Articles

Evaluation of Mowing Frequency on Right-of-Way Plant Communities in Mississippi

Edward D. Entsminger,* Jeanne C. Jones, John W. Guyton, Bronson K. Strickland, Bruce D. Leopold

E.D. Entsminger,* J.C. Jones, B.K. Strickland, B.D. Leopold
Department of Wildlife, Fisheries & Aquaculture, Mississippi State University, Mississippi State, Mississippi 39762-9690
Present address of E.D. Entsminger: 876 Dorroh Road, Eupora, Mississippi 39744

J.W. Guyton
Department of Biochemistry, Molecular Biology, Entomology & Plant Pathology, Mississippi State University, Mississippi State, Mississippi 39762-9775

Abstract

Native grasses and native wildflowers are declining, especially along roadside right-of-ways because of intensive mowing and herbicide management practices. Roadside right-of-ways undergo regular disturbances such as mowing, maintenance, and road developments that affect soils, groundwater, surface hydrology, and vegetation composition. We investigated species richness and percent coverage within plant communities along highway right-of-ways to determine if reduced mowing increased native plant coverage. The study was conducted using 10 research plots situated along Highway 25 in Oktibbeha and Winston counties, Mississippi. Each research plot consisted of three different treatments as follows: one that included greater than four mowings per year, one mowing only in fall, and one mowing only in fall with a supplemental native wildflower seeding. Using line transect sampling, we detected 277 plant species, which included native and nonnative forbs, legumes, grasses, rushes, sedges, and woody perennials (vines, shrubs, and trees). Total percent coverage of native and nonnative plants within different growth form categories did not differ among treatments ($F_{2,96} = 0.45$, $P = 0.83$). However, coverage differed between uplands and lowlands ($F_{1,96} = 18.22$, $P \leq 0.001$), between years ($F_{1,96} = 14.54$, $P \leq 0.001$), between fall and spring seasons ($F_{1,96} = 16.25$, $P \leq 0.001$), and interacted between years and seasons ($F_{1,96} = 24.08$, $P \leq 0.001$) and seasons and elevations ($F_{1,96} = 5.00$, $P \leq 0.001$). Nonnative agronomic grasses exhibited the greatest coverage ($> 90\%$) in all treatments. Percent coverage of each plant growth form was greatest in lowlands. Our research showed an increase of native grasses and wildflower species along roadsides with a reduced mowing regimen. We concluded that the timing and intensity of mowing for the duration of our study had little effect on the species composition of plant communities. However, one mowing per year retained agronomic plant coverage for erosion control and soil stabilization during roadside maintenance. Specific proactive management implementations can include native plantings, selective herbicide use to decrease nonnative grasses, continual mowing from roadside edge to 10 m, and only one mowing in late fall, but with an extension of the boundary to reach beyond 10 m from the roadside edge to suppress the invasion of woody plants, which could lead to lower long-term maintenance costs.

Keywords: Native plants; nonnative invasive plants; northeastern Mississippi; reduced mowing; right-of-ways; roadsides; plant communities

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* Corresponding author: edward.entsminger@msstate.edu

Introduction

Roadside right-of-ways can provide a good environment for a variety of native and nonnative plant species, but current management practices have caused declines in native grasses and wildflowers (Hill and Horner 2005; Willard et al. 2010; Yager et al. 2011). Plant communities along roadside right-of-ways can be very diverse depending on type of road, width, slope, and adjacent land uses (Li et al. 2008). Intensive herbicide applications and mowing directly affect native plant communities by killing native plants or preventing their successful reproduction (Hill and Horner 2005; Willard et al. 2010; Yager et al. 2011). General roadside management can also threaten native species by altering soil fertility, soil structure, topography, surface water movement, and other hydrological factors (Schauwecker and MacDonald 2003; Greenfield et al. 2005). Other negative impacts of mowing on native species along roadsides include changes in adjacent ecosystems through modification of plant communities, changes in wetland hydrology, degradation of water quality, and dispersal of invasive nonnative species (Mortensen et al. 2009; Yager et al. 2011).

The two main negative impacts on native plant communities are a direct result of mowing and herbicide use, which have altered roadside environments through increased dominance of invasive species. Over time, direct and indirect impacts of roadside management can cause right-of-ways to become more susceptible to invasions of nonnative and invasive plants (Forman and Alexander 1998; Greenfield et al. 2005; Andrews et al. 2015). More than 42% of native species are listed as species of conservation concern as a direct result of the exacerbated spread of invasive species specifically on road right-of-ways (Clinton 1999; Schauwecker and MacDonald 2003; Center for Environmental Excellence 2017; M. Ielmini, U.S. Forest Service, National Invasive Species Program Manager, personal communication). Simberloff et al. (2012) stated that nonnative invasive species were 40 times more problematic and costly than native species in environments such as road right-of-ways.

Roadsides may provide environments for populations of species of conservation concern and even rare native flora species. During the past 2 decades, roadside wildflower programs in many states have resulted in enhanced native plant communities that have increased the beautification of roadsides (Harrington 1994; Weingroff 2015). The Highway Beautification Act of 1965 has resulted in enhanced visual and aesthetic qualities of roadsides, resulting in points of pride by establishing and beautifying right-of-way communities throughout the United States (Harrington 1994; Aldrich 2002; Weingroff 2015). Furthermore, native plant communities along roadsides can decrease spread of invasive plants, reduce erosion, lessen maintenance costs, and protect water quality and wetlands (Forman and Alexander 1998; Welker and Green 2003; Yager et al. 2011; Green 2016). Native plants within right-of-ways also create habitat for early successional wildlife species including small mammals, birds, herpetofauna, and insects (Bugg et al. 1997; Forman and Alexander 1998; Hopwood 2010; Andrews et al. 2015; Hopwood et al. 2016). Although increasing native plant coverage along highway right-of-ways cannot completely mitigate the negative impacts to wildlife and native flora caused by roadways, the modifications in management approaches of right-of-ways can potentially lessen deleterious effects and benefit wildlife and humans.

Other concerns related to right-of-way management include the restriction of wildlife movement, habitat fragmentation and loss, population isolation, and increases in traffic-related wildlife mortality (Forman and Deblinger 2000; Harper-Lore and Wilson 2000; Ament et al. 2008). However, management of right-of-way vegetation can enhance establishment of native plant communities and improve ecological function and structure for native wildlife (Arner 1959; Harper-Lore and Wilson 2000; Arner and Jones 2009). Several studies have shown that the re-establishment of native flora on right-of-ways did not increase wildlife–vehicle collisions (Machan 1981; Zimmerman 1981; Harper-Lore and Wilson 2000; Jacobson 2005). Furthermore, Machan (1981) reported a 35% reduction in mortality of songbirds and rabbit species where trees and shrubs were planted on Indiana roadway right-of-ways. Similarly, Zimmerman (1981) detected fewer road kills and greater small mammal abundance where road right-of-ways were planted with native wildflowers, grasses, and shrubs. Modifications in seed mixtures used for soil stabilization, application of soil amendments, and mowing regimens have been reported to produce less attractive foraging conditions for herbivores such as white-tailed deer (*Odocoileus virginianus*; Jacobson 2005; Arner and Jones 2009). However, despite the importance of plant communities to white-tailed deer and their use of right-of-ways, there is limited information on the effects of highway right-of-way vegetation management regarding vehicle collisions with white-tailed deer.

In addition, there are some issues related to motorists when native plant communities are enhanced, such as reduction in visibility along roadway right-of-ways, which can be an issue (Louisiana Department of Transportation and Development 2000; Cackowski and Nasar 2003). Concerns exist that enhancing right-of-way environments could potentially increase large mammal– and wildlife–vehicle collisions (Michael and Kosten 1981; Dixon et al. 1984; McKee and Cochran 2012). There is a need for investigations of approaches for effective management options that mutually benefit agencies, motorists, and native fauna and flora along roadway right-of-ways. Two major approaches to improving native plant communities are annual mowing in the fall and seeding native wildflowers along roadsides.

Annual mowing in late fall is one low-maintenance approach that can be used to improve native plant communities along roadsides (Entsminger 2014; Entsminger et al., in press). Reduced mowing frequencies during the growing season result in reduced costs. The annual fall mowing can be conducted after seed maturation in native plants and after nesting seasons for ground-nesting birds and other wildlife. This approach also increases availability of pollen and nectar-producing plants that provide food sources for birds, small mammals, and pollinating insects (Anderson 1996; Dickson and Wigley 2001; Andrews et al. 2015). Reduced mowing also has the potential to create attractive prairie-like environments along roadsides by increasing native grasses and wildflowers (Entsminger et al., in press).

Seeding native wildflowers is another practice to establish native plant communities along roadside right-of-ways. This practice typically requires site preparation to remove existing nonnative plant communities, selection of adapted plant species for seeding, and postplanting competition control methods (Young and Claassen 2007; Native American Seed 2017). Seeding of native wildflowers and warm-season grasses can be expensive because of site preparation, seed and maintenance costs, and competition of nonnative invasive plants; however, benefits have been reported (Bugg et al. 1997; Young and Claassen 2007; Mortensen et al. 2009). A more cost-effective approach to enhancing a native plant community is to implement a reduced mowing regimen (Bugg et al. 1997; Young and Claassen 2007; Arner and Jones 2009; Entsminger 2014; Entsminger et al., in press). In areas where native grasses and wildflowers have been successfully established, very little maintenance is needed because the plant community resists colonization by invasive plants (Daar 1994; Welker and Green 2003; CalTrans 2013; California Department of Transportation 2016).

The objective of this study was to investigate influences of modifications in mowing regimens along a state highway in northeastern Mississippi on native plant community structure. Our approach was to compare species richness and percent coverages among three treatments (greater than four mowings per year; one mowing in late fall; and one mowing in late fall with native supplemental seeds) and among upland and riparian lowland landscapes along the roadside right-of-ways. Our null hypothesis was that there would be no significant differences in total species richness, native species richness, and nonnative species richness among treatments and among upland and riparian lowland landscapes. Our second null hypothesis was that there would be no significant differences in percent coverages of vegetation categorized by growth form (grass, sedge, legume, forb, rush, and woody perennial) and native vs. nonnative status among treatments and between upland and riparian lowland landscapes.

Study site

This study was conducted on roadside right-of-ways along a 48.28-km stretch of Highway 25 beginning at the intersection of Highways 12 and 25, western edge of Starkville, Mississippi (Oktibbeha County), and continuing south 4.5 km into Winston County, in northeastern Mississippi. There was an average distance of 2.7 km between each of 10 research plots. Plots were regionally within the Interior Flatwoods (33°12′N, 88°54′W; Township 15-18N, Range 13-14E; Pettry 1977; Edwards 2009). Soil formation and plant communities were influenced by mild climatic conditions categorized as the humid subtropical climatic region of North America, with temperate winters (0°C to 15°C) and long hot summers (21°C to 38°C; Posner 2012; Brown 2017). Annual mean temperature for the region is 16.67°C, but has had low temperatures drop to −9°C (Brown 2017). High temperatures exceed 32°C for more than 100 d each year, with temperatures routinely exceeding 38°C (Brown 2017). Normal precipitation ranges from 127 to 165 cm across the state of Mississippi from north to south (Brown 2017). Our 48.28-km stretch of right-of-way was intersected by third- to fourth-order streams differentiating upland and riparian lowland plots. Upland areas had well-drained soils in elevations, whereas lowland areas were influenced by overbank inundations by streams and drainage ditches that were typically spanned by bridges or box culvert structures.

Previous highway right-of-way management consisted of multiple mowings during the growing season (greater than four times per season) and selective herbicide applications such as imazapyr, triclopyr, and glyphosate Roundup® to control encroaching woody vegetation and exotic nonnative invasive plant species (e.g., johnsongrass [*Sorghum halepense*], kudzu [*Pueraria montana*], and cogongrass [*Imperata cylindrica*]). Before study initiation, the right-of-way area plant communities were predominately comprised of nonnative grasses including Bermuda grass (*Cynodon dactylon*), tall fescue (*Schedonorus arundinaceus*), bahiagrass (*Paspalum notatum*), Vasey's grass (*P. urvillei*), foxtail (*Setaria* spp.), and johnsongrass. Predominate nonnative legumes along the right-of-way included Japanese clover (*Kummerowia striata*), sericea lespedeza (*Lespedeza cuneata*), field clover (*Trifolium campestre*), crimson clover (*T. incarnatum*), white clover (*T. repens*), bird vetch (*Vicia cracca*), and garden vetch (*V. sativa*). The landscape adjacent to the road right-of-way was comprised of agricultural fields, pastures, fallow fields, forests, and pine plantations with a mix of hilly and flatland topography.

Methods

We compared plant community characteristics along right-of-ways and managed with different types of mowing regimens from 2010 to 2012. Along the highway right-of-way, 10 (30.48 × 30.48 m) research plots consisting of five upland and five riparian lowland plots were randomly selected. Similar to Li et al. (2008), a randomized complete block design was used by dividing each of the 10 plots into three equal subplots (10.16 × 30.48 m each). Each subplot was randomly assigned one of three treatments: 1) annual mowing during November (treatment 1), 2) annual mowing during November with supplemental native wildflower seed mixture (treatment 2), and 3) mowing greater than four times annually in May, July, September, and November (control). In treatment 2, one mowing during late November was conducted to reduce vegetation height before seeding.

The seed mixture was broadcasted onto existing mowed vegetation using hand-dispersal methodology and a Scott's® Company easy handheld broadcast seed spreader. The wildflower seed mixture included black-eyed susan (*Rudbeckia hirta*, 1.55 kg/ha), dense blazing star (*Liatris spicata*, 7.70 kg/ha), and lanceleaf tickseed (*Coreopsis lanceolata*, 7.70 kg/ha; Native American Seed 2017).

A 30.48-m line intercept was used in the middle of each subplot to measure species richness and percent coverages of woody and herbaceous plants during summer to fall (July to September) 2010 and 2011, and spring (March to early June) 2011 and 2012. Line intercepts were $>$ 5 m from subplot edges to avoid potential edge effects, whereas line initiation and end points were marked using a Garmin E-Trex HCx Vista global positioning system (GPS) unit. Plants were identified using two separate parameters: 1) species for species richness and 2) percent coverage of plants that were grouped by growth forms and status categories: native and nonnative forbs, native and nonnative grasses, native and nonnative legumes, native and nonnative sedges, native rushes, and native and nonnative woody plants (i.e., trees, shrubs, and woody vines; Hays et al. 1981; Buckland et al. 2007). Data were grouped by season (fall vs. spring) because of expected vegetation coverage differences within treatment plots between seasons (e.g., taller plants in fall than in spring, and certain species emerge during specific times).

We used mixed-effects, repeated-measures analysis of variance (ANOVA; PROC MIXED) in SAS (SAS Institute Inc. 2011; Ott and Longnecker 2015) to test hypotheses of differences in total species richness, native species richness, and nonnative species richness among treatments and between upland and riparian lowland landscapes. Treatment, elevation, year, and interactions were classified as fixed effects, and site and site by elevation were classified as random effects. We designated year as the repeated measure. We used Akaike's information criterion corrected for smaller sample sizes (AIC_c) to compare autoregressive, compound-symmetry, and unstructured covariance structures for each response variable under the restricted maximum likelihood (Gutzwiller and Riffell 2007), and to determine if random effects were needed in our models. Top model structures (i.e., best covariance structure and inclusion or exclusion of random effect) were designated as models with $\Delta AIC_c \leq 2$ to the next best model (Burnham and Anderson 2002). Fisher's LSD was used for pairwise comparisons of significant effects (Meier 2006).

Using an ANOVA with distance matrices (ADONIS) in program R's vegan package (Anderson 2001; Ott and Longnecker 2015), percent coverage of vegetation categorized by growth form (grass, sedge, legume, forb, rush, and woody perennial) and native vs. nonnative status among treatments and between upland and riparian lowland landscapes were tested. The ANOVA using distance matrices partitioned sources of variation while fitting linear models to distance with permutation tests as pseudo-*F* ratios (Anderson 2001). The interactions of treatment, elevation, and year (fixed effects) and random effects of sites and site by elevation with 999 permutations and Euclidean distances were investigated (Oksanen 2012; R Core Team 2012; Oksanen 2015). When a significant interaction or simple effect occurred, the Wilcoxon signed-rank test for pairwise comparisons was used with sites as a blocking variable to determine how growth form coverages differed with native or nonnative status. We then applied a Wilcoxon signed-rank test to compare greater than two groups because of significant effects within the two levels (McDonald 2009). Level of significance for all tests was $\alpha \leq 0.05$ (Ott and Longnecker 2015).

Results

We recorded 277 plant species, of which 79.1% were native and 20.9% nonnative. Native species counts by category were as follows: forbs 111, grasses 21, legumes four, rushes eight, sedges 15, shrubs seven, trees 24, and vines 21. Nonnative species counts included 23 forbs, 18 grasses, 12 legumes, one sedge, three vines, and nine unidentified species. The greatest plant species richness was recorded in the lowland plots, with $>$ 106 species, with an average of 82.3 species (SE $\pm$ 5.0) recorded among all lowland plots. Differences were detected in species richness among years, seasons, and elevations during fall. Total and native species richness of plants differed significantly between years ($F_{1,96} > 13.43$, $P \leq 0.001$) and elevation ($F_{1,96} > 59.31$, $P \leq 0.001$) during fall (Table 1). Nonnative species richness differed significantly among years ($F_{1,96} = 25.84$, $P \leq 0.001$) and elevations ($F_{1,96} = 10.31$, $P \leq 0.01$), respectively, in fall (Table 1). Total species richness of native and nonnative plants differed significantly among years and elevations, whereas species richness did not differ significantly between treatments ($F_{2,96} < 0.59$, $P > 0.56$) during fall (Table 1).

Significant differences were detected in spring species richness in upland vs. lowland elevations. Total, native, and nonnative species richness differed significantly between elevations ($F_{1,96} > 5.64$, $P < 0.02$; Table 1). In addition, nonnative species richness differed significantly among years ($F_{1,96} = 10.04$, $P \leq 0.01$; Table 1). Species richness of total, native, and nonnative plants did not differ significantly between treatments ($F_{2,96} < 0.87$, $P > 0.42$) or years ($F_{1,96} < 1.68$, $P > 0.20$) during spring (Table 1). Species richness of total, native, and nonnative plants differed significantly among upland and lowland elevations, seasons, and years. Although nonnative agronomic grasses comprised $<$ 5% of the total species detected, they dominated vegetation coverage in all treatments (mowed [mean $=$ 57.70%, SE $\pm$ 3.14%], reduced-mowed [mean $=$ 60.87%, SE $\pm$ 2.87%], reduced-mowed seeded [mean $=$ 58.32%, SE $\pm$ 2.84%]; Figure 1). Treatment effects were not statistically significant for any response variables for plant species richness in fall or spring.

On all study plots, coverage of nonnative grasses averaged 88.6% (SE $\pm$ 3.0%) followed by nonnative legumes with an average of 31.9% (SE $\pm$ 3.5%). Native and nonnative forbs averaged $>$ 22% coverage collectively, whereas other herbaceous plants averaged $<$ 2%

Table 1. Test statistics for comparisons of total, nonnative, and native species richness along the Highway 25 right-of-way in Oktibbeha and Winston counties, Mississippi, during fall 2010 through spring 2012.

		Total native/nonnative species richness		Nonnative species richness		Native species richness	
Source	df	F-value	Pr > F	F-value	Pr > F	F-value	Pr > F
Fall seasons 2010–2011 species richness							
Year[a]	1	24.61	0.001*	25.84	0.001*	13.43	0.001*
TRT[b]	2	0.59	0.560	0.57	0.570	0.43	0.652
Elevation[c]	1	61.40	0.001*	10.31	0.002*	59.31	0.001*
Year × TRT	2	0.13	0.877	0.22	0.804	0.34	0.710
Year × elevation	1	0.26	0.612	2.17	0.148	1.37	0.248
Elevation × TRT	2	0.06	0.942	0.58	0.565	0.20	0.816
Year × elevation × TRT	2	0.21	0.813	0.41	0.668	0.08	0.926
Spring seasons 2011–2012 species richness							
Year[a]	1	0.02	0.894	10.04	0.003*	1.68	0.201
TRT[b]	2	0.26	0.776	0.87	0.424	0.20	0.819
Elevation[c]	1	48.41	0.001*	5.64	0.022*	44.17	0.001*
Year × TRT	2	0.01	0.987	0.41	0.668	0.01	0.989
Year × elevation	1	0.16	0.691	0.12	0.736	0.31	0.581
Elevation × TRT	2	0.83	0.441	0.36	0.703	0.73	0.486
Year × elevation × TRT	2	0.10	0.904	0.30	0.744	0.02	0.976

* Denotes significant differences at alpha level = 0.05.
[a] Over the 2-y study period 2010–2012.
[b] TRT = treatments—mowed, reduced mowed, reduced mowed–seeded.
[c] Upland vs. lowland elevations.

coverage. Woody plants, including vines, trees, and shrubs, comprised < 8% coverage throughout the study. Percent coverage was > 100% because of species overlap along each line transect. In the reduced mowed-seeded subplots, mean percent coverage of native forbs increased from 1.5% to 4.2% ($P < 0.01$) during the study, and there was a slight increase in percent coverage of nonnative forbs from 1.8% to 2.2% ($P > 0.1$). In reduced mowed-seeded plot treatments, mean percent coverage of nonnative grasses exhibited a decrease from 39.5% to 25.2% ($P < 0.001$), whereas native grass coverage increased from 1.1% to 5.3% ($P < 0.01$) during the study. Percent coverage of native forbs tripled, whereas the native grasses increased fivefold from fall 2010 to spring 2012 seasons because of the reduced mowing regimens.

The vegetation coverage by growth form differed significantly between upland and lowland sites in fall ($F_{1,59} = 17.91$, $P \leq 0.001$) and spring ($F_{1,59} = 24.12$, $P \leq 0.001$). In fall, coverages of native forbs ($z = 4.81$, $P \leq 0.001$), native grasses ($z = 3.51$, $P \leq 0.001$), native legumes ($z = 3.37$, $P \leq 0.001$), and native rushes ($z = 4.54$, $P \leq 0.001$) were greatest in lowland sites (Table 2). In spring, coverages of native forbs ($z = 3.03$, $P \leq 0.01$), native legumes ($z = 2.62$, $P \leq 0.01$), nonnative legumes ($z = 3.82$, $P \leq 0.001$), native rushes ($z = 5.00$, $P \leq 0.001$), and native sedges ($z = 4.15$, $P \leq 0.001$) were greatest in lowland sites (Table 2). Total percent coverage of native and nonnative plants by growth forms did not differ significantly among treatments ($F_{2,96} = 0.45$, $P = 0.83$), but differed between uplands and lowlands ($F_{1,96} = 18.22$, $P \leq 0.001$), between years ($F_{1,96} = 14.54$, $P \leq 0.001$), and between fall and spring ($F_{1,96} = 16.25$, $P \leq 0.001$; Table 3). In addition, we detected interactions between years and seasons ($F_{1,96} = 24.08$, $P \leq 0.001$) and seasons and elevations ($F_{1,96} = 5.00$, $P \leq 0.001$; Table 3).

All species richness variables differed between upland and lowland elevations during fall and spring, with greatest species richness in lowland sites. The two subplots with reduced mowing treatments exhibited an increase of native prairie grasses such as broomsedge (*Andropogon virginicus*), panic grasses (*Dichanthelium* and *Panicum* spp.), and little bluestem (*Schizachyrium scoparium*). In addition, native wildflowers such as tall ironweed (*Vernonia gigantea*), partridge pea (*Chamaecrista fasciculata*), purple passionflower vine (*Passiflora incarnata*), asters (*Aster* spp. and *Symphyotrichum* spp.), fleabanes (*Erigeron* spp.), goldenrods (*Solidago* spp., *Euthamia* spp., and *Oligoneuron* spp.), and swamp sunflower (*Helianthus angustifolius*) had an increased percent coverage within the reduced mowing treatments.

Discussion

Our research demonstrates that reduced mowing increased native grasses and wildflower species along roadsides with a reduced mowing regimen. Native species detected in this study increased by three- to fivefold after just 1 y of late-fall-only mowing, suggesting that later-season mowing allowed adequate time for native plants to complete flowering and seed maturation along with fewer disturbances of mowing (Hurst 1972; Anderson 1996; Yarrow and Yarrow 1999; Dickson and Wigley 2001; Arner and Jones 2009). In addition, less frequent mowing may result in lower competition from nonnative agronomic grasses. Reduced competition from nonnative grasses may increase access of native plants to sunlight, moisture, nutrients, and space.

Along with creating more aesthetic roadsides and enhancing native plant diversity, the less frequent mowing of highway right-of-ways could result in

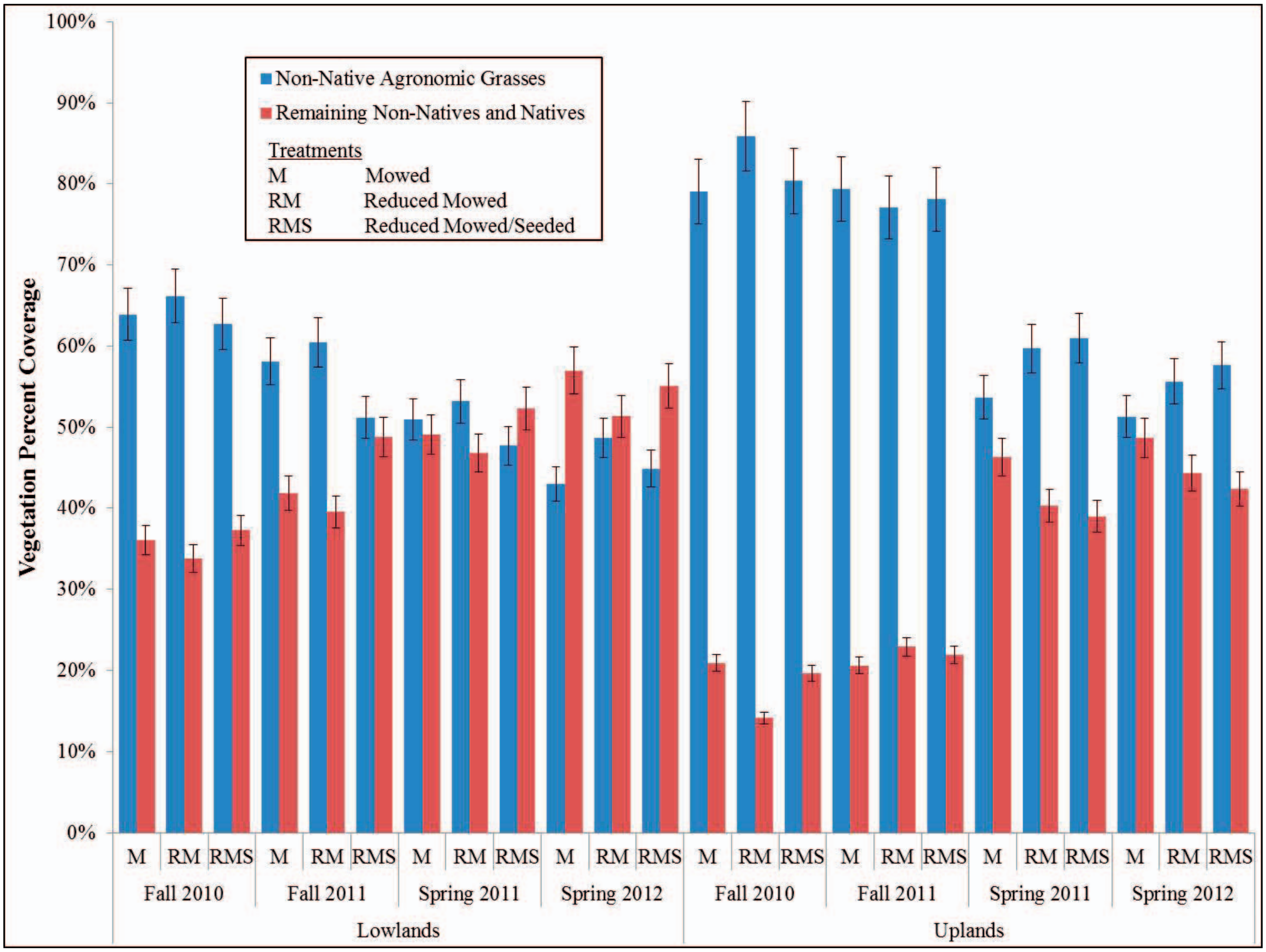

Figure 1. Mean percent coverage with standard error bars of nonnative agronomic grasses and the remaining native and nonnative plant species coverages among mowed (M), reduced mowed (RM), and reduced mowed–seeded (RMS) treatments in lowland and upland elevations along the Highway 25 right-of-way in Oktibbeha and Winston counties, Mississippi, measured using line transect intercepts during fall 2010 through spring 2012.

Table 2. Percent coverage of vegetation growth form categories using pairwise comparisons with means and standard errors (SE) among upland and lowland elevations along Highway 25 right-of-way in Oktibbeha and Winston counties, Mississippi, during fall (2010–2011) and spring seasons (2011–2012).

	Fall season 2010–2011				Spring season 2011–2012			
	Upland		Lowland		Upland		Lowland	
Vegetation growth forms	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Native forb*	7.80	1.53	49.64	7.94	20.10	2.72	47.45	7.21
Nonnative forb	2.54	0.54	2.22	0.46	3.83	0.96	8.07	1.52
Native grass*	1.84	0.47	4.93	0.94	2.08	0.75	5.87	1.27
Nonnative grass	134.51	8.77	115.60	9.01	159.13	9.81	127.51	7.42
Native legume*	0.02	0.02	5.62	2.57	0.00	0.00	4.12	1.94
Nonnative legume*	6.79	2.87	7.16	4.17	84.02	7.43	42.31	5.25
Native rush*	0.03	0.03	3.11	1.06	0.21	0.09	10.68	2.58
Native sedge*	0.33	0.11	0.89	0.25	1.51	0.47	7.17	1.30
Nonnative sedge	0.21	0.17	0.91	0.36	0.00	0.00	0.00	0.00
Native shrub	0.52	0.40	0.34	0.11	0.19	0.13	0.66	0.29
Native tree	0.69	0.23	1.88	0.48	1.30	0.39	5.13	1.70
Native vine	12.02	4.09	2.49	0.76	5.92	1.48	5.02	1.42
Nonnative vine	2.10	1.03	0.92	0.48	2.39	1.03	1.02	0.37

* Denotes statistical significant differences between upland and lowland elevations at alpha level $P \leq 0.05$.

Table 3. Test statistics for comparisons of percent coverage within vegetation growth forms along the Highway 25 right-of-way in Oktibbeha and Winston counties, Mississippi, during fall 2010 through spring 2012.

	df	Sums of squares	Mean squares	*F* Model	R^2	Pr (> *F*)
Year	1	57,292	57,292	14.54	0.08	0.001*
Season	1	64,045	64,045	16.25	0.09	0.001*
TRT	2	3,537	1,768	0.45	0.01	0.828
Elevation	1	71,786	71,786	18.22	0.10	0.001*
Year × season	1	94,883	94,883	24.08	0.13	0.001*
Year × TRT	2	950	475	0.12	0.01	0.997
Season × TRT	2	2,098	1,049	0.27	0.01	0.938
Year × elevation	1	4,486	4,486	1.14	0.01	0.266
Season × elevation	1	19,718	19,718	5.00	0.03	0.001*
TRT × elevation	2	6,214	3,107	0.79	0.01	0.481
Year × season × TRT	2	1,014	507	0.13	0.01	0.997
Year × season × elevation	1	5,867	5,867	1.49	0.01	0.165
Year × TRT × elevation	2	769	384	0.10	0.01	1.000
Season × TRT × elevation	2	2,171	1,085	0.28	0.01	0.934
Year × season × TRT × elevation	2	2,851	1,425	0.36	0.01	0.893
Residuals	96	378,311	3,941	0.53		
Total	119	715,990	1			

Summary metrics include univariate ADONIS output testing sums of squares, mean squares, *F*-value statistics model, R^2 values, and *P*-values significant at alpha = 0.05.

* Denotes significant differences at alpha level = 0.05.

monetary savings to taxpayers without compromising visibility along right-of-ways (Entsminger 2011; Humber and Entsminger 2011; Guyton et al. 2014). Our findings indicate that mowing could be reduced in frequency, which reduces current expenditures for vegetation management on highway right-of-ways.

Our results suggest that low-frequency mowing did not affect the predominant vegetation composition along roadside right-of-ways in Mississippi. Site elevation (upland vs. lowland) was the only parameter with noticeable effects on vegetation coverage and species richness. Greater percent vegetation coverage and species richness within lowland sites may have been caused by greater moisture availability, quality of alluvial substrates, and deposition of vegetative propagules from flooding events (Bush and Van Auken 1989). More plant community diversity can be related to site productivity, and this effect may be related to nutrient loading from seasonal floods and increased water saturation during rainfalls (Greenfield et al. 2005; Huijser and Clevenger 2006).

Throughout our study, nonnative grasses dominated sites with > 70% ground coverage on most plots. Nonnative grasses exceeded coverage of native forbs and grasses by greater than three to five times in reduced mowing treatments. Modifications of mowing regimens during a 10-y study period along Wisconsin highways resulted in an increased percent coverage of native grasses with > 50% native grasses, with > 20% native forbs, and < 40% nonnative grass coverage (Harrington 1995). Our findings were similar to others studies in terms of percent coverages of native grasses, forbs, and woody plants, except we detected a continued dominance of nonnative agronomic grasses during the 2 y. Barras et al. (2000) observed greater coverage of nonnative grasses (81% vs. 68%) in mowed sites compared with unmowed sites, and an increase of native forbs (16% vs. 25%), native grasses (1% vs. 5%), and native woody plants (1% vs. 4%) in unmowed sites. Percent coverage of nonnative forbs and grasses were similar in the frequently mowed treatment across years; however, percent coverage of nonnative species decreased in the reduced mowed treatments in lowland study sites over time. On the basis of our findings and those of previous studies, we suggest that reduction of mowing frequency can increase native plant species richness and enhance roadside aesthetics without loss of grass coverage and subsequent compromise of erosion control from these grasses (Forman and Alexander 1998; Markwardt 2005; Transportation Research Board 2005).

Another concern with reduced frequency of vegetation management along road right-of-ways is maintenance of good visibility for motorists (Johnson 2000; Hill and Horner 2005; Transportation Research Board and National Research Council 2005; Harper 2008; Willard et al. 2010; Entsminger 2014; Guyton et al. 2014). Visibility for motorists may be especially important along right-of-ways transecting areas with dense populations of large mammals, such as white-tailed deer (Dixon et al. 1984; Cackowski and Nasar 2003; McKee and Cochran 2012). Mowing without herbicide application can lead to greater densities of woody plants, which may grow to heights that impede visibility, in part because of the tendency of some tree and shrub species to resprout after mowing or prescribed burning (Arner 1959, 1979; Gruchy et al. 2006; Brown and Sawyer 2012). Greater abundance of woody plants and greater plant heights are both features that can impede visibility of motorists along highway and road right-of-ways (Hamrick et al. 2007; Yager et al. 2011). We observed that mowing once during fall was adequate to maintain good visibility along highway right-of-ways, especially in areas where right-of-ways are > 100 m wide. The height measurements of plants from our study ranged from 0.3 cm to 2.4

m, with an average plant height of 1.0 m from frequently mowed areas as compared with an average height of 1.0 m in areas mowed once. Furthermore, most woody plants that we detected during our study were vine species, such as blackberries (*Rubus* spp.), Japanese honeysuckle (*Lonicera japonica*), greenbriers (*Smilax* spp.), purple passionflower vine (*Passiflora incarnata*), trumpet creeper (*Campsis radicans*), poison ivy (*Toxicodendron radicans*), and grapevines (*Vitis* spp.), that were procumbent in growth form because of the absence of vertical structures (Miller and Miller 1999; Miller et al. 2015).

Reduced mowing frequencies could enhance conditions for developing existing communities of native forbs, legumes, grasses, sedges, rushes, and ground-creeping woody vines. Observed species richness in this study was comparable with Schuster and McDaniel (1973) and Leidolf and McDaniel (1998), who each observed > 150 native plant species in prairie environments near right-of-ways in Alabama and Mississippi.

In addition to a reduced mowing regimen, other factors may have influenced our findings related to species richness of native plants. These factors include below-normal annual precipitation during 2010 and 2011, possible herbivory, and an inadequate site preparation in seeded plots before planting and reseeding in fall seasons (Howard 1950; Chase et al. 2000; Young and Claassen 2007).

Modifications in mowing regimens can allow native plants to become established (Entsminger et al., in press). A single mowing conducted during late fall can provide adequate time for plant maturation, root development, and seed production (Arner and Jones 2009). Production of flowers and seeds without loss from frequent mowings could enhance the seed bank and provide more plant foods for game and nongame wildlife, including insect pollinators (Jones et al. 2007; Hopwood et al. 2016). This approach could be more cost effective than seeding of wildflowers along right-of-ways because of costs of site preparation, site management, and seeds and propagules. In our study plots, supplemental seeding of native plants combined with reduced mowing did not provide the cover and diversity of plants in which we anticipated them; however, proper site preparation to increase seed catchment and limit competition might have improved native plant coverage in our seeded plots (Arner 1959; Arner et al. 1976; Chase et al. 2000; Svedarsky et al. 2002; Jones et al. 2007). Others have reported low establishment rates ($< 10\%$ success rates) for native plants seeded into existing nonnative grass coverage (Burke and Grime 1996). Furthermore, most perennial grasses and forbs need cold-weather scarification and at least 2 y for maximum germination and establishment (Dana et al. 1996; Jones et al. 2007; Tallamy 2009). Other factors that can impede establishment rates of seeded native plants include depredation by rodents and birds (Howard 1950; Anderson 1996).

Management implementations

Specific proactive management implementation techniques can include native plantings, selective herbicide use to decrease nonnative grasses, continual mowing from roadside edge to 10 m, and only one mowing in late fall, but with an extension of the boundary to reach beyond 10 m from the roadside edge to suppress the invasion of woody plants, which could lower long-term maintenance costs. These roadside right-of-way management techniques are very effective in reducing maintenance costs and promoting and enhancing native species of conservation concerns (Russell et al. 2005; Hopwood 2010; Entsminger 2014; Hopwood et al. 2016). One mowing per year retained agronomic plant coverage for erosion control but did not significantly increase native plant species richness. Reduced mowing combined with native plant seeding could enhance roadside beauty through establishment of native plant communities without decreasing roadside visibility (Anderson 1996; Barras et al. 2000; Kutschbach-Brohl et al. 2010; Entsminger 2014; Entsminger et al., in press). Roadside right-of-ways can provide areas where native plants can colonize and survive, serve as population sources for native plant species, and increase habitat quality for native fauna including pollinating insects, small mammals, and birds (Svedarsky et al. 2002; Jones et al. 2007; Tallamy 2009; Andrews et al. 2015). Seeding of native forbs and grasses may not require reseeding because the native plants will naturally colonize as long as the nonnative grasses are controlled with selective herbicides. Other research findings suggest that roadside right-of-way management techniques such as what we have described are highly successful (Russell et al. 2005; Hopwood 2010; Entsminger 2014; Hopwood et al. 2016). Future management efforts can consider the reduced mowing regimen as appropriate management strategies for right-of-ways with other maintenance methods for native plant establishment and retention such as fertilization, selective herbicide and chemical use on nonnatives, prescribed fire, disking, and various seeding techniques.

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Entsminger ED, Jones JC, Guyton JW, Strickland BK, Leopold BD. 2017. Data from: Evaluation of mowing frequency on right-of-way plant communities in Mississippi. Journal of Fish and Wildlife Management 8(1):xx–xx. Archived in Dryad Digital Repository: http://dx.doi.org/10.5061/dryad.960dh/00

Data A1. Raw data from over 276 plant species that were collected along a 48.28-km stretch of roadside right-of-ways in northeastern Mississippi from 2010 to 2012. The data are categorized by years (2010, 2011, and

2012), seasons (fall, spring), elevation (upland, lowland), site location number (1, 2, 3, 4, and 5), and by TRT (treatment; mow, no-mow, and seed). These categories are summarized with NativeSR (native species richness), NonNativeSR (nonnative species richness), UnknownSR (unknown genus), and Total SR (total species richness count). Found at http://dx.doi.org/10.5061/dryad.960dh/22 (14 KB XLSX).

Data A2. Raw data from over 276 vegetation percent coverages by individual species that were collected along a 48.28-km stretch of roadside right-of-ways in northeastern Mississippi from 2010 to 2012. The data are categorized by elevation (upland, lowland), TRT (treatment; M = mow, NM = no-mow, and S = seed), season/year (fall10 = fall 2010, SP11 = spring 2011…), status (N = native, NN = nonnative, Un = unknown status), VegType (vegetation type = forb, grass, legume…), height of vegetation (< 18 in. tall, 18–36-in. height category, > 36-in. height category), and actual scientific name of each species detected. Found at http://dx.doi.org/10.5061/dryad.960dh/20 (2.48 MB XLSX).

Data A3. Raw data from over 276 vegetation percent coverage within each status and height category that were collected along a 48.28-km stretch of roadside right-of-ways in northeastern Mississippi from 2010 to 2012. The data are categorized by a unique identification field with elevation (Low = lowland, Up = upland), site location number (1, 2, 3, 4, and 5), treatments (Mow = mowing, NMow = no-mowing, and Seed = no mowing with seeding), and season/year (F10 = fall2010, Sp11 = spring 2011…). The status (N = native, NN = nonnative, Un = unknown status), vegetation type (forb, grass, legume…), and the height of vegetation (< 18 in. tall, 18–36-in. height category, > 36-in. height category) are displayed for an overall value of percent coverage. Found at http://dx.doi.org/10.5061/dryad.960dh/21 (32 KB XLSX).

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