Impacts and Management of White Pine Needle Damage in the Northeastern United States

Cameron McIntire[1], Isabel Munck[2], and Heidi Asbjornsen[1]
[1]Department of Natural Resources and the Environment, University of New Hampshire, Durham, NH
[2]US Forest Service State and Private Forestry, Northeastern Area, Durham, NH

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Introduction & Background

White Pine Needle Damage (WPND) is a complex of fungal pathogens that have established and become a chronic disease impacting forests in the Northeastern U.S. [1,2]. WPND defoliates mature needles of eastern white pine (*Pinus strobus*) during the summer months, prior to the climax of current-year needle elongation. The four pathogens associated with WPND are all rain-dispersed ascomycete fungi native to the range of white pine: *Lecanosticta acicola, Lophophacidium dooksii, Bifusella linearis,* and *Septorioides strobi.* Annual defoliation severity has been shown to be in part driven by recent increases in springtime precipitation and warming temperatures in the region [3]. This defoliation event dramatically thins the crowns of infected trees, resulting in the premature death of lower branches. With long term ecological and economic impacts in mind, it is critical to develop management recommendations for moderating the negative impacts of WPND. This study uses litterfall and tree ring analysis to quantify the magnitude of defoliation severity and associated growth declines in the Northeast. The work presented here also evaluates the initial effectiveness of mechanical thinning as a means to both enhance growth of white pine and mitigate the severity of WPND within infected stands.

Fig. 1. A white pine in central New Hampshire exhibiting typical symptoms of post-defoliation White Pine Needle Damage.

Methods

Study Area

The study area includes the states of Massachusetts, Vermont, New Hampshire, and Maine (Fig. 2). The climate within this region is characterized by a humid continental climate, with cold winters, moderately warm summers, and a relatively even distribution of rainfall throughout the year. Sites were established in 2012 as long-term WPND monitoring plots that have been observed annually by U.S. Forest Service and state forest health cooperators for crown condition [1]. Within the long-term monitoring sites, trees were initially tagged in pairs of low- and high-severity WPND symptomology, therefore these trees were used to develop tree ring chronologies for growth comparison.

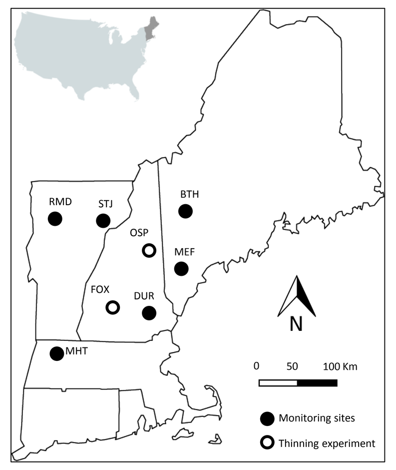

Figure 2. Map of study sites.

Litterfall

Litterfall was measured to quantify the timing and magnitude of WPND induced defoliations in the NE region. Litterfall occurring in the summer is atypical, while October litterfall is a natural event. Monthly litterfall was collected throughout the 2014-2016 growing seasons (May – Oct) at four monitoring sites in NH and ME. Traps were cleaned at the end of each month, dried, sorted, and weighed for white pine foliage. Foliar analysis for nitrogen and carbon was conducted on samples from the 2014 growing season to determine nutrient resorption rates.

Dendrochronology

Increment cores were extracted from dominant eastern white pine at six of the WPND monitoring plots. All trees within a site were split into two master chronologies based on ratings of WPND severity. Detection of the initial onset years of growth decline and quantification of post-WPND reductions in basal area increment (BAI) was calculated using the Decline-score (D-score) method [4]. The D-score is analogous to an independent two-sample *t* test between the 3 year mean BAI before and after each sample year, incorporating the pooled variance of the sample years to account for natural year to year variability within a chronology that are less likely to be the product of a stress induced decline.

Thinning Experiment

Silvicultural thinning was conducted at two NH white pine stands using a blocked experimental design (Fig. 3). A high (110 $ft^2\ ac^{-1}$) and low density (50 $ft^2\ ac^{-1}$) treatment was tested as residual stocking levels to promote growth while mitigating WPND spread and severity. A pre-treatment plot inventory was conducted in 2015 for metrics of stem diameter, canopy position, light exposure, defoliation class, crown transparency, crown dieback, live crown ratio, and crown diameter. Plots were thinned in the winter of 2015 and post-treatment inventories were conducted in the summer of 2016 and 2017. The effectiveness of thinning was evaluated by using z-scores to generate a composite health metric of response variables found to be correlated to WPND symptomology and tree vigor [5].

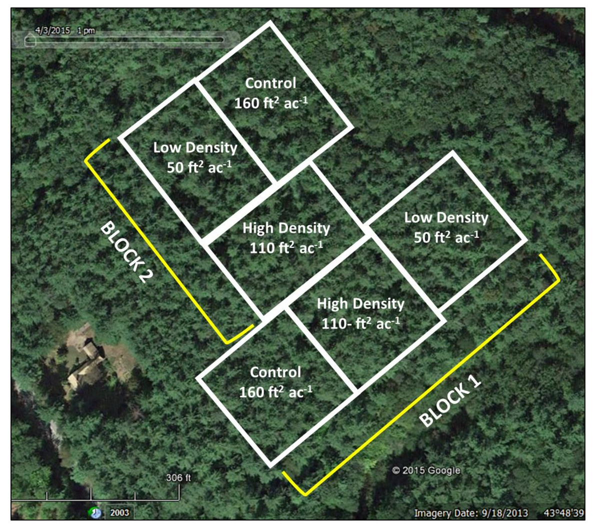

Fig. 3. Experimental design of the thinning plots in West Ossipee, NH.

WPND Impact Results

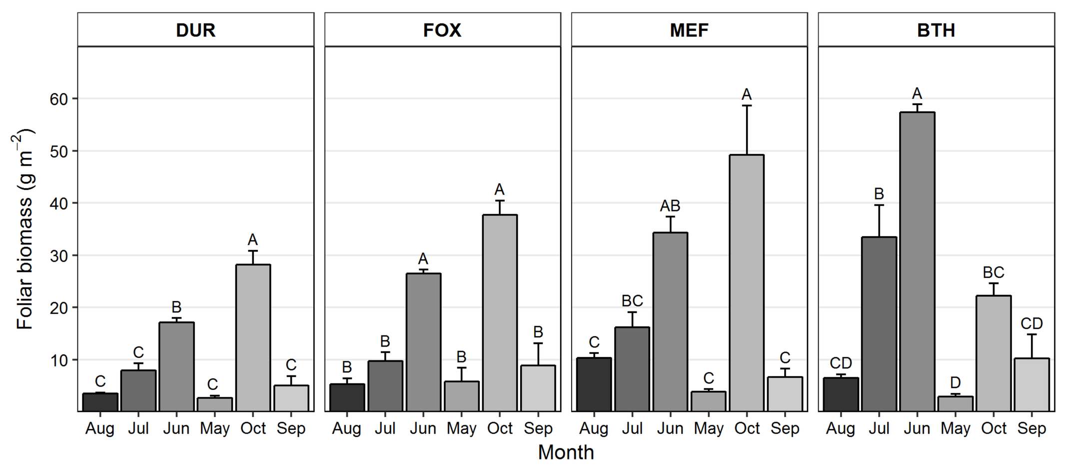

Fig. 3. Mean monthly litterfall totals of eastern white pine foliage normalized by stem basal area (m^2) within plots for the 2014-2016 growing seasons $\pm$ SE. Values with the same letter are not significantly different between months (α = 0.05).

Month	N	C:N	NRE
May	*a* 10.1 (0.13)	*e* 49.85 (5.83)	*d* 17.36 (10.54)
Jun	*b* 7.8 (0.07)	*bc* 63.79 (6.05)	*b* 35.99 (5.67)
Jul	*b* 8.4 (0.11)	*cd* 60.05 (7.52)	*b* 31.14 (9.34)
Aug	*a* 9.5 (0.17)	*de* 54.60 (8.48)	*c* 23.87 (11.11)
Sep	*b* 7.7 (0.09)	*b* 65.79 (8.27)	*b* 36.70 (7.65)
Oct	*c* 4.0 (0.03)	*a* 126.21 (9.99)	*a* 67.00 (2.54)

Table 1. Foliar nitrogen concentration (mg g^{-1}), C:N ratio (mass/mass), and calculated nitrogen resorption efficiency (NRE, %) by month for the 2014 growing season. N content of green needles was set to 12.2 mg g^{-1} according to published values within the study region [6]. Means with different lower case letter are significantly different from each other (α = 0.05).

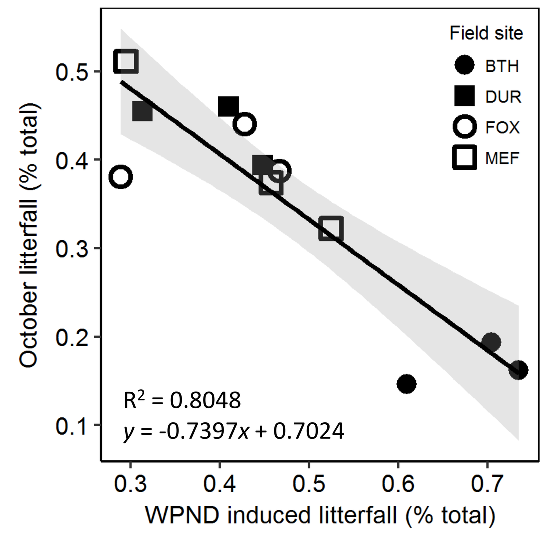

Fig 4. Proportional amount of *P. strobus* foliar biomass collected in the month of October as a function of the WPND induced defoliation. Each shape shows a single year at a field site during the three-year study period. Shaded line is the 95% confidence interval.

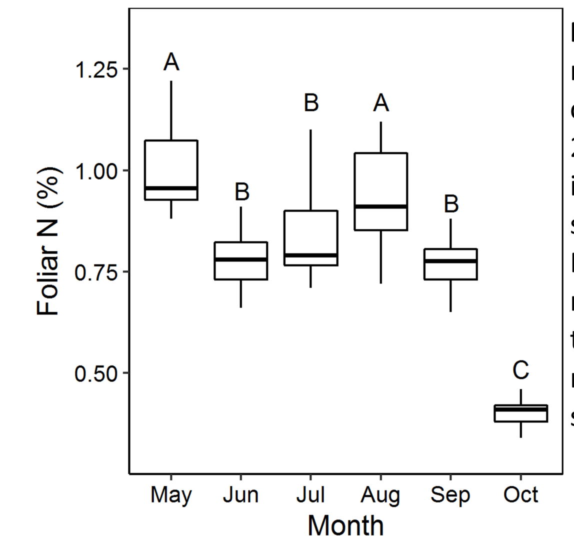

Fig 5. Foliar N content measured in litter samples collected throughout the 2014 growing season. Data is pooled across all four study sites (α = 0.05). Foliar N retained in the month of October is less than half of any other month measured in this study.

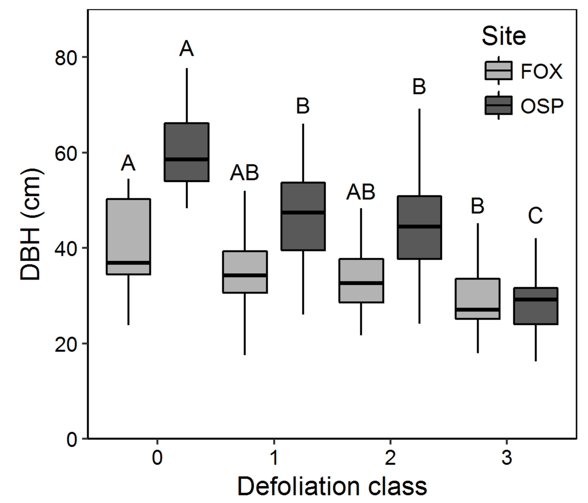

Fig 6. Stem diameter at breast height (DBH) as a function of defoliation class.

Fig 7. Mean crown diameter as a function of defoliation class.

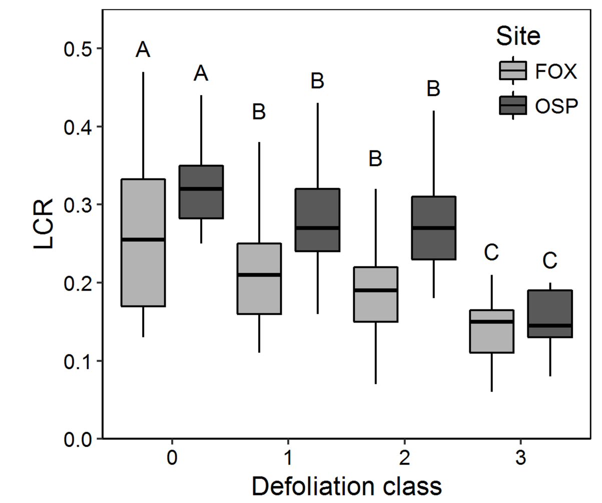

Fig 8. Live crown ratio (LCR) as a function of defoliation class.

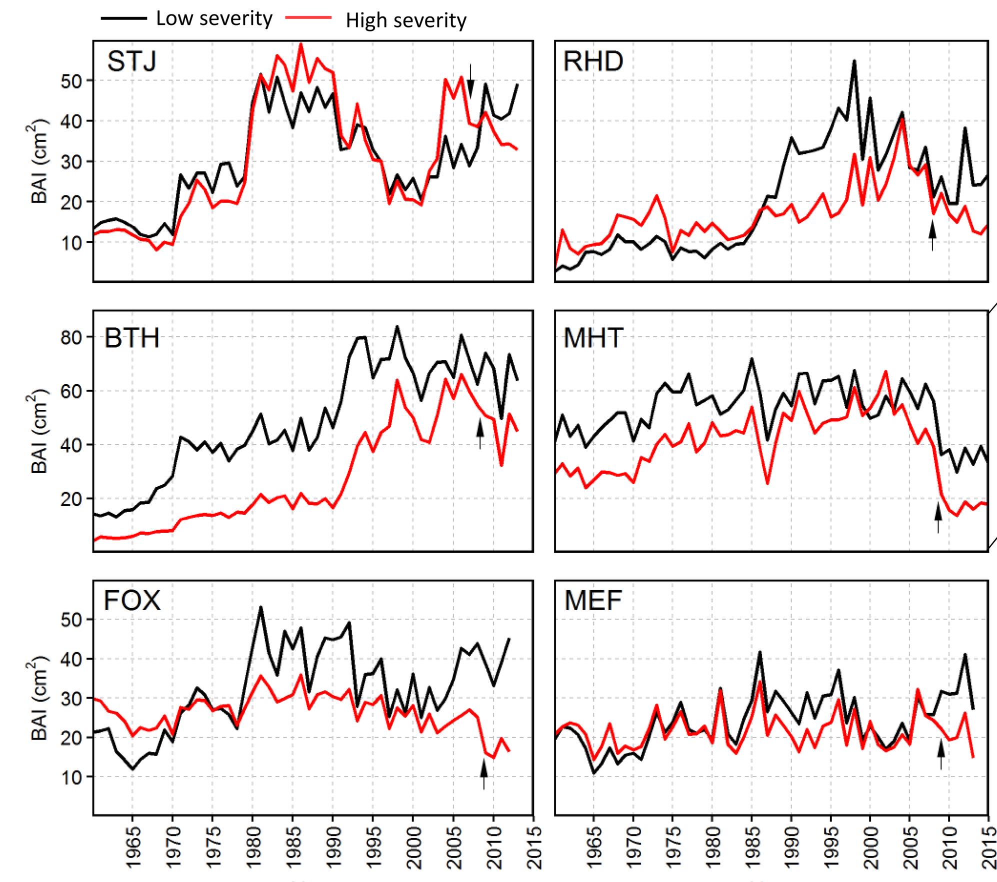

Fig. 9. Master chronologies for low severity (black) and high severity (red) WPND infected eastern white pines by site from 1960-2015. Arrows within each panel indicate the onset of decline (D_{max}) in the high severity chronologies.

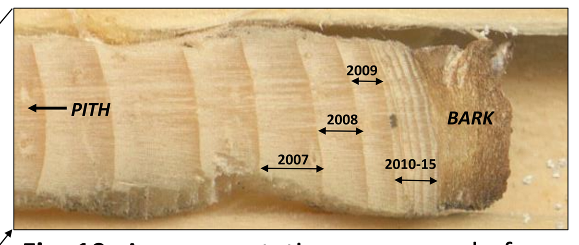

Fig. 10. A representative core sample from a high severity tree at the Mohawk Trail State Forest, MA (MHT). Recent growth declines associated with WPND defoliations at this site are unprecedented in the 100+ year record of the stand. Decline begins in 2009.

Site code	Mean age (yrs)	Mean dbh (cm)	Interseries correlation	D_{max} year	BAI decline
MHT	85	65.0	0.518	2009	72.8%
FOX	65	50.0	0.557	2009	34.7%
MEF	68	56.8	0.680	2009	25.8%
BTH	65	50.9	0.528	2008	29.8%
STJ	73	51.3	0.501	2007	25.4%
RMD	51	44.0	0.570	2008	59.0%

Table 2. Dendrochronology statistics and calculated decline values for stands sampled in MA, ME, NH, and VT. Initiation of decline was found to be between 2007 and 2009 for all sites. Mean post-WPND outbreak BAI decline across sampled sites is 41.3%.

Silvicultural Results

	Ossipee, NH (OSP)				Hillsborough, NH (FOX)				
Variable	Mean	Standard deviation	n	Corr. (R^2)	Mean	Standard deviation	n	Corr. (R^2)	Adjustment
2015 DBH (cm)	45.67	11.45	145	0.843	34.48	9.65	130	0.897	-1
Light Exposure (0-5)	1.37	0.55	145	0.677	1.38	0.69	130	0.738	-1
Defoliation class (0-3)	1.42	0.72	145	1.000	1.53	0.76	130	1.000	1
Die Back (%)	11.34	5.39	145	0.859	12.31	6.56	130	0.969	1
Transparency (%)	25.97	10.72	145	0.915	25.69	12.85	130	0.949	1
Live crown ratio (ft ft^{-1})	0.28	0.07	145	0.981	0.20	0.07	130	0.957	-1
Mean crown diam. (ft)	18.59	7.10	145	0.863	9.52	4.91	130	0.968	-1
BAI ratio ($m^2\ m^{-2}$)	1.00	0.49	145	0.847	1.00	0.66	130	0.811	-1

Table 3. Variables used to calculate the composite z-scores for quantifying tree health and response to thinning treatments. The mean z-score is weighted by each variable according to the strength of correlation to observed WPND severity and adjusted based on exhibiting either a positive or negative relationship with tree health.

$$Zscore = \left(\frac{X-\bar{X}}{\sigma}\right) \times (\pm 1) \times R^2_{WPND}$$

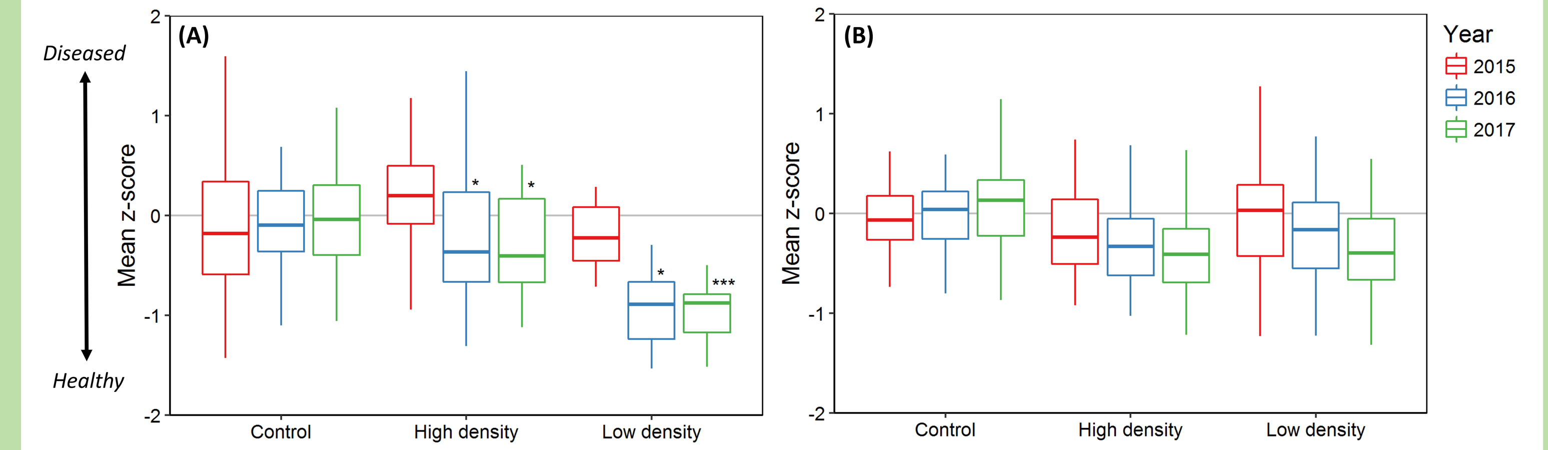

Fig 11. Change in the mean z-score over time in the thinning plots at the Fox State Forest, Hillsborough, NH (A) and the Bear River stand, West Ossipee, NH (B). Thinning was conducted in the winter of 2015; the years 2016 and 2017 show post-treatment response. Tree health and growth appears to be responding positively to reduced stocking densities.

Conclusions

- The majority of WPND induced defoliation is occurring in the months of June and July, accounting for approximately 50% of the total annual litterfall (Fig. 3).
- The amount of needle cast occurring in the summer months (untimely) is proportional to the litterfall measured during the October (natural) needle senescence, suggesting that total litterfall is conserved annually (Fig. 4).
- Foliar nitrogen resorption is significantly lower in the summer months (32%) than in October (67%), thus infected trees are not effectively recycling foliar N prior to summer defoliations caused by WPND (Fig. 5, Table 1).
- Trees exhibiting a high severity of WPND within infected stands of eastern white pine have experienced stem growth declines of 25-73% since initial outbreaks ca. 2009 (Fig. 9, Table 2).
- Crown observations of WPND are significantly correlated to other metrics of growth and crown health such as stem diameter, live crown ratio, and crown diameter (Fig. 6-8, Table 3).
- Trees within thinned stands (110 $ft^2\ ac^{-1}$, 50 $ft^2\ ac^{-1}$) are responding positively to reduced stocking densities (Fig. 11). We are recommending that land mangers adhere to established stocking guidelines for eastern white pine and to take notice of over-stocked stands [7].

References

[1] Broders, K., Munck, I., Wyka, S., Iriarte, G., Beaudoin, E. 2015. Characterization of fungal pathogens associated with White Pine Needle Damage (WPND) in Northeastern North America. *Forests*. 6(11): 4088-4104.

[2] Wyka, S., Broders, K. 2016. The new family Septorioideaceae, within the Botryosphaeriales and *Septorioides strobi* as a new species associated with needle defoliation of *Pinus strobus* in the United States. *Fungal Biology*. 120(8): 1030-1040.

[3] Wyka, S., Smith, C., Munck, I., Rock, B., Ziniti, B., Broders, K. 2016. Emergence of White Pine Needle Damage (WPND) in the northeastern U.S. is associated with changes in pathogen pressure in response to climate change. *Global Change Biology.* 23(1): 392-405.

[4] Livingston, W.H., Pontius, J., Costanza, K.K.L., Trosper, S. 2017. Using changes in basal area increments to map relative risk of HWA impacts on hemlock growth across the Northeastern U.S.A. *Biological Invasions*. 19(5): 1577-1595.

[5] Pontius, J., Hallett, R. 2014. Monitoring of forest decline. *Forest Science*. 60(6): 1156-1163.

[6] Hallett, R. and Hornbeck, J. 1997. Foliar and Soil Nutrient Relationships in Red Oak and White Pine Forests in Northern New England, U.S.A. Canadian Journal of Botany. 27(8): 1233-1244.

[7] Philbrook, J.S., Barrett, J.P., Leak, W.B. 1973. A stocking guide for eastern white pine. Research Note NE-168. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 3p.