SEVEN YEAR EFFECTS OF MEADOW VOLE HERBIVORY ON OAK SURVIVAL

Andrew B. Self[1]

Abstract—Seedling mortality due to meadow vole herbivory is often thought to be small scale in nature in hardwood afforestation efforts. However, in some instances, this source of mortality may play a more important role than typically realized. A total of 1,440 bare-root Nuttall oak (*Quercus texana* Buckley), Shumard oak (*Quercus shumardii* Buckley), and swamp chestnut oak (*Quercus michauxii* Nutt.) seedlings were planted in February 2008 on a northwest Mississippi site. Plots received treatment with one of four mechanical site preparation methods. Also, all plots received an initial post planting application of Oust XP®. In year two, one half of plots were selected for treatment with a second application of Oust XP®. Overall, seedling survival was excellent throughout the duration of the study. However, cumulative annual vole induced seedling mortality was significant and did not stabilize until the seventh year after planting. Overall seventh-year survival was 83.7 percent, with vole damage accounting for approximately 79.1 percent of all seedling/sapling mortality to date. Analyses did not detect treatment interaction with vole induced mortality in the first three years of this study. However, seventh year analyses detected significant main effect differences for both mechanical treatment and species related to vole herbivory. Vole herbivory was greater in areas receiving less intensive mechanical treatments, and Nuttall oak was preferentially selected for herbivory. While seedling survival approaching 84 percent is not normally considered poor, at 12.9 percent mortality, the level of vole damage observed in this study is of serious magnitude and may warrant consideration in planting efforts.

INTRODUCTION

Meadow vole or pine vole (*Microtus pinetorum* LeConte) herbivory is one mortality factor sometimes associated with forest plantings across the eastern United States (Ostfeld and Canham, 1993). Meadow voles (also known as pine voles) are semifossorial, arvicoline rodents found in woodlands and other habitats across the eastern United States. Meadow vole herbivory is typically subterranean, resulting in seedling root systems being eaten below the root collar (Schreiber and Swihart 2009). Several studies have observed that meadow voles may selectively feed on roots of oak seedlings (Ostfeld and Canham 1993, Rathfon and others 2008, Schreiber and Swihart 2009). Mortality levels as high as 19 percent were noted by Rathfon and others (2008) in southern Indiana for white oak, northern red oak, and black oak seedlings under mature, closed-canopy, oak-dominated forests. The highest levels of meadow vole-induced seedling mortality were found in areas that had undergone midstory removal. Self and others (2015a) detected no survival differences due to vole herbivory among four mechanical site preparation treatments or three oak species in three-year-old oak plantations.

Other studies have shown increased frequency of meadow voles in areas with greater levels of herbaceous vegetation due to midstory and overstory removal (Perry and Thill 2005, Schreiber and Swihart 2009). Increased ground cover provides better habitat and serves to aid in increased meadow vole numbers in these settings (Birney and others 1976). Afforestation attempts on retired agriculture fields may be hindered due to protection of voles from predation on these sites resulting from the greater levels of herbaceous vegetation that these sites typically provide (Buell and others 1971, Gill and Marks 1991, Ostfeld and Canham 1993, Self and others 2015a). While typically not a major concern in afforestation attempts, vole herbivory can reach levels with substantial impact to planting success.

MATERIALS AND METHODS

Site Description

This study site is located approximately 5 miles northwest of Coldwater, MS in Desoto County on the Arkabutla Lake Project owned by the U.S. Army Corps of Engineers. The site was in soybean [*Glycine max* (L.) Merr.] production until September 2007. Soils were silt loams, and 40-year average precipitation was 56.1 inches (NOAA 2015). Soil tests indicate that the site had an average pH of 6.2. Dominant herbaceous species on site at study initiation were Brazilian vervain (*Verbena brasiliensis* Vell.), poorjoe (*Diodia teres* Walt.), and thorny amaranth (*Amaranthus spinosus* L.). Twenty-

[1]Andrew B. Self, Assistant Extension Professor, Department of Forestry, Mississippi State University, Grenada, MS 38901

Citation for proceedings: Schweitzer, Callie J.; Clatterbuck, Wayne K.; Oswalt, Christopher M., eds. 2016. Proceedings of the 18th biennial southern silvicultural research conference. e–Gen. Tech. Rep. SRS–212. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 614 p.

one other herbaceous species were observed in small quantities across the site. Cumulative herbaceous coverage of all species was approximately 5 percent.

Experimental Design

This experiment utilized a split-split-plot design with whole plot factors in a randomized complete block design and sub-plot factors completely randomized within whole plot factors and sub-sub-plot factors completely randomized within sub-plot factors. The whole plot factor was site preparation treatment. The sub-plot factor was species. The sub-sub-plot factor was herbaceous weed control (HWC). The experimental unit was a plot with its unique combination of site preparation treatment, species, and HWC. The response variable was seedling mortality resulting as a direct result of vole herbivory.

Three blocks containing all possible site preparation treatment/species/HWC combinations were established. Each block consisted of 12 planting rows split horizontally resulting in the creation of 24 plots. The experimental unit was the plot which was approximately 190 by 10 feet and contained 20 seedlings. For logistical reasons, site preparation treatments were applied singularly as a group; however, these groups were randomized within each block. Individual species were planted by row for each site preparation treatment. Species were randomized by site preparation treatment. Each row was divided into two plots with each plot receiving a different HWC treatment assigned randomly.

Mechanical Site Preparation and Herbaceous Weed Control

Four mechanical site preparation treatments were employed: control (no site preparation), subsoiling, bedding, and combination plowing. Site preparation treatments were applied on 10 foot centers. Subsoil trenches were cut to a depth of 15 inches. Bedding was performed using a furrow plow with the blades set to pull a soil bed approximately 3 feet wide and between 8 and 10 inches deep. Combination plowing involved pulling a soil bed over the top of subsoiled trenches. Mechanical site preparation treatments were applied during the first week of November 2007.

HWC treatments included a one year application and a two year application of Oust XP®. Both treatments were applied in 5 foot wide bands using a rate of 2 ounces of product per sprayed acre and were applied over the top of seedlings prior to bud break. The one year Oust XP® application was applied during March 2008. The two year Oust XP® application was applied during March 2008 and March 2009. A Solo® backpack sprayer was used for herbicide application with total spray volume of 10 gallons per acre.

Seedling Establishment

Nuttall oak, Shumard oak, and swamp chestnut oak were chosen for use in this study. Seedlings were lifted mid-January 2008, and seedling specifications required 1-0 seedlings of overall vigorous appearance with relatively intact root systems. Specified seedling parameters dictated that stems be 18 to 20 inches tall and possess root systems 8 to 10 inches long with a minimum of eight first-order lateral roots (FOLRs). Seedlings not meeting these specifications were culled before planting. A total of 480 seedlings of each species were planted at root collar depth during February 2008 by university personnel using a 10 foot spacing.

Survival Measurements

Seedling/tree survival and cause of death was determined and recorded annually by ocular evaluation during winter from 2008 to 2014. Seedling/tree bases were examined to determine if vole herbivory was the causal agent for mortality. Seedlings dying from vole herbivory were recorded as such.

Data Analysis

All statistical analyses were performed using a mixed procedure Statistical Analysis System version 9.3.1 (Cary, NC). A mixed model analyses of variance (ANOVA) was used to test for effects and interactions. Data were analyzed using least square means (LSMEANS). Survival percentages were arcsine square root transformed for normalization purposes. This transformation was necessary to convert the binomial distribution of the data to one that is nearly normal. No differences were detected between HWC treatments, however analysis detected significant main effect differences among mechanical treatments and species. While transformed survival data were used for analyses, actual means are presented for interpretation. Means were considered significant if $P < 0.05$.

RESULTS AND DISCUSSION

On this same study site, analysis by Self and others (2015a) did not detect survival differences linked to vole herbivory among species, mechanical site preparation, HWC treatments, or their interactions at year three. Overall tree survival at this point was 95.6 percent with vole herbivory accounting for approximately 75 percent of oak mortality. However, tree survival continued to drop in years four through seven, with 3.9 percent survival reductions in 2011 and 2012, and a 4 percent in 2013. In 2014, overall, mortality seemingly plateaued at 83.7 percent with a 0.1 percent increase in mortality from 2013 observations. Approximately 79.1 percent of tree mortality observed throughout the duration of this study resulted from meadow vole herbivory. Analysis of year seven survival data did not detect differences among HWC treatments.

Survival by Mechanical Treatment

Analysis detected a significant main effect survival difference among mechanical treatments ($p = 0.0134$). Trees grown in areas receiving more intensive mechanical site preparation exhibited less vole induced mortality compared to those grown in areas receiving less intensive treatments (table 1). Year seven cumulative mortality in bedded or combination plowed areas was lower than that observed in both control and subsoiled areas (2.78, 2.99, 3.47, and 3.68 percent, respectively). This result was somewhat unexpected; the expectation being greater vole herbivory/tree mortality in the more friable disturbed soils of the bedded and combination plowed treatment areas.

A possible explanation for this deviation in expected tree mortality results may lie in increased root production of seedlings/trees growing in more intensively treated areas. In earlier analyses of this same study, Self and others (2015b) found seedlings in bedded and combination plowed areas possessed root systems with approximately 58 percent greater root biomass compared to seedlings growing in control and subsoiled areas. Additionally, overall height and diameter seedling parameters were greater in more intensively treated areas. It is reasonable to conclude that increased seedling/tree size in more intensively treated areas resulted in more vigorous trees, better equipped to survive vole herbivory.

Survival by Species

Analysis detected a significant main effect difference in survival among species ($p = <0.0001$) due to vole herbivory. Of the three species planted, vole induced mortality was greatest in Nuttall oak followed by Shumard and swamp chestnut oaks (9.51, 2.29, and 1.11 percent, respectively) (table 2). The finding of preferential selection of Nuttall oak by meadow voles is surprising as no differences were detected in earlier analyses of years one through three survival data (Self and others 2015a). Nuttall oak is a faster growing species compared to Shumard and swamp chestnut oaks (Burns and Honkala 1990). It is possible that greater inherent overall vigor of the species and associated nutrient rich root growth flushes served to attract meadow voles to Nuttall root systems compared to those of Shumard and swamp chestnut oak. Additionally, it is entirely possible that Nuttall oak possesses some nutrient highly desired by voles.

Table 1–Cumulative seventh year vole induced oak mortality by mechanical site preparation treatment

Mechanical Treatment	Cumulative Mortality
	----------percent----------
Control	3.47a[a]
Subsoiling	3.68a
Bedding	2.78b
Combination Plowing	2.99b

[a]values followed by different letters are different at the $\alpha = 0.05$ level.

Table 2—Cumulative seventh year vole induced oak mortality by oak species

Species	Cumulative Mortality
	----------percent----------
Nuttall oak	9.51a[a]
Shumard oak	2.29b
Swamp chestnut oak	1.11c

[a]values followed by different letters are different at the $\alpha = 0.05$ level.

MANAGEMENT IMPLICATIONS

Meadow vole-induced mortality of planted seedlings is a known variable, but is ordinarily thought to be a minor factor in afforestation attempts. While typically not a major concern in afforestation efforts, vole herbivory can reach levels with substantial impact to planting success. Furthermore, vole herbivory is typically thought to be relatively nonexistent after the third or fourth growing season. Oak mortality due to vole damage reached levels of greater concern for this study in frequency and seedling age. Most land managers evaluate planting success during the first three years after plantation establishment. In some situations it is possible that the greatest levels of vole damage do not manifest until after this point. Additionally, of the three tree species tested, the finding that Nuttall oak seems to be preferred compared to other oaks may be of particular concern in afforestation attempts.

CONCLUSIONS

Assuming that vole-killed seedlings had survived and not died via some other unforeseen factor, overall seventh year tree survival would have been approximately 96.6 percent. Conventional wisdom dictates that upon entering the third or fourth growing season, vole herbivory should be a lessening problem regarding continued seedling/tree mortality. Vole-induced seedling mortality did not follow this traditional trend in this study. Additionally, the preferential selection of Nuttall oak stems by meadow voles could have far reaching impacts. Due to its quick growth and elasticity regarding suitable planting sites, Nuttall oak has been one of the primary oak species planted in hardwood afforestation efforts over the past few decades. Considering the acreages currently planted and scheduled for plantation establishment, preferential selection of this species by meadow voles warrants consideration in planting efforts.

LITERATURE CITED

Birney, E.C.; Grant, W.E.; Baird, D.D. 1976. Importance of vegetative cover to cycles of *Microtus* populations. Ecology. 57: 757-780.

Buell, M.F.; Buell, H.F.; Small, J.A.; Siccama, T.G. 1971. Invasion of trees in secondary succession on the New Jersey Piedmont. Bulletin of the Torrey Botanical Club. 98: 67-84.

Burns, R.M.; Honkala, B.H. 1990. Silvics of North America. Vol. 2. Hardwoods. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture. 877 p.

Gill, D.S.; Marks, P.L. 1991. Tree and shrub seedling colonization of old fields in central New York. Ecological Monographs. 61(2): 183-205.

NOAA [National Oceanic and Atmospheric Administration]. 2015. Precipitation totals. Washington, DC: U.S. Department of Commerce National Climatic Data Center. Available at http://www.noaa.gov. [Date accessed: May 5, 2015].

Ostfeld, R.S.; Canham, C.D. 1993. Effects of meadow vole population density on tree seedling survival in old fields. Ecology. 74(6): 1792-1801.

Perry, R.W.; Thill, R.E. 2005. Small-mammal responses to pine regeneration treatments in the Ouachita Mountains of Arkansas and Oklahoma, USA. Forest Ecology and Management. 219: 81-94.

Rathfon, R.A.; Lichti, N.I.; Swihart, R.K. 2008. Disking and mid-and understory removal following an above-average acorn crop in three mature oak forests in southern Indiana. In: Jacobs, D.F.; Michler, C.H., eds. Proceedings of the 16th central hardwood forest conference. Gen. Tech. Rep. NRS-P-24. Newtown Square, PA: U.S. Department of Agriculture Forest Service, Northern Research Station: 59-69.

Schreiber, L.A.; Swihart, R.K. 2009. Selective feeding of pine voles on roots of tree seedlings. Canadian Journal of Zoology. 87: 183-187.

Self, A.B.; Ezell, A.W.; Rowe, D. [and others]. 2015a. Meadow vole (*Microtus pinetorum*) induced mortality of oak seedlings in a former agricultural field planting. In: Holley, G.A.; Conner, K.F.; Haywood, J.D. Proceedings of the 17th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-203. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 295-300.

Self, A.B., Ezell, A.W., Rowe, D. [and others]. 2015b. Mechanical site preparation and Oust XP effects on stem biomass in three-year-old Nuttall oak seedlings planted on a former agricultural field. In: Holley, G.A.; Conner, K.F.; Haywood, J.D. Proceedings of the 17th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-203. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 57-61.