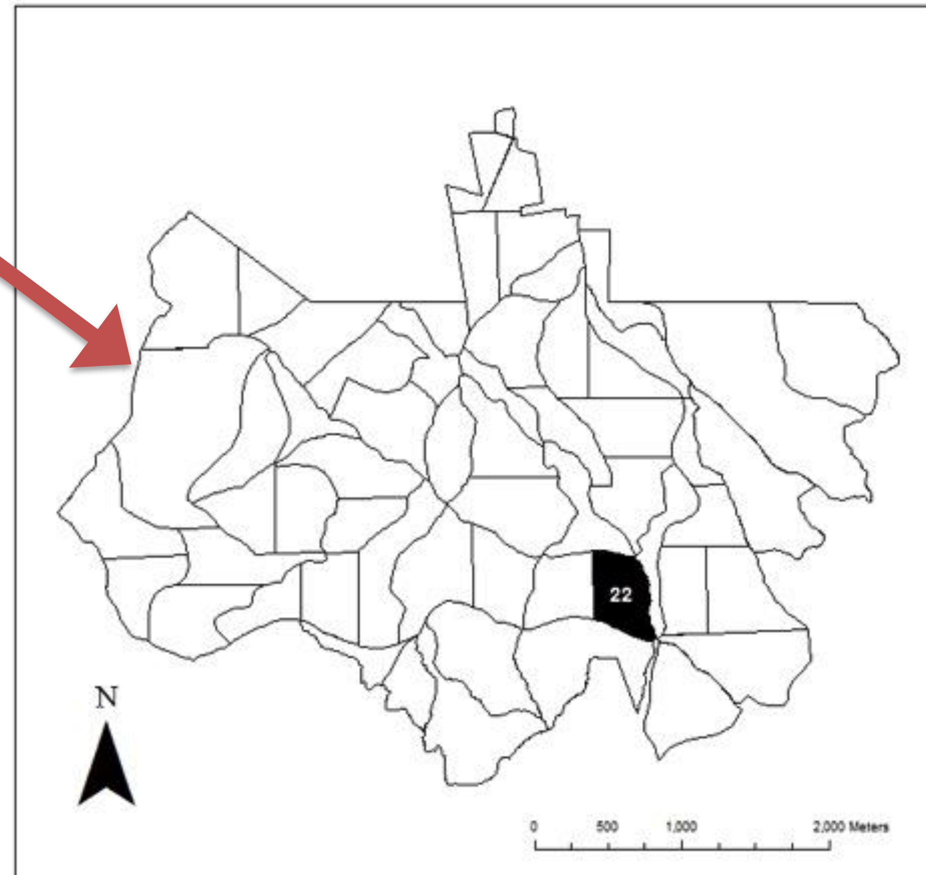


What is commercial thinning?



Bartlett Experimental Forest

New Hampshire



1935

Photo: U.S. Forest Service

1959

Photo: U.S. Forest Service

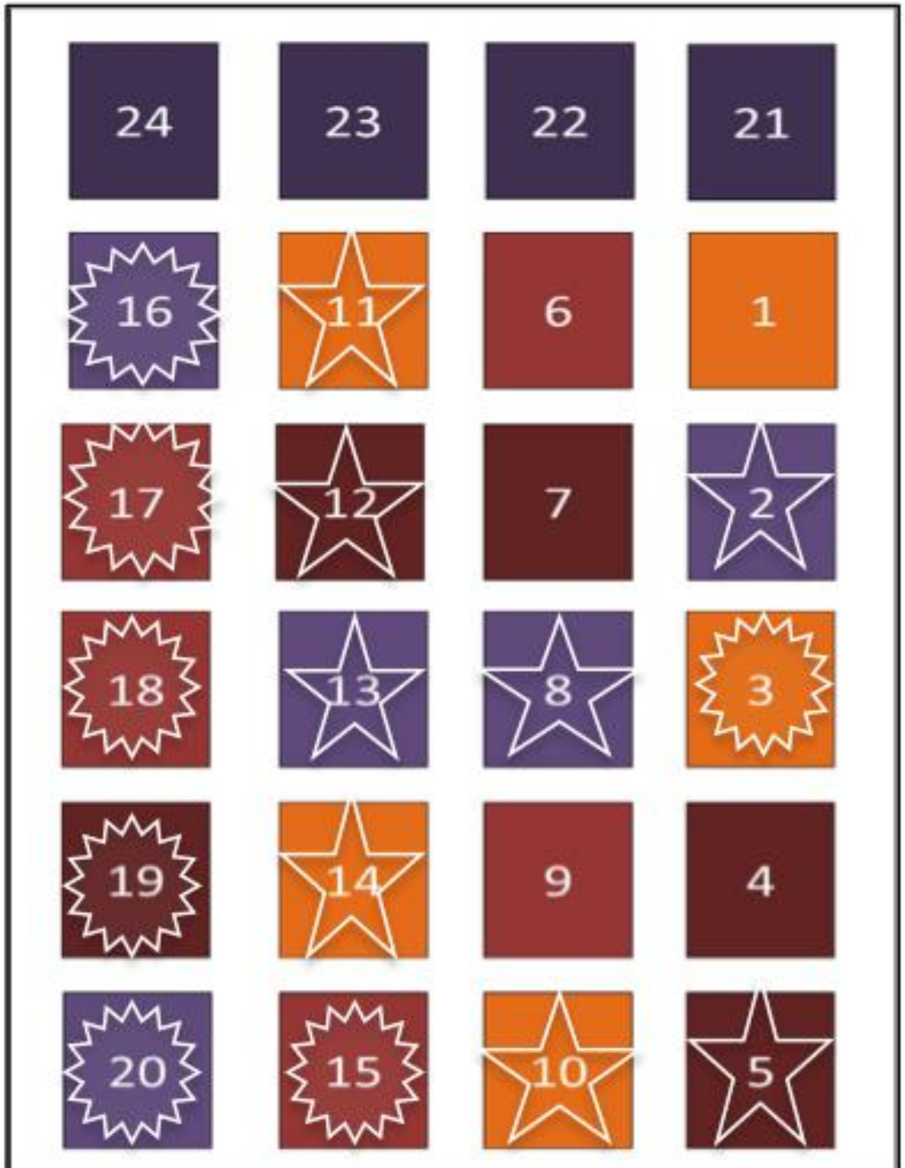
2016

Experimental Plots

- Clear cut winter 1933-1935
- Pre-commercial thinning in 1959- 100 crop trees/plot
- 20, 1/10 ha plots with five treatment replicates
  - Heavy: removed trees competing directly with crop trees
  - Light: removed one tree competing with crop tree
  - Species cleaning: removed aspen, pin cherry, striped maple, and red maple sprout clumps
  - Control
- Commercial thinning in 2003, removing aspen and paper birch
  - Uncut
  - Thinned
  - Paper birch left to retain 11.5 m^2/ha basal area
- Established four 1/10 ha reference plots in 2016
  - No record of harvest

Site Description

- 335-396 m elevation
- North facing slope
- Well-drained glacial till soil
- Plots thinned in 2003 now dominated by white ash, sugar maple, and yellow birch
  - Average basal area of 17 m^2/ha per plot
- Plots not thinned in 2003 now dominated by paper birch, sugar maple, and red maple
  - Average basal area of 32 m^2/ha per plot



Plot	1959 Treatment	2003 Treatment
1	Light	Uncut
2	Clean	Paper birch left
3	Light	Thin
4	Control	Uncut
5	Control	Paper birch left
6	Heavy	Uncut
7	Control	Uncut
8	Clean	Paper birch left
9	Heavy	Uncut
10	Light	Paper birch left
11	Light	Paper birch left
12	Control	Paper birch left
13	Clean	Paper birch left
14	Light	Paper birch left
15	Heavy	Thin
16	Clean	Thin
17	Heavy	Thin
18	Heavy	Thin
19	Control	Thin
20	Clean	Thin
21	Reference	Reference
22	Reference	Reference
23	Reference	Reference
24	Reference	Reference

Previous Work

- Stand development 25 years post-clearcut (Marquis 1969)
- Early financial analysis (McCauley and Marquis 1972)
- Crop-tree growth mid-rotation (Leak and Solomon 1997)
  - Species' growth responses variable
- Species and structural dynamics of the stand (Leak and Smith 1997)
  - No significant differences in the long term
- Financial analysis when stand was 56 and 69 years old (Leak and Sendak 2008).
- Stand growth, composition, and structure after 2003 commercial thinning (Leak 2015)

Part II:

Assessing Timber Quality and Financial Return Following Pre-commercial and Commercial Thinning

Research Objectives

- Assess if pre-commercial and commercial thinning treatments influence net timber value 80, 90 years post-harvest

Field Methods

- Tallied and measured all trees in plots 1-24 (species, height, merchantable height, DBH)
- Graded using Hardwood Tree Grades for Factory Lumber (Hanks 1976)
- Given potential grade assuming 2.54 cm diameter growth in 10 years
  - Diameter limiting factor of grade

Analysis

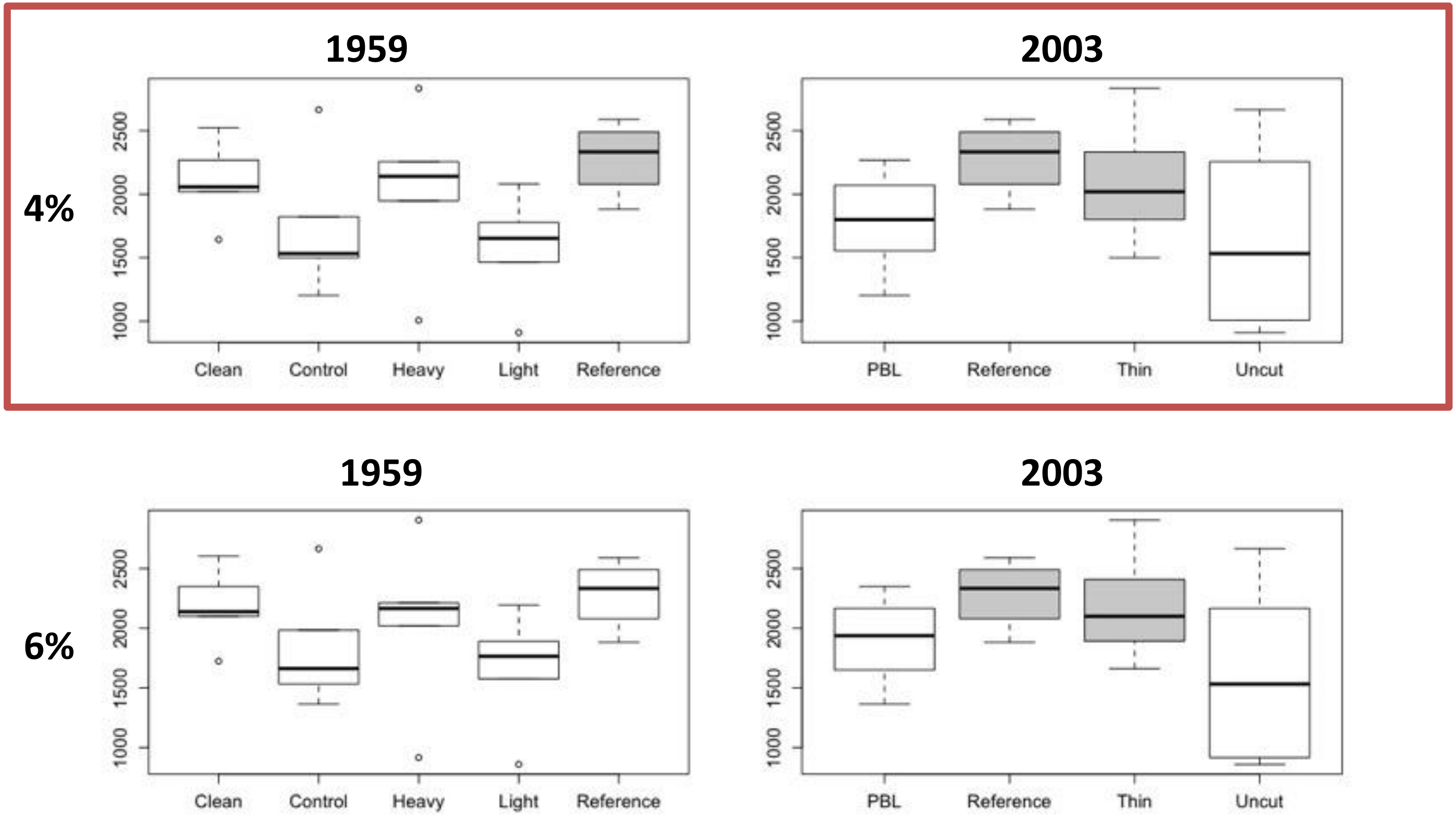
- Excluded Grade 4 trees from analysis
- Calculated value of each tree using Timber Buyer's Network, prices from 2016 Northern Hardwood Market Report
- Plot totals for 2016 and 2026, and 2026 with 2% market price increase
- Subtracted pre-commercial costs
  - Compounded at 4% and 6% interest
- Added revenue from commercial thinning
  - Compounded at 4% and 6% interest
- Net timber value per treatment plot

Data Analysis

- Bayesian linear regression models in *rjags*
- 1959 and 2003 thinning treatments as binary predictor variables
- Net timber value as response variable
  - Different depending on valuation year, interest rate, and market value increase

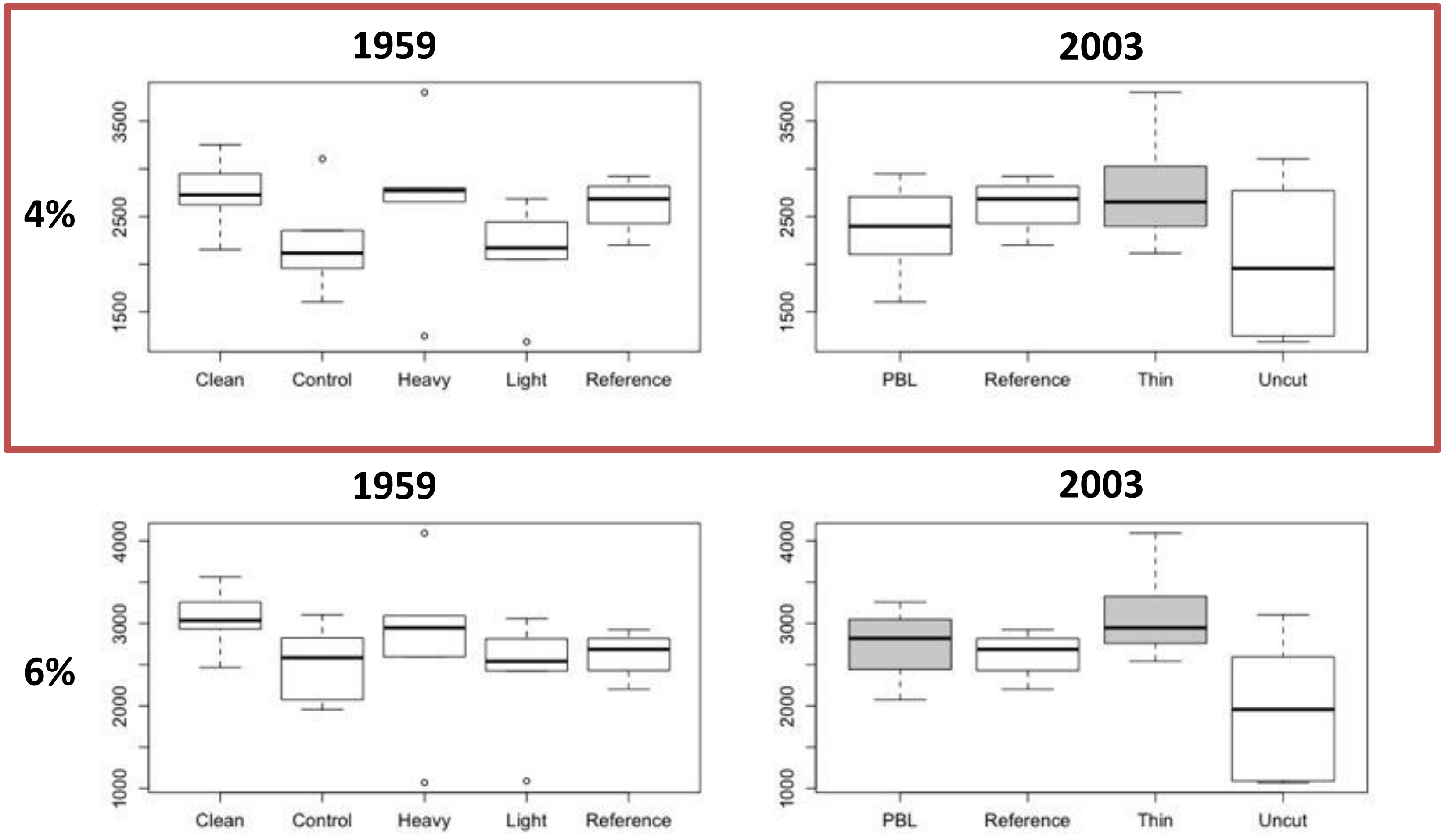
	Regression Model	Valuation Year	Thinning Treatment Year	Interest Rate	Market Value Increase
A	1	2016	1959	4%	0%
	2	2016	2003	4%	0%
	3	2016	1959	6%	0%
	4	2016	2003	6%	0%
B	1	2026	1959	4%	0%
	2	2026	2003	4%	0%
	3	2026	1959	6%	0%
	4	2026	2003	6%	0%
C	1	2026	1959	4%	2%
	2	2026	2003	4%	2%
	3	2026	1959	6%	2%
	4	2026	2003	6%	2%

Results: Net Timber Value 2016



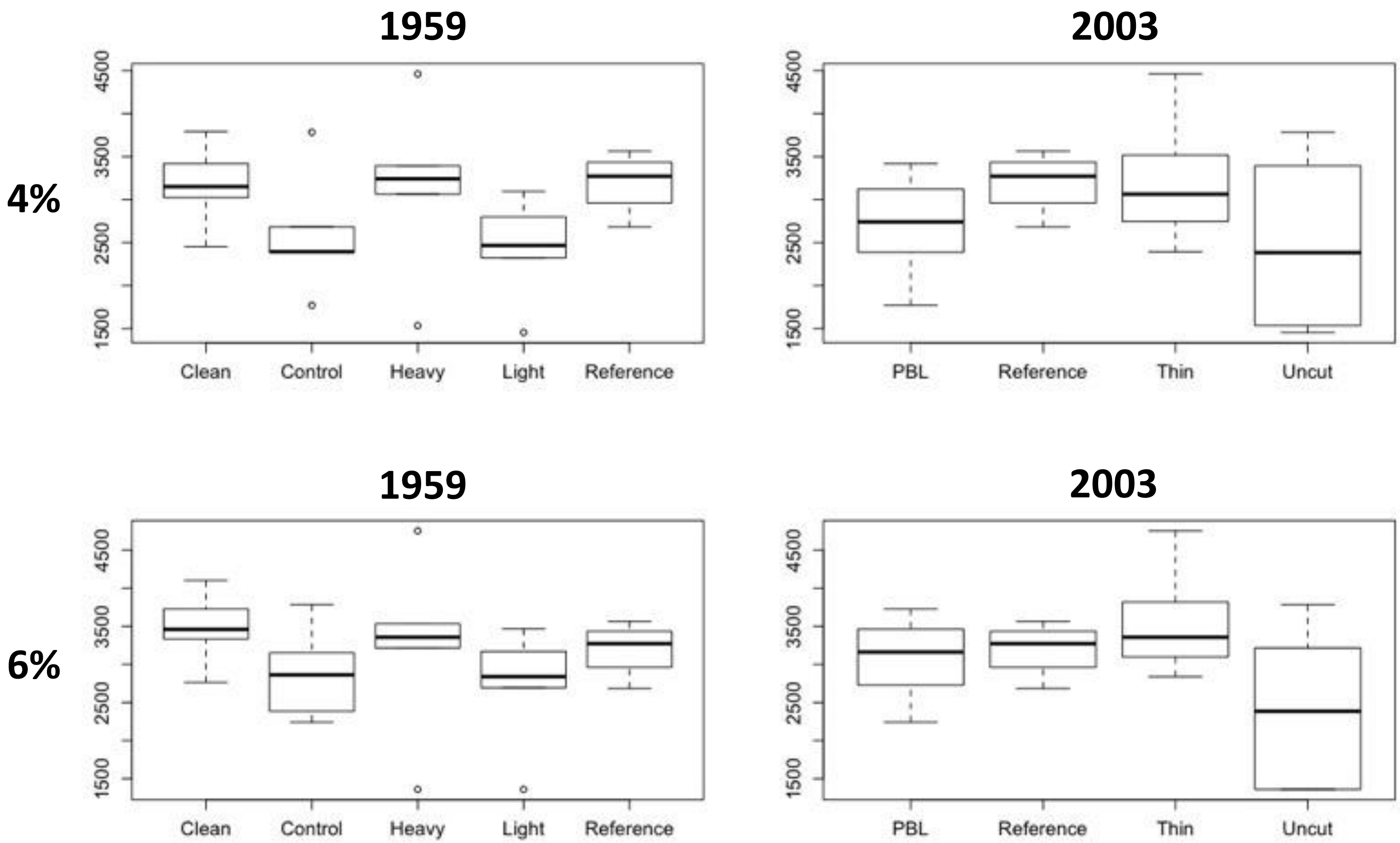
- 1959 treatments at 4% interest, reference plots worth $475.07 (CI: $20.28, $911.1) more than mean intercept value
- 2003 treatments at 4% interest, thinned plots worth $473.80 (CI: $61.26, $880.20) more, reference plots worth $502.80 (CI: $40.29, $948.20) more than mean intercept value

Results: Net Timber Value 2026



- No significant difference among 1959 treatments at 4% interest
- Plots thinned in 2003 at 4% interest worth $635.40 (CI: $155.48, $1,087.00) more than mean intercept value

Results: Net Timber Value 2026 with 2% Market Value Increase



- No significant differences among any treatments

Conclusions: Economic Assessment

- For both 2016 and 2026 end-points, **pre-commercial thinning not worth the investment** at either low or high interest rates
- Commercial thinning increases plot value, due to mid-rotation revenue
  - At 2016, low interest rate, **reference** and thinned plots worth more
  - At 2016, high interest rates, **thinned** and reference plots worth more
  - At 2026, low interest rate, thinned plots worth more
  - At 2026, high interest rates, **thinned** and plots with paper birch left worth more

Part III:

Ecological Outcomes of Pre-commercial and Commercial Thinning

Background

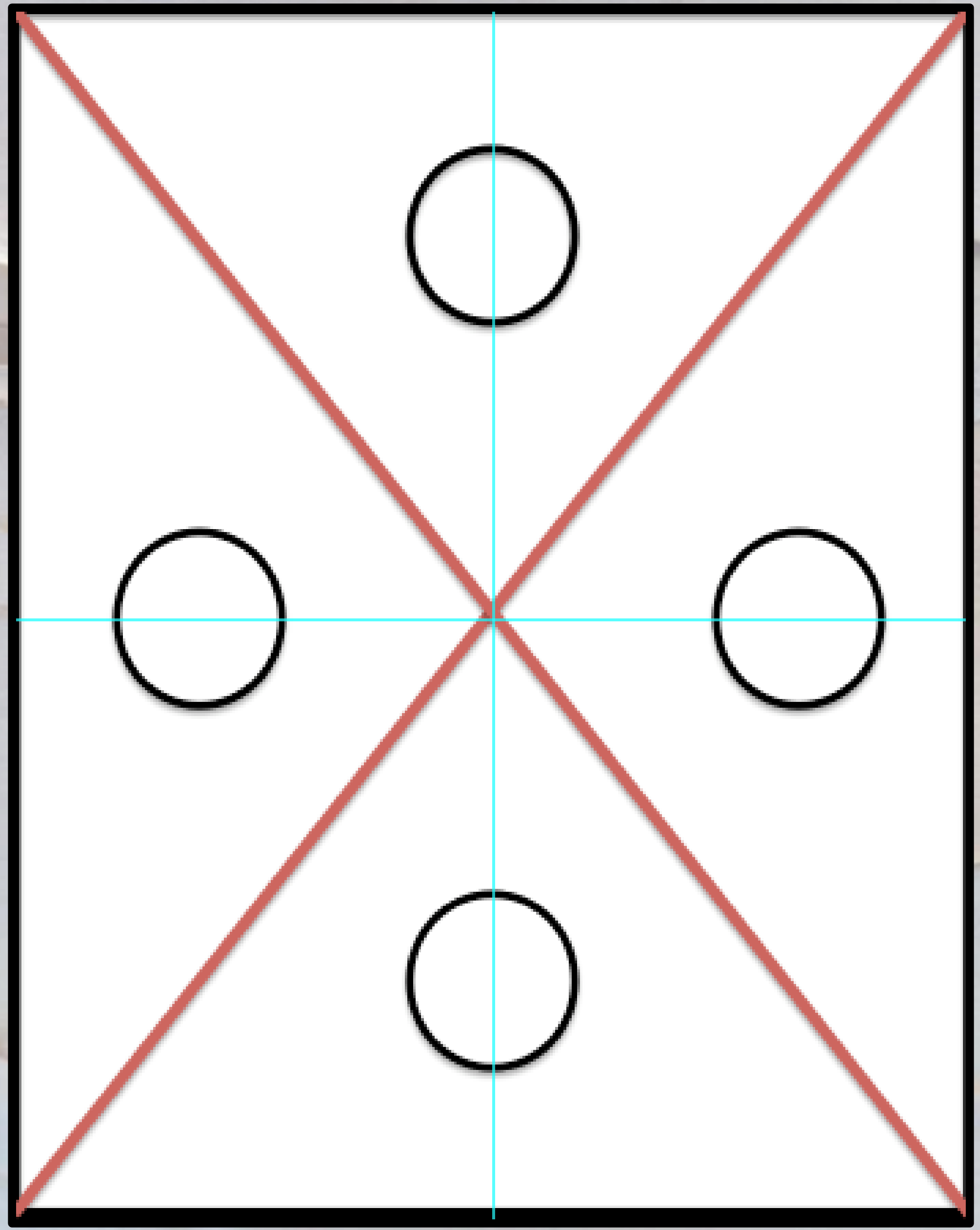
- Understory species influence forest regeneration, wildlife habitat, water and nutrient cycling, and forest productivity (Metzger and Schultz 1984)
  - Conflicting results in literature on effects of harvesting on diversity in the long term
  - Light availability, site characteristics influence understory species compositional development post-harvest (Duguid et al. 2013)
- Coarse woody debris for nutrient cycling and carbon storage in forest ecosystems (Goodburn and Lorimer 1998, Janisch and Harmon 2002)
  - 40 northern hardwood vertebrate species dependent on down dead wood for habitat (DeGraaf et al. 2005)
- Snags provide shelter, foraging sites, roosts (Healy et al. 1989, Goodburn and Lorimer 1998, Leak and Yamasaki 2006)

Research Objective

- Assess if pre-commercial and commercial thinning in northern hardwood forests influence:
  - Understory species composition
  - Down dead wood volume and abundance
  - Snag density and abundance

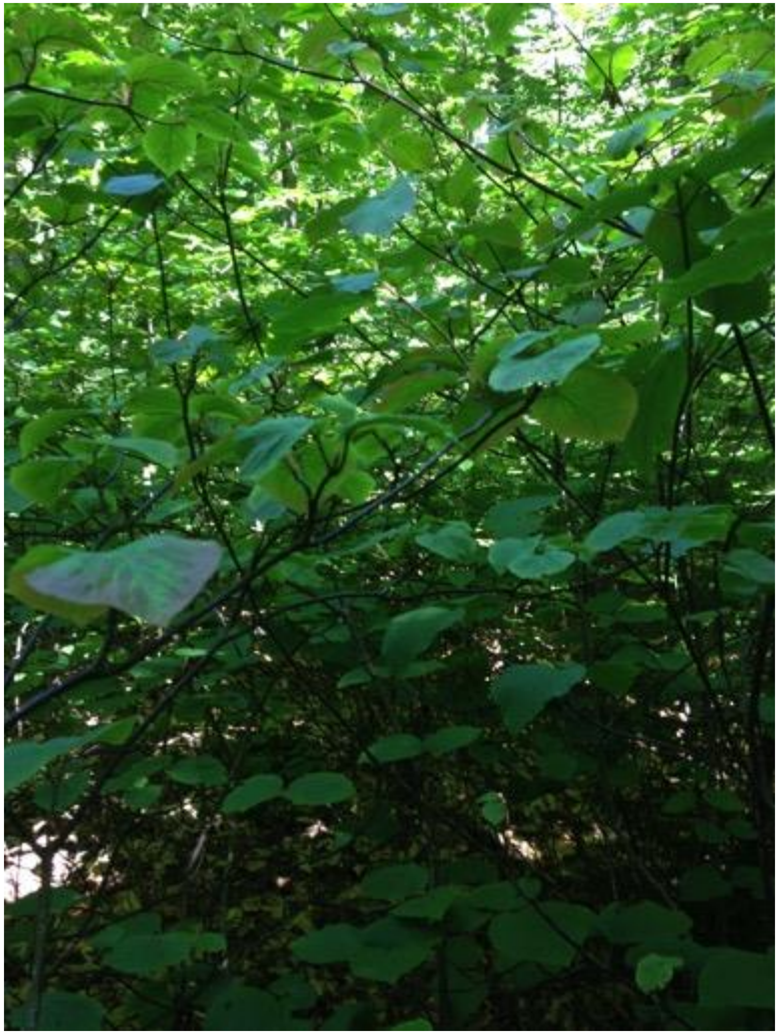
Field Methods

- Measured down dead wood using line intersect sampling
- Tallied snags in each plot, measured DBH, height
- Understory
  - Tallied all species < 3 m tall from four, 4.046 m^2 plots in each 1/10 hectare plot



Analysis: Understory

- Understory
  - 1959, 2003 treatments, elevation, riparian adjacency, skid road adjacency
  - Multivariate analysis in *vegan*
    - Nonmetric multidimensional scaling
    - Multiplicative response permutation procedure
    - Indicator species analysis



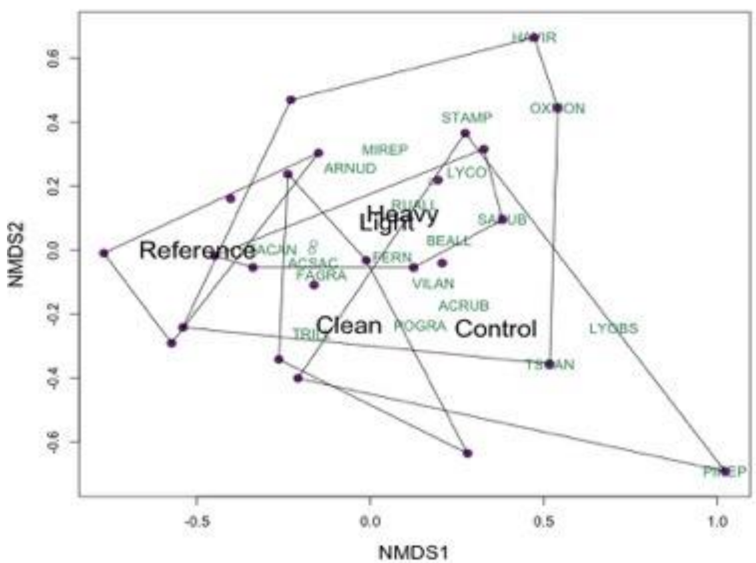
Analysis: Down Dead Wood

- Determine volume/ha, pieces/ha for each plot
- Bayesian linear regression models in *rjags*
- 1959 and 2003 thinning treatments as binary predictor variables
- Volume/ha, pieces/ha as response variables

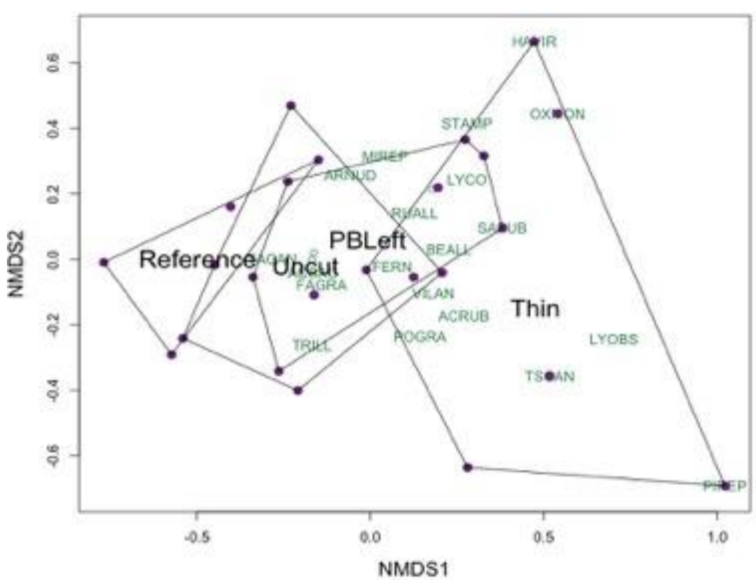
Analysis: Snags

- Determine basal area/ha, snags/ha for each plot
- Bayesian linear regression models in *rjags*
- 1959 and 2003 thinning treatments as binary predictor variables
- Basal area/ha, snags/ha as response variables

Results: Understory



- *NMDS:* species abundance, composition within plots with overlay of 1959 treatments
- *MRPP:* no significant differences among 1959 treatments (p=0.07), skid road adjacency (p=0.286), or riparian adjacency (p=0.103)



- *NMDS:* species abundance, composition within plots with overlay of 2003 treatments
- *MRPP*: Significant differences among 2003 treatments (p=0.001), elevation class (p=0.009)

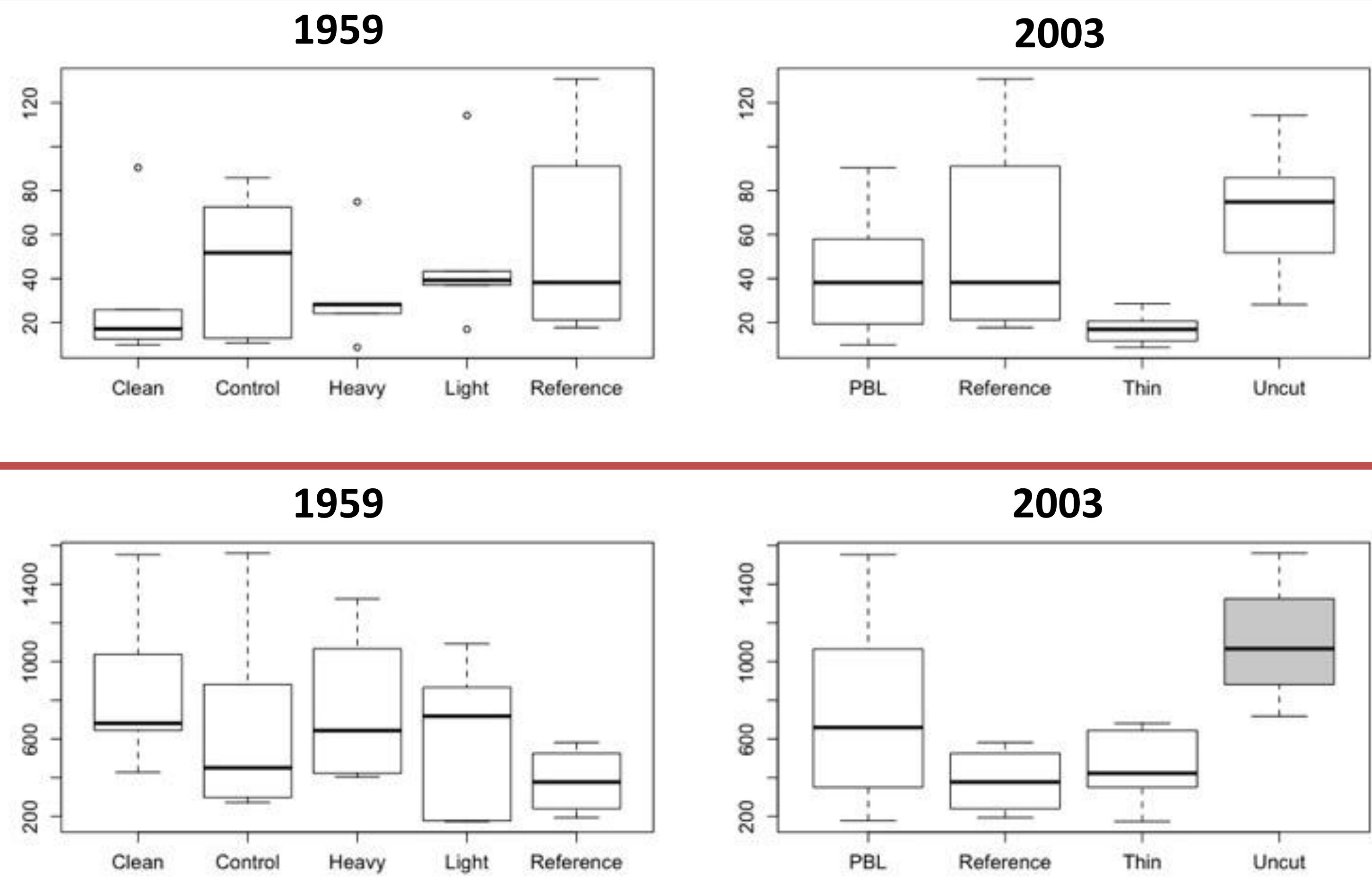
Results: Understory

Group	Cluster	Species	Indicator Value	p-value
1959 Treatment	Reference	*Fagus grandifolia*	0.5994	0.006
2003 Treatment	Reference	*Fagus grandifolia*	0.6762	0.002
	Reference	*Fraxinus americana*	0.4654	0.010
	Paper birch left	*Rubus allegheniensis*	0.5720	0.016
	Thin	*Viburnum latanoides*	0.5023	0.038
	Thin	*Lycopodium obscurum*	0.4286	0.050
	Uncut	*Acer pensylvanicum*	0.4155	0.006
Riparian Area	no	*Acer pensylvanicum*	0.6913	0.017
	yes	*Lycopodim spp*	0.608	0.041
	yes	*Lycopodium obscurum*	0.3855	0.038
Skid Road	no	*Fagus grandifolia*	0.7952	0.049
	yes	*Mitchella repens*	0.9785	0.001
	yes	*Aralia nudicaulis*	0.8053	0.005
	yes	*Lycopodim spp*	0.5477	0.045
	yes	*Rubus allegheniensis*	0.5374	0.026
Elevation Class	335-365 m	*Acer rubrum*	0.5976	0.007
	335-365 m	*Lycopodium obscurum*	0.5521	0.013
	365-396 m	*Taxus canadensis*	0.7716	0.005

Results: Down Dead Wood

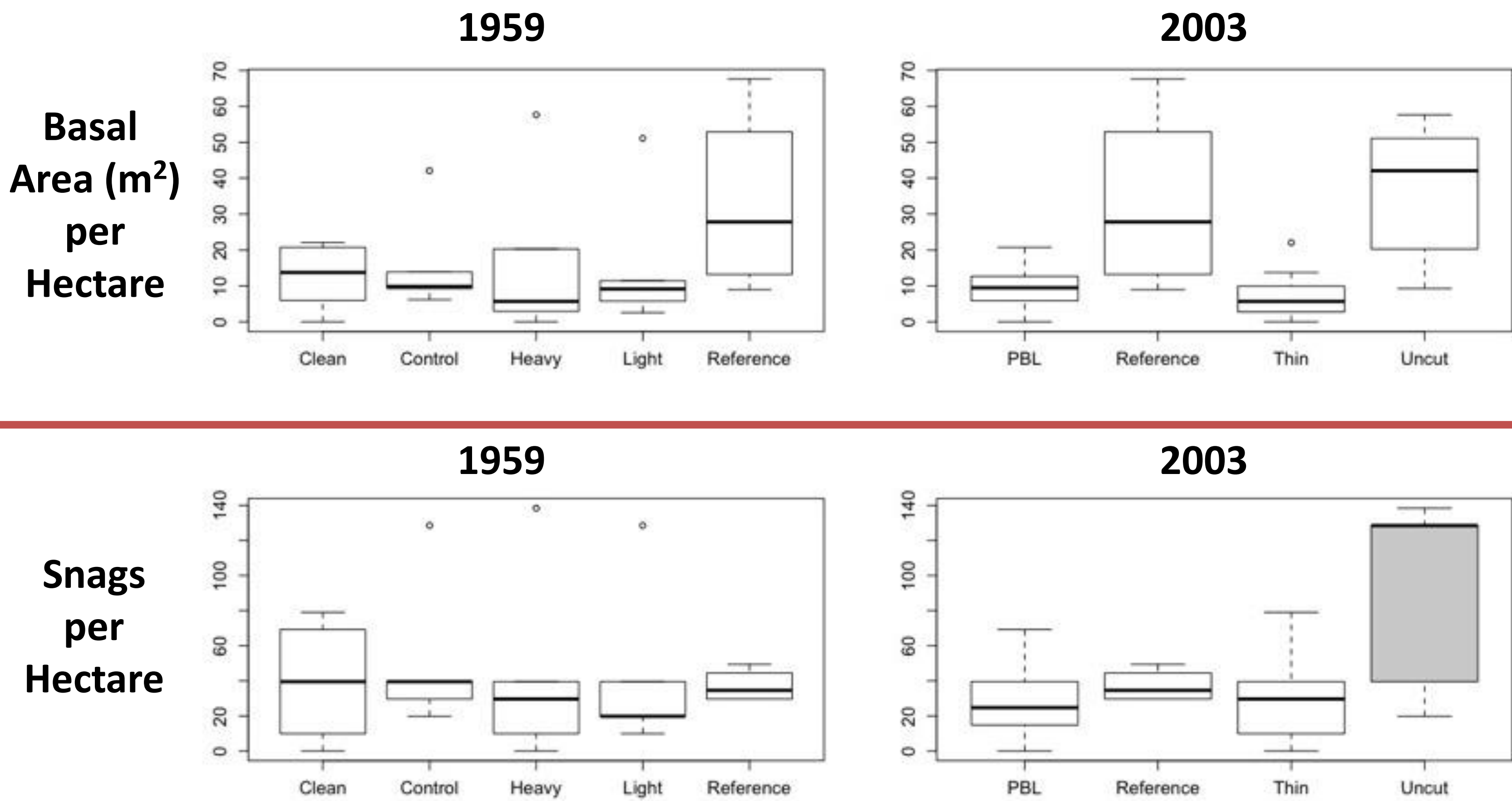
Volume per Hectare (m^3)

Pieces per Hectare



- No significant differences in volume/ha among 1959 or 2003 treatments
- No significant difference in pieces/ha among 1959 treatments
- Uncut plots in 2003 have an average of 471.1 (CI: 93.58, 840) more pieces/ha than mean intercept value

Results: Snags



- No significant differences in snag basal area/ha among 1959 or 2003 treatments
- No significant difference in snags/ha among 1959 treatments
- Uncut plots in 2003 have an average of 43.359 (CI: 8.746, 81.2) more snags/ha than mean intercept value

Conclusions: Ecological Assessment

- Pre-commercial thinning had no effect on understory species composition, down dead wood volume or abundance, snag density or abundance
  - Understory species resilient over long term
  - Dead wood decayed over time
- Commercial thinning influenced understory species
  - Increased light availability, soil disturbance alter habitats
- Pieces of down dead wood, snags per hectare significantly greater in plots that were not commercially thinned in 2003
  - Paper birch, aspen remaining reached maturity and died

Part IV:
Management Applications

Management Applications

- No significant differences in economic return or measured ecological impacts from pre-commercial thinning
- Some significant differences in economic return from commercial thinning
  - Harvest of paper birch and aspen appropriate when abundant in stand
  - Minimize logging damage to protect tree grade
- Loss of down dead wood, snags from commercial thinning
  - Retain some paper birch and aspen for habitat if there is concern regarding associated wildlife species

Current Research

- Economic and Ecological Impacts of Timber Stand Improvement Practices in New Hampshire
  - Private and public returns
  - Ecosystem services: snags, CWD, understory vegetation, and C storage.

Photo: Mackenzie Kalp

Current Research

- Study Site
  - 7,000 acres of Blue Hills Foundation Forest, Strafford, NH
  - Records for 1400 acres of TSI work, mostly girdling, spanning 20 years

Photo: Mackenzie Kalp

Acknowledgements

- New Hampshire Agricultural Experiment Station
- University of New Hampshire: Dr. Mark Ducey and Dr. Jenica Allen; Maitland Ianiri, field assistant.
- USDA Forest Service Northern Research Station: William Leak, Christine Costello and Mariko Yamasaki

QUESTIONS?

Hardwood Tree Grades for Factory Lumber (Hanks 1976)

Grade Factor	Tree Grade 1	Tree Grade 2	Tree Grade 3
Length of grading zone (feet)	Butt 16	Butt 16	Butt 16
Length of grading section (feet)	Best 12	Best 12	Best 12
DBH, minimum (inches)	16[a]	13	10
Clear cuttings (on 3 best faces): length, minimum (feet)[c]	5	3	2
Cull deduction, including crook and sweep, excluding shake, maximum within grading section (%)	9	9	50

Prices from NHWMR 2016

Species	Kiln-dried price ($/MBF)
White ash	$1,050
Aspen	$795
Birch	$1,170
Sugar maple	$1,205
Red maple	$1,165
Beech	$727

Multivariate Analysis

- NMS to visualize and quantify differences in species composition among plots
  - Avoids the assumption of linear relationship among variables, effective ordination for ecological data
  - Bray-Curtis distance, with random starting configurations and 20 runs with real data
  - Dimensionality starting with 6 dimensions, decreasing dimensions for best fit until the final solution reached with 3 dimensions, where stress = 9.97
- MRPP
  - Nonparametric procedure for testing hypotheses positing no difference between multiple groups.
  - No distributional assumptions
  - Euclidean distance, 999 free permutations
- ISA works well alongside an MRPP and gives good description of how species present separate among groups

Bayesian Model Specifications

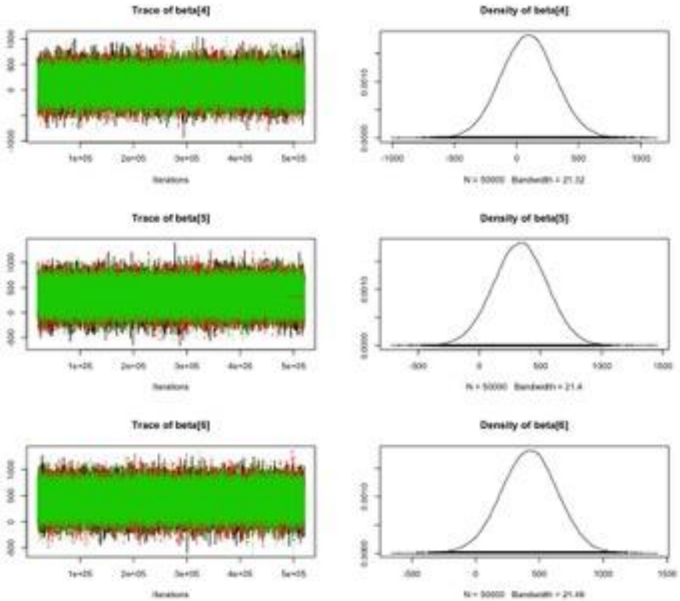
	Regression Model	Valuation Year	Thinning Treatment Year	Interest Rate	Market Value Increase	Number of Iterations	Discarded Burn-in Iterations[a]	Thinning Interval[b]	Final Posterior Sample Size[c]
A	1	2016	1959	4%	0%	500,000	25,000	10	50,000
	2	2016	2003	4%	0%	400,000	20,000	5	80,000
	3	2016	1959	6%	0%	500,000	20,000	10	50,000
	4	2016	2003	6%	0%	500,000	25,000	10	50,000
B	1	2026	1959	4%	0%	600,000	20,000	10	60,000
	2	2026	2003	4%	0%	600,000	20,000	10	60,000
	3	2026	1959	6%	0%	400,000	20,000	10	40,000
	4	2026	2003	6%	0%	500,000	20,000	10	50,000
C	1	2026	1959	4%	2%	550,000	20,000	10	55,000
	2	2026	2003	4%	2%	700,000	25,000	10	70,000
	3	2026	1959	6%	2%	500,000	20,000	10	50,000
	4	2026	2003	6%	2%	650,000	30,000	10	65,000

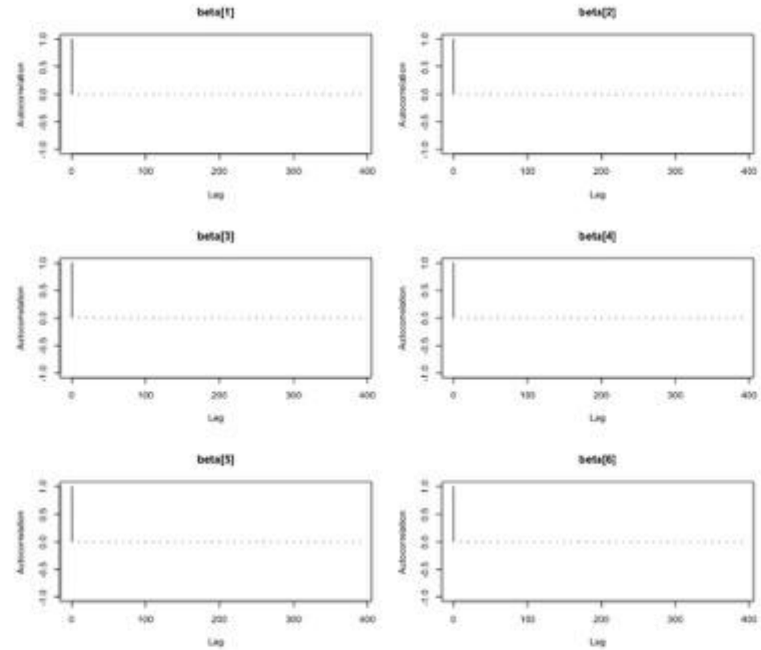
[a] Iterations are discarded as burn-ins so the starting point of the chains are random (Kass et al. 1997).
[b] The thinning interval is used to reduce autocorrelation in MCMC sampling chains.
[c] Final posterior sample size is the number of samples generated in the posterior distribution, or the posterior density

Bayesian Model Specifications

Response Variable	Thinning Treatment Year	Uninformative Prior Distribution	Number of Iterations	Discarded Burn-in Iterations[a]	Thinning Interval[b]	Final Posterior Sample Size[c]
Volume (m^3)/ha	1959	(0, 0.02)	5,000,000	100,000	150	33,334
Volume (m^3)/ha	2003	(0, 0.03)	5,000,000	100,000	150	33,334
Pieces/ha	1959	(0, 0.00001)	2,000,000	100,000	10	2,050,000
Pieces/ha	2003	(0, 0.00001)	3,000,000	200,000	10	3,050,000

Response Variable	Thinning Treatment Year	Uninformative Prior Distribution	Number of Iterations	Discarded Burn-in Iterations[a]	Thinning Interval[b]	Final Posterior Sample Size[c]
Basal area (m^2)/ha	1959	(0, 0.001)	1,000,000	60,000	20	50,000
Basal area (m^2)/ha	2003	(0, 0.001)	3,000,000	75,000	30	1,050,000
Snags/ha	1959	(0, 0.001)	1,000,000	75,000	10	1,050,000
Snags/ha	2003	(0, 0.001)	3,000,000	75,000	10	3,050,000


Trace of beta[4]
Density of beta[4]
Trace of beta[5]
Density of beta[5]
Trace of beta[6]
Density of beta[6]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beta[2]
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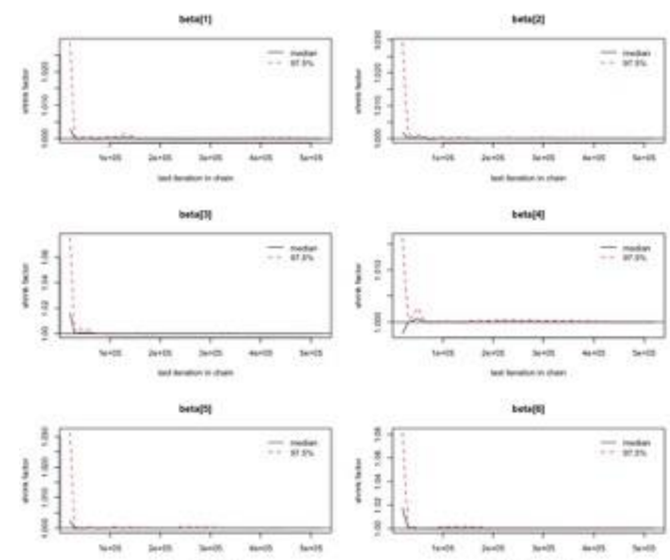
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