

2023 Ecosystem Monitoring Fund Final Report



Project: Continued Long-Term Ecological Monitoring in a Northern Red Oak-White Pine Research Forest Over Five Decades

Organization: Maine Timber Research and Environmental Education Foundation (Maine TREE)

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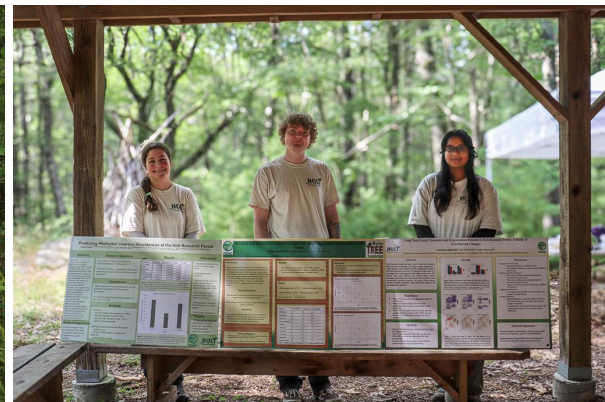
Narrative

Abstract

A red oak-white pine ecosystem on Maine's coast, Holt Research Forest (HRF), has filled a key niche of long-term ecosystem monitoring since its establishment in 1983. While many landowners in Maine steward oak-pine forests, HRF is a rare research generator on this critical forest type. A recent harvest at HRF in the fall of 2020 provided a timely opportunity to monitor and distribute data on the impact of disturbance on oak-pine ecosystems, particularly in the context of climate change. With funding provided by the Forest Ecosystem Monitoring Fund through Forest Ecosystem Monitoring Cooperative, we collected, digitized, and distributed pre- and post-harvest data on overstory composition and regeneration at HRF. This effort gave landowners practical data and tools to inform their management while providing researchers with a long-term foundational dataset for future studies. It additionally contributed to an established body of research from HRF, housed by FEMC, tracking ecosystem change on-site as climate change shifts ecological systems across the region. Lastly, the project contributed to workforce development in forestry and forest research by providing students and early-career professionals with practical, applied experience working in the field and with HRF datasets.

Activities

Maine TREE hired a Holt Research Forest Fellow (HRFF) in the winter of 2023 and three technicians for the 2024 summer field season. The technicians came from various educational backgrounds and experiences, including forest ecology, forest management, and bioinformatics. Two technicians were in the final stages of completing their undergraduate degrees, one at the University of Maine studying ecology and environmental sciences with a concentration in forest ecosystems and one at The Pennsylvania State University studying forest ecosystem management with a concentration in forest biology. The third technician was completing their Master's in bioinformatics with a concentration in data analytics at Northeastern University.



Summer 2024 Holt Research Forest technicians at the Maine TREE welcome and end-of-year celebration events.

Under the HRFF's guidance, the technicians collected regeneration and forest composition data, specifically post-harvest seed, seedling, sapling, and overstory

data, following the historical methods outlined in the Holt Research Forest Methods Manual (Witham, 1983). Furthermore, the technicians independently completed a fundamental analysis of pre- and post-harvest datasets. Their studies were summarized in written reports and presented as posters to Maine TREE staff, the Board of Directors, and the HRF Committee on August 1, 2024.

The HRF digitized pre- and post-harvest regeneration and composition data to make it publicly available on the FEMC data repository. All pre-harvest seed, seedling, sapling, and overstory data have been digitized, cleaned, quality-checked, and published. Datasets collected this summer are being cleaned, digitized, quality-checked, and will be published on the FEMC data repository by the end of summer 2024. A field tour sharing our results and findings will be scheduled for fall 2024.

Data Availability

Project	Years Published	Years Unpublished
Annual Tree Seed Collection	2016, 2017, 2018, 2019, 2020, 2021, 2022	2023
Regeneration Inventory	2022	2024
Timber Inventory	2019 (Partial), 2020 (Complete)	2022-ongoing (Complete)

Results and Impacts

Data Collection and Publication

- Seed, seedling, sapling, and overstory data:** Summer research technicians collected data for four projects related to regeneration and overstory dynamics at HRF: the Annual Tree Seed Collection, the Regeneration Inventory, S-1 Understory Seedling Revele, and the Complete Timber Inventory. The technicians developed scientific research skills such as field instrument operation and maintenance, navigation, tree and vegetation identification, and teamwork. All three of the students have expressed interest in pursuing graduate studies and working in the fields of ecology or forest management.



Technician Olivia Case (left) taught high school-aged students from Bowdoin College's Upward Bound Program how to identify and measure tree seedlings. Technician Toby

Ouellette (right) investigated harvest impacts on tree mortality.

- **Data availability:** The project successfully cleaned, digitized, and published six datasets to the FEMC data repository. Specifically, we published two datasets for the Annual Tree Seed Collection (seedTraps-S1_2016-2022 and seedTraps-SM_2016-2021), two datasets for the Regeneration Inventory (regen4m2_2022 and regen200m2_2022), and two datasets for the Timber Inventory (TimberInv2019 and TimberInv2020). This effort significantly enhanced the availability and accessibility of long-term ecological monitoring data, especially for the understudied coastal oak-pine ecosystems. The datasets now serve as valuable resources for landowners and researchers, providing practical data and tools for forest management and foundational datasets for current and future studies.

Analysis of Coastal Oak-Pine Ecosystem Response to Harvest

- **Variable Retention Harvest:** The project included comprehensive analyses of the coastal oak-pine ecosystem's response to variable retention harvest conducted by the summer research technicians. These analyses filled critical gaps in understanding the impacts of variable retention harvest on canopy composition and regeneration within a coastal oak-pine forest ecosystem. This work contributed to the broader body of research from HRF and is crucial for informing forest management practices in similar ecosystems. The independent research projects provided the technicians with hands-on experience in applied forestry research, expanding their professional networks and exposing them to various career pathways. The contributions and experiences of our technicians were highlighted in our newsletter, "Seedlings."

Ecological Monitoring and Future Research

- **Foundation for ecological monitoring:** The comprehensive datasets now include pre- and post-harvest data, with future data collection planned for 2024 and beyond. This continuity ensures that the datasets remain relevant and useful for ongoing and future ecological research, providing a valuable resource for investigating various ecosystem components in a managed northern oak-pine forest.
- **Foundation for Ongoing/Future Research:** The project established a robust foundation for continued ecological monitoring and future research at HRF. This year, HRF welcomed a diverse array of regional scientists and research initiatives. Notable examples include a researcher from the Biodiversity Research Institute studying bald eagle nestlings and a PhD student from the University of Maine studying red spruce management and resiliency. This shift towards a collaborative model of hosting diverse research practitioners and projects has expanded HRF's research scope and capabilities.

Lessons Learned

- **Data management and accessibility:** Ensuring data quality and consistency before publication enhances the utility and reliability of the datasets for various users, including landowners and researchers.

- **Challenges in Data Integration:** Integrating historical data with newly collected data posed challenges, particularly in maintaining consistency and accuracy across different time periods. Developing standardized data collection and management protocols can help mitigate these issues in future projects.

Future Directions

- **Ongoing and Future Data Collection:** The project has set a strong foundation for continued data collection and publication. Future efforts will continue prioritizing forest growth and health, ensuring that these datasets remain up-to-date and comprehensive while expanding research efforts to focus on other priority topics like climate change and wildlife. Furthermore, HRF will strengthen its ecological monitoring programs by incorporating new technologies and methodologies to improve data accuracy and collection efficiency.
- **Workforce development:** HRF will continue prioritizing workforce development by providing more opportunities for students and early-career professionals. This includes expanding technician programs, offering research fellowships, and facilitating mentorship from experienced researchers.
- **Collaboration and networking:** Strengthening collaborations with academic institutions, research organizations, and industry partners will facilitate and host a wider array of regional scientists and research initiatives.

Literature Cited

Witham JW, Moore EH, Hunter ML, Kimball AJ, White AS. (1983). *A Long-Term Study of an Oak Pine Forest Ecosystem: Techniques Manual for the Holt Research Forest*. (Technical Bulletin 153). The University of Maine.

Budget Detail

Item	FEMC Funds	Non-Federal Match	Total
Individual personnel	\$22,840.92	\$18,740.60	\$41,581.52
Personnel fringe benefits		\$8,521.65	\$8,521.65
Travel		\$1,219.52*	\$1,219.52
Supplies	\$2,159.08	\$5,003.48	\$7,162.56
Utilities		\$4,224.33	\$4,224.33
Indirect Costs		\$6,270.96**	\$6,270.96
Total	\$25,000.00	\$43,980.54	\$68,980.54

*not on the original budget

***not on the original budget, 10% de minimis, reflected here for match documentation*

Individual Personnel

- FEMC funds for this project supported the Holt Research Forest Fellow responsible for completing the project, our Forest Programs Manager, who managed the project before moving on to a new role with another organization, and a portion of one of three research technicians' time.
- Non-Federal Match for personnel includes the three research technicians, excluding the portion allocated to the FEMC funds, and administrative and supervision support from Maine TREE's Executive Director and Office Manager.

Personnel Fringe Benefits

- All personnel fringe benefits associated with this project were allocated to the project's non-federal match.

Travel

- Not included in the initial budget and documented here as a match includes lodging and registration for conferences Maine TREE staff attended that were relevant to the project.

Supplies

- FEMC Funds supported the purchase of office supplies and research equipment to facilitate the delivery of this project.
- Non-Federal Match was housing provided to personnel at \$500/month/person as identified in our initial proposal

Utilities

- All costs allocated as non-federal match for maintaining our facilities throughout the project

Indirect Costs

- Not included in the original project budget, indirect costs were allocated to the non-federal match at the 10% de minimis rate.

See the invoice attachment for more details on the budget breakdown.

Appendix

Predicting *Plethodon cinereus* Abundances at the Holt Research Forest

Olivia Case ^{The Pennsylvania State University}; Jack Witham, MA ^{Holt Research Forest, University of Maine}; Paulina Murray, MS ^{Holt Research Forest, Maine TREE Foundation}

Abstract

Counts of previously-monitored species are no longer feasible at the HRF. To ease strain on researchers, this project attempted to predict populations of *P. cinereus* in 2011 based on groundcover and shrub data from 1994. A multiple linear regression model with the most significant predictor variables was created. If this project is expanded, it could open opportunities to monitor and predict biodiversity while incurring less costs for the researchers themselves. More studies and predictions of populations need to be made before this idea becomes reasonable, but it could serve as a potential solution to the continuous dilution of resources the HRF is trying

Acknowledgements

Financial support was provided by the Forest Ecosystem Monitoring Cooperative, grant number 34650SU00000484.

Research Questions

- How have *P. cinereus* populations fluctuate between 1994 and 2011?
- How do *P. cinereus* populations fluctuate depending on groundcover and shrub layer variables?

Hypotheses

- Moss, bare rock, and log indicators will be positively correlated with *P. cinereus* abundance
- *P. cinereus* abundances will be greater in 2011 than in 1994

Methods

- Datasets
 - Shingle Station Groundcover (1994)
 - Shingle Station Shrubs (1994)
 - Salamander Shingle (1994, 2011)
 - 2011 S1 Groundcover
- Multiple Linear Regression (R Studio)
- Significance
 - Predict 1994 values, compare to observed
 - Predict 2011 values

Results

Predictor	Coefficient	Standard Error	T-Value	P-Value
Intercept	1.2048	0.69809	1.726	0.08479
Path	-0.1099	0.05028	-2.186	0.02912
Mixed DL	0.0216	0.00749	2.885	0.00403
Log	-0.071	0.02531	-2.804	0.00518
Deciduous DL	0.02385	0.00738	3.23	0.00129
Coniferus DL	0.03031	0.00765	3.964	8.07E-05
Lichen	-0.6297	0.33756	-1.865	0.06252

Figure 1: A table of summary statistics from the final multiple linear regression model. It predicts salamander abundance based on the percentages of groundcover components. This model has an adjusted R-squared value of 0.05124 and a root mean square error (RMSE) value of 1.6777. DL is dry litter.

Figure 2: A bar graph comparing the summed *P. cinereus* abundances that were observed in 1994, observed in 2011, and predicted in 2011. The summed observed abundance from 1994 was 876, the observed abundance from 2011 was 462, and the summed predicted abundance in 2011 was 781.5.

Discussion

- Negative correlations for path and lichen make sense
- Hypotheses were incorrect
- Between 1994 and 2011, observed abundances decreased by 414 sample units, 47% less than 1994
- 2011 observed and predicted values had a difference of 319.5
- Anthropogenic spread of Chytridiomycosis, climate change
- Salamander abundance is complicated

Future Considerations

- Basal area, canopy cover, pH, humidity...
- Keep recording methods constant

Figure 1. Olivia Case presented “Predicting *Plethodon cinereus* Abundances at the Holt Research Forest.”

Long-Term Forest Dynamics and Regeneration Patterns in Holt Research Forest: A Study of Post-Harvest Changes

Gursimran Sahota BS¹, Jack Witham MA², Paulina Murray MS³

(1)Bioinformatics Department, Northeastern University, Boston, MA, (2)Holt Research Forest, University of Maine, Orono, ME, (3)Holt Research Forest, MaineTREE Foundation

Abstract

Holt Research Forest has been a site of long-term ecological data collection for decades, providing a unique opportunity to study changes in tree species diversity, regeneration patterns, and forest structure over time. The objective of this study is to investigate how anthropogenic disturbances, such as the 1987 harvest, may have affected tree growth rates, relative abundance, and basal areas. We focus on four of Maine’s most economically significant species: red spruce (*Picea rubens*), balsam fir (*Abies balsamea*), white pine (*Pinus strobus*), and red maple (*Acer rubrum*).

Results

Figure 1: Relative Abundance of Red Maple and White Pine Seedlings by Period. Relative abundance of seedlings and saplings for Red Maple (a) and White Pine (b) across different time periods (Pre-Harvest, Post-Harvest, Late Post-Harvest) in Holt Research Forest. Bars represent data from eastern and western blocks. Significant differences in relative abundance were observed across periods for Red Maple ($p = 0.048$) and White Pine ($p < 0.001$).

Figure 2: Basal Area Maps of White Pine and Balsam Fir by Period. Spatial distribution of mature white pine pre-harvest (a), post-harvest (b), and late post-harvest (c) as well as mature balsam fir pre-harvest (d), post-harvest (e), and late post-harvest (f) were mapped on the Holt Research Forest study grid. Each map represents the total basal area in square meters per hectare across the study area, with color intensity indicating the magnitude of basal area.

Discussion

- Impact of 1987 Harvest
 - Significant increase in seedling counts
 - No significant difference in growth rate or DBH of mature trees
- Species-Specific Responses
 - Red maple seedlings decreased post harvest, increased late post-harvest
 - White pine seedlings increased post harvest, decreased late post-harvest
 - Largest basal area increase in white pine, smallest in balsam fir
- Regional Differences
 - Red maple more abundant in eastern blocks, red spruce in western blocks
- Future Direction
 - Standardizing data collection methods and time lines will ensure more consistent and accurate results in the future
 - Consider other environmental factors such as soil composition and pH when analyzing spatial differences.

Hypotheses

1. There will be increased tree regeneration after the 1987 harvest.
2. White pine and red maple will show more regeneration than red spruce and balsam fir after harvesting.
3. There will be an initial decrease in basal area and average diameter at breast height (DBH) after the harvest with a subsequent increase as the forest regenerates

Methods

- Datasets: Timber Inventory, Annual Seedling Counts, 4m² Regeneration
- Time Periods Analyzed: 1984-1986 (pre-harvest), 1988-1996 (post-harvest), and 2004-2009 (late post-harvest)
- Analyses: Mixed-effects model, t-tests, ANOVA, graphs and maps using R programming

Acknowledgements

Financial support was provided by the Forest Ecosystem Monitoring Cooperative, grant #34650SU00000484.

Special thanks to MaineTREE and the Holt Research Forest for providing the research site and resources.

Figure 2. Gursimran Sahota presented “Long-Term Forest Dynamics and Regeneration Patterns in Holt Research Forest: A Study of Post-Harvest Changes.”



Mortality and Recruitment Rates Pre and Post Timber Harvest in the Holt Research Forest

Toby Ouellette¹, Jack Witham², Paulina Murray³

(1) College of Earth, Life, and Health Sciences, University of Maine, Orono, ME, (2) MA; Holt Research Forest, University of Maine, Orono, ME, (3) MS; Holt Research Forest, Maine



Introduction

Timber harvests are an effective way to examine the effects of small to large scale anthropogenic disturbances on forested ecosystems. In this study, past complete and partial timber inventories were examined to find statistical significance within mortality and recruitment rates for 10 tree species for both a pre-harvest year (1984) and post-harvest year (1988), as well as a modern partial inventory (2007) to compare past and more current results.

Research Questions

How do partial timber harvests affect tree mortality and ingrowth in the Holt Research Forest?

What ecological factors significantly affect these rates pre and post harvest?

Hypothesis

We hypothesized that the mortality rates and number of recruitment trees would differ significantly pre harvest (1984) and post harvest (1988) because of ecological factors associated with partial timber harvests.

Acknowledgements

- Financial support was provided by the Forest Ecosystem Monitoring Cooperative, grant number 34650SU00000484
- Thanks to the Maine TREE Foundation and Holt Research Forest

Methods

- Holt timber inventory datasets 1984, 1988, and 2007
- RStudio used to subset data by species, condition, or DBH
- T tests used to find significance of mortality rates

Results

- 1984 mortality rate: 13.7% - 1988 mortality rate: 14.3%
- 1984 recruitment: 3,520 - 1988 recruitment: 3,198
- P-value of 0.39 - T stat of 0.29

Species	1984 MR (%)	1988 MR (%)	2007 MR (%)
White pine	18	20	27
Red spruce	11	14	16
Balsam fir	33	20	31
Eastern hemlock	2	3	9
Red oak	7	11	8
White oak	15	17	19
Red maple	6	7	18
Yellow birch	7	6	8
Paper birch	17	14	34
American beech	24	13	27

Table 1. Mortality rate (MR) percentages for the 10 studied species by year.

Discussion

- Results show no significance between mortality rates pre and post harvest
- Variability in rates due to other ecological factors
- Results fit with other published studies

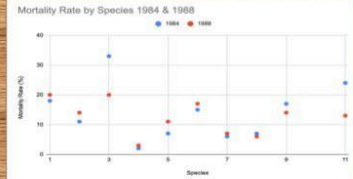


Figure 2. Mortality rates vs species for *Pinus strobus*, *Pinus rubens*, *Abies balsamea*, *Tsuga canadensis*, *Quercus rubra*, *Quercus alba*, *Acer rubrum*, *Betula alleghaniensis*, *Betula papyrifera*, and *Fagus grandifolia* in the pre-harvest year (1984) and the post-harvest year (1988).

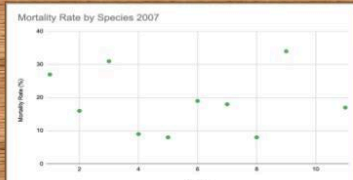


Figure 3. Mortality rates vs species for *Pinus strobus*, *Pinus rubens*, *Abies balsamea*, *Tsuga canadensis*, *Quercus rubra*, *Quercus alba*, *Acer rubrum*, *Betula alleghaniensis*, *Betula papyrifera*, and *Fagus grandifolia* in the year 2007.

Figure 3. Toby Ouellette presented "Mortality and Recruitment Rates Pre and Post Timber Harvest in the Holt Research Forest."