ISSN 1946-7664. MCFNS 2016
Vol. 8, Issue 2, pp. 1–7
Mathematical and Computational Forestry & Natural-Resource Sciences

AVAILABLE ONLINE AT HTTP://MCFNS.COM

Submitted: Feb. 1, 2016
Accepted: Apr. 21, 2016
Published: Sep. 30, 2016
Last Correction: Sep. 30, 2016

SPATIAL ASSESSMENT OF MEADOW VOLE HERBIVORY ON A REPLANTED AGRICULTURE FIELD IN MISSISSIPPI

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Abstract. Successful afforestation of fields formerly used for agricultural production is dependent upon manageable seedling mortality rates. Animal herbivory can exacerbate mortality of planted seedlings beyond acceptable levels. A study conducted at a planted site in Desoto County, Mississippi, of 1,440 bare-root seedlings comprised of Nuttall oak (*Quercus texana* Buckley), Shumard oak (*Quercus shumardii* Buckley), and swamp chestnut oak (*Quercus michauxii* Nutt.) exhibited high levels of mortality as a result of herbivory by meadow voles (*Microtus pinetorum* LeConte) seven years after planting. Tree locations, according to planting, were analyzed using hot-spot (Getis-Ord Gi*) and cluster-outlier (Anselin Moran's I) analyses to determine if a spatial pattern exists for herbivory by meadow voles. Meadow voles accounted for 94 percent of the mortality on the planting site. A spatial relationship was determined for mortality caused by meadow vole herbivory, particularly for the Nuttall oak seedlings (i.e., cold spots). Overall, it was determined that meadow voles favored Nuttall oak seedlings throughout the planting area over Shumard and swamp chestnut oaks. Should animal herbivory lead to unacceptably high mortality for seedlings, this information will be useful to resource managers for the application of counter-measures to prevent increased mortality.

Keywords: Getis-Ord Gi*, Afforestation, Oak Plantings

1 Introduction

Increased demand for forest products and improved wildlife habitat has led to afforestation efforts on vast tracts of land in the Lower Mississippi Alluvial Valley (LMAV; Ezell and Shankle, 2004). These efforts extend beyond the LMAV as Wear and Greis (2002) estimate that planted acreage of hardwood species will increase through 2040 throughout the southern United States. To affect this degree of change, a variety of methods and a high degree of effort and resources are involved. Still, afforestation efforts can and have failed and areas had to be replanted due to poor species-site interactions, flood, drought, competition, and herbivory (Schoenholtz et al., 2005). Large-caliper seedlings were developed and are planted in an effort to maximize survival and a variety of planting methods and herbicide treatment regimens are utilized to minimize herbaceous competition (Moree et al., 2010; Self, 2011; Self et al., 2014). Recent efforts have aided establishment and afforestation success in most areas. However, herbivory is difficult to overcome. A variety of animals can impact a planting site, including white-tailed deer, mice, squirrels, etc. (see Schoenholtz et al., 2005). One often overlooked animal that can greatly impact seedling survival is the meadow vole (*Microtus pinetorum* LeConte).

The meadow vole is a rodent found throughout the eastern United States that burrows and feeds on taproots below the root collar (Schreiber and Swihart, 2009). It has been associated with mortality levels in planted sites of up to 20 percent (Rathfon et al., 2008). Meadow voles have been reported to feed on a variety of species, favoring white oak (*Quercus alba*), although they did not exhibit a preference for either increased levels of tannins or alkaloids (Bélanger and Bergeron, 1987). Previous work on an afforested site in Mississippi indicated that meadow voles have an impact on mortality rates of oak species (Self et al., 2015). Meadow voles could impact afforestation efforts throughout the region if they are present within a planting site. The objectives of this study are to 1) evaluate levels of mortality caused by meadow vole herbivory and 2) determine if one species

is being favored over another by analyzing spatial relationships in meadow vole herbivory within the planting site.

2 Methods

The study site was 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 (northwest Mississippi; Figure 1). Prior to study initiation, the site had been planted in soybeans (*Glycine max* (L.) Merr.) until September, 2007. Soils were silt loams, and 40-year average precipitation was 56.1 inches (NOAA 2015). Soil tests indicate that pH averaged 6.2 across the study area. Dominant herbaceous onsite species were Brazilian vervain (*Verbena brasiliensis* Vell.), poorjoe (*Diodia teres* Walt.), and thorny amaranth (*Amaranthus spinosus* L.). Twenty-one other herbaceous species were observed in small quantities across the site. Cumulative herbaceous coverage of all species was approximately 5 percent.

A total of 1,440 Nuttall oak (*Quercus texana* Buckley), Shumard oak (*Quercus shumardii* Buckley), and Swamp chestnut oak (*Quercus michauxii* Nutt.) bareroot seedlings (480 of each species) were planted on 10-foot centers during February 2008 (Figure 2). A split, split-plot design with whole plot factors in a randomized complete block design was utilized. A variety of mechanical site preparation and herbaceous weed control treatments (HWC) were used (Self, 2011). Mechanical site preparation treatments included: a control (no site preparation), subsoiling, bedding, and combination plowing. Mechanical site preparation treatments were applied during the first week of November 2007. Two HWC treatments were utilized including a one year application and a two year application of Oust XP®. Both HWC treatments were applied during March of their respective years. Since establishment, seedling survival and cause of death has been monitored annually since initial establishment by visual inspection of seedling bases.

A spatial representation of seedling locations was created in ArcMap 10.2, depicting each tree with correct spacing. This was then joined to a table containing data collected on mortality over a seven-year period and includes species, treatment type, and status at year seven (i.e, live (3), dead/natural mortality (2), or meadow vole herbivory/mortality (1)). Spatial clusters were determined by using Anselin Moran's I (Cluster-Outlier Analysis), which identifies Local Moran's I to determine clusters of features similar in magnitude. Where there were clusters of high or low values, HH and LL were used, respectively. LL clusters would indicate areas where dead trees are surrounded by dead trees. Also possible are low values (e.g., 1/meadow vole mortality) surrounded by higher values (i.e., dead trees surrounded by live trees (classified as 3)) and higher values surrounded by lower values (i.e., live trees surrounded by dead trees; Mitchell, 2005).

Hot/cold spots were assessed by using Getis-Ord Gi* statistic that analyzes features while considering neighboring features. If found to be statistically significant, when a features value is higher/lower than expected considering surrounding features, and the difference too large to randomly occur, a hot/cold spot is assigned (Mitchell, 2005). Tree status (live, natural mortality, meadow vole mortality) was assessed to determine whether hot/cold spots exist. If the Gi* statistic yields groups of high values, the location is identified as a hot spot (i.e., clusters of live trees); where there are groups of low values, cold spots are identified (i.e., clusters of meadow vole-killed trees).

3 Results and Discussion

Considering the total planting, 86 percent of seedlings survived to year seven (Table 1). Noteworthy is that 13 percent of all trees planted were subject to meadow vole herbivory, accounting for 94 percent of total seedling losses. When viewing a map of the trees lost to vole induced mortality, a distinct pattern is discernable (Figure 2). The cold spots or clusters of low values, indicating mortality due to meadow vole herbivory, can be viewed throughout the planting. Analysis of Getis-Ord Gi* reveals cold spots throughout the planting (Figure 3) where trees subject to meadow vole herbivory appear to occur in clusters. These clusters follow a north-south, rather than an east-west, pattern which follows the plantings of the species in rows. This can be viewed as a preference for certain species as there are cold spots located throughout the planting, all following the same north-south pattern. The intensity of the clustering also varies, further indicating a change in mortality as different species are encountered. If the meadow voles were consuming seedlings in a non-selective manner, it is likely that the cold spots would occur in a more concentrated pattern (i.e., mortality would be concentrated in contiguous areas instead of smaller clusters throughout the planting). When selected by species, the majority of the trees marked as a cold spot belong to the Nuttall oak plantings (92 of 122 cold spots). Additionally, 92 of 133 Nuttall oak seedlings lost to meadow voles are cold spots and there was no difference between treatment effects on mortality due to meadow voles (Table 2).

Additional analysis using Moran's I (cluster-outlier; Figure 4) was conducted to confirm the clustering of meadow vole induced mortality. A pattern emerged when considering the whole planting. Most of the trees lost to meadow voles were Low-Low (LL) clusters, meaning

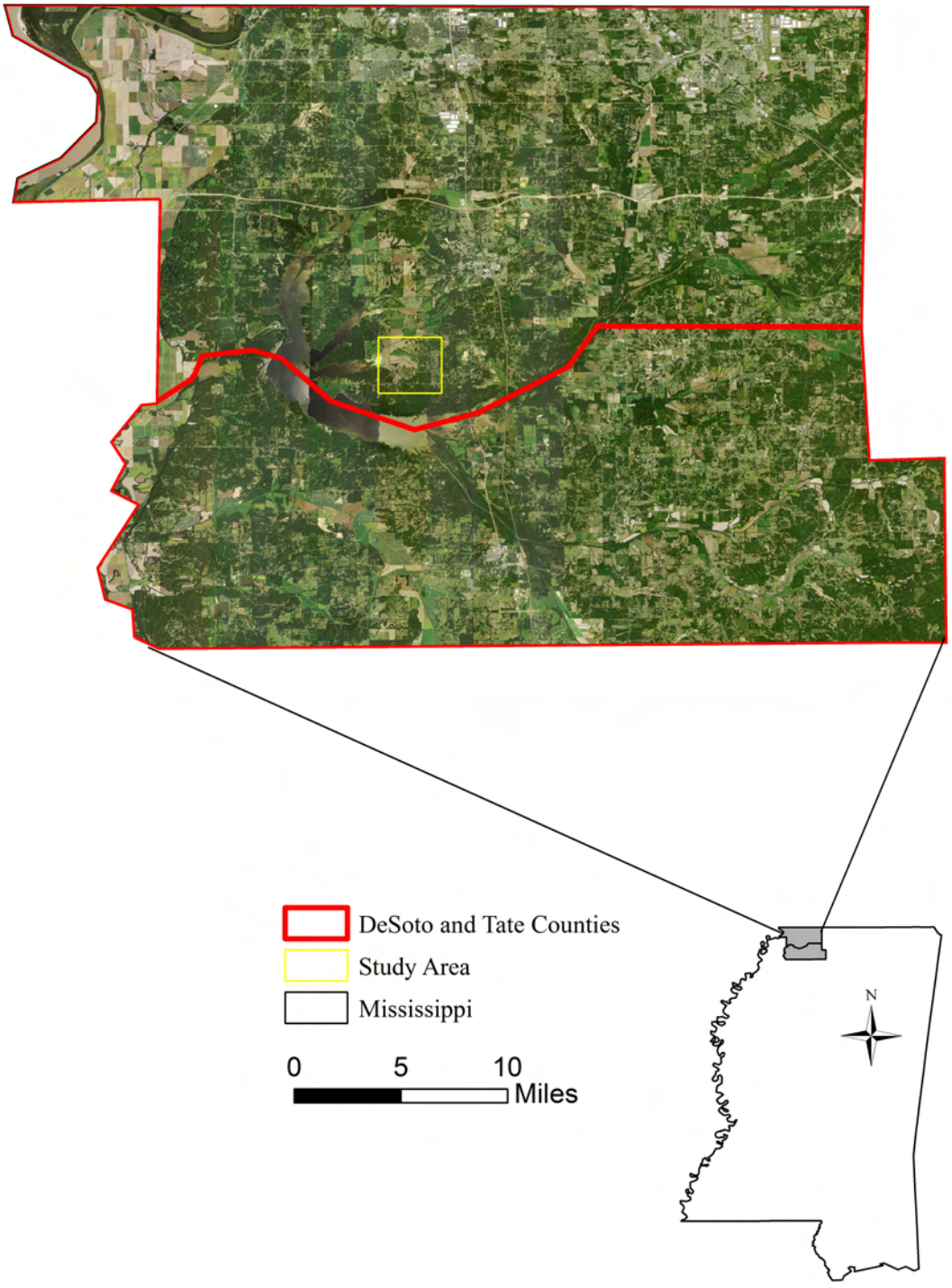

Figure 1: Map of study area near Arkabutla Lake in DeSoto County, MS.

that low values (i.e., meadow-vole killed trees) occurred surrounded by other low values (i.e., other meadow-vole killed trees). Of 186 trees subject to meadow vole herbivory, 113 were found to be clustered. Only 60 of the clustered trees were LL clusters with the remaining being LH outliers, or meadow vole killed trees surrounded by live trees. The majority of the LH outliers belong to the Nuttall oak species. Observations of the plantings indicates that Nuttall oaks are lost while live Shumard or Swamp chestnut oak seedlings remain on either side.

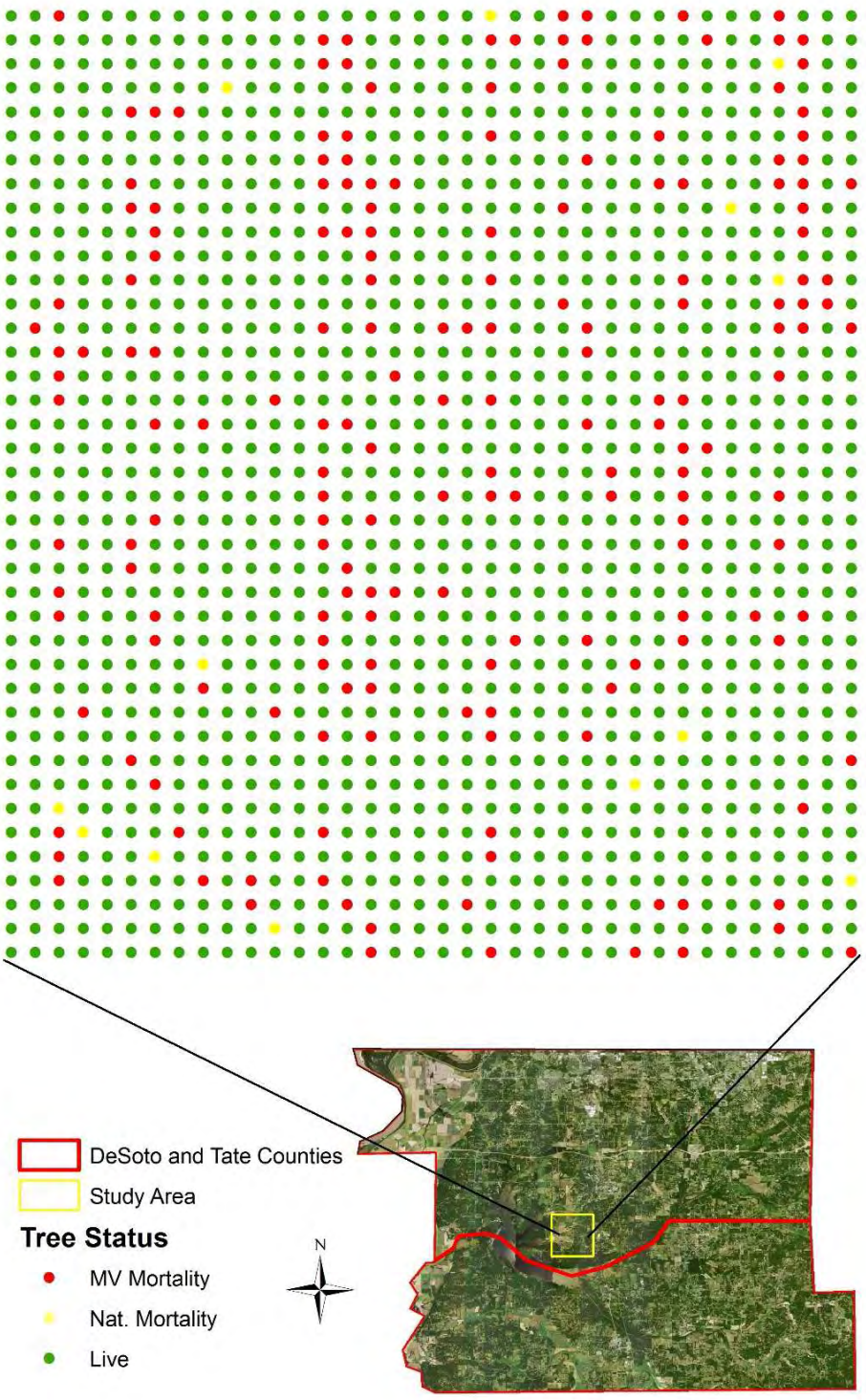

Figure 2: Status of trees planted in DeSoto County, MS after year seven.

Table 1: Tree status, by species, for Arkabutla Lake planting site.

Species	Code	Count	%
Nuttall	Vole Mortality	133	27.7
	Natural Mortality	7	1.5
	Live Tree	340	70.8
Shumard	Vole Mortality	37	7.7
	Natural Mortality	2	0.4
	Live Tree	441	91.9
Swamp Chestnut	Vole Mortality	16	3.3
	Natural Mortality	4	0.8
	Live Tree	460	95.8

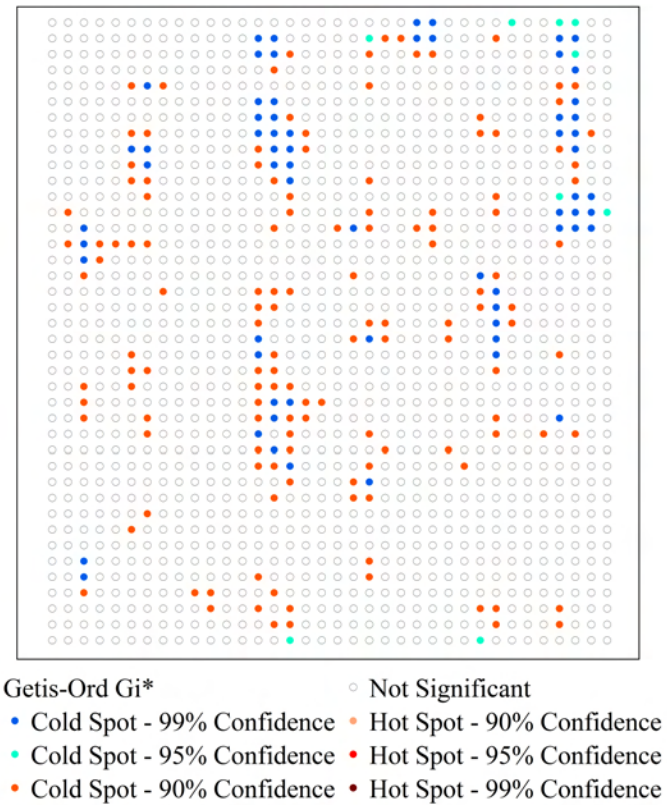

Figure 3: Getis-Ord Gi* cluster analysis.

Nuttall oak experienced the greatest amount of mortality, in total and in terms of meadow vole herbivory, compared to other species planted (Table 1). Approximately 70 percent of Nuttall seedlings survived to year seven with the majority (95 percent) of the mortality resulting from meadow vole herbivory. Approximately 30 percent of the planted Nuttall seedlings have succumbed to meadow voles and the mortality pattern is observed in

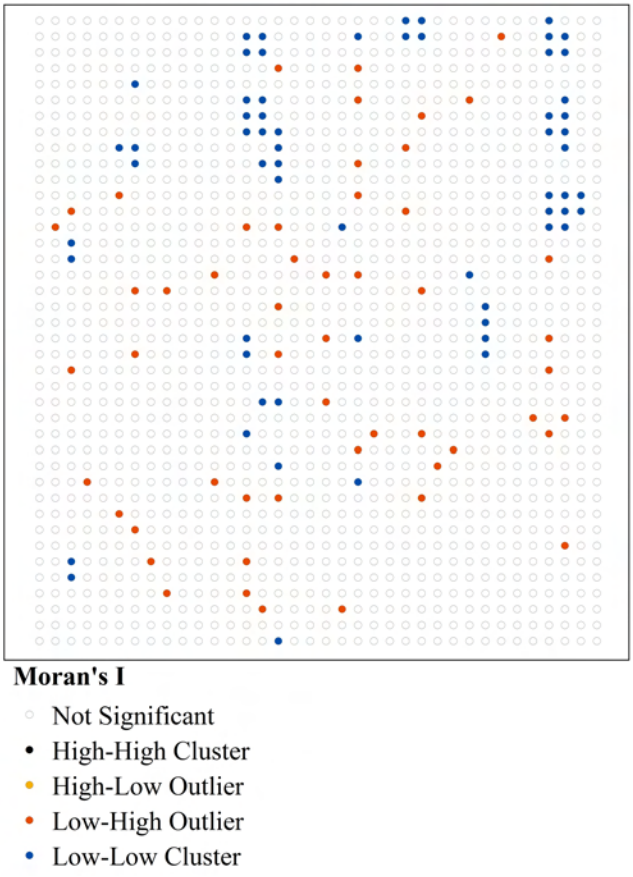

Figure 4: Moran's I results depicting spatial clusters and outliers.

clusters throughout the study area. The majority (69%) of Nuttall oak seedlings lost to meadow vole herbivory are cold spots, as indicated by analysis of Getis-Ord Gi* statistic (Figure 3). Cluster-outlier analysis reveals that 42% of clusters are LH. That this species is not subject to herbivory exclusively in clusters serves as an indication that it is being sought for consumption by meadow voles. There is no clear reason as to why voles may be consuming Nuttall oaks to such an extent. Previous research indicated a preference for white oak (Schreiber and Swihart, 2009) but that is not the case at this study site. It has been suggested that tannin content may be a factor in food selection for meadow voles but Bélanger and Bergeron (1987) found no relationship between food preferences and tannin or alkaloid content.

The Shumard oak seedlings fared better than Nuttall with 92 percent survival to year seven (Table 1). Approximately eight percent of the seedlings planted were lost to meadow vole herbivory, which accounted for 95 percent of total seedling mortality for Shumard oak. The mortality due to meadow voles is more dispersed in Shumard oak although some clustering does occur. Getis

Table 2: Tree status, by treatment, for Arkabutla Lake planting site.

	Nuttall			Shumard			Swamp Chestnut		
Treatment	Status	Count	%	Status	Count	%	Status	Count	%
	MV	36	30	MV	6	5	MV	4	3.3
Control	Natural	3	2.5	Natural	1	0.8	Natural	1	0.8
	Live	81	67.5	Live	113	94.2	Live	115	95.8
	MV	34	28.3	MV	8	6.7	MV	5	4.2
Subsoiling	Natural	1	0.8	Natural	0	0	Natural	2	1.7
	Live	85	70.8	Live	112	93.3	Live	113	94.2
	MV	30	25	MV	6	5	MV	5	4.2
Bedding	Natural	2	1.7	Natural	0	0	Natural	0	0
	Live	88	73.3	Live	114	95	Live	115	95.8
	MV	33	27.5	MV	17	14.2	MV	2	1.7
Combination Plowing	Natural	1	0.8	Natural	1	0.8	Natural	1	0.8
	Live	86	71.7	Live	102	85	Live	117	97.5

Ord Gi* analysis reveals that over 60 percent of meadow vole impacted trees are cold spots but that only about half (45 percent) are clustered (mixed evenly between LL and LH, see Figure 4). The majority of Shumard oak seedlings lost to meadow voles occur in clusters involving Nuttall oak. Swamp chestnut oak experienced the greatest survival of the three species with 96 percent survival (Table 1). Only three percent of seedlings planted were lost to meadow vole herbivory accounting for eighty percent of the Swamp chestnut oak mortality. Approximately 60 percent of Swamp chestnut seedlings lost were clustered but less than 50 percent were considered cold spots. Further, as with Shumard oaks, the clusters and cold spots occur near Nuttall oak species.

The natural seedling mortality levels were less than 20 percent (considered acceptable for most plantings) for mortality through year seven. Vole herbivory is thought to slow as trees get larger/older (Schreiber and Swihart, 2009). While the majority of the vole induced mortality occurred during the second growing season, the expectation was that their impact would taper in subsequent growing seasons (Self et al., 2015); however, abatement in vole activity has yet to occur. Vole activity in this area may be a factor of microsite characteristics and pretreatment of planting site. The silt-loam soils may allow for ease of movement for the voles, allowing access to the trees beyond the first few growing seasons. Plant spacing is considered a factor (Ostfeld and Canham, 1993). While spacing was not a variable in this study, it would appear spacing would not factor in vole herbivory as the majority of Shumard and Swamp chestnut oaks were passed over.

4 Conclusion

This study has shown that seedling mortality in an afforested area due to meadow vole herbivory occurs in a clustered pattern. It also appears that meadow voles favor Nuttall oak. While some mortality is expected and acceptable, the fact that 13 percent of all seedlings planted were lost to the presence of meadow voles could prove problematic. Vole herbivory accounted for 94 percent of seedling mortality within the study area. This amount of loss over larger areas would not be acceptable and thus, it may be advisable to suggest eradication/control programs be instituted where voles are present. Additional research is needed to determine if Nuttall oaks exhibit some specific characteristic (nutritional or otherwise), sought by voles. This would allow for landowners to be advised to plant less desirable species in areas with a known meadow vole presence.

Acknowledgement

The authors wish to thank Dr. Kody Mullins at Shorter University for his review of an earlier version of this manuscript. We also wish to thank two anonymous reviewers for their constructive reviews, which greatly improved the readability of this manuscript.

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