

Using Pioneering Growth and Yield Studies to Inform Management and Modeling

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Cooperators:

- U.S. Forest Service, Northern Research Station and White Mountain National Forest
- Paul Smith's College

Completion Date:

- May 2011

Summary: Archived, unpublished, and remeasurement data from long-term U.S. Forest Service studies were used to generate new findings about responses to silviculture, inform contemporary forest management, and strengthen modeling efforts in the Northern Forest region.

Funding support for this project was provided by the Northeastern States Research Cooperative (NSRC), a partnership of Northern Forest states (New Hampshire, Vermont, Maine, and New York), in coordination with the U.S. Forest Service (<http://www.nsrcforest.org>) and by the University of Maine, School of Forest Resources.

Project Summary

Despite more than a century of research in the Northern Forest, many forest management questions remain unanswered. The most important include long-term growth response to silviculture, drivers of stand dynamics, and variability of growth and yield. Archives from U.S. Forest Service studies established between the 1920s and 1960s in the northern conifer (previously called eastern spruce-fir) forest type present an opportunity for addressing these research questions. In addition to data from long-term studies at the Penobscot Experimental Forest (EF), we attempted to recover data from the now-closed Finch-Pruyn and Paul Smith EFs in New York, the Gale River EF in New Hampshire, and other studies on commercial forestland in Maine. Incomplete records, data, and metadata from historical studies limited their utility, though some experimental plots were relocated. Ultimately, we used archived, unpublished, and remeasurement data to generate new findings, inform contemporary forest management, and strengthen regional modeling efforts. Key outcomes include documentation of the history of Forest Service research in northern conifers, development of recommendations for record management, new datasets for growth and yield model development and validation, and a focused study of the effects of browsing on northern conifer regeneration and recruitment.

Background and Justification

Though Forest Service research in northern conifers is now primarily conducted on the Penobscot EF in Maine, this forest type was initially the focus of research by the Northeastern Forest Experiment Station (now Northern Research Station). In fact, the first study initiated after the Station was established in 1923 was an investigation of spruce-fir growth and yield. The first EF in the Station was the 1,365-acre Gale River EF on the White Mountain National Forest in New Hampshire; work began there in 1927. Studies directed by Marinus Westveld (the Father of Spruce-Fir Silviculture) investigated the role of partial cutting in establishing softwood regeneration and accelerating the growth of crop trees. The 1938 New England Hurricane destroyed many of the experiments. Though some studies were resurrected, the Gale River EF was disestablished in 1958.

Marinus Westveld (left) at the Gale River Experimental Forest (note peeled spruce). Photo courtesy of the U.S. Forest Service.



Background and Justification

Though the Gale River EF and regional growth and yield plots were the primary sources of northern conifer data in the first half of the twentieth century, another study in this forest type had been established by the Forest Service in 1934: the 623-acre Finch-Pruyn EF in Newcomb, New York. The 2,200-acre Paul Smith's EF was added in 1945 and the two forests were administratively combined under the Adirondack Research Center; research included timber stand improvement, cutting methods demonstration, and a compartment- (or stand-) level study of silvicultural treatments in spruce-fir and mixedwoods. The EFs were disestablished and turned over to Paul Smith's College in 1961.



Photo courtesy of the U.S. Forest Service.

Background and Justification

The 1938 hurricane, aftermath, and World War II motivated Station leadership to reflect on future direction. It was decided that replicated compartment-level studies were desirable. One such study was established in cooperation with forest industry and the University of Maine: the 3,800-acre Penobscot EF in Bradley, Maine. The experiment included silvicultural treatments applied to demonstration areas and approximately 20-acre compartments (management units, MUs); this work has largely continued to the present. In addition to their work on the Penobscot EF, Forest Service scientists conducted a number of growth and yield studies on industry land in the 1950s and 1960s. A regional study of the influence of soils and site on growth of spruce-fir and mixedwoods is of particular interest; measurements of more than a dozen stand, site, and soil variables were made over 10 years.

Photo courtesy of the U.S. Forest Service.



Methods: Overview

This research was conducted by University of Maine, School of Forest Resources M.S. student Kate Berven under the direction of the PIs. Berven's thesis included three chapters:

1. The lost research of early northeastern spruce-fir experimental forests
2. Sapling recruitment on the Penobscot Experimental Forest: How long-term data can provide information about stand dynamics
3. Seedling herbivory in the Acadian Forest

Chapter 1 reports the history of spruce-fir experimental forests in the Northern Forest, based on literature and archive reviews, and site visits and sampling. Chapters 2 and 3 quantify regeneration and recruitment dynamics using data from long-term silvicultural experiments on the Penobscot Experimental Forest.

Additional work by the PIs related to this study included evaluating long-term predictions by the Northeast Variant of the Forest Vegetation Simulator (FVS-NE), compiling an extensive soil-site study collected in the 1960s, and analyzing trends from a regional dataset collected in the 1970s.

Results: Historical Studies

U.S. Forest Service research records and data from the Paul Smith and Finch Pruyn EFs were found in the basement of a dormitory at Paul Smith's College in 2009. These files have been made available for on-site review and there are plans to digitize the records in the future. Preliminary site visits suggest that while some of the compartments have been harvested, others remain intact and may yield worthwhile re-measurement data.

Residual tree from U.S. Forest Service research, on the Paul Smith College Forest (2010). Photo courtesy of the U.S. Forest Service.



Results: Historical Studies

Some Gale River EF records were found in the attic of a field office in Maine in 2008. The bulk of the files had been sent to the Federal Records Center (FRC); the paperwork needed to recall those has been lost and efforts to locate the files through the FRC were unsuccessful. We visited the former Gale River EF in 2009 and found mortality from a 1980s windstorm, thinning by the White Mountain National Forest, and no field notes or data from the research conducted decades prior. We could not reopen the study, but monumented nine of ten blocks established by Westveld in 1933 and took measurements of species composition and stocking.

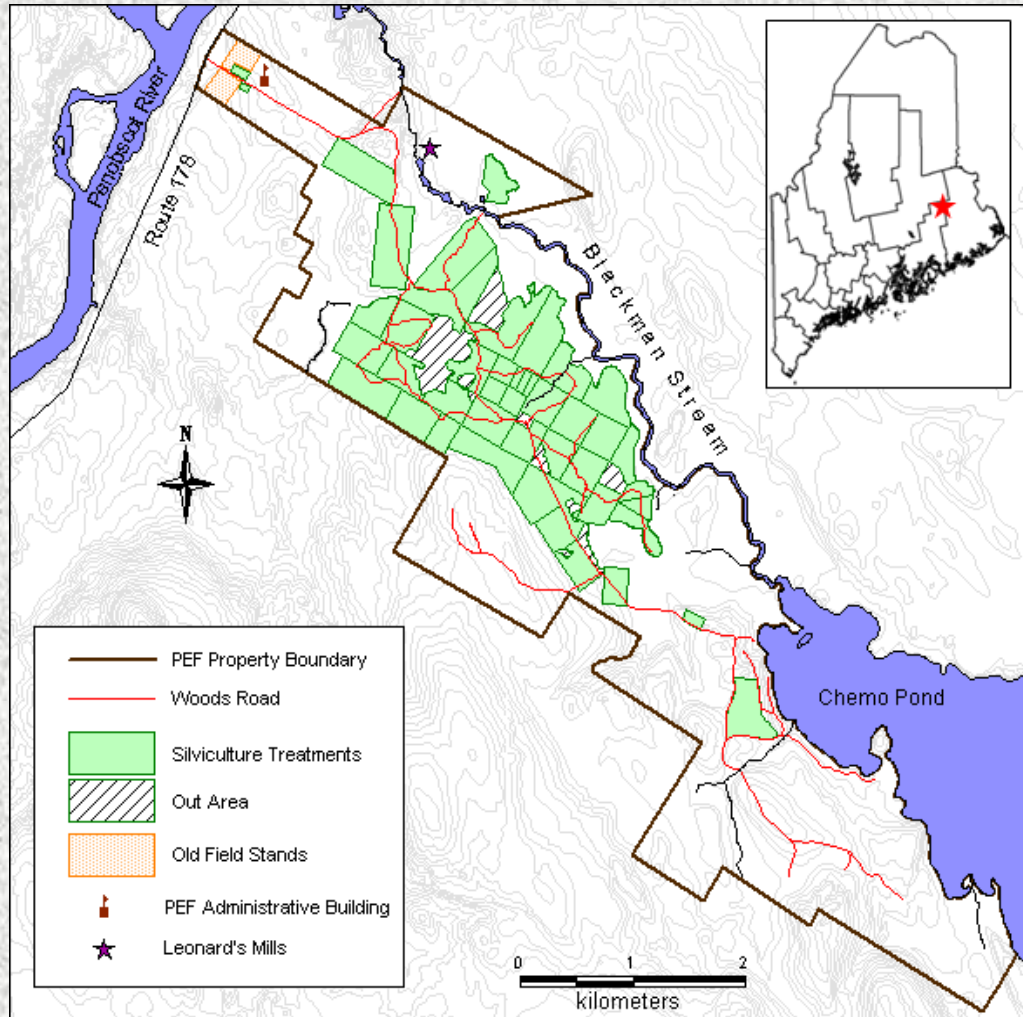
Kate Berven with a plot stake we found from the former Gale River EF (2009).
Photo courtesy of the U.S. Forest Service.



Using long-term data to quantify stand dynamics
following disturbance

**SAPLING RECRUITMENT ON THE
PENOBSCOT EF**

Methods: Study Area

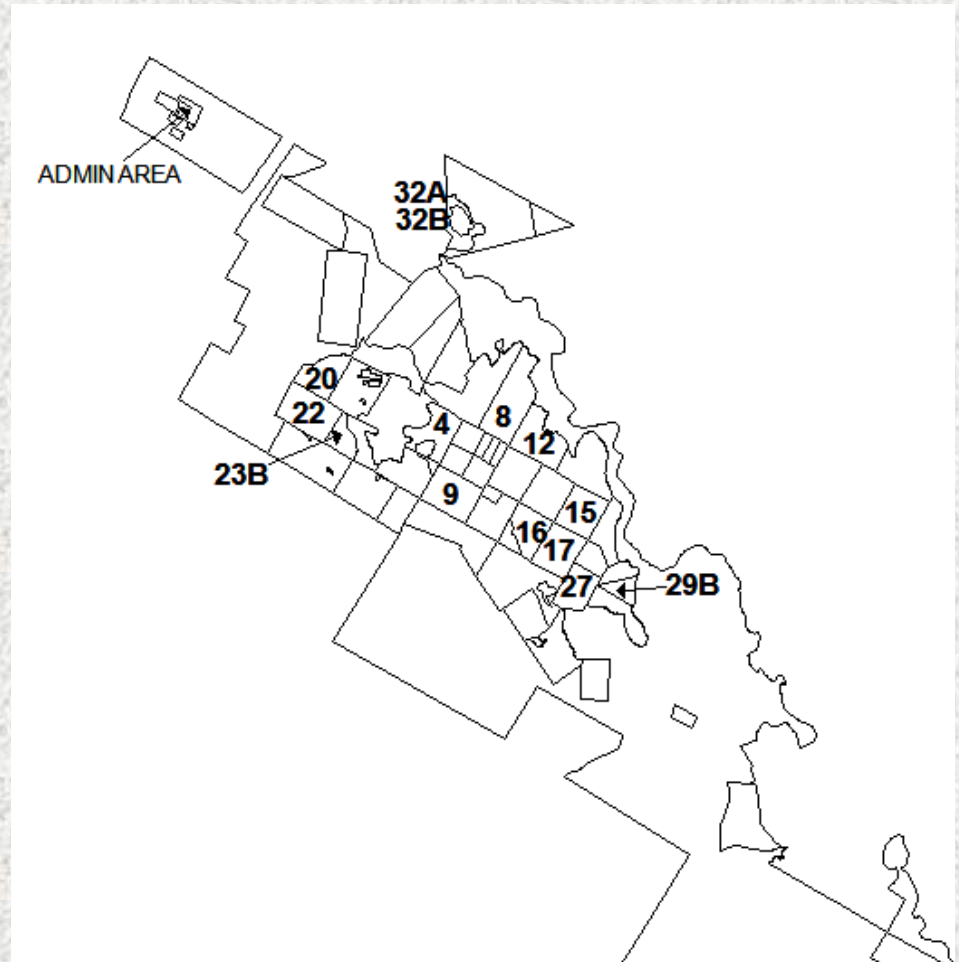


- Penobscot EF
- Bradley and Eddington, Maine
- Acadian Forest
- U.S. Forest Service
- Replicated silvicultural treatments established between 1952 and 1957

(Bryce 2009)

Methods: Treatments

- 5-, 10-, 20-year selection cuttings (S05, S10, and S20)
- Fixed diameter-limit cutting (FDL)
- 3-stage shelterwood (3SW)
- Commercial clearcutting (CC)
- Reference (UC)

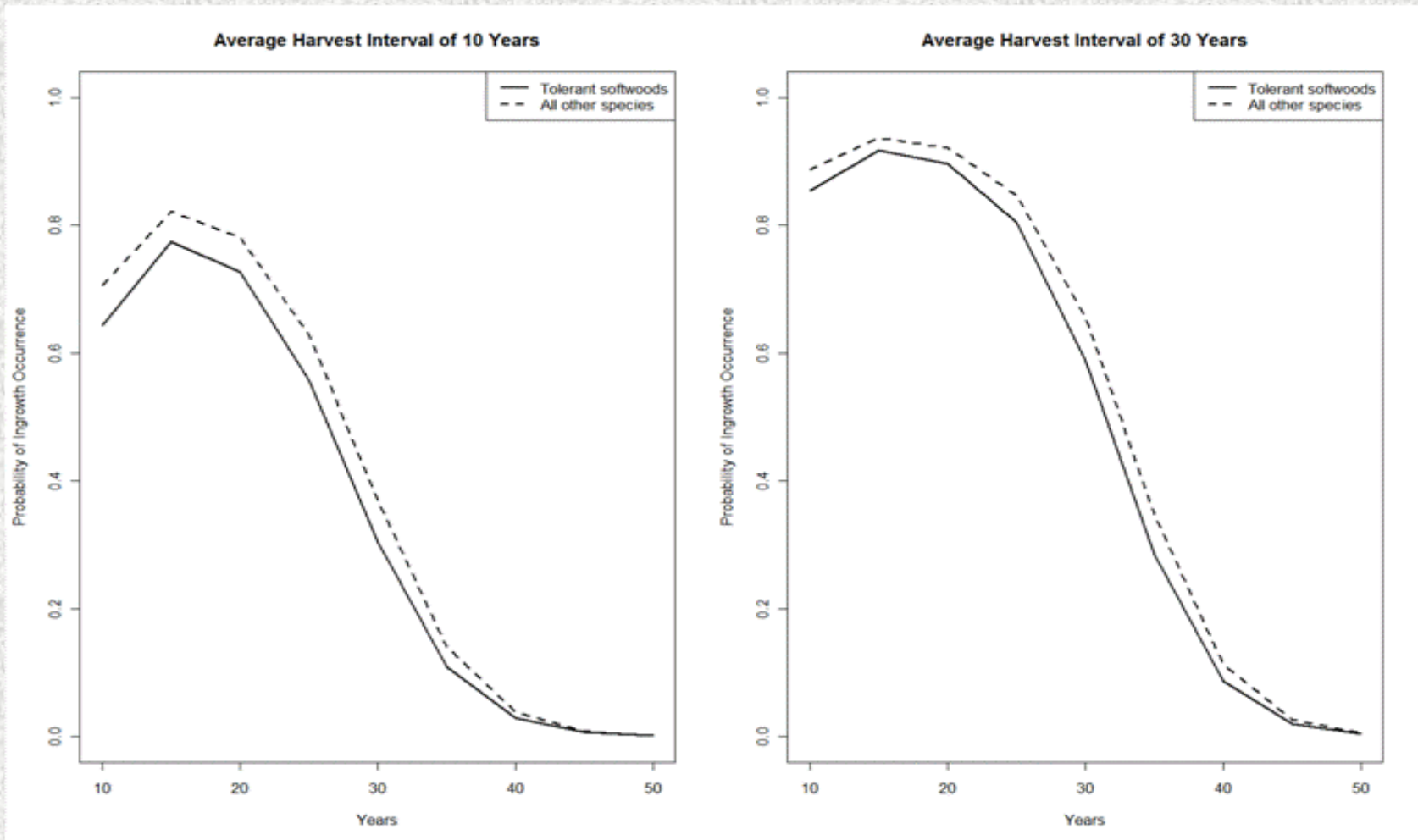


Methods: Data Preparation and Analysis

- Recruitment data beginning in 1977
 - Recruitment is defined as saplings not previously recorded (0.5 to 4.4 in dbh)
- All data used were from the Penobscot EF database
 - <http://www.fs.usda.gov/rds/archive/Product/RDS-2012-0008>
- Species grouped according to shade tolerance
- Zero inflated mixed model used to assess the probability and density of recruitment
 - Plot and compartment (management unit) were random effects

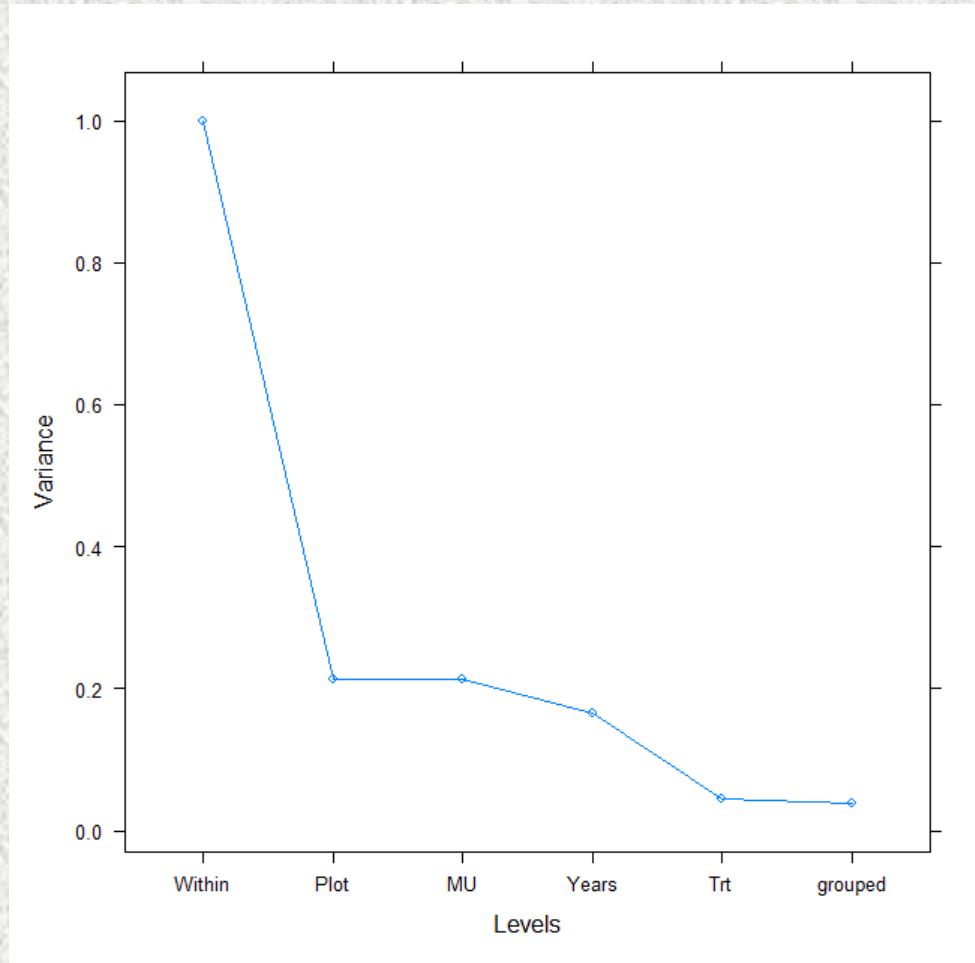
Species Group	Abbreviation	Associated Species
Intolerant Softwoods	ISW	Tamarack (<i>Larix laricina</i>); Red pine (<i>Pinus resinosa</i>)
Tolerant Softwoods	TSW	Balsam fir; Spruce spp.; Eastern hemlock; Northern white-cedar
Intermediate Softwoods	INTSW	Eastern white pine
Intolerant Hardwoods	IHW	Paper birch; Gray birch; Trembling aspen; Bigtooth aspen; Black cherry (<i>Prunus serotina</i>); Balsam poplar (<i>Populus balsamifera</i>); Pin cherry (<i>Prunus pensylvanica</i>)
Tolerant Hardwoods	THW	Sugar maple; American beech; Eastern hophornbeam (<i>Ostrya virginiana</i>); American basswood (<i>Tilia americana</i>); Striped maple (<i>Acer pensylvaticum</i>); Mountain maple (<i>Acer spicatum</i>)
Intermediate Hardwoods	INTHW	White ash; black ash (<i>Fraxinus nigra</i>); Yellow birch; Red maple; Northern red oak (<i>Quercus rubra</i>)

Results: Probability of Recruitment



Probability of recruitment a function of time since treatment establishment and harvest interval.

Results: Variance Component Analysis



Primary source of variance in the recruitment density model is within plot (i.e., across subplots within individual sample plots).

Results: Overview

- Management goals of northern mixed-conifer forests often aim to increase tolerant conifers and decrease hardwoods
- Highest densities of tolerant conifers were found in the three-stage shelterwood, but these species also do well under selection management
- Hardwoods typically higher following unregulated harvesting operations (commercial clearcutting and fixed diameter-limit cutting)
- Ingrowth peaked and began declining in three-stage shelterwood, as other (partial cutting) treatments continued to rise in ingrowth
- Recruitment in selection stands is continuous as partial overstory removals take place

Photo courtesy of the U.S. Forest Service.



Using a long-term study to address contemporary forest management problems



**SEEDLING HERBIVORY
IN THE ACADIAN FOREST
OF EAST-CENTRAL
MAINE**

Methods: Sampling

- Browsing was measured on each of 3 to 4 milacre regeneration plots located on each permanent sample plot in the MUs
- Each seedling was recorded by species, height class, whether it was browsed or not (1 – browsed, 0 – not browsed), animal group, and damage class

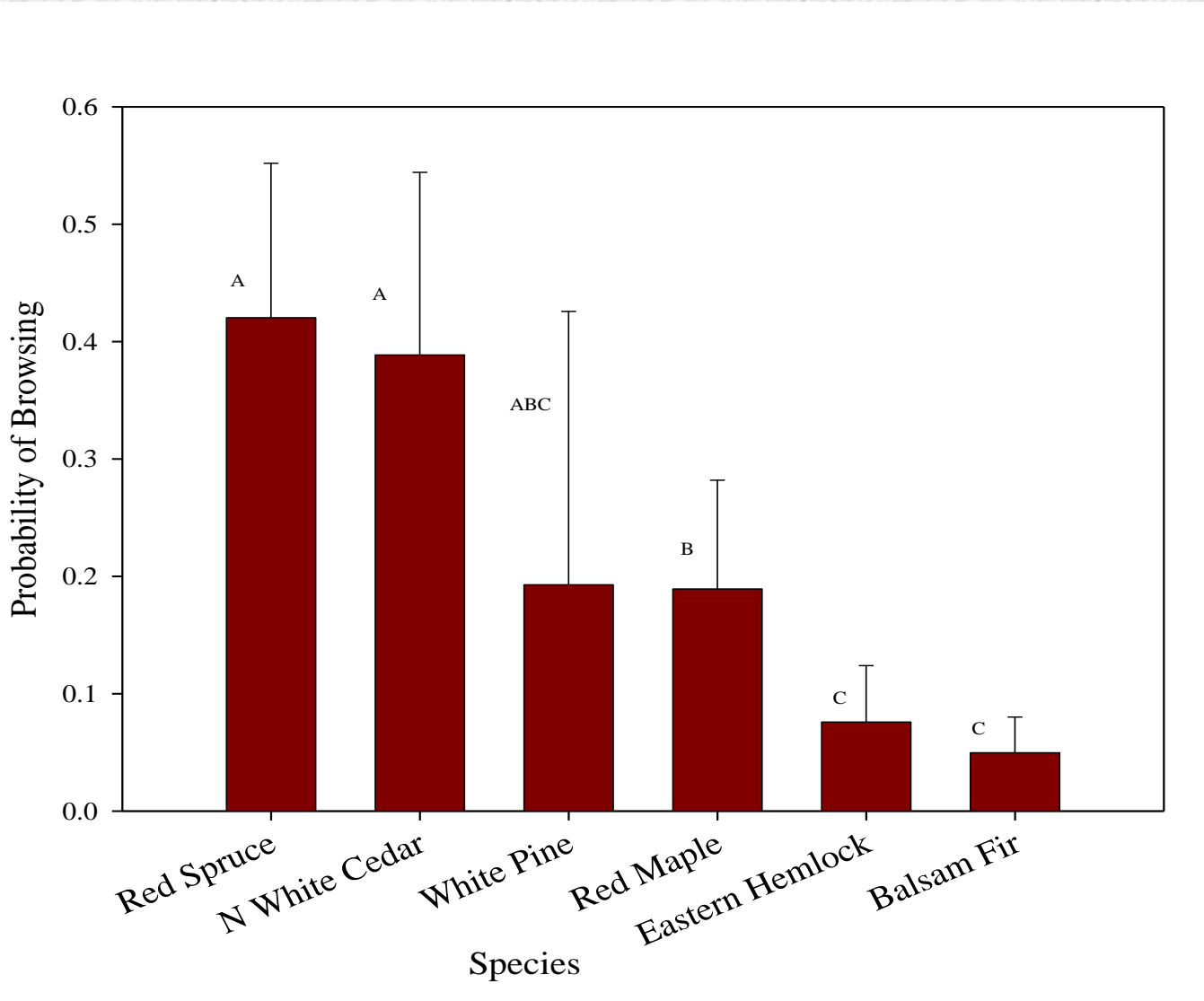
Damage Class	Percentage of Foliage Removed due to Browsing
1	< 25%
2	26% - 50%
3	51% - 75%
4	76% - 99%
5	100%

Class	Height
1	< 6"
2	6" – 1'
3	1.1' – 2.0'
4	2.1' – 4.5'
5	4.5' – 0.49" dbh

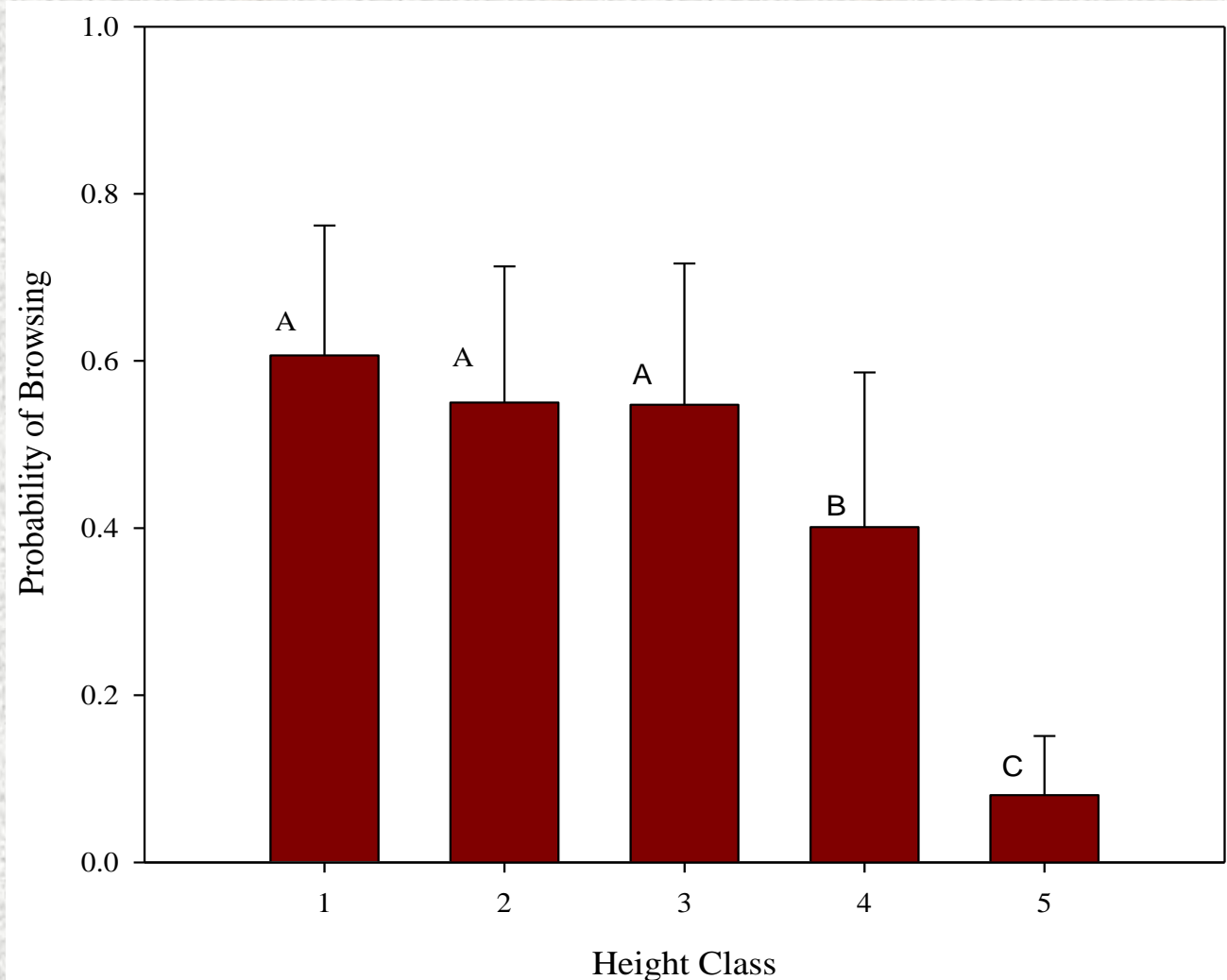
Methods: Statistical Analysis

	Dependent Variable	Independent Variables	Model Used
Tree-Level Analysis	Browsed or Not (1 or 0)	Species, Treatment, Height Class	Multiple Logistic Regression
Tree-Level Analysis	Damage Class	Species, Treatment, Height Class, Animal Group	Linear Mixed Effects Model
Plot-Level Analysis	Severity	Treatment	Linear Mixed Effects Model

Results: Probability of Browsing by Species



Results: Probability of Browsing by Height Class



Browsed

Species	No	Yes	N	Severity
American Beech	4	2	6	33.3%
Black Ash	53	17	70	24.3%
Black Cherry	0	6	6	100.0%
Balsam Fir	1827	89	1916	4.6%
Basswood	1	11	12	91.7%
Eastern Hemlock	773	61	834	7.3%
Gray Birch	6	5	11	45.5%
Ironwood	0	1	1	100.0%
Mountain Maple	0	1	1	100.0%
N White Cedar	142	46	188	24.5%
Paper Birch	18	9	27	33.3%
Pin Cherry	3	5	8	62.5%
Red Maple	2032	136	2168	6.3%
Red Oak	6	5	11	45.5%
Red Pine	0	1	1	100.0%
Red Spruce	243	145	388	37.4%
Sugar Maple	0	2	2	100.0%
Tamarack	1	0	1	0.0%
White Ash	5	20	25	80.0%
White Pine	41	5	46	10.9%
White Spruce	2	0	2	0.0%
Yellow Birch	6	25	31	80.6%

Results: Browsing Severity

Results: Overview

- There is little in the literature suggesting that red spruce is a favored browse species, yet we found a significant impact by hare and rodents
 - 37% of red spruce seedlings were browsed
- Deer populations are high
 - Currently, there are 15-25 deer per square mile in central and southern Maine (Maine IF&W)
 - 25% of northern white-cedar seedlings were browsed
- Browsing should be considered in forest management plans where herbivores are present
- Probability of browsing goes down as height class increases
 - Release treatments may be beneficial in achieving faster height growth on slower growing conifers



Implications: Overview

- Long-term studies
 - Provide valuable information that is difficult to otherwise obtain
e.g. Penobscot EF recruitment data
 - Retention and care for records is imperative for future use
- Data from historical studies can be applied to contemporary forest management questions
- Long-term data inform and improve forest growth modeling efforts
- Long-term data are easily lost and require special attention
- Value of long-term data will continue to increase with time given that it is properly documented and maintained

Future Directions

- Paul Smith EF archive will be reviewed and digitized.
 - Cutting Practice Level plots may be re-established and re-inventoried, in cooperation with Paul Smith's College faculty.
- Creation of digital archive of Penobscot EF records in underway.
 - Online access to records is a long-term goal; raw data are already available through the Research Data Archive.
- Additional research on species-specific recruitment dynamics, long-term dynamics of browsing, and effect of browsing on competing species (i.e. shrubs and other non-tree vegetation) is planned.
- Regional modeling of forest dynamics is currently conducted by Co-PI Weiskittel and long-term data such as the Penobscot EF is invaluable for testing model behavior

List of Products: Publications

- Berven, K. 2011. U.S. Forest Service northern conifer experimental forests: historical review and examples of silvicultural research applications. University of Maine. M.S. thesis. 115 p.
- Berven, K.; Kenefic, L.S.; Weiskittel, A.R.; Twery, M.; Wilson, J. 2013. The lost research of early northeastern spruce-fir experimental forests: a tale of lost opportunities. In: Long-Term Silvicultural and Ecological Studies, Volume 2. Edited by: Camp, A; Irland, L.; Carroll, C. Yale University, Global Institute of Sustainable Forestry: 103-115.
- Kenefic, L.S.; Brissette, J.C.; Judd, R. *In press*. Northern conifer research: multiple species and multiple values. In: Research for the long-term: the interplay of societal need and research on USDA Forest Service Experimental Forests and Ranges. Edited by: R. Crawford, D. Hayes, and S. Stout. Springer.
- Kenefic, L.S.; Kern, C.C.; Brissette, J.C.; Weiskittel, A.R.; Russell, M.; Berven, K. 2013. Suggestions for maintaining records for long-term field studies. In: Long-Term Silvicultural and Ecological Studies, Volume 2. Edited by: Camp, A; Irland, L.; Carroll, C. Yale University, Global Institute of Sustainable Forestry: 126-134.
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List of Products: Presentations

- Berven, K.; Kenefic, L.S.; Weiskittel, A.R. 2010. The Gale River Experimental Forest: a lost legacy. New England Society of American Foresters 90th Annual Winter Meeting. 9-11 Mar. 2010. Concord, NH. Poster and oral.
- Berven, K.; Kenefic, L.S.; Weiskittel, A.R. 2011. Woody browse and mammalian herbivory: consequences regarding sapling recruitment and forest succession in the Acadian Forest of east-central Maine. New England Society of American Foresters 91st Annual Winter Meeting. 30-31 Mar. 2011. Fairlee, VT. Poster.
- Kenefic, L.S.; Brissette, J.C. 2009. U.S. Forest Service research on experimental forests: past, present, and future. University of Maine, School of Forest Resources, Noontime Seminar Series. 24 Apr. 2009. Orono, ME. Invited oral.
- Kenefic, L.S.; Weiskittel, A.R. 2013. U.S. Forest Service research in northern conifers: historical perspective, management implications, and modeling applications. Northeastern States Research Cooperative Webinar. 21 Mar. 2013. Invited oral.

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