Plant community response to reduced mowing regimens along highway right-of-ways in Northeastern Mississippi

By

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I investigated percent coverage, plant height, species richness, and woody stem density in plant communities in ten study plots during spring and fall (2010-2012) within 3 different treatments (continual mowings, one fall mowing, and one fall mowing with native wildflower seeds) on Highway 25 right-of-way in Oktibbeha and Winston counties, Mississippi. I recorded 277 plant species including native and non-native forbs, legumes, grasses, rushes/sedges, and woody plants. Non-native agronomic grasses exhibited greatest coverage greater than 90 percent occurring in all treatments. Percent coverage of plants less than 0.46m height category exceeded 100 while, greater than 0.46m plant height categories averaged 55 percent. Woody stem density ranged from 7,772 year 1 to 10,025 stems/hectare year 2. I detected no significant differences in plant height or woody stems among treatments. One mowing per year retained agronomic plant cover for erosion control and annual cost savings up to 75 percent for roadside maintenance.

DEDICATION

I would like to dedicate this thesis to God, Jesus my Lord and Savior, and the Holy Spirit who kept me moving in the tough and easy times of life. In addition, I would like to dedicate this thesis to my family: David, Annette, Amber, Nicole and especially Juanita Riggs (grandmother) for all their support, love and encouragement along the way. Finally, I dedicate this to my best friends at Mississippi State University, Perry Jinkerson (University Christian Student Center Campus Minister at Starkville Church of Christ), Perry Pugh (Associate College Minister at Calvary Baptist Church), Terrell Jackson (Music Minister at Calvary Baptist Church), Wilburn and Bonner Whittington (best friends ever), and many others who are my brothers and sisters in Christ who have kept me on track spiritually, especially Brandon Nichols and Hunter Greene.

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Roadside right-of-ways (ROWs) are described as the land area directly adjacent to the roadway width depending on the classification of the roadway and determined by legal jurisdiction enforced by the transportation agency. Areas of plant communities along ROWs can be very diverse depending on type of road, width, slope and adjacent land uses (Li et al. 2008). Native and introduced (non-native) plant species are typically present in this narrow strip of the environment. ROWs can enhance aesthetics and certain wildlife species and their habitat, if roadsides are managed to encourage native wildflowers and grasses (Telfair 1999; U. S. Department of Transportation – Federal Highway Administration 2004). In recent decades, highway roadside beautification and wildflower management programs in the Southeastern United States have become common due to their many benefits (U. S. Department of Transportation – Federal Highway Administration 2011). ROWs are often intensively managed to reduce height of vegetation and to increase drivers' visibility. Intensively managed land areas have be considered "biological deserts," especially those that are managed to reduce competing vegetation through frequent mowing, herbicide application, and soil disturbance (Hunter 1990; Hunter and Schmiegelow 2010). Harper-Lore (1996) stated that in the 1950's, roadside ROWs were maintained intensively to create vegetation coverage similar to that of urban lawns and golf courses. Maintenance methods often included combined use of

herbicides and repeated mowing during the growing season (Harper-Lore 1996). By the 1950's, state highway agencies no longer had adequate budgets to maintain manicured ROWs, so better and more cost-effective ecological approaches to maintain vegetation were needed. The 1965 Highway Beautification Act, catalyzed by the activities of Lady Bird Johnson, expanded perceptions that roadsides could provide pleasing visual and aesthetic quality (U. S. Department of Transportation – Federal Highway Administration 2011). In the 1970's, increase in cost of fuels renewed the efforts of highway administrators to seek alternatives that could potentially reduce costs of roadside maintenance (Harper-Lore 1996). By the early 1990's, the Federal Highway Administration (FHWA) had recognized a nationwide trend toward an ecological approach in roadside maintenance (Harper-Lore 1996). The FHWA had gathered ecological data and reports to understand the environmental and budgetary considerations for ROW management and to identify plant communities that were best adapted to roadside environments. The FHWA also worked with other organizations to incorporate use of native plants along roadsides (Harper-Lore 1996). By 1994, the FHWA had produced an Executive Memorandum on landscaping, which recommended use of native plants along roadsides when feasible. In 1995, the bill was signed by President William J. "Bill" Clinton (Harper-Lore 1996).

In 1999, the United States Presidential Executive Order 13112 defined alien, exotic, non-native and introduced species and reported the economic and environmental impacts of exotic, non-native species (Clinton 1999). Over 42% of native species were threatened and endangered as a direct result of the exacerbated spread of invasive species on roadway ROWs (Clinton 1999; Center for Environmental Excellence 2008; M.

Ielmini, U.S. Forest Service, National Invasive Species Program Manager, Personal Communication). Maintenance of ROW's contributes to spread of non-native species. Simberloff et al. (2012) stated that non-native invasive species were 40 times more problematic and costly than native species in environments such as along ROWs. Native plant communities typically do not result in negative economic impacts to property values (Simberloff et al. 2012), and enhancement of native plants along roadsides can decrease rate of spread of invasive non-native plants (Forman and Alexander 1998). Other benefits of native plants on ROWs may include reduction in erosion, protection of water quality, and enhancement of roadside aesthetics and wildlife environments. Roadside plantings of native wildflowers, grasses, and shrubs are often used to help control erosion and promote cost-effective vegetation maintenance (Transportation Research Board 2005). Furthermore, visual aesthetics of native plantings along highways can have positive impacts by reducing motorists' stress and improving their enjoyment of the landscape (Forman and Alexander 1998; Cackowski and Nasar 2003). Along Mississippi's roadsides, many native wildflowers will colonize if frequencies of mowing and herbicide applications are modified (Arner and Jones 2009). Proactive management of vegetation that features roadside beautification through establishment of native plant communities can provide motorists with safe travel experiences, increases in life quality on a daily basis, and enhancement of public perception of the environment and management agencies (Arner and Jones 2009).

Vegetation along roadside ROWs can have positive and negative effects depending on localized conditions, traffic intensity, and management agency requirements. Vegetation on ROWs is an important aspect of limiting negative impacts

of road construction and maintenance by absorbing sound and reducing visual impacts to adjacent lands (Forman and Alexander 1998). Visibility along roadways, public perception of ROWs, and loss of native plant coverage are concerns reported by Louisiana Department of Transportation and Development (2000). Young and Claassen (2007) stated that the dense annual vegetation coverage on roadside ROWs generates several undesirable characteristics, including fire hazard, mowing and herbicide requirements, and exclusion of native plants. Benefits have been reported for native plant enhancement along roadways, while conversion to native plant species can be challenging due to the high cost of seeding and competition of non-native invasive plant species (Bugg et al. 1997; Young and Claassen 2007). However, establishment of native annual and perennial plants can result in a stable plant community typified with a high resistance to non-native plant invasions within each plant community area (Bugg et al. 1997; Young and Claassen 2007). For instance, Young and Claassen (2007) studied establishment of native grasses in road medians and ROWs, and reported that after three years of chemical and prescribed burn managements, native perennial grasses were more abundant in plots that had been burned once and sprayed at least twice. In areas where native grasses and wildflowers have been successfully established, very little maintenance needed, and herbicide applications typically reduced, because the plant community resists colonization by invasive plant (Daar 1994; CalTrans 2013; Green and Welker 2003). Native forbs, legumes, and selected grasses may also reduce roadside fire hazards, because many native plants produce less biomass than growing non-native grasses. In addition, drought-tolerant native plants provide erosion control through deep root systems that develop in the absence of soil alteration and irrigation (CalTrans 2013).

Road management agencies seek to establish and manage native plant coverage along ROWs through plantings of native wildflowers and grasses. Primary management components needed for successful establishment of native vegetation along roadsides include site preparation, plant selection, and weed management (Young and Claassen 2007). Initial costs to establish native plants on ROWs can be >$100 per ha (>$250 per acre), but long-term savings after establishment has resulted in lesser maintenance and replanting costs (Young and Claassen 2007). Long-term economic benefits from establishment native plant communities can produce savings in terms of erosion control and vegetation maintenance costs. If native plants exist along the ROWs then purchase and establishment is not generally necessary due to existing sources of seed and propagules in the soil seedbank (Arner and Jones 2009). Seed sources may also be present in adjacent vegetation patches, while wind or animals can transport seeds to adjacent areas. Native plants, over time, may colonize ROWs through dispersal of seeds from adjacent areas to the ROW. If herbicide application and mowing are modified or curtailed on ROWs, wildflowers may become established within one to two growing seasons through propagules dispersal by wind, water, and wildlife (Arner and Jones 2009).

Reducing mowing methods and frequency of management may be necessary to maintain native vegetation communities on ROWs. Mowing regimen and herbicide application frequencies are often reduced to benefit native wildflowers, legumes, and warm season grasses (Telfair 1999; U. S. Department of Transportation – Federal Highway Administration 2004; Arner and Jones 2009). Primary savings have been reported due to reduced mowing requirements and invasive plant control (Young and

Claassen 2007). Texas Department of Transportation estimated an annual mowing cost savings of $20 – $30 million from wildflower program establishment (Texas Department of Transportation 2013). Many benefits of roadside wildflowers have been reported in Texas, including a 25% reduction (approximately $8 million per year) in maintenance costs from less frequent mowing and reduced herbicide use (Markwardt 2005). As mowing was reduced in Texas, the following impacts were reported: wildlife habitat improved, biodiversity of species increased, erosion decreased, enhanced aesthetics and tourism occurred, planting success increased with survival of hardy native plants, partnerships with natural resource agencies and volunteer groups were strengthened, noxious non-native weed invasions were suppressed, and the commitment by managers and the public to preserve and perpetuate native flora were emphasized (Markwardt 2005). These numerous outcomes were a result of more aesthetically pleasing roadways due to reduced mowing initiatives and occurrences of wildflowers. Low maintenance ROWs that are mowed once annually during late fall (i.e., November) will allow time for seed maturation in native plants (Arner and Jones 2009). With reduced mowing frequencies, woody plant colonization may occur on ROWs, and these plants can be controlled through selective herbicide application (Arner and Jones 2009). In addition to woody plant colonization, other changes in vegetation composition and structure occur over time. As plant communities undergo succession, the vegetative litter and woody debris accumulate on the ground causing bare ground decline (Greenfield et al. 2005). Deposition of plant material at ground level improves organic matter content of soil, which lessens impacts of rainfall and reduces surface water runoff. As succession progresses, it enhances vegetation community quality for many wildlife species, and

reduces colonization rates of non-native invasive plants. Factors that influence plant and wildlife environments depend on site location, soil fertility, rainfall, local hydrology, temperature, and length of growing season (Greenfield et al. 2005). Rotational mowing can be used to maintain communities in various stages of growth and vegetation diversity, whereas annual mowing once in late fall may be beneficial to promote maturation and germination of seeds and attract insects along open fields and ROWs (USDA and NRCS Wildlife Habitat Management Institute 1999).

Mowing and herbicide is a recurring cost associated with roadside ROWs management. In the early 1980's, Huntley and Arner (1984) reported costs for three methods used on ROWs: prescribed burning $2.11/hectare ($5.21/acre); selective mowing $3.52/hectare ($8.70/acre); and selective basal-spraying herbicide $39.32/hectare ($97.12/acre). Huntley and Arner (1984) also reported that companies can achieve effective maintenance and reduced costs by using a combination of prescribed burning and selective mowing as a maintenance method. Arner (1959) described use of prescribed burning to increase wildlife food production and control of woody plant growth on utility ROWs in Alabama. Arner et al. (1976) summarized vegetation management studies conducted on utility ROWs in Mississippi, concluding that winter-prescribed burning was cost-effective over mowing or herbicide application and produced a greater abundance of wildlife food plants. Cost of equipment maintenance, mowing, personnel wages, and herbicide spraying gets expensive as the state of Mississippi has approximately 23,524 km (14,617 miles) of highways and mows over 56,354 hectares (139,253 acres) each year. From 2009 to 2013, the Mississippi Department of Transportation's (MDOT's) annual cost for mowing the roadside ROWs was >$100 per

ha (>$250 per acre; D. Thompson, Vegetation Manager for MDOT, Personal Communication). As the cost of mowing ROWs increased, many states have implemented effective ways of native plant enhancement on ROWs (Louisiana Department of Transportation and Development 2000).

The Louisiana Department of Transportation and Development (2000) recognized the presence of native vegetation as a positive value for wildlife and humans along highway ROWs. Trees, shrubs, and herbaceous plants all benefit by mitigating impact of highway systems, resulting in increasing soil stabilization, providing vegetation communities, and moderating microclimate extremes. Furthermore, preservation of existing vegetation under bridges can be very beneficial for many wildlife species, plant communities, and people (Gonser and Horn 2007). This approach enables safe passage for wildlife under these bridge corridors and deters their use from roadways while reducing human-wildlife vehicle collisions (McKee and Cochran 2012). Large mammals, such as white-tailed deer (*Odocoileus virginianus*) are often involved in human-wildlife collisions and may be of major concern in management of visibility and safety on high traffic roadways and highways (McKee and Cochran 2012). Large landscapes comprised of forest cover, agricultural areas, and patches of native grasses can benefit white-tailed deer as they supply cover and foraging areas (Gonser and Horn 2007). The native plants that will emerge include those that are not highly palatable to deer and could deter deer grazing along the ROWs. An alarming increase in number of vehicle-deer collisions have been contributed to growth in deer populations apparently associated with a reduction in number of licensed hunters (Aiken 2010). Landscapes with abundant areas of plant communities and in urban interface zones, roadsides can be

managed by transportation agencies to facilitate wildlife movement to reduce and prevent vehicle wildlife-collisions (Wolf 2003).

Maintenance of native plant coverage creates a habitat for species (e.g., small mammals, birds, herpetofauna, and insects) that use early successional areas (Forman and Alexander 1998). Wildflowers, insects, and grassland-shrub birds are among the animals that can benefit from reduced mowing roadside management (Arner and Jones 2009). With proper management, roadside vegetation can provide a diversity of plant foods and nesting cover for some birds and mammals (Louisiana Department of Transportation and Development 2000). Ecotones may also be created by ROWs, and this "edge effect" may be preferred by many wildlife species. Roadside ROWs can serve as linear reservations for wildlife, while simultaneously acting as conservators of the native flora (Leopold 1949; Forman and Alexander 1998).

Vegetation management for wildlife along highways often consists in attempting to attract species (e.g., songbirds, butterflies, insects, rabbits, red and gray fox, raccoons, and opossums) that are aesthetically pleasing and pose limited threats of negative impacts to motorists (Michael and Kosten 1981). In general, seed, pollen, nectar, and forage production by wildflowers and native grasses provides important foods for native birds and small mammals (Anderson 1996). Pollen and nectar production of wildflowers attracts a diversity of insects that serve as high protein foods for the eastern wild turkeys (*Meleagris gallopavo*), northern bobwhite quail (*Colinus virginianus*), and nongame birds, such as indigo buntings (*Passerina cyanea*) and eastern meadowlarks (*Sturnella magna*; Hurst 1972; Anderson 1996; Yarrow and Yarrow 1999; Dickson and Wigley 2001). Most native wildflowers and native grasses are also preferred food and larval host

plants of many butterflies and moths (Dole et al. 2004). Wildlife food plants that can be expected to grow naturally along forest edge-roadside areas may include sunflowers (*Helianthus*), daisies (*Erigeron*), asters (Asteraceae), partridge peas (*Chamaecrista*), lespedezas (*Lespedeza*), coreopsis (*Coreopsis*), blazing stars (*Latris*), mints (Lamiaceae), milkweeds (*Asclepias*), and many native grasses (Poaceae) and sedges (Cyperaceae; Miller and Miller 1999; Dickson and Wigley 2001). In contrast to smaller species of wildlife, large animals, such as white-tailed deer, that pose threats to vehicles are often discouraged from highway ROWs by establishment of plants with low palatability (Michael and Kosten 1981). In particular, concerns may arise over attracting cervids, such as deer and elk (*Cervus* spp.), to roadsides due to increased plant food availability. However, many native grasses and many native forbs are not highly palatable deer food plants, especially compared to highly palatable non-native legumes such as clovers (*Trifolium* spp.), lespedezas (*Lespedeza* spp.), and vetches (*Vicia* and *Securigera* spp.) that are often seeded along roadsides (Arner and Jones 2009). Native wildflowers of low palatability to deer may occur or be established along highways may include species of the genera of black-eyed-susans (*Rudbeckia*), sunflowers (*Helianthus*), laserworts (*Silphium*), blazing stars (*Liatris*), and milkweeds (*Asclepias*; Miller and Miller 1999; Schummer et al. 2012).

In Mississippi, the collision between wildlife and vehicles have continued to be a safety concern and financial issue (MDWFP Deer Committee 2010; MDWFP Deer Committee 2012). Chad Dacus, Deer Program co-coordinator for the Mississippi Department of Wildlife, Fisheries and Parks, stated that most collisions occur at dawn and dusk during winter. Increases in populations of white-tailed deer and numbers of

roadways statewide have resulted in increases in deer-vehicle collisions (MDWFP Deer Committee 2010). Accidents involving white-tailed deer and vehicles are a major concern in wildlife management nationwide (Dixon et al. 1984). Vehicle collisions with cervids have been estimated at 720,000 to 1.5 million annually in the United States (Conover et al. 1995). In 2006, State Farm Insurance indicated that >1,000,000 wildlife-vehicle collisions occurred annually based on the number of claims for collisions with cervids (M. Miles, State Farm Insurance, Personal Communication). In 2008, Mississippi's transportation officials reported >3,000 vehicle-deer collisions (MDWFP Deer Committee 2010). Additionally, roadways are often located within and bisect areas of plant communities used by wildlife, which is a primary reason why wildlife travel across or use ROWs (Hewitt 2011; Fulbright and Ortega-Santos 2013). Also, vegetation management that includes frequent mowing, fertilization, and seeding of palatable forage plants for erosion control often results in attracting herbivorous wildlife species to ROWs (Harper-Lore and Wilson 2000; Arner and Jones 2009).

Deer and other herbivores influence vegetation growth and development through herbivory (McShea 2012). On highly productive areas, selected plant species often respond to herbivory through defense or tolerance adaptations that allow specific plant species to dominate (Chase et al. 2000). However, if plants are unable to produce large amounts of biomass growth, then plant competition and reproduction diminishes greatly. Similarly, composition of plant communities are affected as more biomass is eaten by herbivores; thus the likelihood of a plant species being eliminated in that environment by herbivory increases (Chase et al. 2000). A greater understanding of the interactions of herbivores and plant communities is necessary to understand plant community succession

in the presence of herbivory and attraction of white-tailed deer and other large herbivores to ROWs (Hewitt 2011; Fulbright and Ortega-Santos 2013).

Roadsides can attract wildlife and support diverse native flora and fauna, despite these areas may be associated with increased wildlife mortality. However, reduced mortality has been achieved by allowing woody plants to develop in areas that are not important for visibility and safety can increase wildlife use and survival along ROWs. Numerous studies have reported that shrub and tree plantings along road ROWs may result in a 35% reduction of small mammals and songbird species mortality and have greater diversity of wildlife (Machan 1981; Zimmerman 1981). Similarly, Huntley and Arner (1981) found the enhancement of bobwhite quail, wild turkey, many non-game birds, and white-tailed deer habitat was an important opportunity on utility ROWs in the southeast U.S. Foster (1956) found that wildlife used ROW strips in Michigan more than adjacent woodlands. Traffic-related mortality may be dependent on species, related to traffic intensity, and impacted by palatable vegetation proximity to roadways (Jacobson 2005; Arner and Jones 2009). Jacobson (2005) reported that several species of owls, particularly barn owls (*Tyto alba*), great horned owls (*Bubo virginianus*), and short-eared owls (*Asio flammeus*), often forage near roads and are common victims of vehicle collisions. These raptors also fall victim to electrocution by power lines, possibly in greater numbers along highways due to the attraction of road kill scavenging opportunities and availability of rodent prey in vegetation of ROWs (Jacobson 2005).

Roads and ROWs also result in loss of species environment, fragmentation of wildlife and many native plant species (Forman and Deblinger 2000). Short-term and long-term impacts include changes in wetland hydrology, degradation of water quality,

dispersal of invasive non-native species (Miller et al. 2010), restriction of animal movement, and increases in traffic-related mortality in wildlife (Forman and Deblinger 2000). Road construction and maintenance typically alter plant and animal communities through soil substrate disturbance, erosion, seeding of non-native plant coverage for erosion control, and disturbances associated with road and ROW maintenance (Huijser and Clevenger 2006).

Creation of a road and enhancement of food plants can lead to greater incidence of wildlife-vehicle collisions. These types of human-wildlife conflicts are an ever-increasing problem due to the increased road construction and traffic intensity (Harper-Lore and Wilson 2000). Harper-Lore and Wilson (2000) reported that road ROWs covered >4.05 million hectares of land in the United States. This degree of roadway development and increased urbanization has resulted in degradation of vegetation communities associated with long-term impacts of roadways and cumulative impacts of increased urbanization (Harper-Lore and Wilson 2000). Vegetation communities' loss and disturbance associated with roads can lead to changes in vegetation quality, quantity, and connectivity that in turn may cause changes in animal behavior (Harper-Lore and Wilson 2000). Roadways act as barriers to dispersal and movement through disturbance or mortality increases and may lead to isolation of wildlife populations (Ament et al. 2008). In addition, Rost and Bailey (1979) detected that deer species in Colorado avoid roads because of difficulties in escaping predators, particularly areas that were located within 200 meters (656.17 feet) of a road. Roads may also cause big game species (i.e., deer, elk, moose) to reduce their use of adjacent habitat use from the road edge to a

distance of >0.805 km (>0.5 mile) from the road edge (Perry and Overly 1976; Perry and Overly 1977).

Quality and diversity of vegetation species along roadside ROWs have steadily declined for years due to anthropogenic activities, such as road expansion and maintenance, intensive mowing, broad-spectrum herbicide use, loss of native plant cover, colonization of non-native invasive species, and lack of prescribed burning (Miller et al. 2010). However, in Mississippi, ROWs can contain remnants of rare ecosystems, such as native prairies and pitcher plant savannas. Roadsides may provide environments for populations of threatened, endangered, and rare native flora species. Because these factors may be important to conservation of biological diversity and Mississippi's citizens, this study was conducted along Highway 25 in Oktibbeha and Winston counties, Mississippi from 2010 to 2012, was designed and conducted to gain a better understanding of plant communities' development under different mowing treatments on a highway ROW in north-central Mississippi.

Objectives and Hypotheses

Objectives of this research were: 1) Estimate and compare differences in percent coverage and species richness of native and non-native plants in areas that received two different mowing treatments and one reduced mowing with supplement seed treatment in upland and riparian lowland locations within highway ROWs, 2) Estimate and compare differences in percent coverage of vegetation in three height categories and woody plant stem densities in two mowing treatments and one reduced mowed-seeded treatment in upland and riparian lowland locations within the highway ROW, and 3) Estimate white-

tailed deer use of ROWs through spotlight count observations along ROW corridor in upland and riparian lowland location within the highway ROW.

Anticipated Benefits of Study

The potential establishment and enhancement of coverage of native flora along Mississippi's highways are anticipated ecological benefits of this research. Use of information obtained from this research can result in aesthetic qualities of Mississippi's roadside ROWs through enhancement of native wildflowers and grasses coverage, subsequent reduction in litter visibility, and reduction in expenditures for vegetation management. Quantification of costs associated with different vegetation treatments can elucidate cost benefits of intensive vegetation management versus a reduced mowing regimen while enhancing native plant diversity and roadside aesthetics, and possibly reducing road collisions along Mississippi highway ROWs.

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CHAPTER II

STUDY AREA METHODS

Study Area

This study was designed to evaluate plant community characteristics in different mowing regimens on Highway 25 right-of-ways (ROWs) along a 48.28 km (30 miles) stretch beginning at the intersection of Highway 12 and 25, western Starkville in Oktibbeha County, and continuing south 4.5 km into Winston County, in northeastern Mississippi (Figure 2.1). Plots were located outside of the Black Belt Prairie, within the Interior Flatwoods in northeastern Mississippi (33°12'N, 88°54'W; Township 15-18N, Range 13-14E; Pettry 1977; Edwards 2009).

Mississippi Highway 25 landscape is variable which causes the roadside ROWs to vary in size and shape due to the countryside and adjacent properties. The landscape along the highway is diverse, including agricultural fields, pastures, fallow fields, forests, and pine plantations, with a mix of hilly and flatland areas. The 48.28 km (30 miles) length of this study was crossed by 3rd to 4th order streams differentiating upland and riparian lowland plots. Upland areas had well drained soils in elevations of ROW, whereas lowland areas were influenced by overbank inundations from streams and drainages, and typically spanned by bridges or box culvert structures. Each plot was proposed different due to shade, water, soil chemistry, pH, and the plant communities.

Soil formation and vegetation 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 (32° F to 59° F) and hot summers 21° C to 38° C (70° F to 100° F; Posner 2012). Annual mean temperature was 16.7° C (62° F) and precipitation ranged from 127 cm to 165 cm (50 to 65 inches) across the state from north to south (Mississippi State University Department of Geosciences 2010).

Current Highway 25 ROW management for this area consisted of multiple mowings per growing season (≥4 times per season) and selective herbicide application of Imazapyr (non-selective plant herbicide), Tryclopyr (foliar herbicide), and Glyphosate Roundup (broad-spectrum herbicide) to control invasive non-native plants species such as Johnsongrass (*Sorghum halepense*), kudzu (*Pueraria montana* var. *lobata*), and cogongrass (*Imperata cylindrica*) and encroaching woody vegetation (D. Thompson, Vegetation Manager for MDOT, Personal Communication). In spring 2010, prior to the study's initiation, primary vegetation cover of ROWs was comprised of non-native grasses, such as Bermudagrass (*Cynodon dactylon*), tall fescue (*Schedonorus phoenix*), and Vasey's grass (*Paspalum urvillei*). The landscape adjacent to the ROW was comprised of agricultural fields, pastures, fallow fields, forests, and pine plantations, with a mix of hilly and flatland areas.

Soil horizons of the ROW were not well defined and can be classified as drastically disturbed substrates due to road construction activities, including removal and deposition of substrate and fill material. Ground cover debris was classified as leaf and other vegetation litter as well as fine woody debris; however, bare ground exhibited a visible soil surface with no debris coverage.

Field Methods

Study Design and Plot Establishment

In April 2010, ten plots consisting of five upland and five lowland plots were established through stratified random selection based on lowland and upland topography along the highway. The plots were delineated as 30.48 m x 30.48 m (100 ft. x 100 ft.) and were divided into three equal subplots that measured approximately 10.16 m x 30.48 m (33.33 ft. x 100 ft.) in size (Figure 2.2). Plot sizes ranged from 10.67 m x 28.96 m to 30.48 m x 30.48 m. Each subplot ranged in size from 9.65 m x 10.67 m to 10.16 m x 30.48 m. The size of each plot and subplot varied depending on landscape aspect conditions and roadway characteristics of the roadside ROW. Distance between each of the 10 plots along the highway corridor ranged from 1 to 3 km.

I used a randomized complete block design by dividing each plot into three equal subplots (10.16 m x 30.48 m each) and assigned one of three treatments randomly to each subplot: 1) the control: mowing > four times annually in May, July, September and November, 2) treatment 1: annual mowing during November only, and 3) treatment 2: annual mowing during November only and seeding with native wildflower seed mixture (Li et al. 2008). Control subplots were mowed four or more times annually during the growing season, whereas treatments 1 and 2 subplots were mowed once during late November of each study year. In seeded subplots, one mowing was conducted during late November to reduce vegetation height after the natives on ROW had seeded and prior to supplemental native seeding. The seed mixture was broadcast using hand dispersal and a hand-held broadcast seeder over existing mowed vegetation during March 2011. Planting of native wildflowers for treatment 2 included seeding of the following

species at the following rates: black-eyed Susan (*Rudbeckia hirta*) at a seeding rate of 1.55 kg per ha, dense blazing star (*Liatris spicata*) at a seeding rate of 7.70 kg per ha, and lanceleaf tickseed (*Coreopsis lanceolata*) at a seeding rate of 7.70 kg per ha (Native American Seed 2013). Seeds of black-eyed Susan, lanceleaf tickseed, and blazing star were obtained commercially from Native American Seed Company while additional seeds from nearby wild plants were collected locally near each plot in Oktibbeha and Winston counties, Mississippi.

Transect Establishment

Line intercept transects measuring 30.48 m (100 ft.) in length were established in each subplot to estimate plant community characteristics: percent coverage of woody and herbaceous plants, species richness, percent coverage height of woody and herbaceous, and stem densities (per hectare) of woody plants (Tables 2.1 and 2.2; Hays et al. 1981; Buckland et al. 2007). Line transects were established in each of the 30 subplots. Lengths of line intercepts and adjacent quadrats varied depending on size of each plot and subplot. For example, the largest plot designs were 30.48 m x 30.48 m (100 ft. x 100 ft.) in size and the smallest plot size were 10.67 m x 28.96 m (35 ft. x 95 ft.); therefore, I sampled each of the three subplots for vegetation with a 30.48 m (100 ft.) long line-transect for the largest plot and 28.96 m (95 ft.) length for the smallest plot (Figure 2.2). Transect lines were established in the middle of each subplot to avoid influences associated with the edge of subplots and plots. Line transects initiation and termination points were located at least one meter from subplot edge to avoid potential edge effects on plant community characteristics. One belt transect measuring 0.5 m x 30.48 m (1.65 ft. x 100 ft.) was established adjacent to each line transect to estimate stem densities of

woody plants (stems per hectare; Hays et al. 1981; Buckland et al. 2007). In this method, a belt transect was laid out in each of the subplot areas, 0.5 m (1.65 ft.) to the right of each line transect, to count the woody plant stems inside the quadrat area (0.5 m [1.65 ft.] x length line transect) then identified and estimated woody stem abundance. Beginning and end points of each line transect were recorded using a Garmin E-Trex HCx Vista GPS unit and overlaid into ArcMap GIS (ESRI 2011).

Vegetation Surveys

I conducted vegetation surveys during summer and fall (July – September) and spring (April – early June) from 2010 through 2012. Transects within each subplot were surveyed to estimate species composition, percent coverage of vegetation within different height categories, percent coverage of woody and herbaceous plants, and woody stem densities during spring and fall periods. One transect line per subplot was sampled during each season which yielded sampling of 30 subplots transect per survey period (Table 2.2). Along line transects, I recorded species richness of native and non-native plants, and percent coverage of plants occurring in three height categories: ≤ 0.46 m (≤ 18 inches) in height, ≥ 0.46 m - ≤ 0.91 m (18-36 inches) in height, and ≥ 0.91 m (≥ 36 inches) in height (Hays et al. 1981; Buckland et al. 2007). Plants were identified to genus and species and percent coverage of plants were recorded into the following categories: native and non-native forbs, native and non-native grasses, native and non-native legumes, native and non-native sedges, native rushes, and native and non-native woody plants (i.e., trees, shrubs, and vines; Hays et al. 1981; Buckland et al. 2007). Stem counts of woody plants were conducted in belt transects which were established 0.5 meters (1.65

ft.) to the right of each line transect to derive density estimates of trees, shrubs, and woody vines occurring with subplots (Hays et al. 1981; Buckland et al. 2007).

Plant species were identified using the following references: Knobel (1899), Knobel and Faust (1899), Radford and Bell (1968), Hitchcock and Chase (1971), USDA (1971), Petrides and Peterson (1973), Brown (1978), Godfrey and Wooten (1979), Godfrey and Wooten (1981), Allen (1989), Newcomb and Morrison (1989), McKenny and Peterson (1998), Petrides et al. (1998), Tobe (1998), Midgley (1999), Miller and Miller (1999), Harper-Lore (2000), Harper-Lore and Wilson (2000), Midgley (2003), Miller (2003), Peacock and Schauwecker (2003), Duncan and Duncan (2005), Foote and Jones (2005), Horn and Cathcart (2005), Timme (2007), Bryson et al. (2009), Hodges et al. (2012), Schummer et al. (2012), and USDA and NRCS (2013). Dr. Victor Maddox, a plant taxonomist at Mississippi State University, identified any unknown plants.

Equipment Used

A Garmin E-Trex HCx Vista GPS unit was used to delineate each of the 10 research plots. Each plot had a metal sign at the road frontage plot perimeter outer boundary. Each sign was 0.76 m x 0.38 m (30 in x 15 in) with a white reflective background with black letters stating "Do Not Mow or Spray." For plot establishment, 80 wooden stakes 1 meter tall x 7.62 cm wide x 2.54 cm thick (3.28 ft. x 3 in x 1 in) with pink, plastic flagging were used for delineating the difference between each subplot treatment. The line transect methodology (Hays et al. 1981; Buckland et al. 2007) used required placing an additional four wooden stakes evenly within each subplot. Height categories of vegetation were measured using white nylon string that was attached to wooden stakes. A 9.07 kg (20 lb.) sledge hammer was used to pound each of the wooden

stakes into the ground before tying the white nylon string onto each for the line transect. A 30.48-meter (100 feet) measuring tape was used to go directly beneath the string on the vegetation to begin sampling and recording percent coverage, height, species richness, and species of all herbaceous plants.

When implementing the supplemental seeded subplots, a Scotts® Company Seed Easy Hand Held Seed Spreader was used for seeds of black-eyed susans (*Rudbeckia hirta*), while hand spreading techniques were used for the dense blazing star (*Liatris spicata*), and lanceleaf tickseed (*Coreopsis lanceolata*) seeds. I walked in a uniform line taking multiple trips up and down the entire seeded subplot scattering seeds these selected seeds. I was very careful not to contaminate the other subplots by not overlapping the outer boundaries. The seeded subplots were not mowed prior to seeding; however, they were mowed once during late fall seasons, after the seed set of plants within the plots had occurred. Contractors employed by MDOT conducted the mowing. Commodities, equipment, and tools used for transect establishment, vegetation surveys, and seeding of wildflowers in subplots are listed in Table 2.3.

Spotlight Count Surveys for Wildlife

Wildlife spotlight surveys were conducted from January 2011 to January 2012, mainly for white-tailed deer (*Odocoileus virginianus*). Observations of other wildlife species were noted and recorded as incidental sightings. Surveys were conducted from dusk until approximately 3 hours after dark and $\geq$ 3 times a month (>10 times per season) along the 48.28-km (30 miles) ROW corridor of Highway 25 corridor in Winston and Oktibbeha counties. Permits to conduct spotlight counts for this research were obtained from Chad M. Dacus, the Deer Program Coordinator for Mississippi Department of

Wildlife, Fisheries, and Parks (MDWFP). The Mississippi State Highway Patrol Officers under Major Clark McMinn, Northern Region Administrator, and the local Starkville Police departments were notified of this research activity along the roadside ROW in the regions of Oktibbeha and Winston counties in Mississippi for deer spotlighting and schedules of each event. Two types of spotlights were used: a 300,000 Candle Power (C.P.) Brinkman's Q-Beam and a 1,000,000 C.P. Optics Beam. A Bushnell Scout 1000 Arc Rangefinder was used to determine distance of animal observation point from the road edge (Table 2.3). The Garmin E-Trex HCx Vista Global Positioning System (GPS) handheld unit was used to pinpoint the location at where wildlife was observed (ESRI 2011). The GPS points were used to overlay map in ArcMap GIS (Global Information System) program for identifying wildlife observations in different physiographic regions along ROW corridor and at a landscape scale using GAP analysis land cover data (Figure 2.3; USGS 2010; ESRI 2011).

Hypothesis Testing And Statistical Analyses

Null hypotheses were tested at $\alpha \leq 0.05$ using multiple approaches as follows:

H_1

There will be no significant differences in total species richness, native species richness, and non-native species richness among treatments.

Response variables for H_1 included species richness of native and non-native plants. The independent treatments were the control (mowing $\geq$ 4 per year), treatment 1 (naturally growing with reduced mowing to once in November per year), treatment 2 (naturally growing with reduced mowing to once in November per year plus selective

supplemental native wildflower seeding), seasons (spring and fall), upland vs. riparian locations, and the years (2010-2012; Table 2.4).

Statistical analyses included mixed models, univariate repeated measures analysis of variance (PROC MIXED) in Program SAS (Anderson et al. 2000; Stafford and Strickland 2003; Dickey 2008; SAS Institute 2008; Ott and Longnecker 2010). Multiple measurements of biological plant metrics structure over time was incorporated by going to the same plot each season was not random. I investigated interactions of treatment, elevation, and year (fixed effects) and random effects of elevation with year as the repeated measure. I used model selection Akaike's Information Criterion corrected (AIC_c) to compare auto-regressive [AR (1)], compound symmetry (CS), and unstructured (UN) covariance structures for each response variable under restricted maximum likelihood (REML) for comparisons of species richness variables (Littell et al. 1996; Wolfinger 1996; Wolfinger 1997; Burnham and Anderson 2002; Gutzwiller and Riffell 2007; SAS Institute 2008). I selected the best top model structures according to the lowest ΔAIC_c values. After the AIC_c tests, I used pairwise comparisons of Fisher's Least Significant Difference (LSD) to compare significant effects of means of each variable (Meier 2006).

H_2

There will be no significant differences in percent coverage vegetation categorized according to growth forms and native/non-native status among treatments.

Response variables for H_2 included percent coverage of native and non-native plants according to growth forms. The independent treatments were the control (mowing $\geq$ 4 per year), treatment 1 (naturally growing with reduced mowing to once in November

per year), treatment 2 (naturally growing with reduced mowing to once in November per year plus selective supplemental native wildflower seeding), seasons (spring and fall), upland vs. riparian locations, and the years (2010-2012; Table 2.4).

Statistical analyses used included analysis of variance using distance matrices (ADONIS) in Program R's vegan package (Anderson 2001; Ott and Longnecker 2010; R Core Team 2012). Analysis of variance included distance matrices by partitions distance matrices among sources of variation while fitting linear models to distance matrices using permutation test with pseudo-*F* ratios (Anderson 2001). The permutation test used randomized data by rearranging data back to analyze to get replicates. Biplot Sord, Scree Plots (Broken-stick), Eigenvectors and Eigenvalues loadings (Appendix Table A.13), Princomp Correlation Matrix within Principle Component Analysis (PCA) were used to investigate interactions of treatment, elevation, and year (fixed effects) and random effects by elevation with 999 permutations and Euclidean distances. When a significant interaction was detected, I used Wilcoxon Signed-Rank Test for pairwise comparisons with elevation as a blocking variable to determine which growth form coverages differed. The Wilcoxon Signed-Rank Tests test was used versus Friedman's tests or other analyses to allow for comparison of >2 groups (McDonald 2009) because there was a lack of treatment effect within my study.

H_3

There will be no significant differences in percent coverage of vertical height as $\leq$ 0.46 m, $\geq$ 0.46 m to $\leq$ 0.91 m, and $\geq$ 0.91 m of herbaceous and woody vegetation among treatments.

Response variables for H_3 included percent coverage of vertical heights of herbaceous and woody vegetation. Over the 2010-2012 study period, independent treatments were the control (mowed: $\geq$ 4 mowing per year), treatment 1 (reduced-mowed: one mowing per year in November), treatment 2 (reduced-mowed/seeded: one mowing per year in November and supplemental native wildflower seeding), seasons (spring and fall), and elevation (upland vs. lowland locations; Table 2.4).

Statistical analyses used included mixed models, univariate repeated measures analysis of variance (PROC MIXED) in Program SAS (Anderson et al. 2000; Stafford and Strickland 2003; Dickey 2008; SAS Institute 2008; Ott and Longnecker 2010). Multiple measurements of biological plant metrics structure over time was incorporated by going to the same plot each season was not random. I investigated interactions of treatment, elevation, and year (fixed effects) and random effects of elevation with year as the repeated measure. I used model selection Akaike's Information Criterion corrected (AIC_c) to compare auto-regressive [AR (1)], compound symmetry (CS), and unstructured (UN) covariance structures for each response variable under restricted maximum likelihood (REML) for comparisons of percent coverage of height variables (Littell et al. 1996; Wolfinger 1996; Wolfinger 1997; Burnham and Anderson 2002; Gutzwiller and Riffell 2007; SAS Institute 2008). I selected the best top model structures according to the lowest ΔAIC_c values. After the AIC_c tests, I used pairwise comparisons of Fisher's Least Significant Difference (LSD) to compare significant effects of means of each variable (Meier 2006).

H_4

There will be no significant differences in stem densities of woody plants within vine, shrub, and tree growth forms among treatments.

Response variables for H_4 included woody plant (vine, shrub, and tree) stem densities (stems/ha) of native vs. non-native species. Over the 2010-2012 study period, independent treatments were the control ($\geq$ 4 mowing per year), treatment 1 (naturally growing with reduced mowing to once in November per year), treatment 2 (naturally growing with reduced mowing to once in November per year plus supplemental native wildflower seeding), seasons (spring and fall), and elevation (upland vs. lowland; Table 2.4).

Statistical analyses used included mixed models, univariate repeated measures analysis of variance (PROC MIXED) in Program SAS (Anderson et al. 2000; Stafford and Strickland 2003; Dickey 2008; SAS Institute 2008; Ott and Longnecker 2010). Multiple measurements of biological plant metrics structure over time was incorporated by going to the same plot each season was not random. I investigated interactions of treatment, elevation, and year (fixed effects) and random effects of elevation with year as the repeated measure. I used model selection Akaike's Information Criterion corrected (AIC_c) to compare auto-regressive [AR (1)], compound symmetry (CS), and unstructured (UN) covariance structures for each response variable under restricted maximum likelihood (REML) for comparisons of woody stem density variables (Littell et al. 1996; Wolfinger 1996; Wolfinger 1997; Burnham and Anderson 2002; Gutzwiller and Riffell 2007; SAS Institute 2008). I selected the best top model structures according to the lowest ΔAIC_c values. After the AIC_c tests, I used pairwise comparisons of Fisher's Least

Significant Difference (LSD) to compare significant effects of means of each variable (Meier 2006).

Data distribution characteristics of all plant metrics of woody stem density including normality and homogeneous variance assumptions were tested using IBM SPSS Statistics v.20 software (IBM Corp. 2011). To test for the true significance of normality, Kolmogorov-Smirnov Z-test and Lilliefors Significance Correction were used to test the upper and lower bounds (IBM Corp. 2011). Shapiro-Wilk goodness-of-fit test, Kurtosis and Skewedness were also used to test for normality (Royston 1992; IBM Corp. 2011). After square root and $\log_{10}$ transformations of plant metric data of percent coverage within growth forms, species richness, percent coverage of three different height categories, and woody stem density, I discovered that not all the data would transform into normally distributed data (Baker 1934; Kutner et al. 2004; McDonald 2009). Based on data characteristics and data transformation results, I elected to retain all data as non-normal distributions and elected to use nonparametric analysis methods rather than the normal parametric analyses. I also grouped the analyzed data among each season (fall vs. spring) as I expected a difference due to growing seasons and ecological differences among vegetation species coverage, species richness, and species occurrences during certain seasons. Differences between comparisons of data were considered significant at $p \leq 0.05$ (Fisher 1925). Specific information on statistical analyses used in this study are provided in each of the following chapters.

Table 2.1 Overview of study methods used to assess vegetation characteristics during 2010-2012.

Type of Survey	**Methodology**	**Sampling Design**	**Sampling Periods Season of Surveys**
Genera and/or species composition and percent coverage of herbaceous and woody plants	Line intercept and transects (Hays et. al 1981)	Treatment plots in upland (N=5) and stream bottoms (N=5) AND 3 subplots in each treatment plot. Total Number of Plots (N_1=10) and Subplots (N_2=30) with associated dimensions of plots	Early spring and late summer/fall (2 times/year)
Stem density of woody plants (shrubs, trees, and woody vines)/hectare	Belt transects along line intercept (Hays et. al 1981)	Line intercept (length of plot in m) and belt transects 1 m x length in m) in each subplot	Early spring and late summer/fall (2 times / season)
Spotlight counts of White-tailed Deer (*Odocoileus virginianus*)	- Drive vehicle $\leq$ 20 mph - Spotlight area: area adjacent to roadway within maintained ROW - Observations of deer recorded with GPS unit and distance from observer to animal recorded with Rangefinder.	Number of kilometers per transect for spotlight counts	Winter, spring, summer, and fall during 2011 (2-3 times/month)

Table 2.2 Vegetation sampling schedule of plant community characteristics during 2010-2012.

Vegetation Sampling Schedule (2010 to 2012)		
Season of Survey	Months	Sampling Periods
Vernal (Spring)	April to early June	One transect line per subplot (30 subplot transect line sampled) during this season
Autumnal (Fall)	July to September	One transect line per subplot (30 subplot transect line sampled) during this season

Table 2.3 Equipment used for vegetation transects, and seeding of wildflower seed mixtures during 2010-2012.

Study Activity	**Supplies and Commodities**	**Equipment/Implement**
Plot Establishment, Delineation of Line Intercept, Belt Transect Establishment	Wooden stakes, flagging, nylon string, sledge hammer, two 30.5 m measuring tape 20 Do Not Mow or Spray Metal Signs (30 x 15in) 2 signs at plot perimeter	Garmin E-Trex HCx Vista GPS unit
Vegetation Surveys	Two 30.5 meter measuring tapes, nylon string, wooden stakes, plant identification guides	Plant identification books
Seeding of Subplots	Seed Mixture Black-eyed susan (*Rudbeckia hirta),* Dense blazing star *(Liatris spicata),* Lanceleaf tickseed *(Coreopsis lanceolata)*	Scotts® Company Seed Easy Hand Held Seed Spreader
White-tailed Deer Observation Surveys	ATM fuses for vehicle power source Data sheets, GPS unit, Binoculars, Rangefinder	Spotlights: 300,000 C.P. Brinkman's Q-Beam and 1,000,000 C.P. Optics Beam

Table 2.4 Response and independent variables for vegetation sampling metrics.

Vegetation Responses	
Response Variables (y)	**Independent Variables (x)**
Mean Height of Woody Vegetation (meters) • $\geq 0 \leq 0.46$ • $\geq 0.46 \leq 0.91$ • ≥ 0.91	Seasons • Fall • Spring Treatments • Control (mowed) • Reduced mowed • Reduced mowed with seeding Elevations • Upland • Lowland

Mean Percent Coverage
• Herbaceous Plants
  • Forb
  • Grass
  • Legume
  • Sedge
  • Rush
• Woody Plants
  • Trees
  • Shrubs
  • Vines
	Seasons
	• Fall
	• Spring
	
	Treatments
	• Control (mowed)
	• Reduced mowed
	• Reduced mowed with seeding
	
	Elevations
	• Upland
	• Lowland

Species Composition
• Herbaceous Plants
  • Native
  • Non-Native
• Woody Plants
  • Trees
  • Shrubs
  • Vines
	Seasons
	• Fall
	• Spring
	
	Treatments
	• Control (mowed)
	• Reduced mowed
	• Reduced mowed with seeding
	
	Elevations
	• Upland
	• Lowland

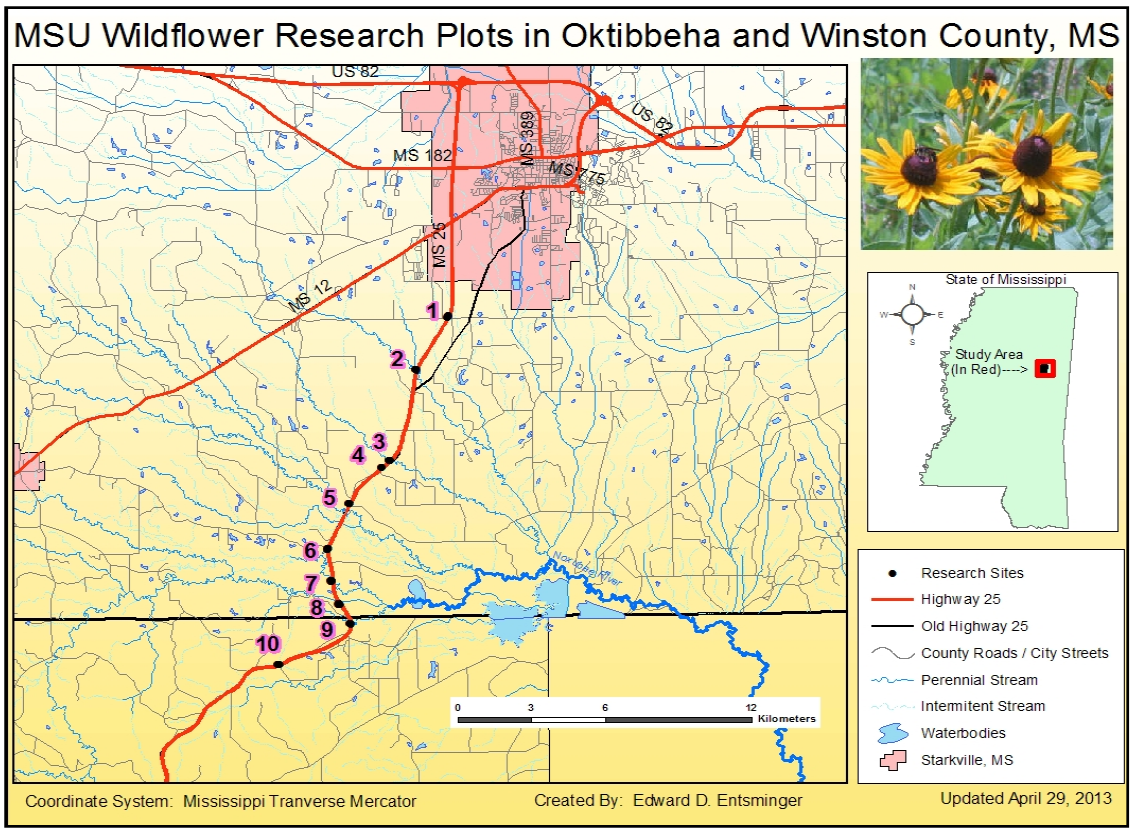

Figure 2.1 Study area along Highway 25 right-of-ways in Oktibbeha and Winston counties, Mississippi.

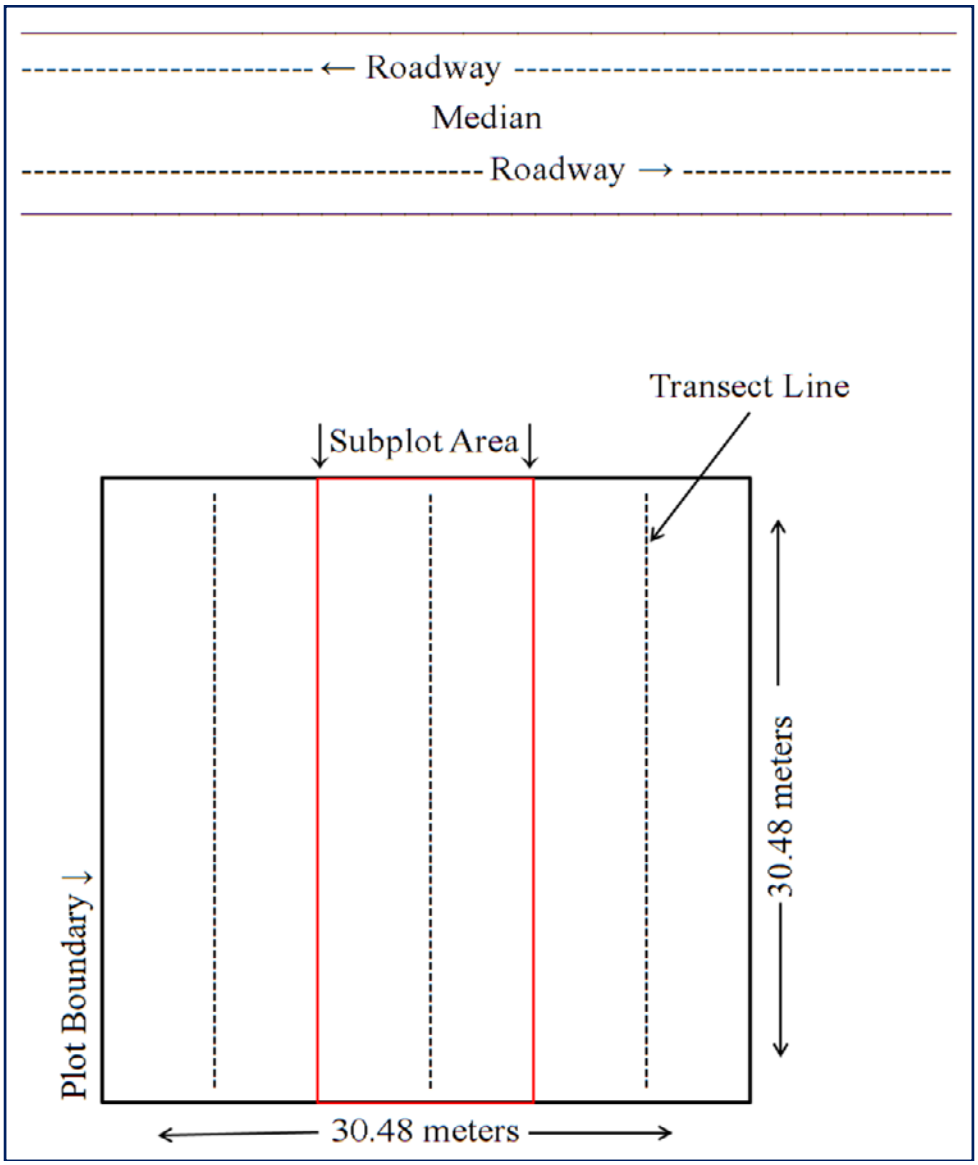

Figure 2.2 Plot and subplot design using line transect methodology for evaluating vegetation characteristics.

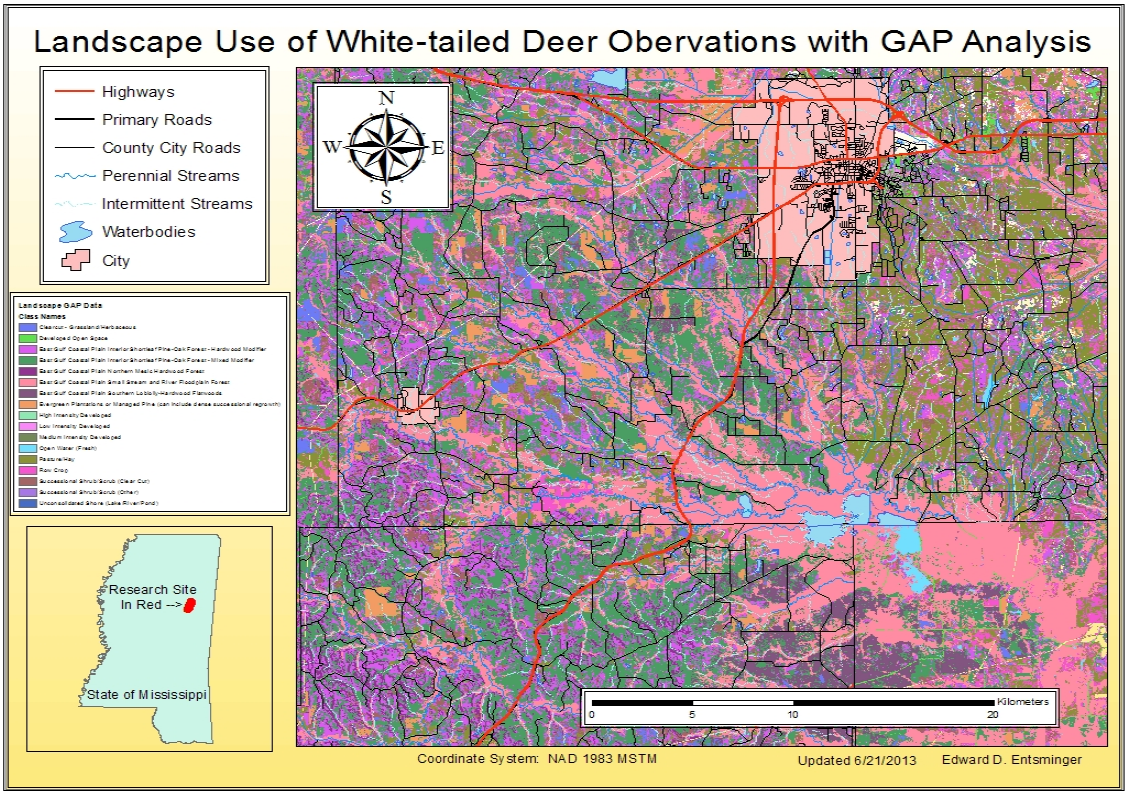

Figure 2.3 ArcMap GAP land cover scale for recording observations of white-tailed deer (*Odocoileus virginianus*).

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CHAPTER III

PERCENT COVERAGE AND SPECIES RICHNESS OF PLANTS IN VEGETATION MANAGEMENT TREATMENTS

Introduction and Study Area

In recent decades, native grasses and wildflowers have declined on roadside right-of-ways (ROWs) due to direct and indirect management practices such as intensive herbicide application, repeated mowing, competition from seeded agronomic grasses, invasive non-native plants, and other disturbances associated with road maintenance (Hill and Horner 2005; Willard et al. 2010). The decline in native plant species is directly related to the pervasiveness and expansion of non-native plant species (Miller 2003; Li et al. 2008). Ullmann et al. (1995) stated that areas suitable for farming and pasture lands are dominated by non-native introduced species, whereas less developed areas (i.e., fallow fields, un-improved pastures, areas of native forests) are transected by ROWs that exhibit a greater abundance of native plant species. Direct effects of intensive vegetation management on ROWs include killing plants with herbicides or preventing their reproduction with intensive mowing. Road construction and maintenance alter plant and animal communities through substrate disturbance and seeding of non-native plants for erosion control (Ament et al. 2008). Indirect effects that may influence plant communities include changes to edaphic factors, such as soil fertility and structure, surface water movement and other hydrological factors, as well as slope and aspect

influences on ground surface microclimate (Greenfield et al. 2005; Huijser and Clevenger 2006). As a plant community ages, these indirect effects may become apparent through successional alterations, such as decline of bare ground and accumulation of vegetation litter; therefore, such changes to the plant community can affect availability of food and cover resources for native animal species. Other impacts of ROWs include changes in wetland hydrology, degradation of water quality, dispersal of invasive non-native species, restriction of animal movement, and increase in traffic-related mortality for wildlife (Forman and Deblinger 2000). Negative impacts of ROWs include changes in adjacent areas and impacts in wetland hydrology, degradation of water quality, dispersal of invasive non-native species, fragmentation of vegetation communities, and barriers to animal movements (Forman and Deblinger 2000; Harper-Lore and Wilson 2000; Miller et al. 2010).

Nearly 50% of plant species were non-native in study areas of New Zealand (Ullman et al. 1995) and Europe (Ullmann and Heindl 1989). However, in study areas of South Africa only 26% of plant species were introduced (Cilliers and Bredenkamp 2000). Despite these statistics, status of roadside vegetation research remains in the stage of exploration worldwide. Numerous studies about native vegetation establishment on the roadside suggest different and even conflicting findings. European researchers concluded that continual mowing helped increase establishment of native plants (Melman et al. 1988; Persson 1995; Ryel et al. 1996), whereas other studies in America recommended reduced mowing to increase native plants (Bolin et al. 1990; Ritzer 1990). Vegetation composition may depend on the species studied, herbivory, damage to lands,

management regimens (including long-term history of land management), and hydrological and soil (edaphic) characteristics (Arner and Jones 2009).

Road construction and associated ROW management can have negative impacts to native flora and fauna, proactive management of ROW vegetation that enhances native plant communities can improve ecological function and structure of ROWs for native wildlife (Dana et al. 1997; Harper-Lore and Wilson 2000:665; Arner and Jones 2009). Enhancement of native wildflower management programs can result in roadside beautification along highways. Because of aesthetic enhancement and positive perceptions, wildflower programs along highway ROWs have become common in many states over the past two decades (U. S. Department of Transportation – Federal Highway Administration 2011). Wildflower programs have entailed seeding and modifications in vegetation management resulting in increases in plant diversity and coverages over time (Dana et al. 1997; Tilman 1997). Native plant cover can address some of the negative impacts of roadway construction and management through benefits by decreasing spread of invasive plants, reducing erosion, lowering maintenance costs, protecting water quality, and creation of visual and noise buffers along intensely used roadways (Forman and Alexander 1998). Native plant cover within ROWs create habitat for early successional species, such as small mammals, birds, herpetofauna and insects (Bugg et al. 1997; Forman and Alexander 1998; Hopwood 2010). These programs reported to have positive life quality ramifications for humans. Roadside wildflowers can also have positive effects on motorists, making them more relaxed and happier when driving (Cackowski and Nasar 2003, Transportation Research Board 2005). These studies mentioned that reduced mowing created habitat needs for many species of wildlife that

use early successional areas, and greater diversity of native plants was attributed primarily to less intense maintenance regimens of reduced mowing and selective herbicide use.

Concerns exist over native plant cover related to attraction of wildlife to roadsides and increased potential of vehicle-wildlife collisions, while enhancement of native plant cover along roadside ROWs can have positive effects. Furthermore, loss of visibility for drivers along roadways reported in many states with regard to large mammals (i.e., white-tailed deer and coyotes (*Canis latrans*) and vehicle collisions (Michael and Kosten 1981; Dixon et al. 1984; Conover et al. 1995). Visibility can be an issue for motorists (Louisiana Department of Transportation and Development 2000), whereas roadsides can attract and support wildlife. Roads and ROWs may have negative impacts on wildlife because of fragmentation and environmental loss (Forman and Deblinger 2000). Roadways act as barriers in dispersal movement through mortality, and may lead to isolated wildlife populations (Ament et al. 2008). Enhanced native plant coverages along highway ROWs can help mitigate the potential negative impacts to wildlife and native flora, while modifications in management approaches can potentially lessen the deleterious effects of roadways to wildlife.

One low-maintenance approach to improving ROWs for native vegetation is a reduction in number of mowings within the growing season once annually during fall. This approach allows adequate time for native plant seed maturation, protects nest of ground nesting wildlife, and allows pollen and nectar producing plants to provide food sources for birds, small mammals, and pollinating insects (Hurst 1972; Anderson 1996; Yarrow and Yarrow 1999; Dickson and Wigley 2001; Arner and Jones 2009). With a

reduced mowing frequency, woody plant colonization may still occur on ROWs; however, these plants can be controlled through selective herbicide application (Dana et al. 1997; Arner and Jones 2009). Reduction of mowing along ROWs, to one time per year in late fall, has the potential to create attractive environments along Mississippi roadsides by increasing native grasses and wildflowers with less establishment of non-native plant species (Green and Welker 2003; U. S. EPA 2012).

Long-term benefits for restoring and maintaining native plant species can include sustainability of ecosystem through preservation of productivity and health. Cole and Hundy (1999) reported that native plant species are well adapted to their natural environments and that native species typically require less management over time. Some of the adaptive characteristics that plants have include morphological and physiological features. These features include ability to conserve water and maintain carbon fixation under drought conditions, limit use by herbivores with chemical and physical features, have allelopathy competition in their roots, and adapt to seasonal growth patterns for seed production, and dispersion.

This study was designed to evaluate native and non-native plant community characteristics along roadside ROWs in response to various alternative mowing procedures. Specific objectives of this portion of the study were to estimate plant species richness along a highway ROW in northeastern Mississippi and to estimate response of plant communities in two different mowing regimens and reduced mowing-wildflower seeding treatments. A greater understanding of plant community characteristics and structure on a highway ROWs should enhance plant diversity under different mowing

regimens in lowland and upland elevations. Specific objectives outlined in this chapter include the following:

1. To estimate and compare relationships between native and non-native plant species richness along Highway 25 roadside ROWs in Oktibbeha and Winston counties, Mississippi, and between treatments, upland vs. lowland elevations, seasons, and year effects.
2. To estimate and compare percent coverage characteristics of native and non-native herbaceous and woody plant species along Highway 25 roadside ROWs in Oktibbeha and Winston counties, Mississippi, and between treatments, upland vs. lowland elevations, seasons, and year effects.
3. To estimate and compare percent coverage for leaf litter and bare ground along Highway 25 roadside ROWs in Oktibbeha and Winston counties, Mississippi.

Field Methods

I conducted surveys along transect lines to measure plant species richness and percent coverage of woody and herbaceous plants during fall 2010 and 2011 and spring 2011 and 2012 based on Hays et al. (1981) and Buckland et al. (2007). This is the design used to sample vegetation once per season in the center zone of each subplot treatment in all plots. Specific details on field methods and study area are described in Chapter II.

Statistical Analyses

Prior to statistical analyses, data were tested for distributional normality and homogenous variances using Kolmogorov-Smirnov Z-test, Normal and Detrended Normal Q-Q plots, Lilliefors Significance Correction, Kurtosis and Skewedness

evaluation tests, and Shapiro-Wilk goodness-of-fit tests in SPSS Statistics v.20 (Levene 1960; Shapiro and Wilk 1965; Chakravarti et al. 1967; Royston 1992). The integrated product SPSS was used to addresses the entire analytical process from data collection to analysis and reporting results (IBM Corp 2013). Multiple methods were used to test for normality and variance conditions of the percent coverage and species richness data. Based on normality and homogeneous variance testing, I transformed data that were non-normally distributed. However, following transformation procedures, I discovered that not all data transformed into a normal distribution. Based on normality testing and outcomes of data transformation, non-parametric statistical analyses were used instead of parametric statistical analyses for the plant community metrics mentioned in my objectives (Ott and Longnecker 2010).

I tested the null hypothesis of no difference in native and non-native plants species richness among treatments or between upland and lowland elevations using mixed models, univariate repeated measures analysis of variance (PROC MIXED) in Program SAS (SAS Institute 2008, Ott and Longnecker 2010). I investigated interactions of treatment, elevation, and year (fixed effects) and random effects of elevation with year as the repeated measure. I used model selection using Akaike's Information Criterion corrected (AIC_c) to compare auto-regressive [AR (1)], compound symmetry (CS), and unstructured (UN) covariance structures for each species richness variable under restricted maximum likelihood (REML; Gutzwiller and Riffell 2007). I also designated top model structures (i.e., best covariance structure and inclusion or exclusion of random effect) as models with $\Delta AIC_c \leq 2$ to the next best model (Burnham and Anderson 2002). After the AICc tests, I used pairwise comparisons of Fisher's Least Significant

Difference (LSD) to compare means of each plant variable among treatments, elevations, seasons, and years (Meier 2006). I evaluated differences in species richness of the following growth forms: native and non-native forbs, grasses, legumes, rushes, sedges, shrubs, trees, woody vines. Differences were considered to be significant at an alpha level of 0.05 (Ott and Longnecker 2010).

Data were grouped by season (fall vs. spring) due to vegetation coverage differences and varying structure by species composition between seasons. For testing differences in percent coverage of vegetation between treatments and elevations, I ran a Principle Component Analysis (PCA) using Program R Gui (Jackson 1993; King and Jackson 1999; Anderson 2001; McCune and Grace 2002; Ott and Longnecker 2010). PCA was used to visually estimate segregation of data summaries within treatments, uplands/lowlands, and seasons by vegetation growth forms, height of vegetation, and native/non-native status (Figure 3.1). I used analysis of variance using distance matrices (ADONIS) in Program R's vegan package to test the null hypothesis of no differences among treatments or upland and lowland elevation in percent vegetation coverage of different growth forms and native/non-native status (Anderson 2001; Ott and Longnecker 2010). The analysis of variance using distance matrices partitioned sources of variation while fitting linear models to distance with permutation tests as pseudo-*F* ratios (Anderson 2001). I investigated interactions of treatment, elevation, and year (fixed effects) and random effects of elevation on plant community metrics with 999 permutations and Euclidean distances (Oksanen 2012; R Core Team 2012). When a significant interaction was detected, I used Wilcoxon Signed-Rank Test for pairwise comparisons with elevation as a blocking variable to determine which growth forms

differed. I was then able to use Wilcoxon Signed-Rank Tests versus Friedman's tests or other analyses, allowing for comparison of > 2 groups, because of the lack of a treatment effect and significant effects only including 2 levels. The upper and lower limits of a 95% confidence interval (C.I.) were calculated using the Wilcoxon's Pairwise Comparisons Tests or Mann Whitney U Tests to compare percent coverage of plant growth forms with non-overlapping 95% C.I. between lowland and upland elevations (Conover 1999; Sheskin 2004; Teetor 2011; R Core Team 2012; Tressler and Chow 2013). Differences were considered significant at an alpha level of 0.05 (Ott and Longnecker 2010).

Results

Species Richness

Between April 2010 and June 2012, I recorded 277 species plants within the ten upland and lowland research plots along Highway 25 roadside ROW in Oktibbeha and Winston counties, Mississippi. Of the total plant species detected, 79% (219 species) were native and 21% (58 species) were non-native. In lowlands, approximately two-thirds (64%) of the observed plant species were native, whereas less than half (44%) of the species in uplands were native plants. These native plants included 111 forbs, 21 grasses, 4 legumes, 8 rushes, 15 sedges, 7 shrubs, 24 trees, and 21 vines (Figure 3.2; Appendix Table A.1). Non-natives included 23 forbs, 18 grasses, 12 legumes, 1 sedge, 3 vines, and 9 species unidentified (Figure 3.2; Appendix Table A.1).

During fall survey periods, I detected 10 native species and 20 non-native species in uplands, and 92 native species and 45 non-native species in lowlands during the two-year study period, 2010-2012. During spring survey periods, I detected 30 native species

and 45 non-native species in uplands, and 106 native species and 68 non-native species in lowlands over the two-year study period, 2010-2012 (Table 3.1).

Within lowland plots of the three different treatments, total plant species richness during fall seasons ranged from 33 to 88 species in mowed treatments, 34 to 84 species in reduced mowed treatments, and 34 to 92 species in reduced mowed-seeded treatments (Table 3.1). In lowland plots during spring periods, species richness counts ranged from 48 to 106 species in mowed treatments, 52 to 90 species in reduced mowed treatments, and 54 to 102 species in reduced mowed-seeded treatments (Table 3.1). In upland plots during fall surveys, I found from 18 to 43 species in mowed treatments, 10 to 37 species in reduced mowed treatments, and 22 to 36 species in reduced mowed-seeded treatments (Table 3.1). In upland plots during spring surveys, total species richness within treatments I found from 34 to 52 species in mowed treatments, 41 to 53 species in reduced mowed treatments, and 30 to 56 species in reduced mowed-seeded treatments (Table 3.1).

In lowland subplots, I estimated a mean plant species richness of 22.13 ($\pm$ 1.13) during fall sampling seasons and 29.67 ($\pm$ 1.11) during spring sampling seasons (Table 3.2). Of the plant species detected in lowlands, 63.88% were native species and 36.08% were non-native species (Table 3.2). In upland subplots, I detected an average of 10.87 ($\pm$ 1.13) plant species during fall and 17.50 ($\pm$ 1.11) during spring (Table 3.2). Upland plots plant communities were comprised of 44.4% native and 56.0% non-native species (Table 3.2).

Greatest plant species richness was recorded in lowland plots with over 106 species and an average of 82.33 species ($\pm$ 4.96) being recorded over all lowland plots

during the study period. For spring and fall survey periods, mean species richness of native plants in lowland plots was about three times that of upland plots (Table 3.2). Mean species richness of non-native plants averaged 5.97 species ($\pm$ 0.40) in upland plots and 7.57 species ($\pm$ 0.40) in lowland plots (Table 3.2). Total species richness, native species richness, and non-native species richness means were significantly greater ($P < 0.01$) in the lowlands during fall and spring seasons (Table 3.2).

Differences were detected in species richness among years, seasons, and elevations during fall. The *F* and *P* values were used because it is the preferred format required for most journals. Total and native species richness of plants differed between year ($F_{1, 96} > 13.43$, $P \leq 0.001$) and elevation ($F_{1, 96} > 59.31$, $P \leq 0.001$) during fall seasons of the study period (Table 3.3). Non-native species richness differed among years ($F_{1, 96} = 25.84$, $P \leq 0.001$) and elevations ($F_{1, 96} = 10.31$, $P \leq 0.01$) respectively (Table 3.3). Total species richness of native and non-native plants was similar among years and elevations; however, species richness did not differ between treatments during the fall seasons over the two-year study period (Table 3.3).

Significant differences were detected in spring species richness in upland versus lowland elevations. Total, native, and non-native species richness differed between elevations ($F_{1, 96} > 5.64$, $P \leq 0.02$; Table 3.3). In addition, non-native species richness differed among years ($F_{1, 96} = 10.04$, $P \leq 0.01$; Table 3.3). However, species richness of total, native, and non-native plants did not differ between treatments and years during spring seasons. Species richness of total, native, and non-native plants differed between upland and lowland elevations, seasons, and years over the two-year study period (Table 3.3).

I detected native forbs and native grass plant species on >95% of the line transects sampled during the study period (Appendix Table A.1). Species of the family Asteraceae were detected on >90% of transects. Native herbaceous legumes were detected on >50% of the line transects sampled during the study period with the most frequently encountered legume was partridge pea (*Chamaecrista fasciculata*; Appendix Table A.1). Native grasses, sedges, and rushes were detected on >65% of transects, even on the ditches of the upland slopes. Of the native grasses, panic grasses (*Dichanthelium* and *Panicum* spp.), paspalums (*Paspalum* spp.) and bluestem grasses (*Andropogon* spp.) were the most frequently encountered (Appendix Table A.1). In addition, woody plants, including shrubs, trees and vines were detected on 60% of the line transects, whereas non-native legumes, forbs, and grasses were detected on >95% of transect lines (Appendix Table A.1). Five species of non-native grasses were the most dominant detected with coverages of >60% on most study plots. These species included Bermudagrass (*Cynodon dactylon*), tall fescue (*Schedonorus phoenix*), Bahiagrass (*Paspalum notatum*), Johnsongrass (*Sorghum halepense*), and Vasey's grass (*Paspalum urvillei*).

Vegetation Percent Coverage

Non-native agronomic grasses comprised < 5% of the total species detected, they prevailed vegetation coverage in all treatments [mowed ($\bar{x}$ = 57.70%, SE $\pm$ 3.14), reduced-mowed ($\bar{x}$ = 60.87%, SE $\pm$ 2.87), reduced-mowed seeded ($\bar{x}$ = 58.32%, SE $\pm$ 2.84); Figure 3.3]. I observed no treatment effects for percent vegetation coverages for any response variables in fall or spring. On all study plots, percent coverage of non-native grasses averaged 88.63% ($\pm$ 3.03) followed by non-native legumes with an average

of 31.86% (± 3.49) over the study period (Table 3.4). Native and non-native forbs averaged >22% coverage collectively, whereas other herbaceous plants averaged < 2% coverage over the two-year study period (Table 3.4). Woody plants comprised almost 8% coverage over the duration of the study (Table 3.4).

In the reduced mowed-seeded subplots, mean percent coverage of native forbs increased from 1.5% to 4.2% during the study, and there was a slight change in ground coverage of non-native forbs from 1.8% to 2.2% (Figure 3.4). However, in reduced mowed-seeded plot treatments, mean percent coverage of non-native grasses exhibited a decrease from 39.5% to 25.2%, whereas native grass coverage increased from 1.1% to 5.3% during the study (Figure 3.5).

During fall survey periods, percent coverage of vegetation within upland study plots was dominated by non-native grass species that exhibited an average coverage of 134.51% (± 8.77) over all study plots. Percent coverage >100% are due to species overlap along each line transect. Non-native legumes averaged 6.79% (± 2.87) while native and non-native forbs comprised approximately 10% coverage within study plots (Table 3.5). Native grasses, legumes, rushes, and non-native sedges averaged < 2% coverage during fall. Of woody species measured, native and non-native woody vines were dominant. Greatest coverage of native woody vines was detected in upland elevations during fall seasons, with an average percent coverage of 12.02% (± 4.09), whereas the least percent coverage of woody vines was recorded for non-native vines during the fall season with an average coverage of 2.10% (± 1.03; Table 3.5).

Percent coverage of most plant growth forms were greater in lowlands than in uplands during fall sampling seasons; however, non-native grasses comprised the

majority (>100%) of ground coverage in lowlands. Coverage of native forbs, primarily in the Asteraceae family, exhibited greater coverage in lowlands than in uplands, averaging approximately 50% coverage in lowlands. All other plants, including native grasses, legumes, rushes, sedges, shrubs, trees, vines, and non-native forbs, sedges, and vines, exhibited percent coverage of ≤ 10% (Table 3.5). Dominant non-native species that comprised most of fall seasons ground coverage included agronomic grasses, such as field brome (*Bromus arvensis*), soft brome (*Bromus hordeaceus*), Bermudagrass (*Cynodon dactylon*), Dallisgrass (*Paspalum dilatatum*), Vasey's grass (*Paspalum urvelli*), bahiagrass (*Paspalum notatum*), yellow foxtail (*Setaria pumila*), green foxtail (*Setaria viridis*), tall fescue (*Schedonorus phoenix*), Johnsongrass (*Sorghum halepense*) and non-native legumes, such as Japanese clover (*Kummerowia striata*), sericea lespedeza (*Lespedeza cuneata*), field clover (*Trifolium campestre*), crimson clover (*Trifolium incarnatum*), white clover (*Trifolium repens*), bird vetch (*Vicia cracca*), and garden vetch (*Vicia sativa*; Appendix Table A.1).

During spring on uplands, non-native grasses and legumes comprised the greatest percent coverage of the roadside ROW vegetation with an average of 159.13% (± 9.81) and 84.02% (± 7.43), respectively (Table 3.6). Percent coverage >100% are due to species overlap along each line transect. Most dominant non-native grasses and legumes during spring included Bermudagrass (*Cynodon dactylon*), bahiagrass (*Paspalum notatum*), Vasey's grass (*Paspalum urvelli*), tall fescue (*Schedonorus phoenix*), yellow foxtail (*Setaria pumila*), and Johnsongrass (*Sorghum halepense*). Percent coverage of native and non-native forbs had an average of 20.10% (± 2.72) and 3.83% (± 0.96), respectively, during the spring seasons of the study period (Table 3.6). The primary

native forb species occurred on ROW plots during spring were hairy white old-field aster (*Symphyotrichum pilosum*), Carolina geranium (*Geranium carolinianum*), goldenrods (*Solidago* spp.), goldentops (*Euthamia* spp.), roundleaf thoroughwort (*Eupatorium rotundifolium*), Canadian horseweed (*Conyza canadensis*), and annual ragweed (*Ambrosia artemisiifolia*; Appendix Table A.1). Native grasses, legumes, and other herbaceous plant cover types averaged < 3% coverage and included species of the genera bluestems (*Andropogon*), partridge peas (*Chamaecrista*), bundleflowers (*Desmanthus*), rosette grass (*Dichanthelium*), crabgrass (*Digitaria*), barleys (*Hordeum*), panicgrasses (*Panicum*), little bluestems (*Schizachyrium*), foxtails (*Setaria*), and tridens (*Tridens*; Appendix Table A.1). Percent coverage of native trees and shrubs comprised < 2% coverage included red maple (*Acer rubrum*), eastern baccharis (*Baccharis halimifolia*), common persimmon (*Diospyros virginiana*), green ash (*Fraxinus pennsylvanica*), sweetgum (*Liquidambar styraciflua*), black gum (*Nyssa sylvatica*), loblolly pine (*Pinus taeda*), oaks (*Quercus* spp.), black willow (*Salix nigra*), and winged elm (*Ulmus alata*; Appendix Table A.1). Percent coverage of native and non-native woody vines averaged < 10% on all plots included sawtooth blackberry (*Rubus argutus*), southern dewberry (*Rubus trivialis*), Japanese honeysuckle (*Lonicera japonica*), purple passionflower vine (*Passiflora incarnata*), greenbriers (*Smilax* spp.), trumpet creeper (*Campsis radicans*), eastern poison ivy (*Toxicodendron radicans*), summer grapevine (*Vitis aestivalis*), and muscadine grapevine (*Vitis rotundifolia*; Table 3.6; Appendix Table A.1).

In lowlands during spring, non-native grasses were the dominant cover type averaging 127.51% (± 7.42). Other dominant cover included native forbs and non-native legumes with an average percent coverage of 47.45% (± 7.21) and 42.31% (± 5.25),

respectively. Other herbaceous plants included non-native forbs, native grasses, legumes, sedges, and rushes, exhibited an average percent coverage of < 11%. Woody plants, including vines, trees and shrubs, exhibited an average coverage of < 12% coverage in lowlands during spring seasons (Table 3.6).

Percent coverage of native forbs ($z = 4.81$, $P \leq 0.001$), grasses ($z = 3.51$, $P \leq 0.001$), legumes ($z = 3.37$, $P \leq 0.001$), and rushes ($z = 4.54$, $P \leq 0.001$) was greatest in lowlands during fall (Table 3.5). The z-statistic values were used to test the normal distribution from the mean and standard deviation. Spring percent vegetation coverage by species also differed between uplands and lowlands ($F_{1, 59} = 24.12$, $P \leq 0.001$), with coverage of native forbs ($z = 3.03$, $P \leq 0.01$), legumes ($z = 2.62$, $P \leq 0.01$), rushes ($z = 5.00$, $P \leq 0.001$), sedges ($z = 4.15$, $P \leq 0.001$), and non-native legumes ($z = 3.82$, $P \leq 0.001$), was greatest in lowlands (Table 3.6). Total percent coverage of native and non-native plants by growth forms did not differ significantly among treatments ($F_{2, 96} = 0.85$, $P = 0.48$) but differed between uplands and lowlands ($F_{1, 96} = 18.22$, $P \leq 0.001$), between study years ($F_{1, 96} = 14.54$, $P \leq 0.001$), and between fall and spring seasons ($F_{1, 96} = 16.25$, $P \leq 0.001$; Table 3.7). In addition, I 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 3.7).

Debris and Bare Ground Percent Coverage

During the two-year study period, percent coverage of bare ground in all plots exhibited a mean coverage ranging from 0% to 19.11% (Table 3.8). Over 50% of the subplots within the study exhibited < 5% coverage of bare ground during the two-year study period. Bare ground on most plots was due to soil disturbance from installation of water pipelines, contour grading, and erosion. Debris was classified as dead grass

clippings and other vegetation litter, whereas fine woody debris was classified as sticks, twigs, and branches (Hays et al. 1981). Percent coverage of debris ranged from an average of 6.79% (± 2.72) in reduced mowed-seeded subplots during fall 2011 to an average of 42.48% (± 5.46) in reduced mowed-seeded subplots during spring 2012. Of the treatment plots, subplots that received frequent mowing exhibited a minimal average of 1.75% (± 1.09) coverage of bare ground in upland plots during fall 2011 to a maximum average of 13.34% (± 9.22) in lowland plots during fall 2010. Subplots receiving reduced mowing treatment exhibited average bare ground coverage of < 12.20% over the two-year study period. Subplots that were seeded and received a reduced mowing treatment exhibited an average of < 19.11% bare ground with no change from 2010 to 2012 (Table 3.8).

During fall sampling seasons of 2010 and 2011, percent coverage of bare ground ranged from 12.20% (± 12.20) in reduced mowed subplots to 13.34% (± 9.22) in mowed subplots and 19.11% (± 18.97) in reduced mowed-seeded subplots. Percent coverage of debris on plots during fall sampling seasons ranged from a mean of 17.83% (± 6.82) in mowed subplots to a mean of 19.46% (± 6.42) in reduced mowed-seeded subplots and a mean of 23.87% (± 6.09) in reduced mowed subplots (Table 3.8).

During spring sampling seasons of 2011 and 2012, percent coverage of bare ground ranged from 8.97% (± 4.59) in mowed subplots to 7.50% (± 6.89) in reduced mowed subplots and 5.70% (± 5.10) in reduced mowed-seeded subplots. Percent coverage of debris on plots during fall sampling seasons ranged from a mean of 34.34% (± 6.11) in mowed subplots to a mean of 35.59% (± 4.22) in reduced mowed subplots and a mean of 42.48% (± 5.46) in reduced mowed-seeded subplots (Table 3.8).

Discussion

Species richness of 277 plants was detected in upland and lowland plots during the study period. Similar results have been reported by Schuster and McDaniel (1973) and Leidolf and McDaniel (1998) with native plant species richness >150 being reported in each prairie environments near ROWs in Alabama and Mississippi. In my study, approximately 78% of the plants detected were native species with non-native species comprising approximately 21%. Agronomic grasses and other non-native plant species comprised < 25% of the total species in this study, while non-native species typically dominated vegetation coverage (≥ 90%) in all treatment subplots with mean ranges in percent coverage of 74.64% (± 18.27) in reduced-mowed treatments to 117.63% (± 17.93) in mowed treatments. The enhancement of native plants and use of erosion control species may be compatible objectives on roadside ROWs. Harrington (1995) stated that prairie sites sampled along highways in Wisconsin exhibited increases in percent coverage of native grasses over time with coverages of >50% in native grasses and >20% in native forbs within communities dominated by < 40% non-native grass coverage over a 10-year period. In my study, I detected an increase in native species over the study period within plant communities typified by >50% coverage of agronomic grasses, such as Bermudagrass (*Cynodon dactylon*), tall fescue (*Schedonorus phoenix*), Bahiagrass (*Paspalum notatum*), Vasey's grass (*Paspalum urvillei*), and Johnsongrass (*Sorghum halepense*) and percent coverage of these species remained dominant over the study period. My results were similar to those of Young and Claassen (2007) who reported increases in native plant species richness and success with native plant establishment along ROWs in northern California.

Agronomic grasses on highway ROWs are favored by ROW maintenance personnel for erosion stabilization. Retention of agronomic grass coverage and native plant species supports multiple goals of native flora conservation, erosion control, and ROW beautification (Forman and Alexander 1998). In this study, I found that modifications in frequency of mowing might allow for increases in native plant species richness and reduction of erosion. I also found that season when surveys were conducted, years, and elevations may influence plant species richness and percent coverage on roadside ROWs. However, based on dominance of agronomic grasses during my study, I concur with other studies that reported an increase in native plant species without a decrease in erosion-control grass coverage (Forman and Alexander 1998; Markwardt 2005; Transportation Research Board 2005).

Burke and Grime (1996) reported similar findings in a study that compared mowing vegetation at different heights and different times of the year. In this study, susceptibility of native plant communities to invasion relates to bare ground, but greatest susceptibility occurred where disturbance coincided with fluctuations in nutrient availability, site productivity, and existing plant coverage (Burke and Grime 1996). Their results demonstrated that composition, abundance, and diversity of native species in grass-dominated ROWs could be limited by interspecific competition from non-native grasses. Processes that disrupt natural dispersal, such as fragmentation and human influences, lead to changes in species diversity, including extinction of the remaining fragments of native ecosystems (Diamond 1972; Terborgh and Winter 1980; Usher 1988; Nee and May 1992; Tilman et al. 1996). Human influences and fragmentation occurring along ROWs can cause reduced native plant establishment due to inability of plants to

complete life cycles and loss of seeds or propagules through erosion and competition from non-native plants (Inouye et al. 1987).

Differences in native and non-native species richness and the percent coverage of growth forms throughout the two-year study revealed significant interactions between seasons, elevations, and years. I detected the greatest plant species richness in lowland plots along streams in riparian zones. These findings may be due to site productivity factors, such as moisture availability and nutrient quality of alluvial soils and water transported propagules (Bush and Van Auken 1989). Site productivity and increased plant diversity may be related to nutrient loading from seasonal floods and increased water saturation (Bush and Van Auken 1989; Burke and Grime 1996; Greenfield et al. 2005; Huijser and Clevenger 2006). Lowlands within stream floodplains typically exhibit greater soil moisture, flat topography, and periodic flooding, whereas uplands are generally drier due to slope, aspect, elevation, and other soil conditions (Simberloff and Cox 1987; EPA 2013). Native species richness was greater within the reduced mowed and reduced mowed-seeded subplots treatments. Percent coverage of native forbs tripled and native grasses increased fivefold from fall 2010 to spring 2012 seasons. Of the non-native species, agricultural grasses remained the most dominant coverage in lowlands with >60% coverage, whereas uplands had >75% coverage over the two-year study period. My findings were similar to Barras et al. (2000) who reported percent coverages of non-native grasses to be 81% in mowed plots and less than 68% in non-mowed research plots. Additionally, Barras et al. (2000) reported that less often mowed plots exhibited greater ground coverage >25% coverage of native forbs. Combinations of reduced mowing with prescribed burning may enhance native plant communities on

Mississippi ROWs. Collins et al. (1998) found plots burned and not mowed had more than twice the species richness than plots that were annually mowed. I suggest that further management practices in addition to reduced mowing regimes could enhance percent coverage and species richness of native plants on ROWs. However, use of prescribed fire may not be feasible along highway ROWs due to fire control and smoke liability issues that could endanger adjacent properties and motorist safety (Arner et al. 1976; Forman and Deblinger 2000; Huijser and Clevenger 2006).

During the two-year study, approximately 15 native prairie indicator plants and >85 woodland plants were recorded from fall 2010 to spring 2012 seasons within the reduced mowed and reduced mowed-seeded treatment subplots. Native plant species, including prairie species, may colonize ROWs from adjacent vegetation communities if management on ROWs allows for plant maturation and seed dispersal. Bouta (1990) found that >20% of native prairie grasses and forbs species were in nearby open fields, pastures and meadows with around 13% of native prairie forbs and grasses growing in the adjacent land along the roadside ROWs in Iowa. Modifications in mowing regimens can allow native plants to become established (EPA 2013). If single year mowing operations are limited to late fall after seed set, plant species may have adequate time to complete life cycles, including above ground growth, root development, flowering maturation, seed production, and dispersal of seeds (Arner and Jones 2009).

During my study, several challenges were encountered that could have influenced success of treatment applications. Communication with contract mowing crews for correct timing of fall season mowings of study plots was a challenge. Placement of signage at borders of plots that received reduced mowing treatments was necessary to

provide concise guidance on management actions. In addition, seeding of wildflower seed into existing agronomic grass cover may have negatively influenced germination and establishment of seeded wildflowers in reduced mowed-seeded subplots. The late sowing timeframe, in March, could have been a significant factor in the delay or lack of supplemental seed growth in seeded subplots during the two-year study period. However, other research has indicated that greater native plant establishment occurs in areas that have received site preparation through herbicide control of agronomic plants and soil scarification (Greenfield et al. 2005). Dense vegetation and leaf litter following mowing may have prevented seed of wildflowers from contact with bare mineral soil. Leaf litter from mowed vegetation might have also acted as mulch preventing germinating seedlings of wildflowers from contact with bare soil reducing the seeds establishment (Greenfield et al. 2005).

Season was an important factor in this study and was related to species richness and percent coverage of warm season versus cool season plant species on ROW study plots. Warm season native and non-native grasses were typically more dominant in late summer – fall sampling periods, and cool season grasses, such as tall fescue (*Schedonorus phoenix*), were more commonly detected during spring. Seasonal differences in plant community characteristics could have been related to unique growth periods for spring and fall species, including periods of active aboveground growth, flowering, and seed maturation (Miller and Miller 1999). Due to seasonal variation in plant communities, I recommend at least two sample periods per growing season as done in my study. This approach can reduce potential for sampling error and bias that can result from a single sampling period per growing season. With multiple sampling

periods, greater accuracy can be expected in estimates of species richness, species composition of communities, and plant community structure (Godt et al. 1997; Forman et al. 2003).

This research can potentially help enhance decisions for enhancement of native plant communities and establishment of wildflowers and native grasses along roadside ROWs in Mississippi, just as Texas, North Carolina, Georgia, Virginia, Ohio, and other states have done (Markwardt 2005; U. S. Department of Transportation – Federal Highway Administration 2011; Texas Department of Transportation 2013). Educational programs on ecological, budgetary, and aesthetic impacts of reduced mowing regimens on ROWs could improve public understanding and perceptions of multiple benefits of reduced mowings. This study produced knowledge of native and non-native plant species interaction and documented the plants occurrences along the Highway 25 ROW in Oktibbeha and Winston counties. According to Harper-Lore and Wilson (2000) enhancement of native plant communities can help beautify roadways and can sustain roadside wildflower programs with cost-effective approaches. Reduced mowing frequency in outer edges of ROWs could be used with repeated mowings within 5 m to 20 m (16.4 ft. to 65.6 ft.) of the roadway edge and at intersections. This approach would maintain good visibility and safety for motorists, while allowing areas >20 m (>65 ft.) from the roadway to be areas where native plants can thrive with less frequent mowings. In this manner, managers can integrate native plant management with maintenance for safety concerns on roadside ROWs. Without compromising human safety, this reduced mowing approach improves roadside aesthetics, reduces stress levels, and saves money (Forman and Alexander 1998; Cackowski and Nasar 2003).

Table 3.1 Numbers of native and non-native plant species detected along line transects.

		Species Richness							
		Native Status				Non-Native Status			
Elevation	Treatments[a]	Fall 2010	Spring 2011	Fall 2011	Spring 2012	Fall 2010	Spring 2011	Fall 2011	Spring 2012
Lowland[b]	Mowed	65	92	88	106	33	61	43	48
Lowland[b]	Reduced Mowed	51	74	84	90	33	56	39	52
Lowland[b]	Reduced Mowed/Seeded	57	87	92	102	34	68	45	54
Upland[c]	Mowed	18	34	27	41	23	52	43	46
Upland[c]	Reduced Mowed	10	41	34	43	20	53	37	45
Upland[c]	Reduced Mowed/Seeded	22	30	36	39	22	56	34	45

a) Treatments: Mowed – 3 to 4 mowing throughout the growing seasons; Reduced Mowed – only one mowing during late fall; Reduced Mowed/Seeded – only one mowing during late fall with supplemental native wildflowers.
b) Lowland elevation N=5, flat, periodical flooding, and moist soils.
c) Upland elevation N=5, hilly, slope, and dry soils.

Table 3.2 Mean and standard errors (SE) of total, native, and non-native number of plant species detected in different elevation types.

Species Richness							
Fall Seasons 2010-2011				Spring Seasons 2011-2012			
Type	ELEVATION	Mean[a]	SE[b]	Type	ELEVATION	Mean[a]	SE[b]
Total Species Richness	Lowland[c]	22.13	1.13	Total Species Richness	Lowland[c]	29.67	1.11
	Upland[d]	10.87	1.13		Upland[d]	17.50	1.11
Native Species Richness	Lowland[c]	14.57	0.91	Native Species Richness	Lowland[c]	18.37	1.05
	Upland[d]	4.90	0.91		Upland[d]	7.60	1.05
Non-Native Species Richness	Lowland[c]	7.57	0.40	Non-Native Species Richness	Lowland[c]	11.30	0.42
	Upland[d]	5.97	0.40		Upland[d]	9.90	0.42

a) Mean number of species richness within each season, elevation, and type differences.
b) SE - Standard Error of the Mean.
c) Lowland elevation N=5, flat, periodical flooding, and moist soils.
d) Upland elevation N=5, hilly, slope, and dry soils.

Table 3.3 Test statistics for comparisons of total, non-native, and native species richness.

Source	DF	Total Native/Non-Native Species Richness F Value	Pr > F		Non-Native Species Richness F Value	Pr > F		Native Species Richness 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 two-year study period 2010-2012.

b) TRT = Treatments – mowed, reduced mowed, reduced mowed-seeded.

c) Upland vs. lowland elevations.

Table 3.4 Means and standard errors (SE) of percent coverage of all plants within growth form categories.

Percent Coverage of Plants		
Growth Forms	Mean	SE
Native Forb	19.75	1.56
Non-Native Forb	2.63	0.35
Native Grass	1.50	0.30
Non-Native Grass	88.63	3.03
Native Legume	0.72	0.38
Non-Native Legume	31.86	3.49
Native Rush	1.50	0.49
Native Sedge	1.99	0.36
Non-Native Sedge	0.07	0.04
Native Shrub	0.21	0.05
Native Tree	1.57	0.41
Native Vine	4.45	0.76
Non-Native Vine	1.34	0.37

SE - Standard Error of the mean.

Table 3.5 Means and standard errors (SE) of percent coverage of vegetation within growth form categories during fall 2010-2011.

	Upland[a]		**Lowland[b]**	
Vegetation Growth Forms	Mean	SE	Mean	SE
Native Forb*	7.80	1.53	49.64	7.94
Non-Native Forb	2.54	0.54	2.22	0.46
Native Grass*	1.84	0.47	4.93	0.94
Non-Native Grass	134.51	8.77	115.60	9.01
Native Legume*	0.02	0.02	5.62	2.57
Non-Native Legume	6.79	2.87	7.16	4.17
Native Rush*	0.03	0.03	3.11	1.06
Native Sedge	0.33	0.11	0.89	0.25
Non-Native Sedge	0.21	0.17	0.91	0.36
Native Shrub	0.52	0.40	0.34	0.11
Native Tree	0.69	0.23	1.88	0.48
Native Vine	12.02	4.09	2.49	0.76
Non-Native Vine	2.10	1.03	0.92	0.48

a) Upland elevation N=5, hilly, slope, and dry soils.
b) Lowland elevation N=5, flat, periodical flooding, and moist soils.
* Differed between upland and lowland elevations at $P \leq 0.05$.

Table 3.6 Means and standard errors (SE) of percent coverage of vegetation within growth form categories during spring 2011-2012.

	Upland[a]		**Lowland**[b]	
Vegetation Growth Forms	Mean	SE	Mean	SE
Native Forb*	20.10	2.72	47.45	7.21
Non-Native Forb	3.83	0.96	8.07	1.52
Native Grass	2.08	0.75	5.87	1.27
Non-Native Grass	159.13	9.81	127.51	7.42
Native Legume*	0.00	0.00	4.12	1.94
Non-Native Legume*	84.02	7.43	42.31	5.25
Native Rush*	0.21	0.09	10.68	2.58
Native Sedge*	1.51	0.47	7.17	1.30
Native Shrub	0.19	0.13	0.66	0.29
Native Tree	1.30	0.39	5.13	1.70
Native Vine	5.92	1.48	5.02	1.42
Non-Native Vine	2.39	1.03	1.02	0.37

a) Upland elevation N=5, hilly, slope, and dry soils.
b) Lowland elevation N=5, flat, periodical flooding, and moist soils.
* Differed between upland and lowland elevations at $P \leq 0.05$.

Table 3.7 Test statistics of percent coverage comparisons within vegetation growth forms.

	Df	Sums Of Squares	Mean Squares	F Model	R2	Pr (>F)
YEAR	1	57292	57292	14.538	0.08	0.001
SEASON	1	64045	64045	16.252	0.09	0.001
TRT	2	3537	1768	0.449	0.01	0.828
ELEVATION	1	71786	71786	18.216	0.10	0.001
YEAR:SEASON	1	94883	94883	24.077	0.13	0.001
YEAR:TRT	2	950	475	0.121	0.01	0.997
SEASON:TRT	2	2098	1049	0.266	0.01	0.938
YEAR:ELEVATION	1	4486	4486	1.138	0.01	0.266
SEASON:ELEVATION	1	19718	19718	5.004	0.03	0.001
TRT:ELEVATION	2	6214	3107	0.788	0.01	0.481
YEAR:SEASON:TRT	2	1014	507	0.129	0.01	0.997
YEAR:SEASON:ELEVATION	1	5867	5867	1.489	0.01	0.165
YEAR:TRT:ELEVATION	2	769	384	0.098	0.01	1.000
SEASON:TRT:ELEVATION	2	2171	1085	0.275	0.01	0.934
YEAR:SEASON:TRT:ELEVATION	2	2851	1425	0.362	0.01	0.893
Residuals	96	378311	3941	0.528		
Total	119	715990	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.

Table 3.8 Percent coverage of bare ground and debris characteristics with means and standard errors (SE).

Ground Cover Characteristics	Percent Coverage within Treatments											
	Upland Elevation (N=5) [a]						Lowland Elevation (N=5)[a]					
	Mowed		Reduced Mowed		Reduced Mowed/Seeded		Mowed		Reduced Mowed		Reduced Mowed/Seeded	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Fall Sampling Season 2010[b]												
Bare Ground	13.02 (12.75)	0.00 to 64.00	12.20 (12.20)	0.00 to 61.00	19.11 (18.97)	0.00 to 95.00	13.34 (9.22)	0.00 to 47.22	5.74 (4.45)	0.00 to 23.00	4.41 (3.59)	0.00 to 18.50
Debris[c]	14.06 (5.70)	0.00 to 33.89	17.51 (6.09)	4.00 to 40.00	14.06 (5.85)	0.00 to 34.44	17.83 (6.82)	4.29 to 39.38	23.87 (6.09)	2.14 to 36.25	19.46 (6.42)	4.29 to 43.13
Spring Sampling Season 2011[d]												
Bare Ground	8.30 (6.72)	0.00 to 35.00	7.50 (6.89)	0.00 to 35.00	5.70 (5.10)	0.00 to 26.00	8.97 (4.59)	0.00 to 25.56	3.05 (2.75)	0.00 to 14.00	3.93 (1.82)	0.00 to 9.29
Debris[c]	7.94 (3.31)	0.00 to 20.00	16.76 (5.45)	1.00 to 31.25	11.51 (3.95)	0.00 to 22.50	19.56 (2.82)	14.50 to 30.00	18.86 (6.19)	1.67 to 37.50	28.97 (7.58)	12.22 to 55.00
Fall Sampling Season 2011[b]												
Bare Ground	1.75 (1.09)	0.00 to 5.00	8.60 (8.60)	0.00 to 43.00	3.42 (3.15)	0.00 to 16.00	3.20 (1.93)	0.00 to 10.00	0.00 (0.00)	0.00 to 0.00	0.68 (0.44)	0.00 to 2.14
Debris[c]	12.16 (5.62)	2.00 to 32.78	13.59 (5.02)	1.0 to 27.22	8.86 (3.03)	1.00 to 15.56	8.06 (3.08)	0.00 to 14.38	7.90 (3.30)	0.00 to 20.00	6.79 (2.72)	2.00 to 16.88
Spring Sampling Season 2012[d]												
Bare Ground	1.80 (1.80)	0.00 to 9.00	1.80 (1.80)	0.00 to 9.00	1.36 (0.97)	0.00 to 5.00	3.04 (1.61)	0.00 to 8.33	0.25 (0.25)	0.00 to 1.25	0.00 (0.00)	0.00 to 0.00
Debris[c]	31.99 (5.26)	17.00 to 48.75	35.59 (4.22)	24.00 to 45.45	42.48 (5.46)	29.00 to 55.00	34.34 (6.11)	17.22 to 50.71	29.17 (5.40)	17.00 to 47.86	39.39 (3.74)	32.78 to 50.00

a Three $\leq$ 30.48 m line transects on each study plots.
b Fall sampling seasons were during mid-August to October.
c Debris includes leaf and other vegetation litter and fine woody debris.
d Spring sampling seasons were during April to June.

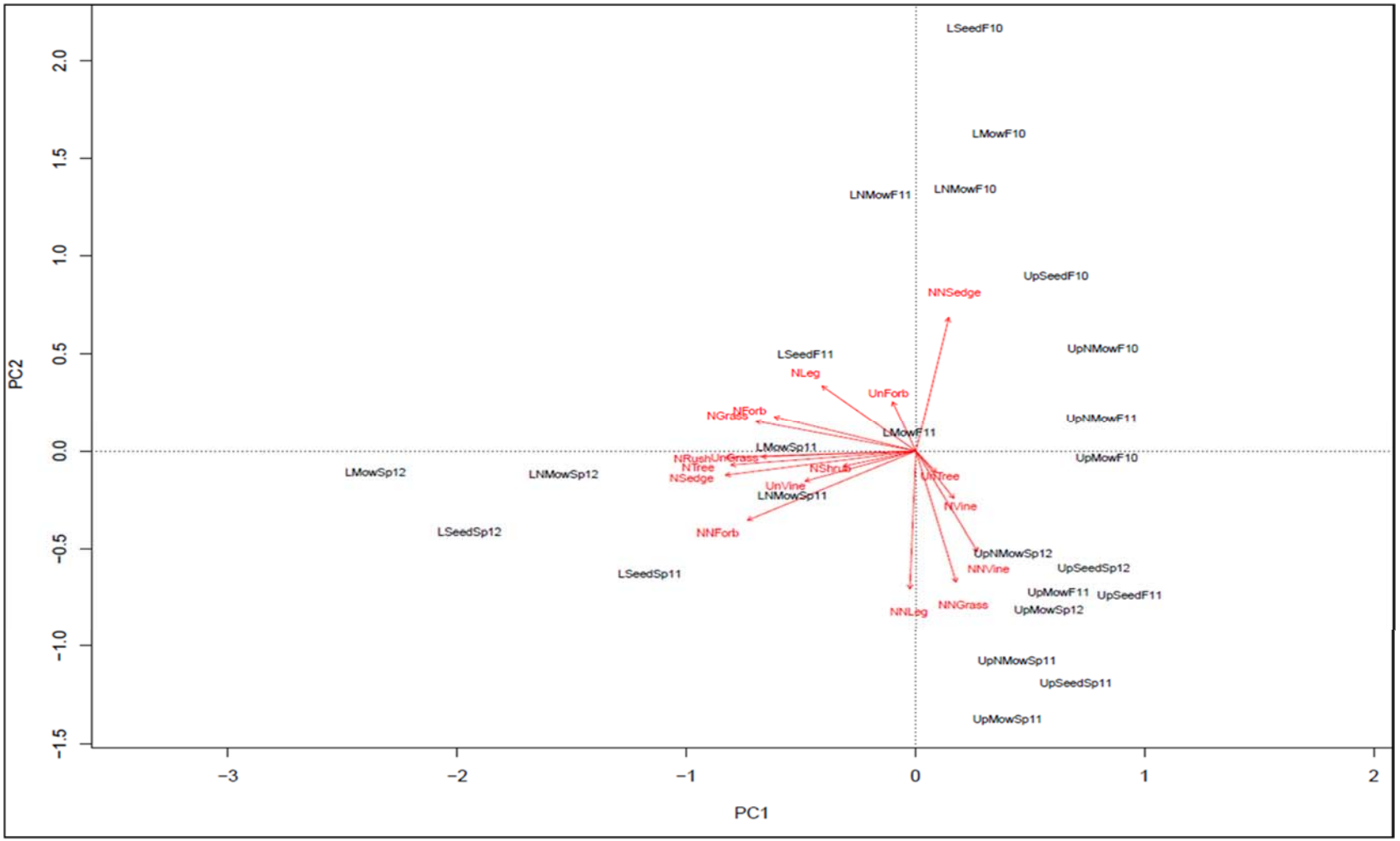

Figure 3.1 PCA visualized of percent coverage of vegetation comparison within growth forms and native/non-native statuses.

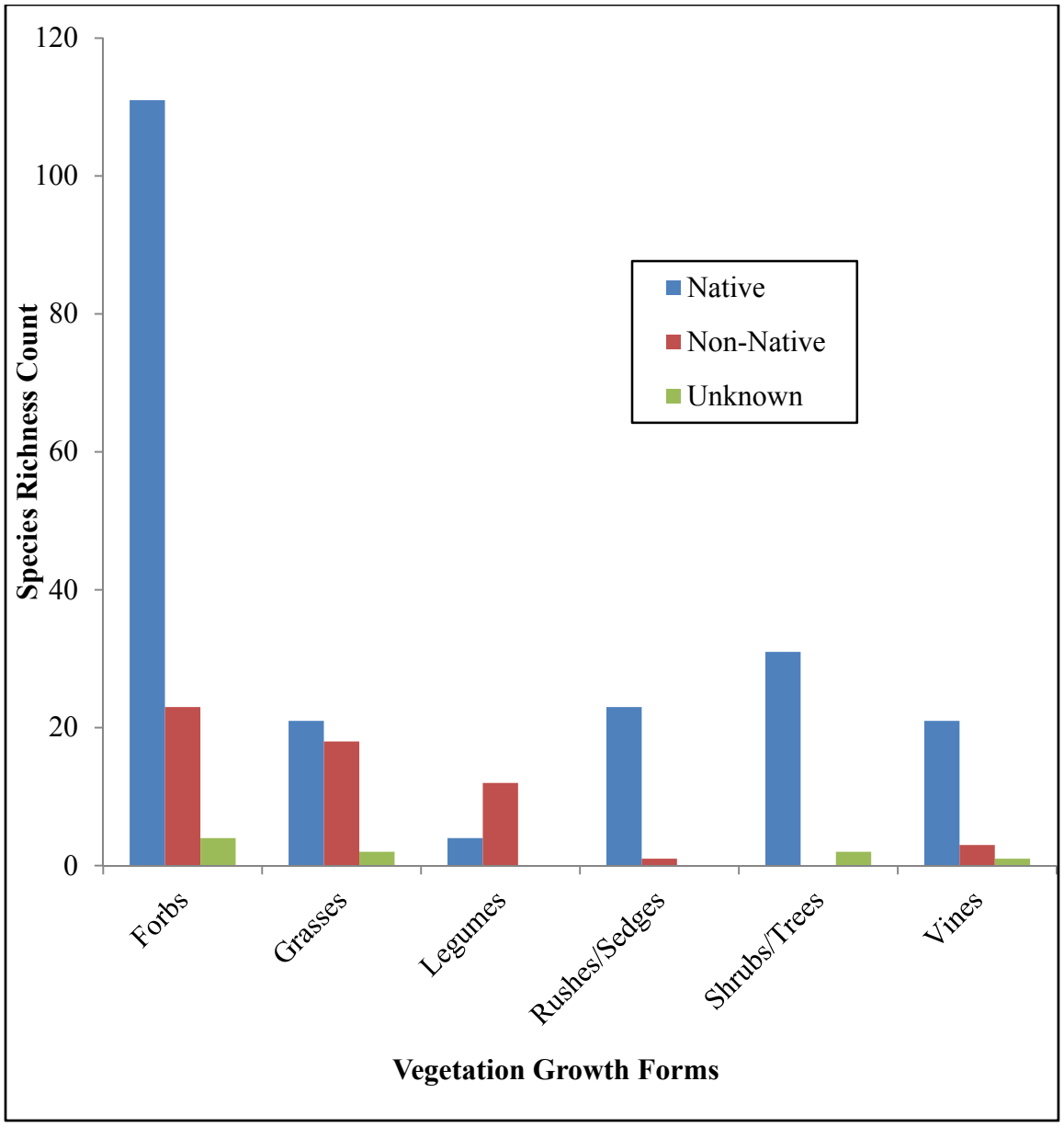

Figure 3.2 Species richness of all plants recorded and identified within 10 research plots (30 subplots) during 2010-2012.

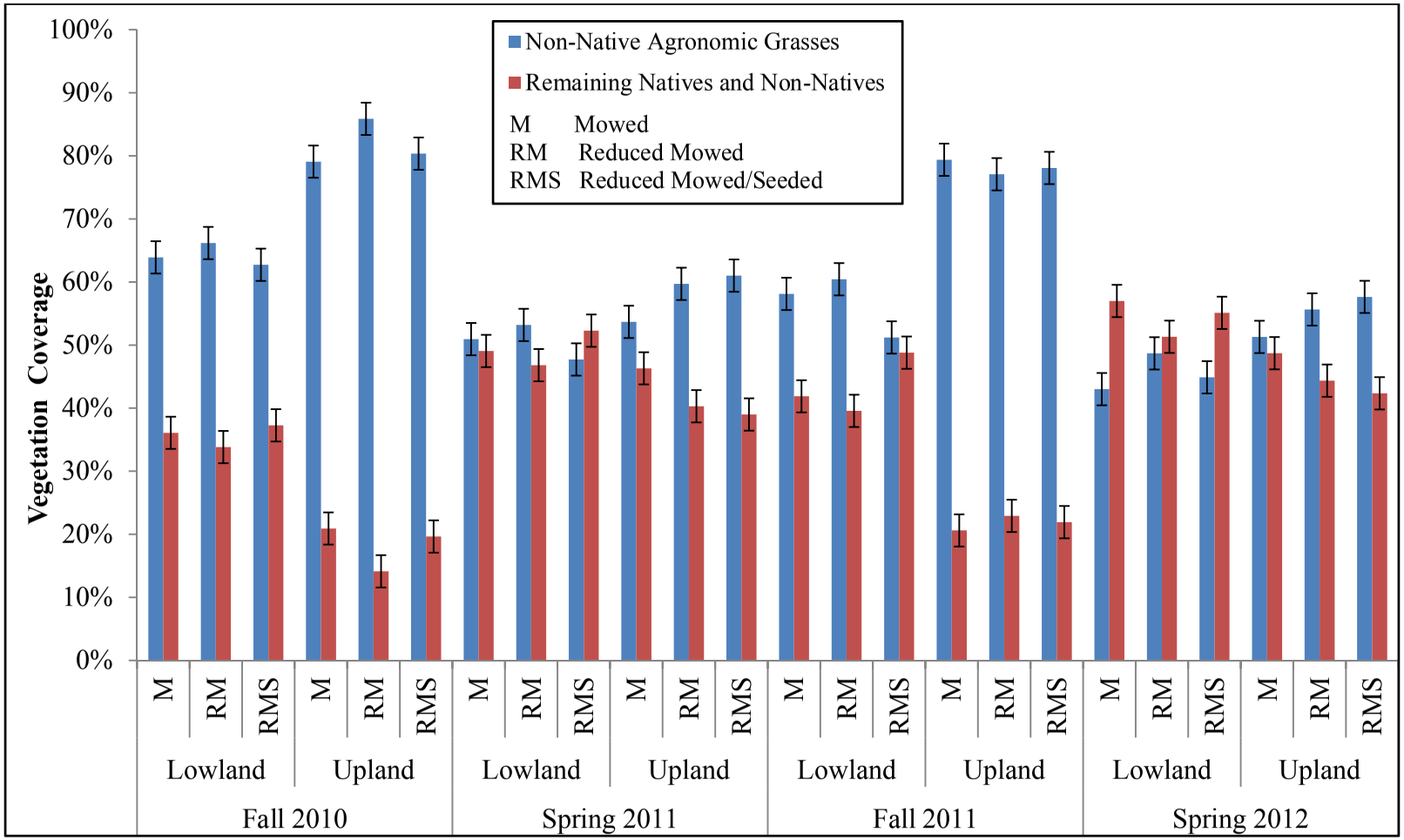

Figure 3.3 Mean percent coverage of non-native agronomic grasses and remaining native and non-native plant species with standard error bars variability from the mean.

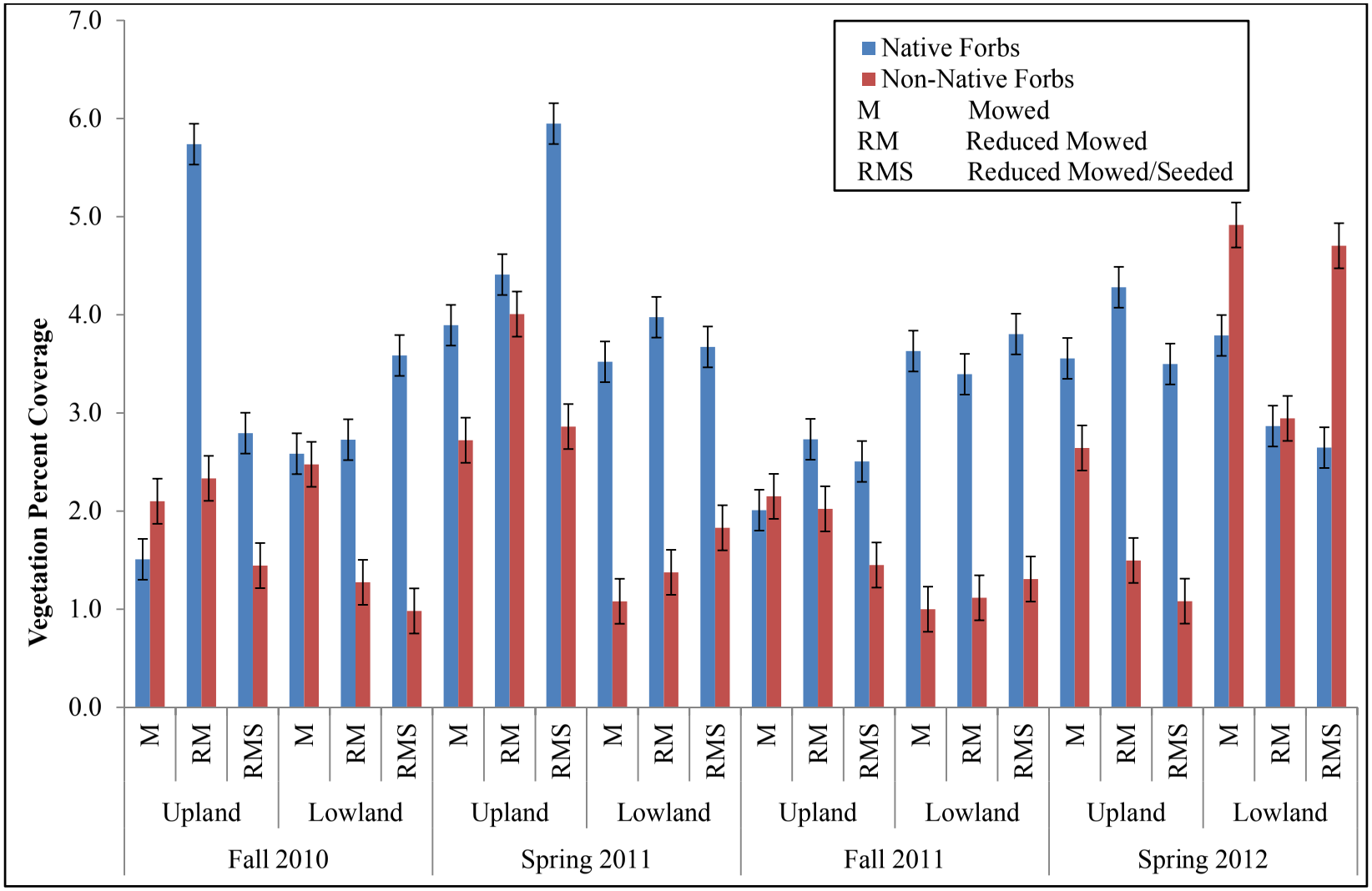

Figure 3.4 Mean percent coverage of native and non-native forbs with standard error bars variability from the mean.

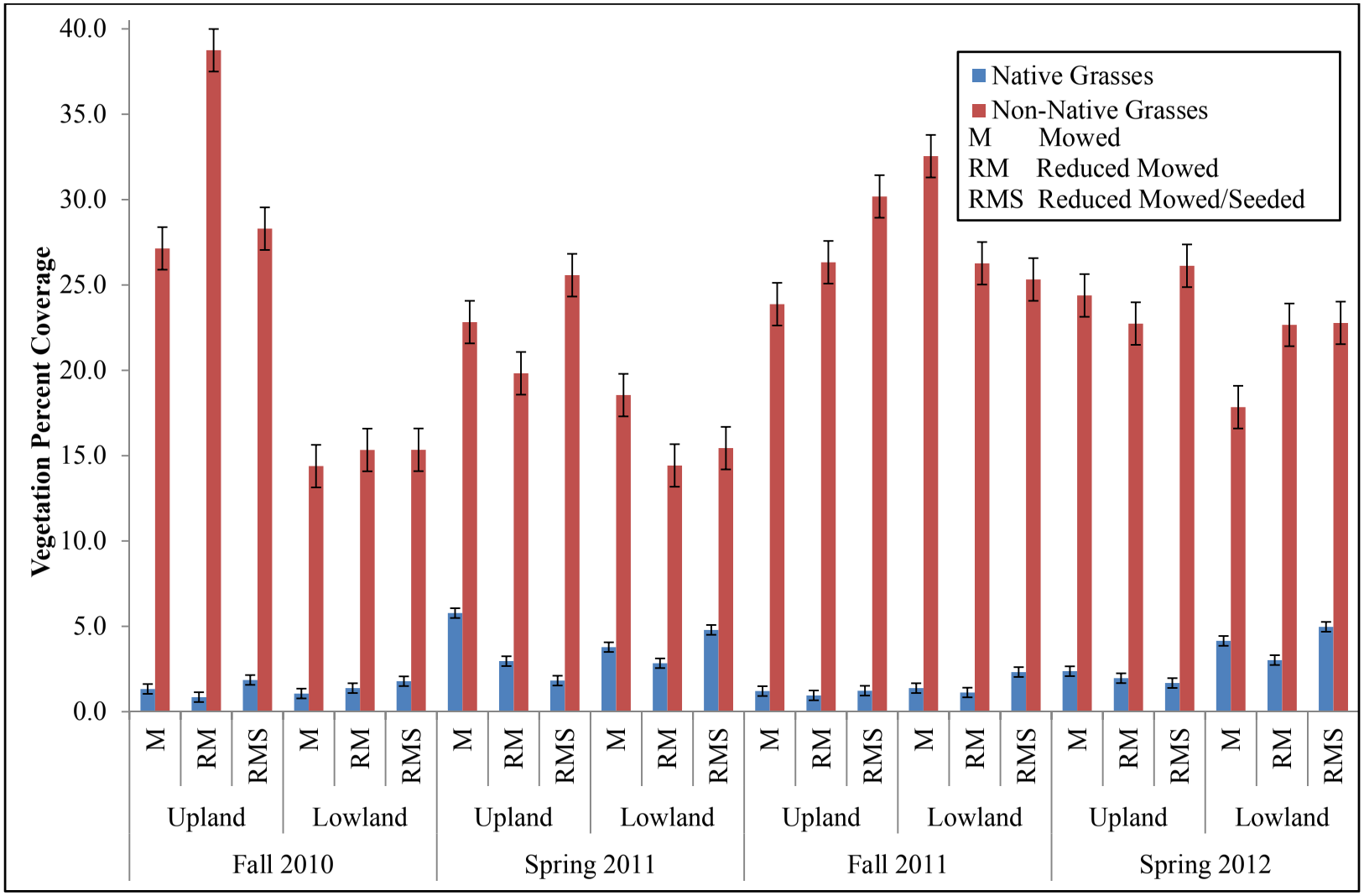

Figure 3.5 Mean percent coverage of native and non-native grasses with standard error bars variability from the mean.

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CHAPTER IV

PLANT HEIGHT CHARACTERISTICS AND WOODY STEM DENSITIES

Introduction

Numerous studies have focused on effects of intensive mowing on plant heights and woody plant densities along roadside right-of-ways (ROWs; Webb et al. 1983; Olander et al. 1998; Milchunas et al. 2000). Management of ROWs that seek to enhance native plant communities must often be approached in a manner that does not compromise soil stability, safety considerations, fire prevention measures, and visibility (Forman and Deblinger 2000; Huijser and Clevenger 2006; Young and Claassen 2007). Factors considered for safety along highway ROWs include vegetation height, density of woody plants, and motorists visibility for avoidance of wildlife along roadsides, such as white-tailed deer (*Odocoileus virginianus*), American black bears (*Ursus americanus*), and other large mammals like coyotes (*Canis latrans*; Michael and Kosten 1981; Hewitt 2011; McKee and Cochran 2012; Fulbright and Ortega-Santos 2013). Visibility can be improved through frequent mowings and even a reduced mowing regime. However, information is limited on effects of reduced mowing frequencies on vegetation height and woody plant composition along Mississippi highway ROWs.

Frequent mowing ROWs and intensive use of herbicides can affect plant communities through reduction of species diversity, plant growth, flowering, and seed maturation periods (Mader 1984; Ewing et al. 2005). Fauna (i.e., cottontail rabbits and

songbirds) that use ROWs can be negatively impacted by reduction of food plant resources and losses of shelter, nesting, and escape cover (Godt et al. 1997; Forman et al. 2003).

Roads, railroads, and associated vehicle traffic can negatively affect native flora and fauna (Forman and Alexander 1998; Spellerberg 1998; Van der Grift 1999). Because of these ecological impacts, effects of roads and ROWs are gaining more attention in recent years among transportation agencies, land managers, local decision makers, and the public. Roadwork and associated disturbances to ROWs and adjacent vegetation communities can often alter plant and animal movements along roadsides (Adams and Geis 1983; Sherburne 1985; Warner 1992; Lamont et al. 1994; Reijnen and Foppen 1994; Angold 1997; Spellerberg 1998). Road maintenance and ROW management spreads non-native invasive plants by providing environments that are suitable for colonization (Borowske and Heidinger 1981; Wilcox 1989; Tyser and Worley 1992; Godt et al. 1997; Greenberg et al. 1997; Parendes and Jones 2000; Gelbard and Belnap 2003; Hansen and Clevenger 2005; Miller et al. 2010).

When soil disturbances occur, non-native grasses and legumes are among the most common groups that colonize roadside ROWs (Miller et al. 2010). Native and non-native woody plants can become established following soil disturbances which resets succession stages (Huijser and Clevenger 2006; Willard et al. 2010). Correspondingly, under conditions in which there is a lack of disturbances (i.e., reduced mowing or no mowing), plant communities go through successional growth stages (Hamrick et al. 2007; Iglay et al. 2010; Miller et al. 2010). Over time, woody plants become denser and well established in the absence of disturbance that sets back succession (De Steven 1991;

Myster 1993; Hodge and Harmer 1996). Establishment of woody plant cover may not always be desirable for traffic safety and visibility along road ROWs; however, establishment of woody plants has been reported to favor selected wildlife species on ROWs. Roach and Kirkpatrick (1985) studied wildlife use of woody plantings in Indiana and recommended woody plantings along roadsides to significantly increase the use of the habitat and diversity for red-winged blackbird (*Agelaius phoeniceus)*, American goldfinch (*Carduelis tristis*), and song sparrow (*Melospiza melodia*) and the plant communities. Cadenasso and Pickett (2001) theorized that dense woody vegetation along forest edges, near roadside ROWs, might serve as a barrier to slow invasion by plant species with wind-borne seeds from fields, forests, and other local sites. In Mississippi, Yager et al. (2011) reported that increased percent coverage and density of woody vegetation along forest edges were associated with decreased seed dispersal and reduced establishment rates of invasive cogongrass (*Imperata cylindrica*) on ROWs and in adjacent forests. Woody plants along highway ROWs can support a variety of wildlife species (e.g. songbirds, cottontail rabbits, deer, turkeys, and quail) and their habitat needs; however, visibility and traffic safety can be issues to consider (Hartley et al. 1984; Johnson 2000; Folck and Kick-Raack 2005).

This component of my study was designed to address potential changes in percent coverage of vegetation within different height regimes, and stem density of woody plants within different mowing treatments. Specific objectives outlined in this chapter include the following:

1. To estimate and compare differences in percent coverage of vegetation in three height categories in three different treatments within upland and lowland

elevations along Highway 25 roadside ROWs in Oktibbeha and Winston counties, Mississippi.

2. To estimate and compare differences in woody plant stem densities (stems per hectare) in three different treatments within upland and lowland elevations along Highway 25 roadside ROWs in Oktibbeha and Winston counties, Mississippi.

Study Area and Field Methods

The study areas were located in the same area along the 48.28-km (30 miles) stretch of Highway 25 ROW in central Mississippi as described in Chapter 2. The plots were regionally located outside the Black Belt Prairie, within the Interior Flatwoods in northeastern Mississippi (33°12'N, 88°54'W; Township 15-18N, Range 13-14E; Pettry 1977; Edwards 2009). Soil formation and vegetation 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 (32° F to 59° F) and hot summers 21° C to 38° C (70° F to 100° F; Posner 2012). Annual mean temperature was 16.7° C (62° F) and precipitation ranged from 127 cm to 165 cm (50 in to 65 in) across the state from north to south (Mississippi State University Department of Geosciences 2010). I recorded percent coverage of plants occurring within three height categories, ≤ 0.46 m (≤ 18 inches) in height, ≥ 0.46 m ≤ 0.91 m (≥ 18 inches ≤ 36 inches) in height, and ≥ 0.91 m (≥ 36 inches) in height, along each 30.48 meter (100 ft.) line intercept in the 30 research subplots (Chapter 2; Hays et al. 1981; Buckland et al. 2007). Stem densities of woody plants were estimated by conducting stem counts within the 0.5 m x 30.48 m (1.65 ft. x 100 ft.) belt transects that were located along each line intercept in 30 subplots.

I established one belt transect measuring 0.5 m x 30.48 m (1.65 ft. x 100 ft.) on the right-side adjacent to each line transect to estimate stem densities of woody plants (stems per ha; Hays et al. 1981). I grouped data by season (fall and spring) due to difference in plant community characteristics between spring and fall seasons. Specific details on the study area and field methods were described in Chapter II.

Statistical Analyses

Data were tested for distributional normality and homogenous variances assumptions using Kruskal Wallis Test, Kolmogorov-Smirnov Z-test, Lilliefors Significance Correction, Kurtosis and Skewedness evaluation tests, and Shapiro-Wilk goodness-of-fit tests (Levene 1960; Royston 1992) for woody stem density. Data of percent coverage within height categories and woody stem densities were not normally distributed, and transformation did not result in normally distributed data (Levene 1960; Royston 1992). Comparison analyses of these data in treatments, years, and seasons were analyzed using non-parametric statistics approach: univariate, repeated measures Analysis of Variance (ANOVA; PROC MIXED; SAS Institute 2008; Ott and Longnecker 2010). In addition, I investigated the interactions of height characteristics and woody plant stem densities in different treatments, elevations, and years (fixed effects) and random effects by elevation. Data collected during year 1 and 2 were treated as repeated measures (Ott and Longnecker 2010).

I selected models using Akaike's Information Criterion corrected (AIC_c) to compare data characteristics, including covariance features, for data on height of vegetation, and woody stem densities (Gutzwiller and Riffell 2007). Top models were designated with $\Delta AIC_c \leq 2$ to the next best model (Burnham and Anderson 2002). After

the AIC*c* tests, I used pairwise comparisons of Fisher's Least Significant Difference (LSD) to compare significant effects of means of percent coverage vegetation in three height categories and stem densities of woody plants within treatments, elevations, seasons, and years (Meier 2006; SAS Institute 2008). Hypothesis testing was conducted at $\alpha = 0.05$ a priori (Ott and Longnecker 2010). The following null hypotheses were tested:

H_{o1}: Percent coverage of vertical vegetation height do not differ among low ($\leq$ 0.46 m), mid ($\geq$ 0.46 m $\leq$ 0.91 m), and high ($\geq$ 0.91 m) height categories among treatments in upland and lowland elevations and in different seasons and years.

H_{o2}: Woody plant stem densities (stems per ha) of native/non-native status, native status, and non-native species do not differ among treatments in upland and lowland elevations and in different seasons and years.

Results

Percent Coverage of Vegetation within Height Categories

Percent coverage of plants in the $\leq$ 0.46 m height category exceeded 110% in upland and lowland plots during study years (Figures 4.1 and 4.2; Tables 4.1 and 4.2) due to overlap of individual species. However, percent coverage of plants occuring in the $\geq$ 0.46 m to $\leq$ 0.91 m height category exhibited mean coverages ranging from 49.15% ($\pm$ 4.69) to 69.20% ($\pm$ 4.42) in upland and lowland plots over two study years, 2010-2012 (Figures 4.1 and 4.2; Tables 4.1 and 4.2). Percent coverage of plants occuring at the $\geq$ 0.91 m heights exhibited mean coverages of < 30% during spring and fall over the two-year study period (Figures 4.1 and 4.2; Tables 4.1 and 4.2). Percent coverage of vegeation in different height categories differed between upland and lowland elevations

($F_{1, 96} > 4.65$, $P \leq 0.03$) and between study years ($F_{1, 96} > 4.91$, $P \leq 0.03$). However, coverage of vegetation did not differ in different height categories among treatments ($F_{2, 96} < 1.34$, $P > 0.27$; Table 4.3).

During fall seasons, percent coverage of plants in the three height categories did not differ among treatments ($F_{2, 96} < 0.47$, $P > 0.62$; Table 4.3). However, coverage in all height categories differed between study years ($F_{1, 96} > 8.39$, $P < 0.01$; Table 4.3; Figure 4.3). Percent coverage of vegetation in all height category did not differ between lowland and upland elevations ($F_{1, 96} < 3.41$, $P > 0.07$) during fall seasons (Table 4.3; Figure 4.3). I detected marginally differences in the interactions between year and elevation in $\geq$ 0.46 m to $\leq$ 0.91 m height category ($F_{1, 96} = 3.71$, $P = 0.06$) during fall seasons (Table 4.3).

During spring seasons, percent coverage of plants in the three height categories did not differ among treatments ($F_{2, 96} < 1.34$, $P > 0.27$; Table 4.3; Figure 4.3). However, percent coverage of plants in the $\geq$ 0.46 m to $\leq$ 0.91 m ($F_{1, 96} = 18.03$, $P \leq 0.001$) and $\geq$ 0.91 m ($F_{1, 96} = 4.91$, $P = 0.032$) height categories differed among years; however, there was no significant differences in percent coverage of vegetation in the $\leq$ 0.46 m height category among study years ($F_{1, 96} = 0.48$, $P = 0.492$; Table 4.3). I detected significant and marginal differences in percent coverage of plants in all three height categories ($F_{1, 96} > 3.60$, $P \leq 0.06$) among upland and lowland elevations during spring seasons (Table 4.3; Figure 4.3). I detected significant interactions between year and elevation for percent coverage of vegetation in the $\geq$ 0.46 m to $\leq$ 0.91 m height category during spring seasons ($F_{1, 96} = 19.17$, $P \leq 0.001$; Table 4.3). Differences in percent coverage of vegetation occurring among three different height categories was greatest during spring with

lowland elevations exhibiting the greatest coverage of vegetation occurring within the ≤ 0.46 m height category (Figures 4.3 and 4.4).

Woody Plant Stem Density

Stem densities of native and non-native woody plants ranged from a mean of 7,771.78 (± 1,981.90) stems per ha during year 1 of the study to 10,025.23 (± 2,031.12) stems per ha in year 2 in all study plots (Figure 4.5; Tables 4.4 and 4.5). Woody vines comprised the majority (>68%) of stem densities, whereas 24% were trees and <8% were shrubs. Of the woody plants detected in the study, 91% were native species and 9% were non-native species during the two-year study period (Figure 4.5; Tables 4.4 and 4.5). Average stem density of all woody plants was greater in upland elevations during fall seasons ranging from 1,276.18 (± 340.81) stems per ha to 10,209.00 (± 1,974.91) stems per ha (Figure 4.5; Table 4.4). In spring seasons, greatest stem densities of woody plants were recorded in lowland elevations with a range of 1,726.47 (± 517.45) stems per ha to 10,880.00 (± 1,987.92) stems per ha (Figure 4.5; Table 4.5). Upland and lowland elevations ($F_{1, 96} < 3.34$, $P > 0.07$), over the two-year study ($F_{1, 96} < 3.21$, $P > 0.08$), and treatments ($F_{2, 96} < 1.19$, $P > 0.31$) did not differ between woody stem density (Table 4.6; Figures 4.6 and 4.7).

During fall seasons, stem densities of native/non-native combined, non-native, and native woody plants did not differ among years ($F_{1, 96} < 2.17$, $P > 0.14$), treatments ($F_{2, 96} < 1.19$, $P > 0.31$), or elevations ($F_{1, 96} < 3.34$, $P > 0.07$; Table 4.6). There were no significant interactions among years, treatments, or elevations during fall. During spring, woody plant stem densities of native/non-native combined, native, and non-native did not differ among years ($F_{1, 96} < 3.21$, $P > 0.08$), treatments ($F_{2, 96} < 0.66$, $P > 0.52$), or

elevations ($F_{1, 96} < 2.32$, $P > 0.13$; Table 4.6). Woody plant stem density did not differ among years, treatments or elevations when data were combined over fall and spring seasons ($F_{1, 96} < 3.34$, $P > 0.07$; Table 4.6). There were no significant interactions among years, treatments, or elevations during spring. Overall, woody stem densities did not differ between study years, treatments, or upland/lowland elevations (Figure 4.8). Stem densities of trees and shrubs did not exhibit increases from year 1 to year 2; however, stem densities of woody vines increased had >2 fold from year one to year two (Figure 4.9).

Discussion

Percent coverage within the specific height categories differed among fall and spring seasons; however, vegetation height characteristics in upland elevations in fall and spring seasons were similar. The greatest percent coverage of vegetation in the fall $\geq$ 0.46 m to $\leq$ 0.91 m and spring $\geq$ 0.91 m height categories were detected in lowlands, whereas vegetation coverages $\leq$ 0.46 m and $\geq$ 0.46 m to $\leq$ 0.91 m height categories were greatest in uplands during spring. The mowed and reduced mowed treatments did not exhibit differences among percent coverage of vegetation in different height categories during the two-year study period; however, other effects of interactions were detected among the height categories. Upland or lowland elevations and season of sampling appeared to exhibit the greatest influences over vegetation height characteristics on my study area. These findings relate in part to the species of plants that dominate the different elevations of the ROW and to plot productivity of lowlands, especially during high rainfall periods of spring (Bush and Van Auken 1989; Burke and Grime 1996; Greenfield et al. 2005; Huijser and Clevenger 2006).

Lack of detection of differences in vegetation height characteristics and woody stem densities among the treatments may have been due to drought conditions during 2010 and 2011. In addition, soil moisture in lowlands during drought conditions may have been associated with greater stem densities of woody plants and greater coverages of vegetation within $\leq$ 0.46 m and $\geq$ 0.46 m to $\leq$ 0.91 m heights in the lowland areas. Similar findings associated with elevation effects have been reported by Alexander et al. (2009) who found that vegetation heights decreased significantly, as elevation increased. I did not detect differences in woody plant stem densities and height characteristics between mowing treatments of my study. Barras et al. (2000) reported differences among composition of vegetation between mowed and unmowed plot treatments. They also found native vegetation heights were greater in unmowed plots, whereas mowed plots had a lesser percentage of woody plants (Barras et al. 2000). My mowing treatments did not include unmowed plots; therefore, my treatments were not comparable to those of Barras et al. (2000), although a single mowing in late fall produced vegetation height conditions that were similar to those of frequently mowed subplots. This reduced mowing regime also led to a greater number of native woody vines occurring in plots over a two-year study period. Similarly, Collins et al. (1998) reported that intensive mowing regimens were related to reduced plant species diversity and decreases in plant species richness. However, they also reported that mowing prevented woody plant species from gaining an establishment (Collins et al. 1998). In my study, woody vine stem densities increased, whereas shrub and tree stem densities remained constant in the reduced mowing and reduced mowing-seeded treatments during the study period.

Gruchy et al. (2006) reported that the greatest diversity of vegetation was in the reduced mowed treatments with an increase in forbs, grasses, and woody vegetation, as opposed to the frequently mowed treatments. Allen (1998) concluded that unmowed areas of plant communities could be beneficial for small mammals (i.e., mice, rats, rabbits), whereas frequently mowed vegetation communities exhibited declines in small mammal numbers. In my study, primary woody plant species detected were the woody vines, such as blackberries (*Rubus* spp.) and greenbriers (*Smilax* spp.). Thickets of woody vines along ROWs provide good cover for birds and small mammals without compromise of height requirements of vegetation related to roadside visibility and safety. However, I recommend abundant woody shrubs and trees on roadside ROWs could impede visibility for motorists at intersections along the highways. Wright (2006) stated that Mississippi's roadsides should be mowed to a height of 15 cm (6 in) for visibility and controlling non-natives, such as Johnsongrass (*Sorghum halepense*). Frequent mowing is still recommended for visibility and a safety issue specifically near intersections, while the vegetation should be mowed at a height of 15.24 cm – 30.48 cm (6 – 12 inches; Ode 1970; Schwarzmeier 1970; Anderson 1996; Barras et al. 2000; Kutschbach-Brohl et al. 2010). However, I recommend that mowing once per growing season could be accomplished in lowlands at >33 m from roadside berms without compromise of visibility. Reduced mowing in these areas could also create greater food plant abundance, insect pollinators, and cover for large mammals. Raising height of mowers' cuts, fewer mowings, and using narrower mowers could reduce disturbances, benefit native perennial wildflower species over annuals, and help reduce maintenance expenditures along roadside ROWs (Brown and Sawyer 2012). Mowing modifications in

lowlands, associated with bridge crossings, could allow safe passage of wildlife beneath bridges provide food and cover plants. Reduced mowing may be beneficial in some ROWs, I suggest that frequent mowing within 4.58 m – 9.15 m (15 ft. – 30 ft.) of the roadside may be necessary for visibility and to reduce vegetation encroachment and fire hazards on roadways (Johnson 2000; Hill and Horner 2005; National Research Council 2005; Harper 2008; Willard et al. 2010).

In Mississippi, primary concerns with woody plant cover and increased vegetation heights along highways are related to deer-vehicle collisions. However, studies have shown that in areas with large amounts of woody cover >2 m (>6.5 ft.) area adjacent to the roadside ROWs, wildlife-vehicle collision appeared to be random (Bellis and Graves 1971; Bashore et al. 1985). In addition, locations of deer-vehicle accidents appeared to be more concentrated in non-woody areas in Pennsylvania (Bashore et al. 1985). Others have suggested that dense woody plants along the edge of forests and roadside ROWs helps maintain an already overgrown woody edge with the potential to reduce invasive non-native plants (Yager et al. 2011). A cluster of woody plants along ROWs may increase biotic resistance for those seeking to restore or maintain an open forest (Yager et al. 2011). Colonization rates of woody plants may depend on species and site conditions, and management regimens. In the absence of mowing or prescribed fire, many early successional environments may be colonized rapidly by pioneer species such as winged elm (*Ulmus alata*), loblolly pine (*Pinus taeda*), sweetgum (*Liquidambar styraciflua*), eastern red cedar (*Juniperus virginiana*), and green ash (*Fraxinus pennsylvanica*; Hamrick et al. 2007; Miller et al. 2010). Similar successional trends could be expected with reduced or no mowing along ROW. In my study, loblolly pine was one of the most

common tree species detected in stem density surveys. At least one mowing per year would be needed to control light seeded pioneer tree species, such as loblolly pine (Arner and Jones 2009).

Rather than repeated mowing and blanket herbicide use, Russell et al. (2005) and Hopwood (2010) suggested an alternative management of ROWs using native plantings, selective herbicide use, and manual removal of woody plants, which reduces maintenance costs. Jacobson et al. (1990) concluded that reduced herbicide use will save state money and it will decrease possibility of contaminating ground water. Decreased mowing can reduce maintenance expenditures and potentially increase tourism. Wildflower areas mean beautiful roadsides, enhanced environment for small mammals and birds, less chemical usage, preservation of natural resources, native seed sources for future planting projects, lessen roadside maintenance costs, and protect rare and endangered plants (Jacobson et al. 1990).

The challenge is managing roadsides in a way that meets the needs of plant species while providing sufficient soil fertility and preventing erosion. One way to enhance species richness is to alter mowing practices to allow native wildflowers and grasses to produce seeds. Brown and Sawyer (2012) suggested mowing once in mid-summer and once in late fall, permitting warm-season and cool-season grasses to produce seeds, while still preventing the growth of woody plants. Bak et al. (1998) stated that sections of highways in the Netherlands that were mowed twice a year resulted in the highest species diversity and density of native plants for pollinating insects. They found that butterfly and insect densities were greatest with a mowing frequency of only once every three years (Bak et al. 1998).

Table 4.1 Percent coverage of vegetation in different height categories during fall 2010-2011.

Height Category	ELEVATION	Mean[a] (SE)
Low (≤ 0.46m)	Lowland[b]	125.22 (± 11.49)
	Upland[c]	126.24 (± 11.49)
Mid (≥ 0.46m ≤ 0.91m)	Lowland[b]	69.20 (± 4.42)
	Upland[c]	53.20 (± 4.42)
High (≥ 0.91m)	Lowland[b]	17.18 (± 3.21)
	Upland[c]	6.64 (± 3.21)

a) Mean percent coverage of vegetation within specified height category.
b) Lowland elevation N = 5, flat, periodical flooding, and moist soils.
c) Upland elevation N = 5, hilly, slope, and dry soils.

Table 4.2 Percent coverage of vegetation in different height categories during spring 2011-2012.

Height Category	ELEVATION	Mean[a] (SE)
Low (≤ 0.46m)	Lowland[b]	216.79 (± 9.74)
	Upland[c]	226.96 (± 9.74)
Mid (≥ 0.46m ≤ 0.91m)	Lowland[b]	49.15 (± 4.69)
	Upland[c]	50.08 (± 4.69)
High (≥ 0.91m)	Lowland[b]	28.63 (± 3.90)
	Upland[c]	16.15 (± 3.90)

a) Mean percent coverage of vegetation within specified height category.
b) Lowland elevation N = 5, flat, periodical flooding, and moist soils.
c) Upland elevation N = 5, hilly, slope, and dry soils.

Table 4.3 Test statistics comparisons of mean percent coverage vegetation within height categories during fall and spring 2010-2012.

Source	DF	≤ 0.46 m Height F Value	≤ 0.46 m Height Pr > F		≥ 0.46 to ≤ 0.91 m Height F Value	≥ 0.46 to ≤ 0.91 m Height Pr > F		≥ 0.91 m Height F Value	≥ 0.91 m Height Pr > F	
Fall Seasons 2010-2011 Mean Percent Coverage of Vegetation within Specified Height Category										
YEAR[a]	1	18.80	0.001	*	46.62	0.001	*	8.39	0.006	*
TRT[b]	2	0.43	0.654		0.47	0.626		0.17	0.846	
ELEVATION[c]	1	0.01	0.917		2.66	0.109		3.41	0.071	
YEAR*TRT	2	0.21	0.808		0.02	0.979		0.02	0.977	
YEAR*ELEVATION	1	0.10	0.756		3.71	0.060	?	0.56	0.459	
ELEVATION*TRT	2	0.07	0.935		0.27	0.761		0.00	0.999	
YEAR*ELEVATION*TRT	2	0.43	0.652		2.76	0.073		0.11	0.896	
Spring Seasons 2011-2012 Mean Percent Coverage of Vegetation within Specified Height Category										
YEAR[a]	1	0.48	0.492		18.03	0.001	*	4.91	0.032	*
TRT[b]	2	1.34	0.273		0.06	0.946		1.08	0.348	
ELEVATION[c]	1	3.60	0.064	?	19.19	0.001	*	4.65	0.036	*
YEAR*TRT	2	0.01	0.989		0.00	0.998		0.43	0.656	
YEAR*ELEVATION	1	2.41	0.127		19.17	0.001	*	0.16	0.689	
ELEVATION*TRT	2	0.10	0.907		0.03	0.970		1.05	0.357	
YEAR*ELEVATION*TRT	2	0.08	0.924		0.24	0.786		0.23	0.797	

(*) Denotes significant differences at alpha level = 0.05.
(?) Denotes marginal significant differences at alpha level = 0.05.
a) Over the two-year study period 2010-2012.
b) TRT=Treatments – mowed, reduced mowed, reduced mowed-seeded.
c) Upland vs. lowland elevations.

Table 4.4 Mean woody plant stem densities during fall seasons 2010-2011.

Woody Species Category	ELEVATION	Mean[a] (SE) number of stems/hectare
Combined Native and Non-Native Plant Species	Lowland[b]	4785.56 (± 1981.90)
	Upland[c]	10758.00 (± 1981.90)
Native Plant Species	Lowland[b]	4247.50 (± 1974.91)
	Upland[c]	10209.00 (± 1974.91)
Non-Native Plant Species	Lowland[b]	1222.18 (± 340.81)
	Upland[c]	1276.18 (± 340.81)

a) Mean woody plant stem density coverage / hectare.
b) Lowland elevation N = 5, flat, periodic flooding, and moist soils.
c) Upland elevation N = 5, hilly, slope, and dry soils.

Table 4.5 Mean woody plant stem densities during spring seasons 2011-2012.

Woody Species Category	ELEVATION	Mean[a] (SE) number of stems/hectare
Combined Native and Non-Native Plant Species	Lowland[b]	11672.00 (± 2031.12)
	Upland[c]	8378.45 (± 2031.12)
Native Plant Species	Lowland[b]	10880.00 (± 1987.92)
	Upland[c]	7315.05 (± 1987.92)
Non-Native Plant Species	Lowland[b]	1726.47 (± 517.45)
	Upland[c]	2077.73 (± 517.45)

a) Mean woody plant stem density coverage / hectare.
b) Lowland elevation N = 5, flat, periodic flooding, and moist soils.
c) Upland elevation N = 5, hilly, slope, and dry soils.

Table 4.6 Test statistics comparison of total, native, and non-native woody plant stem densities during fall and spring seasons 2010-2012.

Fall Seasons 2010-2011 Woody Plant Stem Density (stems/ha)							
		Combined Native/Non-Native Woody Stem Density		Non-Native Woody Stem Density		Native Woody Stem Density	
Source	DF	F Value	Pr > F	F Value	Pr > F	F Value	Pr > F
YEAR[a]	1	2.18	0.146	1.86	0.179	1.61	0.211
TRT[b]	2	1.00	0.377	1.19	0.312	0.79	0.460
ELEVATION[c]	1	3.25	0.078	0.02	0.880	3.34	0.074
YEAR*TRT	2	0.08	0.927	0.40	0.672	0.10	0.902
YEAR*ELEVATION	1	0.13	0.720	0.09	0.763	0.17	0.685
ELEVATION*TRT	2	0.28	0.755	0.26	0.772	0.36	0.702
YEAR*ELEVATION*TRT	2	0.24	0.786	0.00	0.999	0.24	0.788
Spring Seasons 2011-2012 Woody Plant Stem Density (stems/ha)							
YEAR[a]	1	3.18	0.081	0.01	0.910	3.21	0.080
TRT[b]	2	0.66	0.522	0.31	0.732	0.55	0.583
ELEVATION[c]	1	1.96	0.168	0.42	0.521	2.32	0.134
YEAR*TRT	2	0.33	0.719	0.06	0.945	0.35	0.706
YEAR*ELEVATION	1	0.80	0.376	0.04	0.850	0.88	0.353
ELEVATION*TRT	2	0.33	0.721	1.10	0.342	0.53	0.591
YEAR*ELEVATION*TRT	2	0.11	0.895	0.38	0.689	0.19	0.830

a) Over the two-year study period 2010-2012.
b) TRT=Treatments – mowed, reduced mowed, reduced mowed-seeded.
c) Upland vs. lowland elevations.

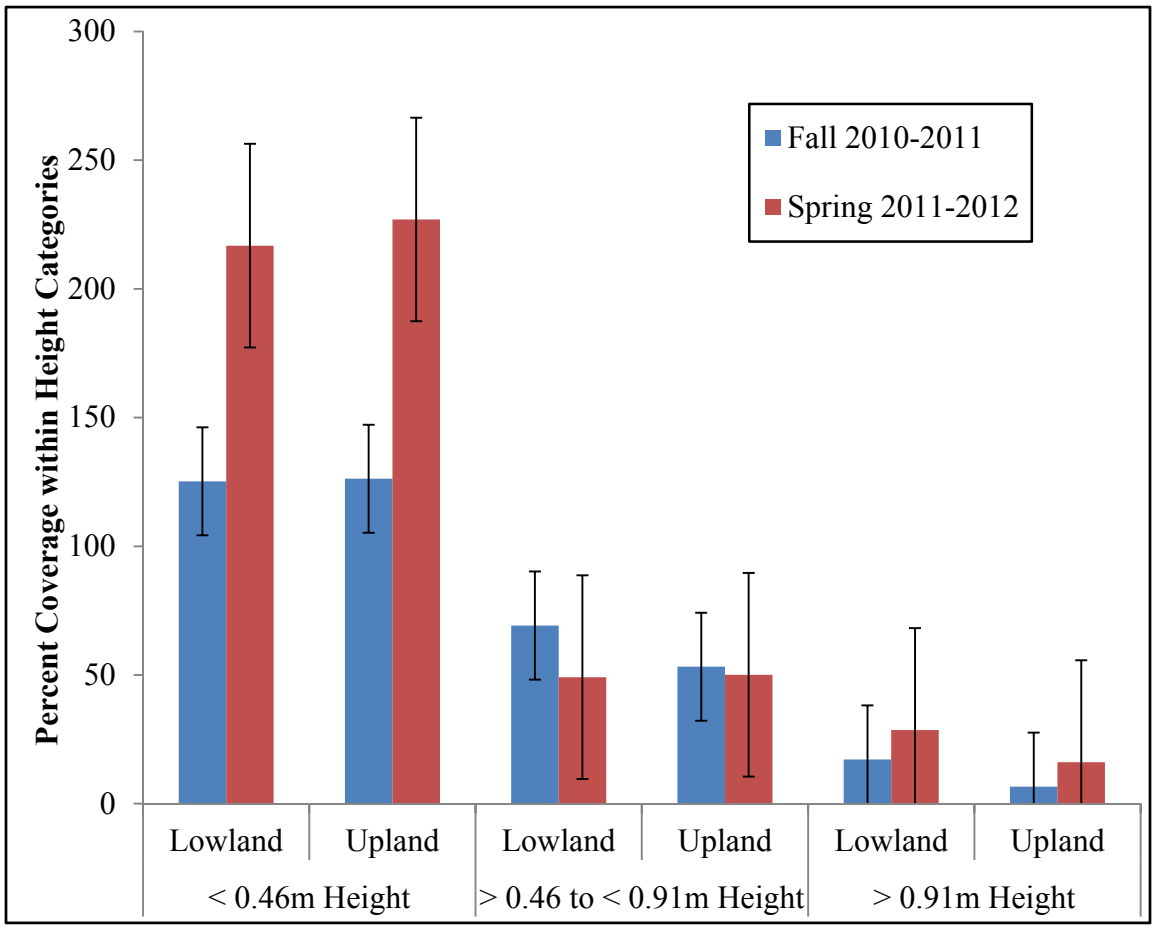

Figure 4.1 Percent coverage of vegetation within height during fall and spring with standard error bars variability of the means.

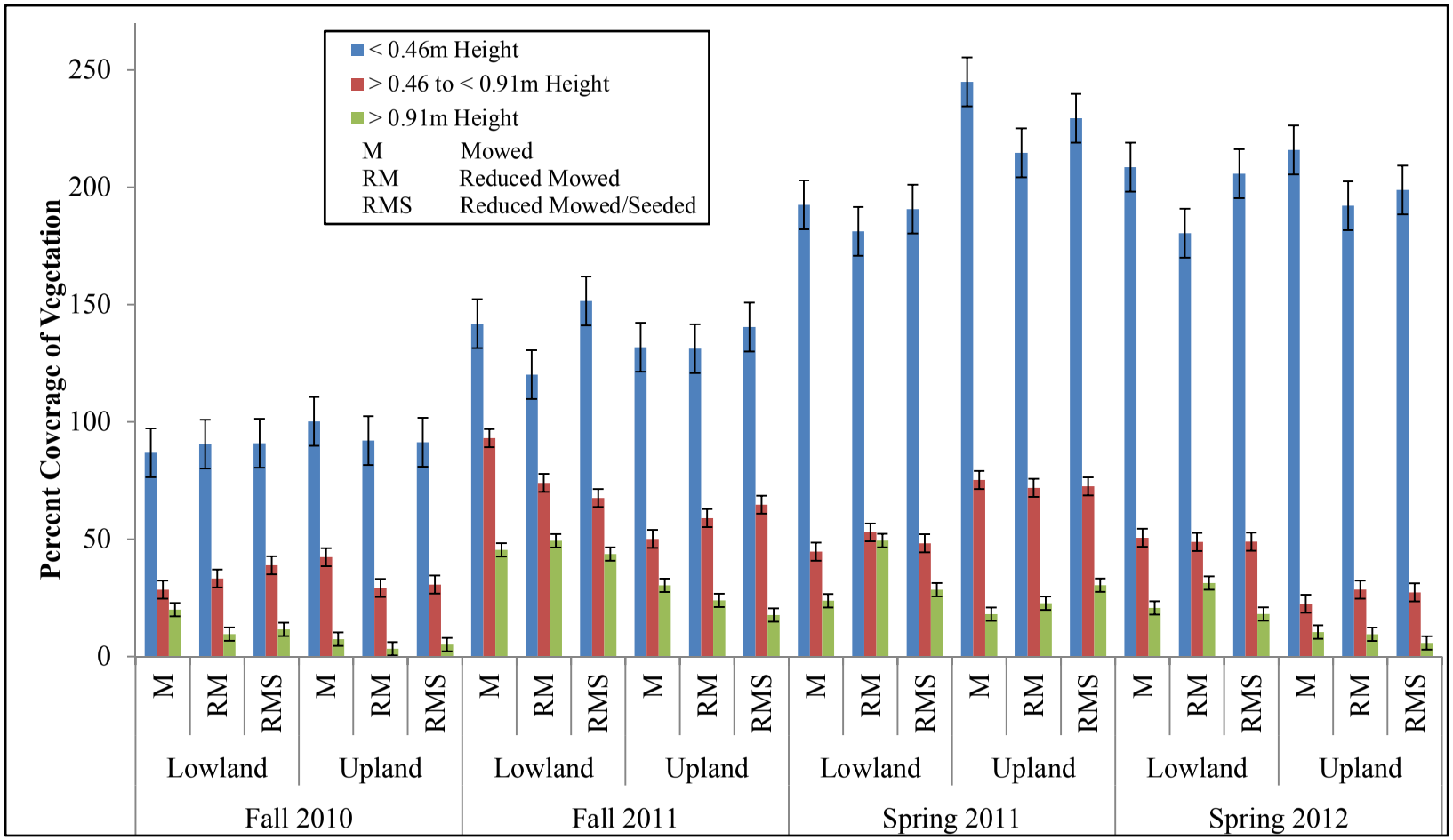

Figure 4.2 Percent coverage of vegetation within height categories during 2010-2012 with standard error bars of the means.

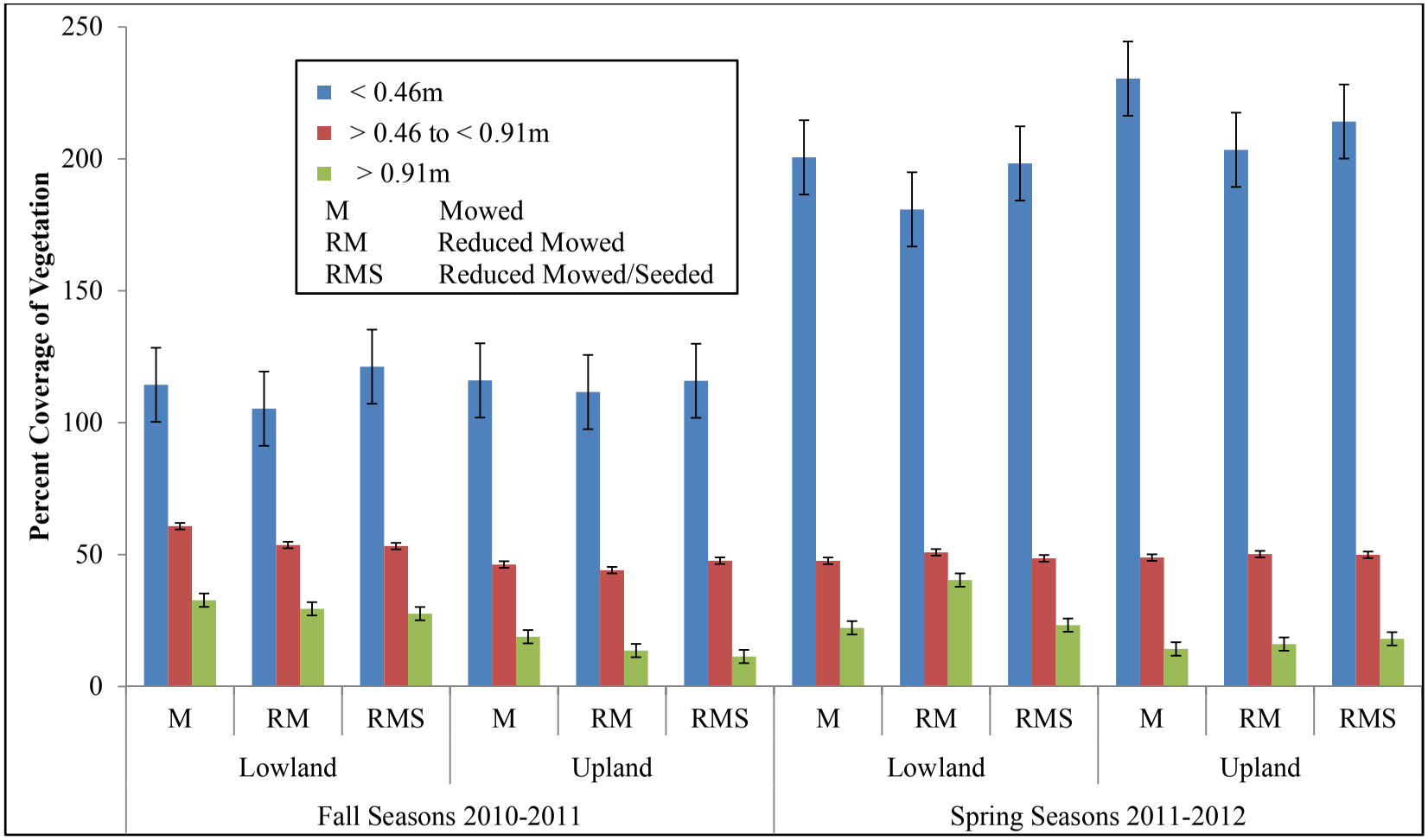

Figure 4.3 Percent coverage of vegetation in height categories during fall and spring with standard error bars of the means.

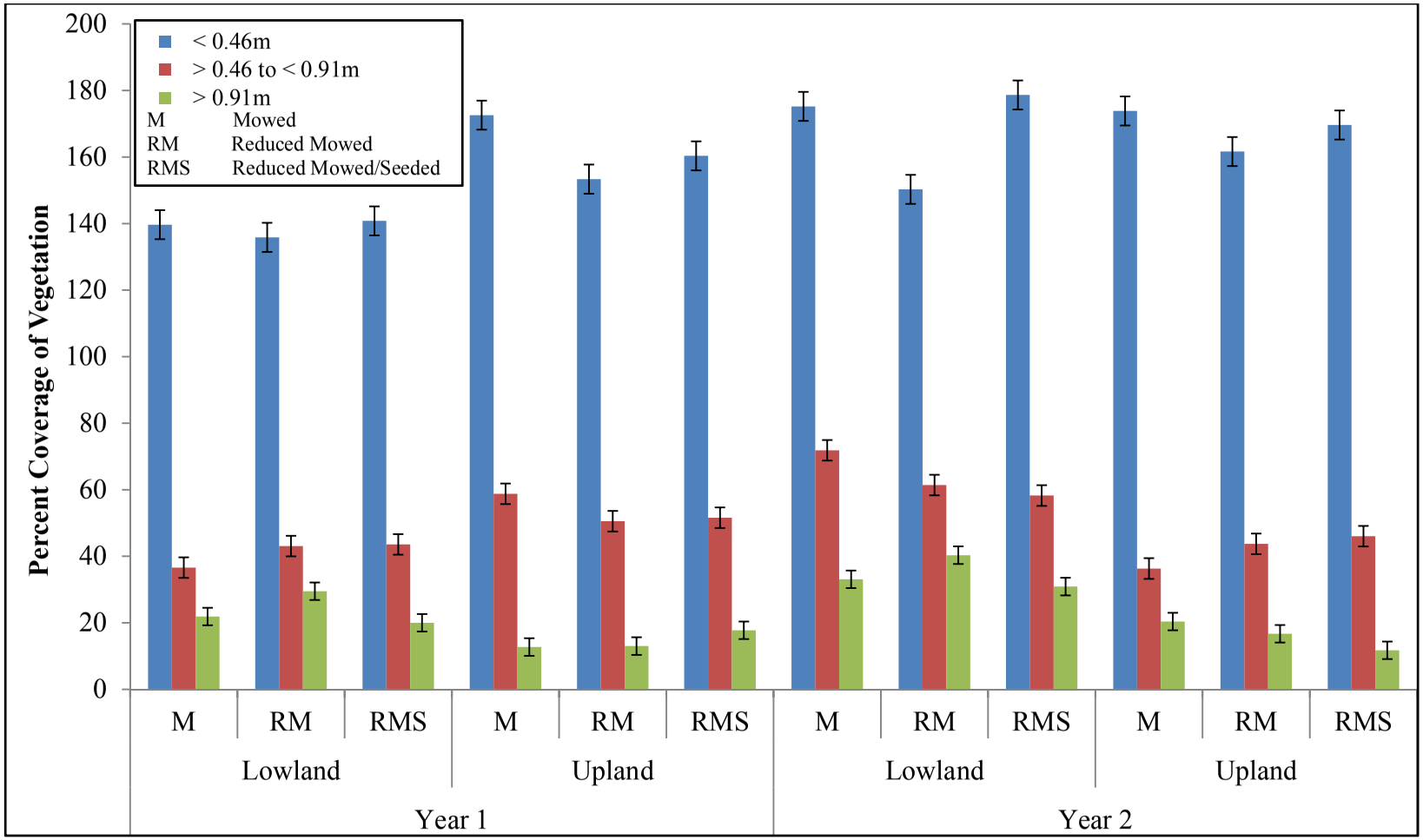

Figure 4.4 Percent coverage of vegetation in height categories from year 1 vs. year 2 with standard error bars of the means.

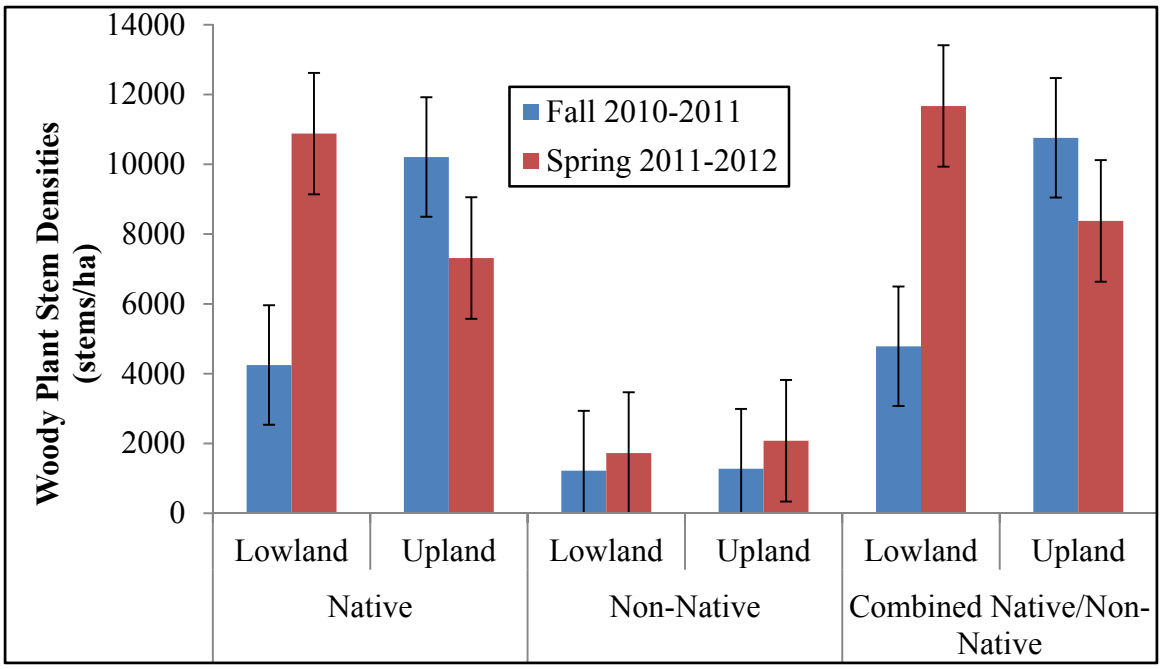

Figure 4.5 Mean stem densities of native and non-native woody plants fall and spring with standard error bars variability of the means.

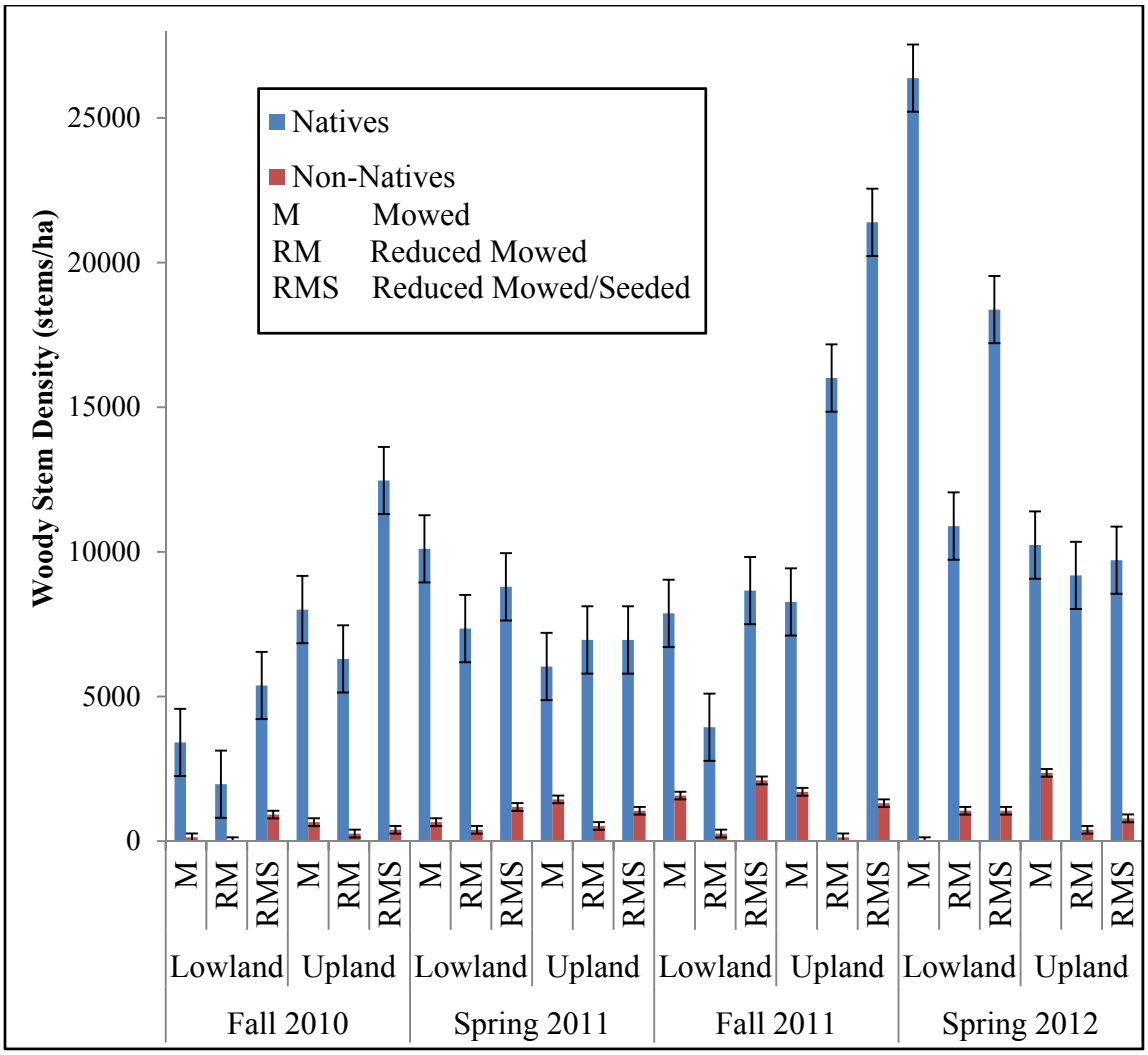

Figure 4.6 Mean woody plants stem densities of native and non-native from 2010-2012 with standard error bars of the means.

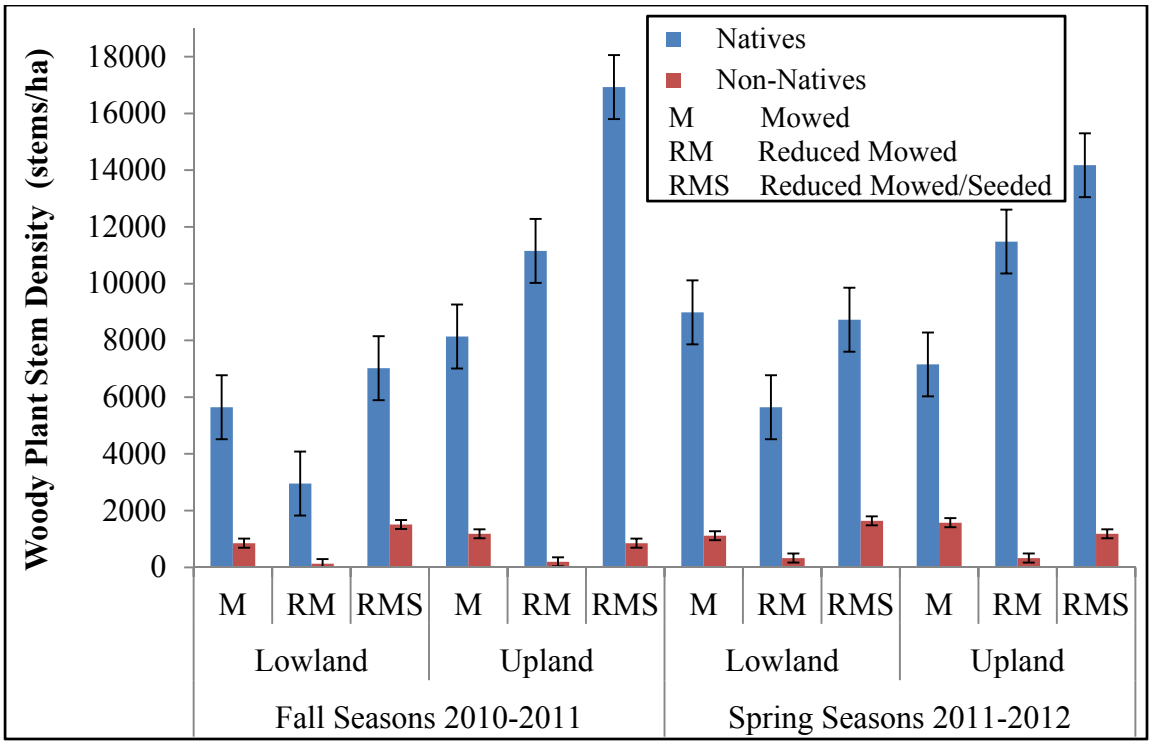

Figure 4.7 Mean stem densities of woody plants during fall and spring 2010-2012 with standard error bars variability of the means.

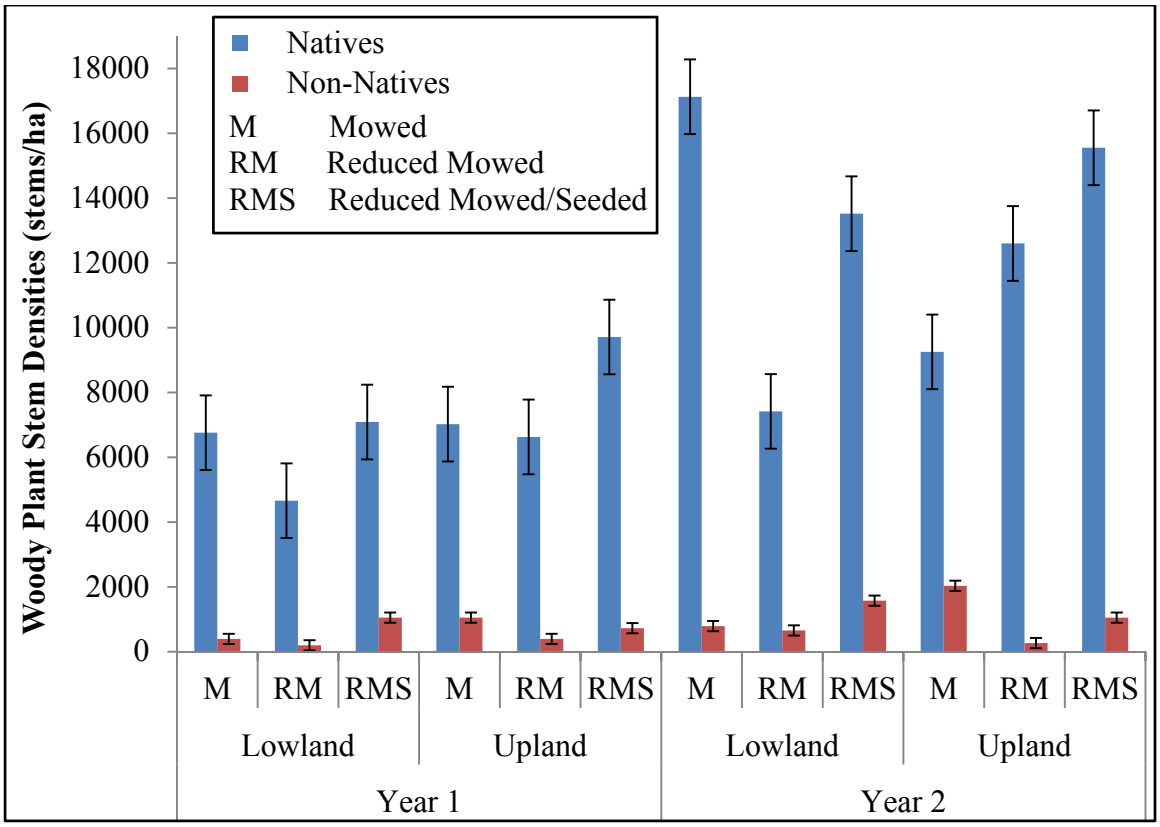

Figure 4.8 Mean stem densities of woody plants during year 1and 2 with standard error bars variability of the means.

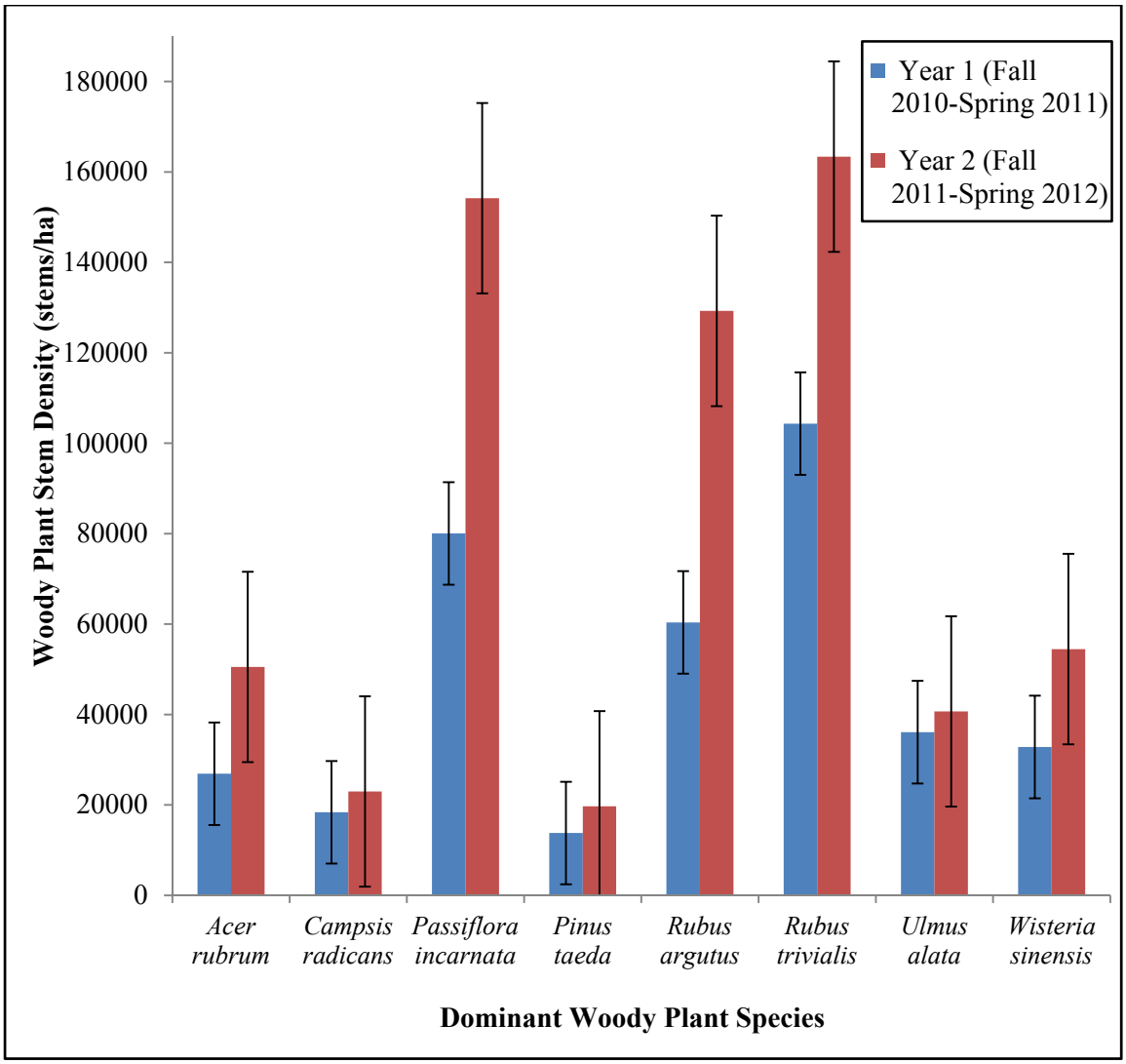

Figure 4.9 Mean stem densities of the most common woody plant species during study year 1 and 2 with standard error bars of the means.

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CHAPTER V

WHITE-TAILED DEER OBSERVATION COUNTS ALONG HIGHWAY 25 RIGHT-OF-WAY

Introduction and Study Area

Attraction of cervids (i.e., white-tailed deer [*Odocoileus virginianus*]) to roadsides right-of-ways (ROWs) by food availability due to planting, fertilization, and increased mowing has been reported in many regions of the United States. Reclamation and vegetation management along highway ROWs may result in plant communities that attract large herbivores such as white-tailed deer (Michael and Kosten 1981). Plants seeded along roadside ROWs for erosion control may include mixtures of annual plants, such as clovers (*Trifolium* spp.), lespedeza (*Lespedeza* spp.) and vetches (*Vicia* spp. and *Securigera* spp.), which are highly palatable food plants for deer (Arner and Jones 2009). Many native grasses (i.e., bluestems (*Andropogon*)) and forbs are not highly palatable deer food plants that grow on roadsides and these natives require little to no maintenance except for a single mowing in late fall each year (Arner and Jones 2009). Many species of native wildflowers include black-eyed-susans (*Rudbeckia*), sunflowers (*Helianthus*), laserworts (*Silphium*), blazing stars (*Liatris*), and milkweeds (*Asclepias*) are less palatable to white-tailed deer and are commonly found on ROWs (Miller and Miller 1999; Schummer et al. 2012). Native grasses and forbs occur in ROWs naturally, but coverage of these plants is restricted due to repeated annual mowing throughout the

growing season. A greater use of what is known about deer food preferences and forage plant availability along highway ROWs would enable highway managers to modify vegetation management that reduces deer on ROWs. Use of this information could potentially reduce incidence of deer-vehicle collisions on highways and save lives.

Accidents involving white-tailed deer and vehicles are a major concern in wildlife and highway management nationwide (Dixon et al. 1984). The number of vehicle collisions with cervids may range from 720,000 to >1.5 million annually in the United States (Conover et al. 1995). In 2006, State Farm Insurance indicated that >1,000,000 wildlife-vehicle collisions occurred annually based on number of claims for collisions with cervids (M. Miles, State Farm Insurance, Personal Communication). In Mississippi, wildlife-vehicle collisions have continued to be a safety and financial concern, and increases in deer population as well as miles of new roadways statewide have resulted in an increase in deer-vehicle collisions (MDWFP Deer Committee 2010; MDWFP Deer Committee 2012).

Deer vehicle collisions are a threat to motorists and wildlife that utilize roadside environments (Hewitt 2011; Fulbright and Ortega-Santos 2013). Wildlife mortality can be modified with alternative vegetation managements. Reduced mortality of wildlife have been achieved by allowing zones of woody plant cover to develop in areas where motorists' visibility is not essential. Machan (1981) reported that songbirds and rabbit species exhibited a 35% reduction in mortality where trees and shrubs were planted on Indiana roadway ROWs. Zimmerman (1981) also detected greater small mammal and rodent species abundance, and fewer road kills in road ROWs planted with shrubs in Indiana. 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 (Jacobson 2005; Arner and Jones 2009).

White-tailed deer are adaptable in their food habits, which include forbs, legumes, woody plants, and grasses, whereas legumes and forbs are generally the preferred diet during the growing season (Warren and Hurst 1981; Moreland 2005). During fall, winter, and early spring, cool season grasses, legumes, and woody plants are typically consumed by deer (Warren and Hurst 1981; Moreland 2005). Availability and composition of food plants on ROWs influence utilization by white-tailed deer throughout the year. Adjacent lands, forests, roadside ROWs, and other land environments that promote a variety of vegetation communities (Stransky 1969; Blair and Enghardt 1976; Conroy et al. 1982; Thill et al. 1990; Ford et al. 1997; Strickland and Demarais 2008) may influence deer density population. Interspersion of forage plants within areas dominated by tree plantations and mature forests can result in deer concentrations within early successional environments such as ROWs. Environments that promote growth of plant communities improve deer habitat within landscapes dominated by a closed canopy forests and pine plantations (Strickland and Demarais 2008). Highways through densely forested areas manage to attract deer will result in increased deer-vehicle collisions. Food plant availability and interspersion of cover types may increase presence of deer along ROWs.

Fragmentations of vegetation communities have been increasing due to urbanization and agricultural practices. Landscape fragmentation has been among the most intensively studied topics in conservation biology for decades (Gates and Gysel

1978; Murcia 1995). Moreover, Hartley and Hunter (1998) stated that the influence of edges have often been investigated as an important feature for white-tailed deer habitat due to differences in vegetation types within fragmentation areas. Stewart (2000) stated that if an area is planted year-round with cool and warm-season forages, this could positively affect nutritional quality and attract white-tailed deer. Despite the importance of plant communities to deer and their influence use of ROWs, there is still limited quantifiable information on highway ROWs in Mississippi.

This portion of the study was conducted in the study area as described in Chapter II. I conducted spotlight counts for white-tailed deer along the entire length of 48.28 km (30 miles) of the Highway 25 ROW. The specific objective of this study was to report frequency counts of deer observed within different seasons, and uplands and lowlands along the Highway 25 ROW in Oktibbeha and Winston counties, Mississippi.

Field Methods

White-tailed deer spotlight counts were conducted from January 2011 to January 2012, during the four seasons (winter, spring, summer, and fall), along the Highway 25 ROW. A total of 30 spotlight survey nights occurred from January 2011 through January 2012 with an average of 7.5 spotlight survey occurring during each of the four seasons during 2011 (Table 5.1). Each deer sighting was recorded using a Bushnell Arc Rangefinder to range deer distance from the highway edge. A Garmin E-Trex HCx Vista GPS unit was used to pinpoint location of white-tailed deer on the roadside ROW. The Mississippi Automated Resource Information System (MARIS) and Gap Analysis Program (GAP) were used in ArcMap 10.1 to view upland and lowland elevation differences in relation to the GPS points of the deer observations (MARIS 1994; USGS

2010; ESRI 2011). Uplands were classified as hillsides with an upward elevation slope while lowlands was an area located within the floodplain < 100 m (< 328 ft.) of a stream or drainage area. GAP program features the forest cover type, land use (forested, old-field, agricultural land, suburban, and roadways), and topography (lowland and upland) layers were used to identify preferred areas of plant communities from highway ROW sightings of white-tailed deer. The landscape scale was used to assess the GPS locations of mean number of observed deer per season in relation to upland/lowland elevations. Mean number of deer observations per season and within two elevations along the ROW was recorded. I calculated the observations by estimating average number of deer per kilometer (km), over each season (winter, spring, summer, and fall), upland and lowland elevations along the 48.28 km (30 miles) of Highway 25 ROW. Specific details on field methods are described in more detail in Chapter II.

Results

I observed 723 white-tailed deer with an average of 24.93 ($\pm$ 2.65) deer per survey period from January 2011 to January 2012. I conducted 30 surveys and detected an average of 0.53 deer per km (0.86 deer per mile) within the survey period (Figures 5.1). Of the 723 total deer observed, 237 deer (33%) were recorded in the upland elevations, and 486 deer (67%) were recorded in lowland elevations (Figures 5.1 and 5.2). During each season, the lowland exhibited $\geq$ 2 times the number of deer sightings compared to upland (Figure 5.2). During winter (January to March), 267 deer were observed, and 156 deer were recorded during spring (April to June; Figure 5.3). Ninety-six deer were recorded during the summer (July to September), and 204 deer during the fall (October to December; Figures 5.3 and 5.4).

Approximately 95% of the deer recorded were observed within 250 meters of the roadside edge in nearby open fields, forest, and adjacent lands using the rangefinder data. Over 58% of observed deer were detected in lowland elevations within 250 meters of the roadsides, and around 42% of deer were detected in upland elevations along the highway ROWs. Nearly 85% of the deer were recorded in a small herd ($\leq$ 4) within the ROWs. Deer observations during each season (winter, spring, summer, and fall) were overlaid into ArcMap to view the landscape area of Highway 25 corridors in conjunction with presence/absence of deer (Figures 5.5 and 5.6). No statistical analyses were used in this chapter due to the lack of replication of different length of study areas and physiographic regions. Result inferences were based on means and standard errors of the mean for the deer observation study.

Discussion

Spotlight surveys for white-tailed deer conducted along ROWs throughout the U.S. have reported ranges of deer numbering from 5 to 12 deer per km (Fafarman and DeYoung 1986; Lancia et al. 1994; Richardson 2002; Hoffman et al. 2011). In comparison to these studies, number of deer that I counted (0.3 to 1.5 deer per km) was less than those reported by Fuller (1989) in Minnesota and Brunjes et al. (2009) in Texas. Variations in survey methods may account for differences between studies. Numerous population assessment methods use direct observations of deer estimate sizes, trends, and sex and age ratios of populations (Michigan DNRE 2009). The ability to detect deer varies among different vegetation types, weather conditions at time of observations, and observers (Michigan DNRE 2009). Many variables such as nearby forest types, hunting, breeding season, traffic, and weather conditions may have caused variations in my

observations. In my study, spotlight counts offered several advantages over daytime observations. Deer are often less reclusive at night, and the eye shine produced when light is reflected by their tapetum makes them more readily observable (Progulske and Duerre 1964; Steger and Neal 1981). Accuracy of spotlight counts often impeded by dense vegetation and tendency for deer to use escape cover (McCullough 1982). Studies have shown that accuracy of estimating deer densities using spotlight counts was influenced by ability of observers to detect deer and to estimate visibility distance within different vegetation communities (Whipple et al. 1994; Collier et al. 2007). In addition, Collier et al. (2007) reported that the greatest concern in many studies was that spotlight routes can only be run where access exists (i.e., along roads, forest trails), and thus people cannot provide an accurate distributed, representative sampling of deer counts. I may have underestimated deer numbers in lowland areas because of the dense vegetation; however, their numbers were greatest in these areas of my study. However, open vegetation types within the ROW along most of the Highway 25 allowed high visibility for spotlight counts for deer.

Seasonal trends of deer observations along the Highway 25 ROW were potentially related to changes in vegetation communities. These trends are directly related to availability of cool season plants during the growing periods. Cool season plants palatable to deer that I detected included yellow hop clover (*Trifolium campestre*), crimson clover (*Trifolium incarnatum*), white clover (*Trifolium repens*), and vetches (*Vicia* spp. and *Securigera* spp.). Other researchers have reported similar findings of the cool season deer forage plants (Dillard et al. 2005; Moreland 2005; Harper 2008). Hanley et al. (2012) and Vandeloecht et al. (2012) reported that vegetation communities

use by deer varied seasonally due to availability of forage plants. In my study, cool season annual plants exhibited percent ground coverages of >72% during spring in comparison to < 46% coverages during early fall. This could be a result of these plants grow between late fall and early spring where they were available to deer during these times. Additionally, overwintering basal rosettes of forb and grass species, such as goldenrods (*Solidago* spp.) and panic grasses (*Panicum* and *Dichanthelium* spp.), were available during winter and early spring. Concentrations of deer along the ROW during winter and spring may have been related to greater availability of forage plants. These forage plants may have been especially attractive to deer in areas where the ROW transected dense pine plantations with closed canopy and limited forage plants. Strickland and Demarais (2008) further stated that deer population was positively influenced by agricultural land uses and negatively influenced by pine plantation forests near roads due to the lack of browse forage and understory vegetation. Increased observation of deer sightings during January to March may have been due to green-up of warm season plants such as Illinois bundleflowers (*Desmanthus illinoensis*), bonesets/thoroughworts (*Eupatorium* spp.), goldentops (*Euthamia* spp.), Carolina geraniums (*Geranium carolinianum*), goldenrods (*Solidago* spp.), and clovers (*Trifolium* spp.). High peaks of deer observed during September through November may have been due to breeding season and green-up of cool season plants.

Wildlife concerns may arise over attracting deer to roadsides due to increased plant food availability. Land environments that promote growth of ground-cover plant communities should positively influence deer habitat quality in dense closed canopy forests (Strickland and Demarais 2008). I recorded increases in species richness and

percent coverages of native and non-native legumes, forbs, grasses, and woody plants in lowland elevations. Deer forage plants that occurred in lowlands included butterfly milkweed (*Asclepias tuberosa*), smallhead Doll's daisy (*Boltonia diffusa*), partridge pea (*Chamaecrista fasciculata*), ticktrefoil sticktights (*Desmodium* spp.), velvet panicum (*Dichanthelium scoparium*), crabgrass (*Digitaria* spp.), Virginia buttonweed (*Diodia virginiana*), eastern daisy fleabane (*Erigeron annuus*), lateflowering thoroughwort (*Eupatorium serotinum*), green ash (*Fraxinus pennsylvanica*), Japanese honeysuckle (*Lonicera japonica*), blackgum (*Nyssa sylvatica*), Maryland meadow beauty (*Rhexia mariana*), cat greenbrier (*Smilax glauca*), greenbriers (*Smilax* spp.), Canada goldenrod (*Solidago canadensis*), crimson clover (*Trifolium incarnatum*), and winged elm (*Ulmus alata*). Increases in food plants and woody vegetation availability along streams may have influenced deer utilization in lowlands of my study area. Cadenasso and Pickett (2000) found that white-tailed deer used lowlands due to food availability and woody cover for protection. Knowlton (1964) and Michael (1965) reported that deer prefer tender succulence vegetation. White-tailed deer browsing could have contributed to an increase in observation of deer along the roadsides. Chamrad and Box (1968) concluded that deer grazing concentrations were more prevalent after vegetation green-up following precipitation.

Native grasses and many native forbs are not highly palatable to deer (Warren and Hurst 1981; Moreland 2005), especially compared to non-native clovers and vetch (Arner and Jones 2009). Large mammals (i.e., deer) that pose threats to vehicles are often discouraged from highways by establishing plants with low palatability (Michael and Kosten 1981). Studies have reported that wildlife mortality (songbirds, rabbits, and

rodents) on Indiana roadways exhibited a 35% reduction in areas where native trees and shrubs were planted, increase in wildlife species numbers, fewer road kills, and found greater diversity of native plants (Machan 1981; Zimmerman 1981). Shrub and tree cover along streams associated with bridges, could potentially have a similar effect on deer while reducing vehicle collisions along Highway 25. Selective mowing could allow for shifts in vegetation communities within ROWs that would provide greater food resources and shrub-vine cover associated with bridge corridors. Possible establishment of food and cover resources near bridge corridors could result in fewer road-associated mortality and wildlife vehicle conflicts.

This study was a one-year white-tailed deer observation along Mississippi roadside ROWs. However, I suggest that numbers of deer detected seasonally in lowland and uplands provide evidence that these topics should be investigated further. Future studies could provide specific information about seasonal and elevational use of ROWs by white-tailed deer on a statewide basis. Several considerations are warranted if future studies are conducted. Based on the seasonal trends observed in this study, I recommend stratification of survey zones into vegetation types, especially stream or lowlands associated with bridge underpasses and uplands. Differences in numbers observed during seasons, spotlight count data within seasons can produce information on peak deer use along highway ROWs. In addition to estimation of peak deer use of ROWs, conducting surveys over the year can provide specific information about deer population demographics. McCullough (1982) found that surveys conducted during October and November revealed information on population levels, and general age class, and sex ratio

estimates, whereas surveys conducted during mid to late summer revealed information on doe to fawn ratios.

Future Studies

In my study, one ROW corridor was investigated, therefore, to strengthen inference power and statistical analysis of data, at least three study plots should be selected within specified physiographic regions of the state. Selection of study plots based on physiographic regions including urbanized and rural landscape would increase the power of investigations. Study plots could be subdivided into large hectare sections based on estimates of white-tailed deer home ranges. In my study, treatment plots were small and close to one another. This design hindered estimations of deer being associated with vegetation within treatment plots or subplots due to the plots/subplots being very small. Other variables could be investigated such as concentrations of seasonal plant community characteristics, assessment of adjacent vegetation types, lowland and upland differences, and estimation of deer population levels within a selected study area. Increased number of study areas and sample plots along highway or road ROWs would allow evaluation of deer observation numbers to be related to afore-listed variables and would avoid challenges associated with low sample size and pseudo-replication (Hurlbert 1984; Millar and Anderson 2004). With an increased number of study plots, relationships of deer sightings and plant community characteristics, elevations, plot locations, seasons, years, and other parameters could more accurately be estimated.

Table 5.1 Total number of white-tailed deer (*Odocoileus virginianus*) observed during spotlight counts from January 2011 to January 2012.

Date	Month Replication	Numbers of Deer Sighted	Deer/km	Deer/mile
Jan-19-2011	1	19	0.41	0.66
Jan-28-2011	2	42	0.90	1.45
Jan-29-2011	3	33	0.71	1.14
Feb-10-2011	1	2	0.04	0.07
Feb-17-2011	2	36	0.77	1.24
Feb-18-2011	3	34	0.73	1.17
Mar-3-2011	1	66	1.41	2.28
Mar-23-2011	2	35	0.75	1.21
Apr-7-2011	1	42	0.90	1.45
Apr-21-2011	2	35	0.75	1.21
May-21-2011	1	27	0.58	0.93
May-29-2011	2	20	0.43	0.69
Jun-23-2011	1	19	0.41	0.66
Jun-24-2011	2	13	0.28	0.45
Jul-27-2011	1	11	0.24	0.38
Jul-29-2011	2	8	0.17	0.28
Aug-9-2011	1	23	0.49	0.79
Aug-30-2011	2	25	0.54	0.86
Sep-18-2011	1	18	0.39	0.62
Sep-22-2011	2	11	0.24	0.38
Oct-13-2011	1	3	0.06	0.10
Oct-27-2011	2	12	0.26	0.41
Oct-28-2011	3	46	0.99	1.59
Nov-17-2011	1	18	0.39	0.62
Nov-30-2011	2	19	0.41	0.66
Dec-7-2011	1	13	0.28	0.45
Jan-17-2012	1	34	0.73	1.17
Jan-20-2012	2	26	0.56	0.90
Jan-31-2012	3	33	0.71	1.14

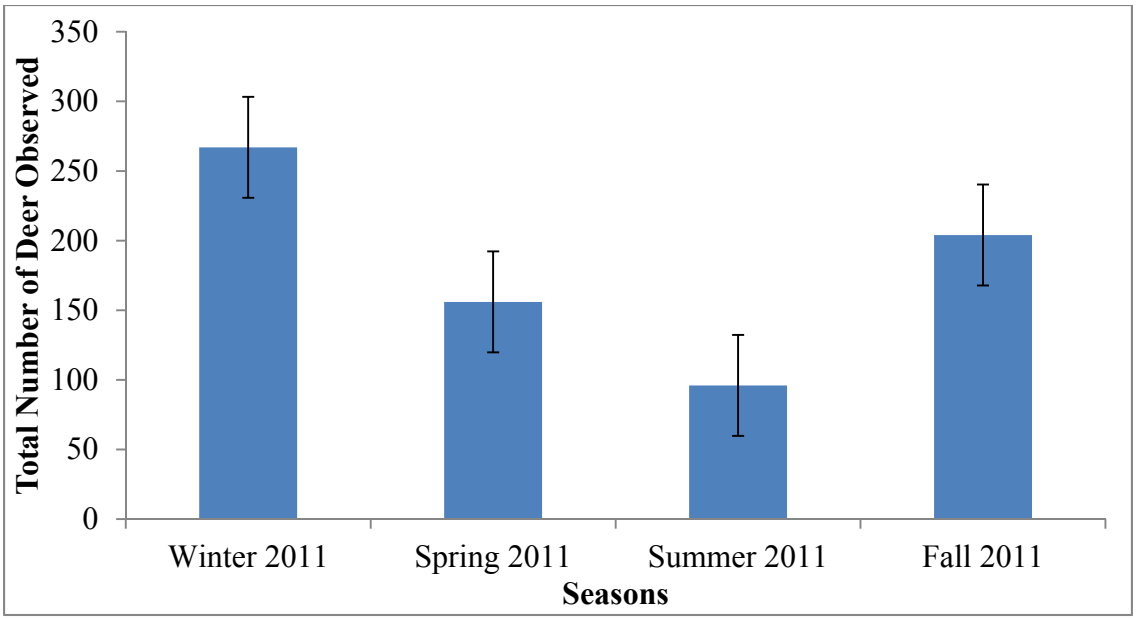

Figure 5.1 Total number of white-tailed deer (*Odocoileus virginianus*) observed during seasons with standard error bar variability from the means.

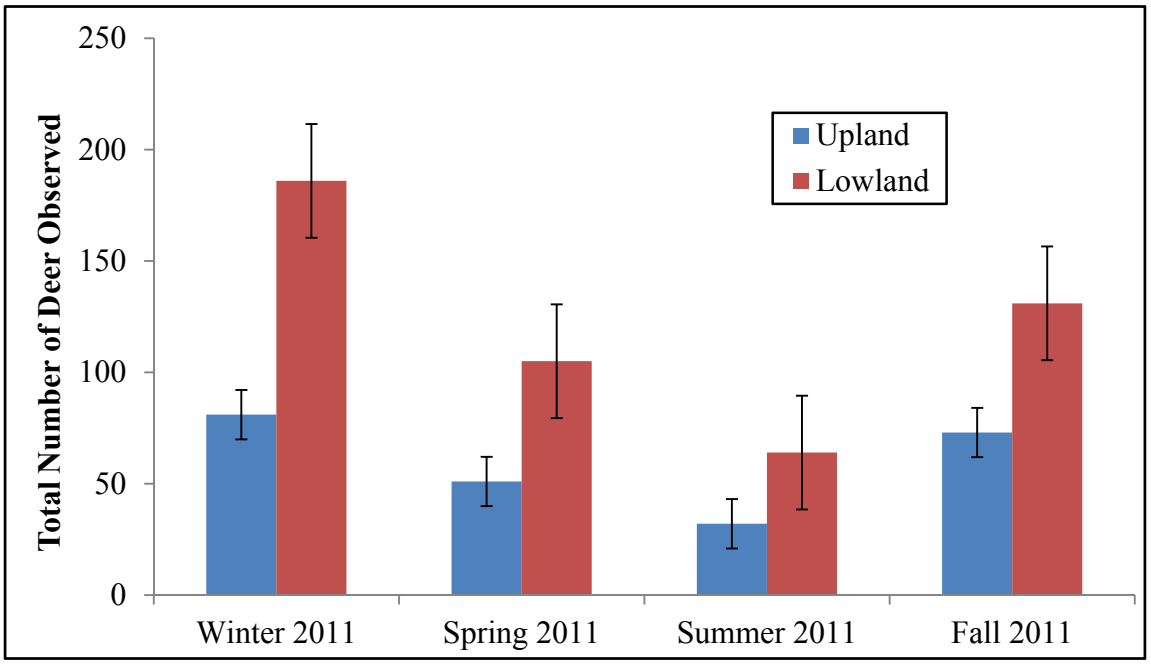

Figure 5.2 Total number of white-tailed deer (*Odocoileus virginianus*) observed during season and elevation with standard error bar from the means.

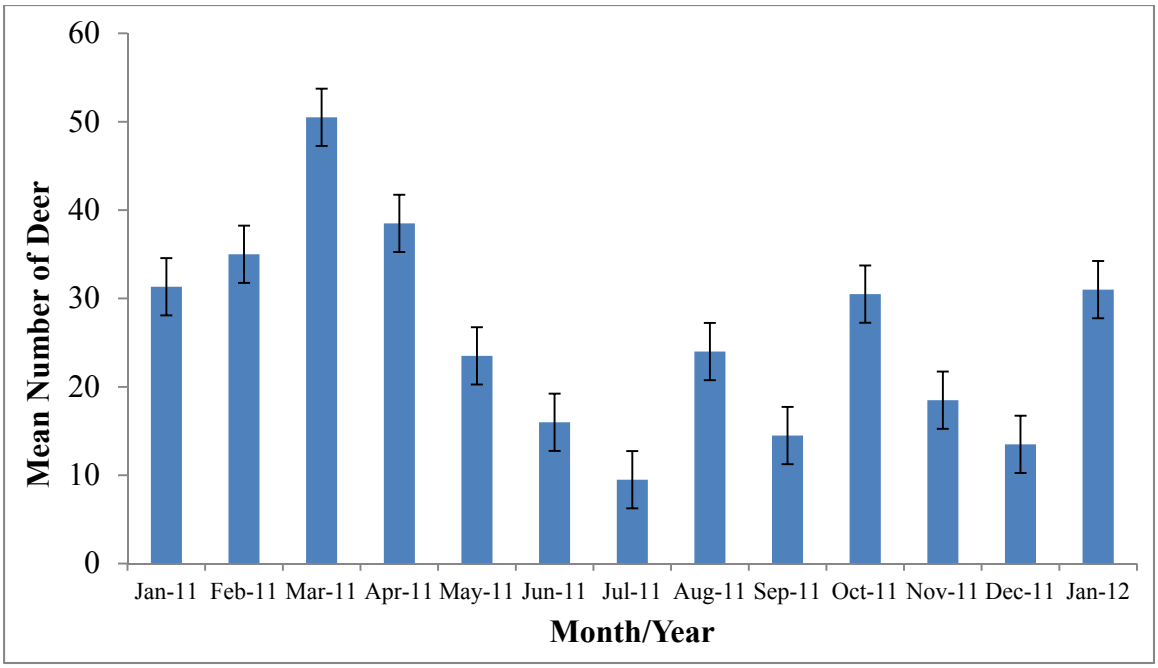

Figure 5.3 Mean number of white-tailed deer (*Odocoileus virginianus*) observed during 2011-2012 with standard error bar variability from the means.

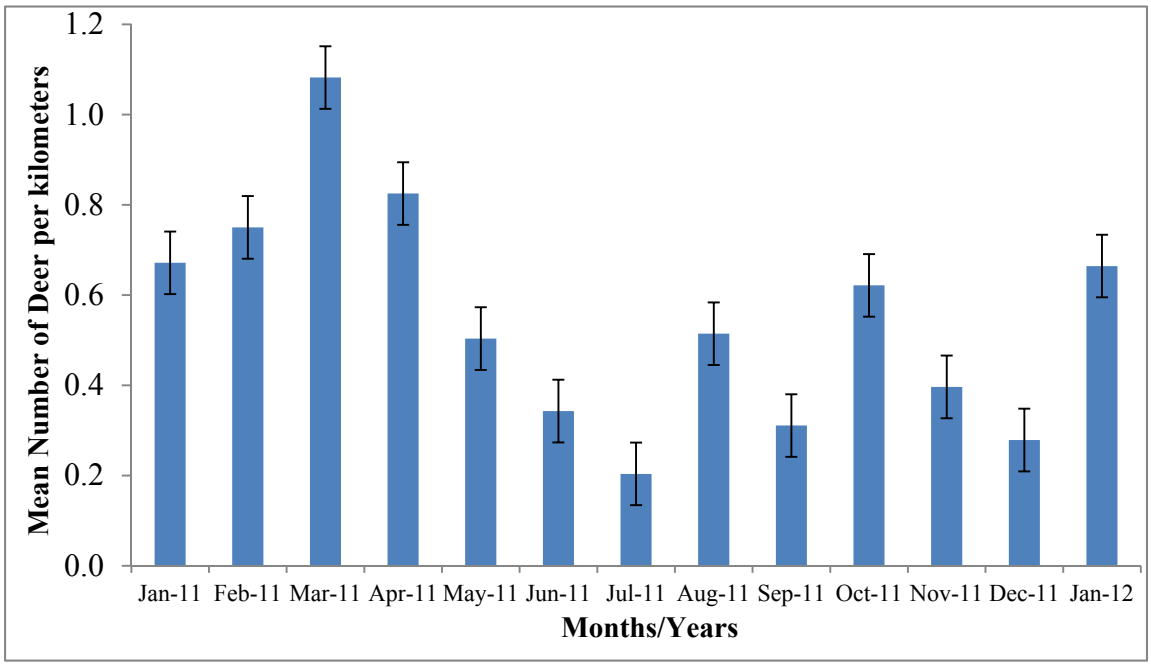

Figure 5.4 Mean number of white-tailed deer (*Odocoileus virginianus*) observations per km from 2011-2012 with standard error bar from the means.

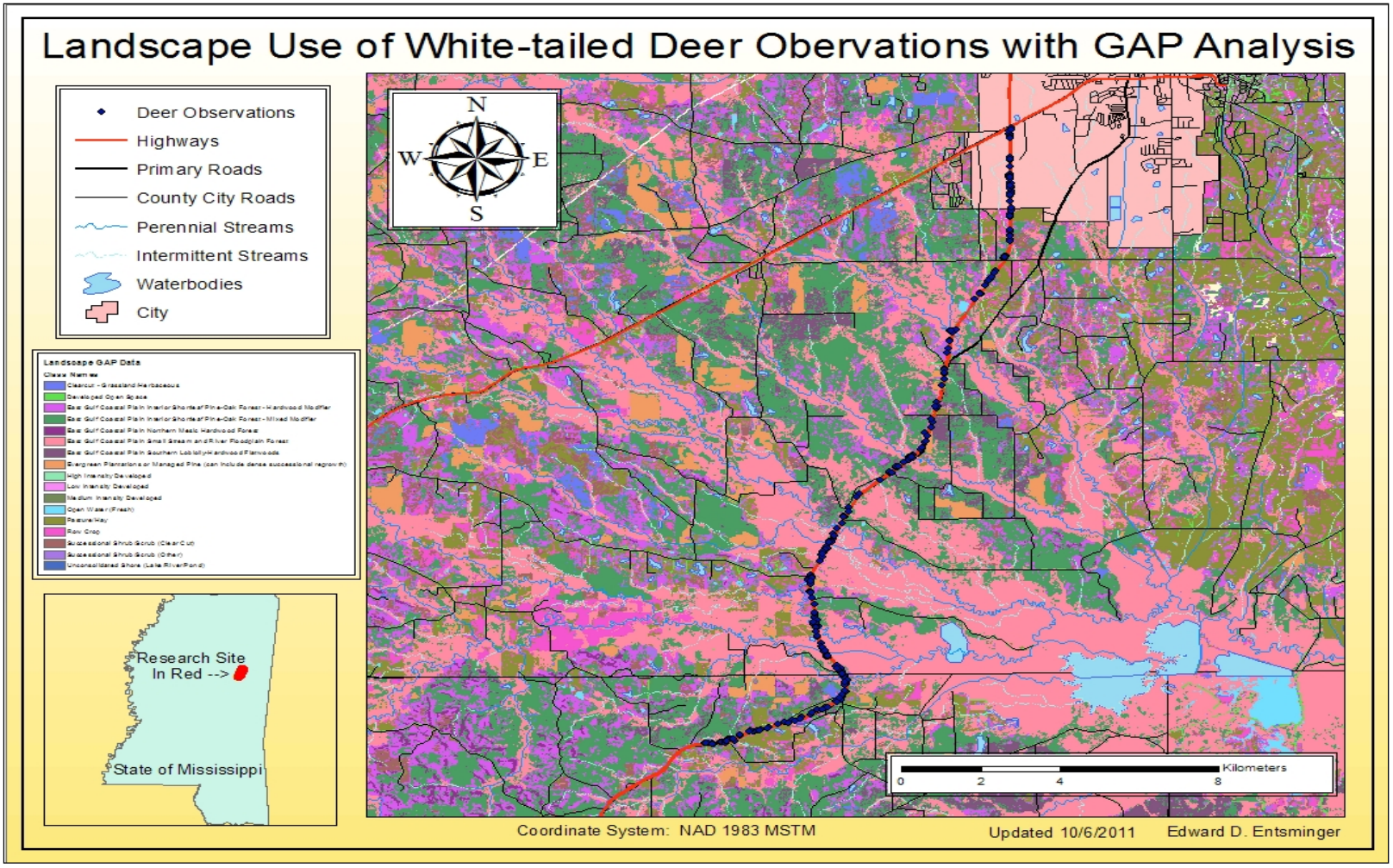

Figure 5.5 GPS points overlay into ArcMap GAP for viewing white-tailed deer (*Odocoileus virginianus*) observation during 2011-2012.

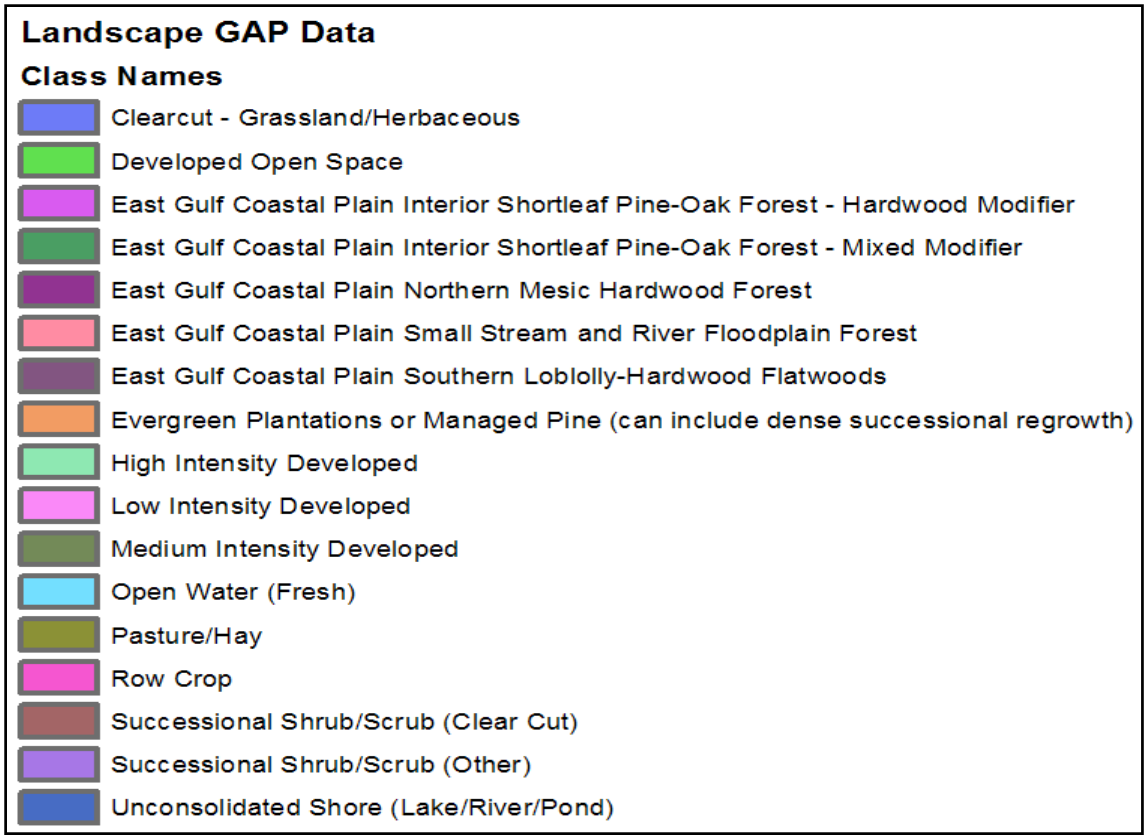

Figure 5.6 GAP land covers legend along Highway 25 ROW during January 2011–January 2012.

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CHAPTER VI

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

My research supports the strategy of one mowing per year, while multiple mowings can be unnecessary. There was no significant difference in vegetation height categories or woody stem density in subplots mowed once or multiple times per year. The continual mowing of roadside right-of-ways (ROWs) reduces funding, while one mowing per year would make more funds available for road and bridge repairs. Intensive management and increases in disturbance related to human population growth may increase colonization of roadway ROWs by non-native invasive plants (Soulé and Simberloff 1986). Managers can learn how ROW acquisition and management complements or conflicts with isolated areas that have intrinsic biological values. Because of current budgetary shortfalls, primary goals of highway vegetation management may focus on reduced frequency of mowing during growing seasons. An alternative reduced management regimen should be implemented with visibility safety, erosion control, and enhancement of roadside aesthetics. Most native plant establishment and wildflower programs accomplish these objectives and result in reduced maintenance costs compared with conventional management practices (Heine 1990; Dana et al. 1996; Dana et al. 1997). In addition, reduced mowing programs have been successfully implemented along roadways throughout the United States (Heine 1990; Dana et al. 1997).

Reducing mowings to once per year in late fall can result in major cost savings. During 2009 to 2013, the Mississippi Department of Transportation (MDOT) was spending approximately $100 per ha ($40 per acre) per mowing (D. Thompson, Vegetation Manager for MDOT, Personal Communication) or >$400 per ha (>$165 per acre) per year for subplots mowed intensively. With one mowing per year, cost could be reduced to around $75 per ha ($30 per acre), a savings of >75% annually. One study showed the cost of mowing roadsides ranged from $14.25 to $568.35 per ha ($5.75 to $230.00 per acre), while the application of herbicides was another option; however, contractors charge from $5.85 to >$1,125.00 per ha ($2.37 to >$455.50 per acre) per application (Armstrong et al. 2007). Considerations for use of intensive mowing and herbicide applications on ROWs include multiple issues that focus on costs, motorist safety, and public perception (Luken 1990). Concerns with herbicides have been a growing problem among the general population since the early 1960's (Carson 1962; Pendleton 1983; Luken 1990). In addition, a growing sector of the public does not tolerate constant mowing and large-scale spraying of herbicides (Niering and Goodwin 1974; Folmar et al. 1979; Freedman 1990; Breeze et al. 1992). Dana et al. (1997) mentioned that programs in Texas and Minnesota reduced mowing frequency and has an annual cost savings of >33%. The costs for native plants establishment can be less expensive than applying sod on ROWs. The Northeastern Illinois Planning Commission (2004) stated that sod costs >$30,000 per ha (>$12,145 per acre), turf grass seeding costs up to $19,600 per ha ($8,000 per acre), and the establishment of native plant mixtures through seeding comparatively costs up to $9,800 per ha ($4,000 per acre). In 1994, a New Jersey study compared a wildflower meadow that cost $0.11 per m^2 ($ 0.01 per ft^2)

more than seeding a traditional turf; however, there was a >90% cost reduction in management of the meadow (EPA 2013). Management of wildflowers required expenditures of around $125 per hectare ($50 per acre) per year, whereas management of the turfgrass areas required expenditures of $1,235 per hectare ($500 per acre; EPA 2013). In 1987, Massachusetts Department of Public Works saved 86% or $700 per hectare ($1,730 per acre) managed as wildflowers compared to grasses (Platt et al. 1994). Modifications in traditional mowing and ROW maintenance regimens using agronomic plant cover for erosion control and native plant species for aesthetic and ecological benefits could result in cost savings (Entsminger et al. 2014).

I detected significant increases in native plant species in plots that received late fall mowings only. I found that reduced mowing frequencies could enhance conditions for development of existing communities of native forbs, legumes, and grasses. Plant communities consisted of 219 species over the two-year study, 2010-2012. Of the 219 species detected, 15 species were native prairie plants that occurred exclusively in the two reduced mowed treatments. These species included nodding onion (*Allium cernuum*), broomsedge bluestem (*Andropogon virginicus*), Cherokee sedge (*Carex cherokeensis*), Carolina coralbead (*Cocculus carolinus*), Illinois bundleflowers (*Desmanthus illinoensis*), clasping coneflower (*Dracopis amplexicaulis*), eastern waterleaf (*Hydrophyllum virginianum*), eastern red cedar (*Juniperus virginiana*), tall blazing star (*Liatris aspera*), cusp blazing star (*Liatris mucronata*), switchgrass (*Panicum virgatum*), wand goldenrod (*Solidago stricta*), New England aster (*Symphyotrichum novae-angliae*), purpletop tridens (*Tridens flavus*), and greasegrass/longspike tridens (*Tridens strictus*; Appendix Table A.1). Based on my findings, establishment of native

plants through modifications in reduced mowing regimens could result in cost savings along ROWs (Entsminger et al. 2014).

Other factors appeared to influence findings of this study as I detected that non-native forb and grass coverages remained consistent in the frequently mowed treatment across the two years, but percent coverage of non-native species decreased slightly in the reduced mowed treatments in lowlands over the study period. In my study, costs of wildflower seeds for seeding the ten 10.16 m x 30.48 m (33.33 ft. x 100 ft.) research subplots approached $800.00, whereas reduction of mowing resulted in no additional costs for ROW management. My study demonstrated poor establishment of seeded wildflowers as I spread the native supplemental wildflower seeds over existing vegetation in early March 2011, and after a year and a half, the seeds had not produce the density of plants anticipated in the study. Several impediments may have limited establishment of seeded species. Lack of site preparation, existing competitive plant cover, and post-mowing vegetation litter may have limited contact of seed with the soil's surface (Jones et al. 2007). Soil chemistry, pH, nutrients, and soil moisture could have affected mineral composition, organic matter and other environmental mitigation factors for seed establishment and vegetation communities along the ROWs. In addition, the seeding time and lack of cold scarification may have negatively influenced seed germination, producing low results of flowering plants from the supplemental seeds (Schultz et al. 1955; Arner et al. 1976; Tilman 1997; Svedarsky et al. 2002; Jones et al. 2007). Burke and Grime (1996) also reported low establishment of <10% success rates of seeding native wildflowers into a dominant non-native agronomic grass coverage during the first growing season after seeding. Most perennial grasses and forbs need to lay out in cold

weather stratifications and require at least two years for maximum germination and establishment (Dana et al. 1997; USDA and NRCS Wildlife Habitat Management Institute 1999; Svedarsky et al. 2002; Jones et al. 2007; Tallamy 2009). Additionally, I did not attempt to ascertain potential depredation of sown seed by rodents and birds (Howard 1950; Howard and Kay 1957; Nelson et al. 1970; Anderson 1996; Harris 2009). These conditions, compounded with competition from established vegetation may have affected germination and establishment of seeds (Evans 1961; Harris 1967; Chase et al. 2000).

Things to consider when implementing native plant seeds on ROWs such as the difficulty of establishment within existing non-native plant communities, control of competing vegetation, site preparation, lack of availability of local seed stock, establishment time periods for native perennial species, and cost of seeds (Dana et al. 1997; Jones et al. 2007; Young and Claassen 2007; Tallamy 2009; Native American Seed 2013). Though the initial costs of this approach can be high >$100 per ha (>$40 per acre), long-term savings come from reduced maintenance and replanting costs (Young and Claassen 2007). Establishment of seeding native plants can be difficult, once established they generally result in a stable native plant community facilitating a reduced mowing regimen (Bugg et al. 1997, Young and Claassen 2007). Native seeds exist in the soil bank and can be maintained by this mowing regimen. This approach might be useful due to budget constraints that would not allow expenditures to purchase native plant seed for planting along ROWs. Reduction in herbicide applications could result in cost savings and a greater on-site resistance to establishment of non-native invasive plants (Daar 1994; Green and Welker 2003; Miller et al. 2010; U. S. EPA 2012; CalTrans

2013). Native drought-tolerant plants could provide erosion control through ground coverage and extensive root systems (CalTrans 2013). Long-term economic benefits can result in the encouragement of native plant communities and produce savings from erosion control and reduced use of herbicides and mowing (Russell et al. 2005; Hopwood 2010).

I found several trends in frequently mowed subplots that are related to visibility and traffic safety along highway ROWs. Frequently mowed plots exhibited the greatest stem densities of woody plants. Various studies have reported findings that increased stem densities may have resulted from coppicing and re-sprouting of trees and shrubs following mowing (Arner 1979; Gruchy et al. 2006; Brown and Sawyer 2012). I did not detect differences in percent coverage of vegetation in the height categories of $\geq$ 0.46 m to $\leq$ 0.96 m and $\geq$ 0.91 m within the different mowing treatments. Reducing mowing frequencies from >4 times per growing season to one time per growing season did not result in statistically greater stem densities of woody plants or greater heights of vegetation along the ROW. Based on my findings, a lower height of the vegetation and densities of woody plants can be achieved with less frequent mowing, thus saving money.

Traditional management regimens are difficult to modify based on personnel training and budgetary allocations (Daar 1994; Dana et al. 1996). Mowing once per year could enhance species richness of native forbs, grasses, legumes, sedges, rushes, and woody vines. This proactive management approach could save maintenance expenditures and enhance roadside aesthetics through establishment of native plants with no significant loss of agronomic grass coverage and no increase in woody plant stem density coverage, while providing enhancement of certain wildlife habitat requirements.

The reduced mowing benefit could be significant in lowland areas where more diverse plant communities attract larger mammals that could cross beneath bridges of highways.

Modifications in mowing frequencies may not be appropriate for the entire ROW. Maintenance of vegetation heights within 4.58 m – 9.15 m (15 ft. – 30 ft.) of the roadside edge is generally necessary for motorists' safety, visibility, emergency stops, and road maintenance (Johnson 2000; Hill and Horner 2005; National Research Council 2005; Harper 2008; Willard et al. 2010). However, reduced mowing may be more appropriate where maintained ROWs intersect with adjacent surroundings >100 meters (328 ft.) from the roadway. One mowing during late fall could enhance ROWs for wildlife, increase aesthetic quality, retain good visibility and save money (Armstrong et al. 2007). Other benefits include creation of partnerships, companies, native plant societies, and other organizations that limit the spread of non-native invasive plants by establishment and preservation of native plant cover along roadside ROWs (Armstrong et al. 2007). However, Guinon (1990) cautions that cost estimates for native plant restoration can widely vary. Companies that market wildflowers seed often provide little or no information about expected seed germination (Dana et al. 1997). Many states within the U. S. have instituted restoration programs along highways that have been published on this topic. Cost analysis has been conducted that evaluates wildflower conversion and long-term maintenance savings with reduced mowing by the implementation of prairie and garden wildflower establishment (Dana et al. 1997).

Native plant diversity along highways can enhance public attitudes about roles of ROWs and the creation of an environment for native flora (Carson 1962; Pendleton 1983; Luken 1990; Arner and Jones 2009). The reduced mowing regimen coupled with public

education campaigns can create public acceptance of alternative management regimens for highway ROWs that enhance aesthetic quality and biological diversity. These programs have been reported in North Carolina and Texas since the 1980's (Markwardt 2005; Bean 2007; U. S. Department of Transportation – Federal Highway Administration 2011; NCDOT 2013; Texas Department of Transportation 2013). Management of ROWs for enhancement of aesthetic quality through increases in native plant diversity can potentially create areas of plant communities for rare species and create areas where rare, relict ecosystem types, such as prairies, can be retained.

In other areas, such as the Blackbelt Prairie Region of the Southeastern United States, ROWs may provide areas in which native prairie plants can colonize and survive (Harrington 1994; Svedarsky et al. 2002; Jones et al. 2007). Retention of native plants within ROWs can improve vegetation communities quality along roads and highways for native flora and fauna, including rare prairie plants, pollinating insects, small mammals, and birds (Jones et al. 2007; Tallamy 2009). These benefits can be accomplished at no additional costs to taxpayers and could result in approximately 75% cost savings per year for vegetation management (Entsminger et al. 2014). This type of reduced mowing management has been successfully applied and implemented on prairie reclamation, restoration sites, and gas, power-line, and railroad ROWs (Arner 1959; Harrington 1994; Arner and Jones 2009). These benefits might be accomplished without decreasing roadside visibility (Ode 1970; Schwarzmeier 1970; Anderson 1996; Barras et al. 2000; Kutschbach-Brohl et al. 2010) and without increasing the population of woody plants along roadside ROWs.

Future Research

Future research efforts could consider evaluating different seed mixtures of native forbs, legumes, and grasses for roadside ROWs. Other maintenance methods for native plant establishment and retention include usage of chemicals, performance of prescribed fire, and various seeding techniques. Future efforts should increase the sample size ($\geq$ 30) for upland and lowland elevation plots to stratify future designs to see changes in plant species richness, stem densities, and percent coverage over different physiographic and soil resource areas of the state. I also recommend an increase in number of upland and lowland plots with additional and more diverse treatments. These treatment plots should be designed such that treatment plots span across greater ROW distances. With this increase in sampling intensity and numbers of study areas, more individuals would be needed to conduct vegetation sampling. The modifications in sampling intensity and study plot design should include additional ROW corridors in different physiographic regions. White-tailed deer observation studies could increase estimate relationships between number of deer observed along ROWs, and vegetation sampling communities within treatment plots on ROWs and in adjacent environments. I also recommend that future studies of deer occurrence along ROWs include year-round surveys of lowlands associated with streams and bridge corridors.

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APPENDIX A

SUMMARY METRICS OF HERBACEOUS AND WOODY VEGETATION CHARACTERISTICS

Table A.1 Complete vegetation species list detected along Highway 25 ROWs in Oktibbeha and Winston counties, Mississippi during 2010-2012.

Complete Vegetation Species List (277)			
Common Name	**Scientific Name**	**Vegetation Type**	**Status**
Common Threeseed Mercury	*Acalypha rhomboidea* Raf.	Forb	Native
Boxelder Maple	*Acer negundo* L.	Tree	Native
Red Maple	*Acer rubrum** L.	Tree	Native
Wild Meadow Garlic	*Allium canadense* L.	Forb	Native
Nodding Wild Onion	*Allium cernuum* Roth.	Forb	Native
Common Annual Ragweed	*Ambrosia artemisiifolia** L.	Forb	Native
Peppervine	*Ampelopsis arborea* (L.) Koehne	Vine	Native
Broomsedge Bluestem	*Andropogon virginicus* L.	Grass	Native
Indianhemp/Dogbane	*Apocynum cannabinum* L.	Forb	Native
Giant Switchcane	*Arundinaria gigantea* (Walter) Muhl. ssp. *gigantea*	Grass	Native
Switchcane	*Arundinaria gigantea* (Walter) Muhl. ssp. *tecta* (Walter) McClure	Grass	Native
Butterfly Milkweed	*Asclepias tuberosa* L.	Forb	Native
Eastern Baccharis	*Baccharis halimifolia** L.	Shrub	Native
Bearded Beggartick	*Bidens aristosa** (Michx.) Britton	Forb	Native
Devil's Beggartick	*Bidens frondosa** L.	Forb	Native
Beggartick	*Bidens* L. spp.*	Forb	Native
Crossvine	*Bignonia capreolata* L.	Vine	Native
False Nettle	*Boehmeria cylindrica* (L.) Sw.	Forb	Native
White Doll's Daisy	*Boltonia asteroids** (L.) L'Hér.	Forb	Native
Smallhead Doll's Daisy	*Boltonia diffusa** Elliott	Forb	Native
Silver Beardgrass	*Bothriochloa laguroides* (DC.) Herter	Grass	Native
Little Quaking Grass	*Briza minor** L.	Grass	Non-Native
Field Brome	*Bromus arvensis** L.	Grass	Non-Native
Soft Brome	*Bromus hordeaceus** L.	Grass	Non-Native
Bald Brome	*Bromus racemosus** L.	Grass	Non-Native
Redvine/American Buckwheat Vine	*Brunnichia ovata* (Walter) Shinners	Vine	Native
Trumpet Creeper	*Campsis radicans* (L.) Seem. ex Bureau	Vine	Native
Green White Sedge	*Carex albolutescens* Schwein.	Sedge	Native
Yellow-Fruited Fox Sedge	*Carex annectens* (E.P.Bicknell) E.P.Bicknell	Sedge	Native
Oval Leafed Sedge	*Carex cephalophora* Muhl. ex Willd.	Sedge	Native
Cherokee Sedge	*Carex cherokeensis** Schwein.	Sedge	Native
Limestone Meadow Sedge	*Carex granularis** Muhl. ex Willd.	Sedge	Native
False Hop Sedge	*Carex lupuliformis** Sartwell ex Dewey	Sedge	Native
Sedge	*Carex* L. spp.*	Sedge	Native
Fox Sedge	*Carex vulpinoidea** Michx.	Sedge	Native
Spurred Butterfly Pea	*Centrosema virginianum* (L.) Benth.	Legume	Native

Table A.1 (Continued)

Partridge Pea	*Chamaecrista fasciculata* (Michx.) Greene	Legume	Native
Prostrate Spurge/Spotted Sandmat	*Chamaesyce maculata* (L.) Small	Forb	Native
Indian Woodoats	*Chasmanthium latifolium* (Michx.) Yates	Grass	Native
Spotted Water Hemlock	*Cicuta maculata* L.	Forb	Native
Field Thistle	*Cirsium discolor* (Muhl. ex Willd.) Spreng.	Forb	Native
Yellow Thistle	*Cirsium horridulum* Michx.	Forb	Native
Carolina Coralbead	*Cocculus carolinus* (L.) DC.	Vine	Native
Asiatic Dayflower	*Commelina communis* L.	Forb	Non-Native
Virginia Dayflower	*Commelina virginica* L.	Forb	Native
Bluemist Flower	*Conoclinium coelestinum* (L.) DC.	Forb	Native
Canadian Horseweed	*Conyza canadensis** (L.) Cronquist	Forb	Native
Lanceleaf Tickseed/Coreopsis	*Coreopsis lanceolata* L.	Forb	Native
Flowering Dogwood	*Cornus florida* L.	Tree	Native
Wooly Croton	*Croton capitatus* Michx.	Forb	Native
Bermudagrass	*Cynodon dactylon** (L.) Pers.	Grass	Non-Native
Globe Flat Sedge	*Cyperus echinatus** (L.) Alph. Wood	Sedge	Native
Yellow Nut Sedge	*Cyperus esculentus* L.	Sedge	Non-Native
Many Spike Flat Sedge	*Cyperus polystachyos** Rottb.	Sedge	Native
Flat Sedge	*Cyperus* L. spp.*	Sedge	Native
Orchard Grass	*Dactylis glomerata* L.	Grass	Non-Native
Queen Anne's Lace	*Daucus carota** L.	Forb	Non-Native
Illinois Bundle flower	*Desmanthus illinoensis* (Michx.) MacMill. ex B.L.Rob. & Fernald	Legume	Native
Hoary Ticktrefoil	*Desmodium canescens* (L.) DC.	Forb	Native
Prostrate Ticktrefoil	*Desmodium rotundifolium* DC.	Forb	Native
Pine Barren Ticktrefoil	*Desmodium strictum* (Pursh) DC.	Forb	Native
Needleleaf Rosette Grass	*Dichanthelium aciculare** (Desv. ex Poir.) Gould & C.A.Clark	Grass	Native
Cypress Panicgrass	*Dichanthelium dichotomum** (L.) Gould	Grass	Native
Velvet Panicum	*Dichanthelium scoparium** (Lam.) Gould	Grass	Native
Roundseed Panicgrass	*Dichanthelium sphaerocarpon** (Elliott) Gould	Grass	Native
Rosette Grass	*Dichanthelium* (Hitchc. & Chase) Gould spp.*	Grass	Native
Southern Crabgrass	*Digitaria ciliaris** (Retz.) Koeler	Grass	Native
Smooth Crabgrass	*Digitaria ischaemum** (Schreb.) Schreb. ex Muhl.	Grass	Non-Native
Boykin's Clusterpea	*Dioclea multiflora* (Torr. & A. Gray) C.Mohr	Legume	Native
Virginia Buttonweed	*Diodia virginiana** L.	Forb	Native
Persimmon	*Diospyros virginiana* L.	Tree	Native
Clasping Coneflower	*Dracopis amplexicaulis* (Vahl) Cass.	Forb	Native
Barnyardgrass	*Echinochloa crus-galli* (L.) P.Beauv.	Grass	Non-Native
Needle Spike Rush	*Eleocharis acicularis* (L.) Roem. & Schult.	Sedge	Native
Blunt Spike Rush	*Eleocharis obtusa** (Willd.) Schult.	Sedge	Native
Spike Rush	*Eleocharis* R.Br. spp.	Sedge	Native

Table A.1 (Continued)

Carolina Elephantsfoot	*Elephantopus carolinianus* Raeusch.	Forb	Native
Daisy Fleabane/Sweet Scabious	*Erigeron annuus** (L.) Pers.	Forb	Native
Fleabane	*Erigeron* L. spp.*	Forb	Native
Prairie Fleabane	*Erigeron strigosus** Muhl. ex Willd.	Forb	Native
Dogfennel	*Eupatorium capillifolium** (Lam.) Small	Forb	Native
Common Boneset	*Eupatorium perfoliatum** L.	Forb	Native
Roundleaf Thoroughwort	*Eupatorium rotundifolium** L.	Forb	Native
Lateflowering Boneset	*Eupatorium serotinum** Michx.	Forb	Native
Flowering Spurge	*Euphorbia corollata* L.	Forb	Native
Slender Goldenrod	*Euthamia caroliniana* (L.) Greene ex Porter & Britton	Forb	Native
Goldenrod	*Euthamia* Nutt. ex Cass. spp.*	Forb	Native
Hollow-Stemmed Joe Pye Weed	*Eutrochium fistulosum* (Barratt) E.E.Lamont	Forb	Native
White Ash	*Fraxinus americana* L.	Tree	Native
Green Ash	*Fraxinus pennsylvanica** Marshall	Tree	Native
Downy Milkpea	*Galactia volubilis* (L.) Britton	Legume	Native
Slickwilly Bedstaw	*Galium aparine* L.	Forb	Native
Bluntleaf Bedstraw	*Galium obtusum* Bigelow	Forb	Native
Bedstraw	*Galium* L. spp.*	Forb	Native
Stiff Marsh Bedstraw	*Galium tinctorium* (L.) Scop.	Forb	Native
Spoonleafed Purple Everlasting Cudweed	*Gamochaeta purpurea* (L.) Cabrera	Forb	Native
Evening Trumpetflower	*Gelsemium sempervirens* (L.) W.T.Aiton	Vine	Native
Carolina Cranesbill Geranium	*Geranium carolinianum** L.	Forb	Native
Cutleaf Geranium	*Geranium dissectum** L.	Forb	Non-Native
Fine-leaved Bittter Sneezeweed	*Helenium amarum* (Raf.) H.Rock	Forb	Native
Common Sneezeweed	*Helenium autumnale* L.	Forb	Native
Swamp Sunflower	*Helianthus angustifolius* L.	Forb	Native
Indian Heliotrope	*Heliotropium indicum* L.	Forb	Non-Native
Swamp/Crimsoneyed Rosemallow	*Hibiscus moscheutos* L.	Shrub	Native
Queendevil Hawkweed	*Hieracium gronovii* L.	Forb	Native
Rattlesnake Hawkweed	*Hieracium venosum* L.	Forb	Native
Little Barley	*Hordeum pusillum* Nutt.	Grass	Native
Virginia/Eastern Waterleaf	*Hydrophyllum virginianum* L.	Forb	Native
St. Andrews Cross/St. Johns Wort	*Hypericum hypericoides* (L.) Crantz	Shrub	Native
Dwarf St. Johnswort	*Hypericum mutilum* L.	Shrub	Native
Hairy Cat's Ear	*Hypochaeris radicata* L.	Forb	Non-Native
Cat’s Ear	*Hypochaeris* L. spp.	Forb	Non-Native
Jewelweed/Touch-Me-Nots	*Impatiens capensis* Meerb.	Forb	Native
Morning Glory	*Ipomoea* L. spp.*	Forb	Unknown
Sumpweed/Annual Marsh Elder	*Iva annua* L.	Forb	Native
Smallflowering Morning Glory	*Jacquemontia tamnifolia* (L.) Griseb.	Forb	Native

Table A.1 (Continued)

Flat Tipped Rush	*Juncus acuminatus* Michx.	Rush	Native
Leathery Rush	*Juncus coriaceus* Mack.	Rush	Native
Common Rush	*Juncus effuses** L.	Rush	Native
Grassleaf Rush	*Juncus marginatus* Rostk.	Rush	Native
Manyheaded Rush	*Juncus polycephalus** Michx.	Rush	Native
Needle Pod Rush	*Juncus scirpoides** Lam.	Rush	Native
Rush	*Juncus* L. spp.*	Rush	Native
Path Rush/Poverty Rush	*Juncus tenuis** Willd.	Rush	Native
Eastern Red Cedar	*Juniperus virginiana** L.	Tree	Native
Weedy Dwarf Dandelion	*Krigia caespitosa* (Raf.) K.L.Chambers	Forb	Native
Japanese Clover	*Kummerowia striata** (Thunb.) Schindl.	Legume	Non-Native
Wild Canada Lettuce	*Lactuca canadensis** L.	Forb	Native
Woodland Lettuce	*Lactuca floridana** (L.) Gaertn.	Forb	Native
Henbit Deadnettle	*Lamium amplexicaule* L.	Forb	Non-Native
Purple Deadnettles	*Lamium purpureum* L.	Forb	Non-Native
Caley Pea Vine (Perennial Pea)	*Lathyrus hirsutus* L.	Legume	Non-Native
Narrowleaf Pinweed	*Lechea tenuifolia* Michx.	Forb	Native
Rice Cutgrass	*Leersia oryzoides* (L.) Sw.	Grass	Native
Mucronate Sprangletop	*Leptochloa panicea* (Retz.) Ohwi	Grass	Native
Serciea Lespedeza/Chinese Bushclover	*Lespedeza cuneata** (Dum. Cours.) G.Don	Legume	Non-Native
Ox-Eye Daisy	*Leucanthemum vulgare* Lam.	Forb	Non-Native
Tall Blazing Star	*Liatris aspera* Michx.	Forb	Native
Blazing Star Gayfeather	*Liatris mucronata* DC.	Forb	Native
Blazing Star	*Liatris* Gaertn. ex Schreb. spp.	Forb	Native
Sweetgum	*Liquidambar styraciflua** L.	Tree	Native
Cardinal Flower	*Lobelia cardinalis* L.	Forb	Native
Italian Annual Rye Grass	*Lolium perenne* L. ssp. *multiflorum** (Lam.) Husnot	Grass	Non-Native
Japanese Honeysuckle	*Lonicera japonica** Thunb.	Vine	Non-Native
Wingleaf Primrose Willow	*Ludwigia decurrens* Walter	Forb	Native
Angled-stem Primrose Willow	*Ludwigia leptocarpa* (Nutt.) H.Hara	Forb	Native
Marsh Seedbox	*Ludwigia palustris* (L.) Elliott	Forb	Native
Floating Primerose Willow	*Ludwigia peploides* (Kunth) P.H.Raven	Forb	Native
Creeping Primrose Willow	*Ludwigia repens* J.R.Forst.	Forb	Native
American Water Horehound Mint	*Lycopus americanus* Muhl. ex W.P.C.Barton	Forb	Native
Yellow Sweet Clover	*Melilotus officinalis* (L.) Lam.	Legume	Non-Native
Mint	*Mentha* L. spp.	Forb	Non-Native
Japanese Stilt Grass/Nepalese Browntop	*Microstegium vimineum* (Trin.) A.Camus	Grass	Non-Native
Black Gum	*Nyssa sylvatica* Marshall	Tree	Native
Pink Primrose	*Oenothera speciosa* Nutt.	Forb	Non-Native
Slender Yellow Woodsorel	*Oxalis dillenii** Jacq.	Forb	Native

Table A.1 (Continued)

Common Yellow Woodsorel	*Oxalis stricta** L.	Forb	Native
Sourwood	*Oxydendrum arboreum* (L.) DC.	Tree	Native
Small's Golden Ragwort	*Packera anonyma* (Alph. Wood) W.A.Weber & Á.Löve	Forb	Native
Butterweed Ragwort	*Packera glabella* (Poir.) C.Jeffrey	Forb	Native
Panic Grass	*Panicum* L. spp.*	Grass	Native
Swithgrass	*Panicum virgatum* L.	Grass	Native
Virginia Creeper	*Parthenocissus quinquefolia* (L.) Planch.	Vine	Native
Dallisgrass	*Paspalum dilatatum* Poir.	Grass	Non-Native
Field Paspalum	*Paspalum laeve* Michx.	Grass	Native
Bahiagrass	*Paspalum notatum** Flueggé	Grass	Non-Native
Vasey's Grass	*Paspalum urvillei** Steud.	Grass	Non-Native
Purple Passion Flower	*Passiflora incarnate** L.	Vine	Native
Beefstake Plant	*Perilla frutescens* (L.) Britton	Forb	Non-Native
Shortleaf Pine	*Pinus echinata* Mill.	Tree	Native
Pine	*Pinus* L. spp.	Tree	Native
Loblolly Pine	*Pinus taeda** L.	Tree	Native
Largebracted Plantain	*Plantago aristata* Michx.	Forb	Native
Narrowleaf English Plantain	*Plantago lanceolata** L.	Forb	Non-Native
Common Plantain	*Plantago major** L.	Forb	Non-Native
Virginia Plantain	*Plantago virginica* L.	Forb	Native
Camphor Pluchea	*Pluchea camphorata* (L.) DC.	Forb	Native
Stinkweed	*Pluchea odorata* (L.) Cass.	Forb	Native
Kentucky Bluegrass	*Poa pratensis* L.	Grass	Non-Native
Little Bluegrass	*Poa* L. spp.	Grass	Unknown
Oriental Lady's Thumb Smartweed	*Polygonum cespitosum** Blume, nom. inq.	Forb	Non-Native
Dense Flowered Knotweed	*Polygonum glabrum* Willd.	Forb	Native
Swamp Smartweed	*Polygonum hydropiperoides** Michx.	Forb	Native
Pennsylvania smartweed	*Polygonum pensylvanicum* L.	Forb	Native
Spotted Lady's Thumb Smartweed	*Polygonum persicaria* L.	Forb	Non-Native
Dotted Smartweed	*Polygonum punctatum* Elliott	Forb	Native
Wild Black Cherry	*Prunus serotina* Ehrh.	Tree	Native
Rabbit Tobacco	*Pseudognaphalium obtusifolium* (L.) Hilliard & B.L.Burtt	Forb	Native
Mock Bishopweed/Herb William	*Ptilimnium capillaceum* (Michx.) Raf.	Forb	Native
Whiteleaf Mountainmint	*Pycnanthemum albescens* Torr. & A.Gray	Forb	Native
Hoary Mountain Mint	*Pycnanthemum incanum* (L.) Michx.	Forb	Native
White Oak	*Quercus alba* L.	Tree	Native
Scarlett Oak	*Quercus coccinea* Münchh.	Tree	Native
Southern Red Oak	*Quercus falcata* Michx.	Tree	Native
Water Oak	*Quercus nigra* L.	Tree	Native
Pin Oak	*Quercus palustris* Münchh.	Tree	Native

Table A.1 (Continued)

Willow Oak	*Quercus phellos* L.	Tree	Native
Oak	*Quercus* L. spp.*	Tree	Native
Post Oak	*Quercus stellata* Wangenh.	Tree	Native
Littleleaf Buttercup	*Ranunculus abortivus* L.	Forb	Native
Early Buttercup	*Ranunculus fascicularis* Muhl. ex Bigelow	Forb	Native
Bristly Buttercup	*Ranunculus hispidus* Michx.	Forb	Native
Low Spearwort	*Ranunculus pusillus** Poir.	Forb	Native
Blisterwort Buttercup	*Ranunculus recurvatus* Poir.	Forb	Native
Creeping Buttercup	*Ranunculus repens** L.	Forb	Non-Native
Hairy Buttercup	*Ranunculus sardous** Crantz	Forb	Non-Native
Buttercup	*Ranunculus* L. spp. *	Forb	Unknown
Maryland Meadow Beauty	*Rhexia mariana* L.	Forb	Native
Snoutbean	*Rhynchosia* Lour. spp.	Forb	Native
Twining Snoutbean	*Rhynchosia tomentosa* (L.) Hook. & Arn.	Forb	Native
Shortbristle Horned Beaksedge	*Rhynchospora corniculata* (Lam.) A.Gray	Sedge	Native
Black Locust	*Robinia pseudoacacia* L.	Tree	Native
Sawtooth Blackberry	*Rubus argutus** Link	Vine	Native
Northern Dewberry	*Rubus flagellaris* Willd.	Vine	Native
Southern Dewberry	*Rubus trivialis** Michx.	Vine	Native
Black-eyed Susans	*Rudbeckia hirta* L.	Forb	Native
Curly Dock	*Rumex crispus** L.	Forb	Non-Native
Common Broadleafed Arrowhead	*Sagittaria latifolia* Willd.	Forb	Native
Black Willow	*Salix nigra** Marshall	Tree	Native
Lyre-Leaved Sage	*Salvia lyrata** L.	Forb	Native
Black Elderberry	*Sambucus nigra* L.	Shrub	Native
Tall Fescue	*Schedonorus phoenix** (Schreb.) Dumort., nom. cons.	Grass	Non-Native
Little Bluestem	*Schizachyrium scoparium* (Michx.) Nash	Grass	Native
Hairy Skullcap	*Scutellaria elliptica* Muhl. ex Spreng.	Forb	Native
Helmet Flower	*Scutellaria integrifolia* L.	Forb	Native
Crown Vetch	*Securigera varia* (L.) Lassen	Legume	Non-Native
Bigpod Coffeeweed	*Sesbania herbacea* (Mill.) McVaugh	Legume	Native
Marsh Bristlegrass	*Setaria parviflora** (Poir.) Kerguélen	Grass	Native
Yellow Foxtail	*Setaria pumila** (Poir.) Roem. & Schult.	Grass	Non-Native
Green Bristlegrass	*Setaria viridis** (L.) P.Beauv.	Grass	Non-Native
Hedge Mustard	*Sisymbrium officinale* (L.) Scop.	Forb	Non-Native
Narrowleafed Blue-eyed Grass	*Sisyrinchium angustifolium* Mill.	Forb	Native
Annual Blue-eyed Grass	*Sisyrinchium rosulatum* E.P.Bicknell	Forb	Native
Saw Greenbrier	*Smilax bona-nox* L.	Vine	Native
Cat Greenbrier	*Smilax glauca* Walter	Vine	Native
Laurel Greenbrier	*Smilax laurifolia* L.	Vine	Native

Table A.1 (Continued)

Roundleaf Greenbrier	*Smilax rotundifolia* L.	Vine	Native
Lanceleaf Greenbrier	*Smilax smallii* Morong	Vine	Native
Greenbrier	*Smilax* L. spp.	Vine	Native
Carolina Horsenettle	*Solanum carolinense* L.	Forb	Native
Tall Canada Goldenrod	*Solidago altissima** L.	Forb	Native
Canada Goldenrod	*Solidago canadensis** L.	Forb	Native
Anisescented Goldenrod	*Solidago odora** Aiton	Forb	Native
Goldenrod	*Solidago* L. spp.*	Forb	Native
Johnsongrass	*Sorghum halepense** (L.) Pers.	Grass	Non-Native
Hairy White Oldfield Aster	*Symphyotrichum pilosum** (Willd.) G.L.Nesom	Forb	Native
Aster	*Symphyotrichum* Nees spp.*	Forb	Native
Common Dandilion	*Taraxacum officinale* F.H.Wigg.	Forb	Non-Native
Eastern Poisoin Ivy	*Toxicodendron radicans* (L.) Kuntze	Vine	Native
White Nymph	*Trepocarpus aethusae* Nutt. ex DC.	Forb	Native
Purpletop Tridens	*Tridens flavus* (L.) Hitchc.	Grass	Native
Pink Rabbit-foot Clover	*Trifolium arvense* L.	Legume	Non-Native
Field Clover/Low Hop Clover	*Trifolium campestre** Schreb.	Legume	Non-Native
Crimson Clover	*Trifolium incarnatum** L.	Legume	Non-Native
Red Clover	*Trifolium pretense** L.	Legume	Non-Native
White Clover	*Trifolium repens* L.	Legume	Non-Native
Clover	*Trifolium* L. spp.	Legume	Non-Native
Common Venus's Looking Glass	*Triodanis perfoliata** (L.) Nieuwl.	Forb	Native
Winged Elm	*Ulmus alata** Michx.	Tree	Native
Unknown – Forb	Unknown	Forb	Unknown
Unknown – Grass	Unknown	Grass	Unknown
Unknown – Shrub	Unknown	Shrub	Unknown
Unknown – Tree	Unknown	Tree	Unknown
Unknown – Vine	Unknown	Vine	Unknown
Broadleaf Signalgrass	*Urochloa platyphylla* (Munro ex C.Wright) R.D.Webster	Grass	Native
Stinging Nettle	*Urtica dioica* L.	Forb	Native
Brazilian Vervain	*Verbena brasiliensis** Vell.	Forb	Non-Native
Tall Iron Weed	*Vernonia gigantea* (Walter) Trel.	Forb	Native
Cow/Bird/Tufted Vetch	*Vicia cracca** L.	Legume	Non-Native
Garden Vetch	*Vicia sativa** L.	Legume	Non-Native
Violet	*Viola* L. spp.	Forb	Unknown
Prostrate Blue/Purple Violet	*Viola walteri* House	Forb	Native
Summer Grapevine	*Vitis aestivalis* Michx.	Vine	Native
Muscadine Grape Vine	*Vitis rotundifolia* Michx.	Vine	Native
Japanese Wisteria	*Wisteria floribunda** (Willd.) DC.	Vine	Non-Native
Chinese Wisteria	*Wisteria sinensis** (Sims) DC.	Vine	Non-Native

Table A.1 (Continued)

Rough Cocklebur	*Xanthium strumarium* L.	Forb	Native

(*) Asterisks in the scientific name column indicate the most frequently seen >65% of the line transects.

Table A.2 Herbaceous and woody vegetation characteristics within mean percent coverage in different treatments during lowland elevations in fall 2010

Vegetation Plant Growth Form Categories During Fall 2010	Lowland Elevation (N=5)[a]								
	Mowed			Reduced Mowed			Reduced Mowed/Seeded		
	Mean (SE)	Range	Median	Mean (SE)	Range	Median	Mean (SE)	Range	Median
Native Herbaceous Plants (≤ 0.46m in height)									
Forbs	17.87 (5.04)	5.00 to 32.50	12.86	15.17 (5.12)	2.22 to 32.00	17.00	16.39 (4.07)	7.14 to 27.50	13.50
Grasses	0.54 (0.23)	0.00 to 1.00	0.71	0.81 (0.55)	0.00 to 2.78	0.00	0.36 (0.23)	0.00 to 1.11	0.00
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	0.33 (0.21)	0.00 to 1.00	0.00	2.00 (1.94)	0.00 to 9.75	0.00
Rushes & Sedges	0.79 (0.29)	0.00 to 2.50	0.61	0.15 (0.15)	0.00 to 1.50	0.00	1.07 (0.54)	0.00 to 4.50	0.00
Non-Native Herbaceous Plants (≤ 0.46m in height)									
Forbs	1.49 (0.82)	0.00 to 4.50	1.43	1.53 (0.84)	0.00 to 4.50	1.00	0.50 (0.39)	0.00 to 2.00	0.00
Grasses	54.28 (14.02)	4.50 to 86.25	52.86	70.33 (9.53)	35.50 to 88.00	75.63	61.84 (17.00)	1.00 to 94.38	69.44
Legumes	0.60 (0.60)	0.00 to 3.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.33 (0.33)	0.00 to 1.67	0.00
Rushes & Sedges	0.25 (0.20)	0.00 to 2.00	0.00	0.05 (0.05)	0.00 to 0.50	0.00	0.40 (0.40)	0.00 to 4.00	0.00
Unidentified Herbaceous Plants[b] (≤ 0.46m in height)	2.27 (1.39)	0.00 to 5.71	0.00	0.60 (0.28)	0.00 to 1.43	0.56	1.67 (0.63)	0.00 to 3.50	2.14
Total Herbaceous Plants	**79.60 (23.53)**	**0.00 to 86.25**	**68.47**	**88.97 (16.73)**	**0.00 to 88.00**	**94.19**	**84.56 (25.53)**	**0.00 to 94.38**	**85.08**
Native Woody Plants (≤ 0.46m in height)									
Shrubs & Trees	0.88 (0.42)	0.00 to 3.57	0.25	0.47 (0.20)	0.00 to 1.88	0.25	0.82 (0.34)	0.00 to 2.50	0.28
Vines	0.53 (0.41)	0.00 to 2.14	0.00	0.40 (0.29)	0.00 to 1.50	0.00	1.39 (0.44)	0.00 to 2.78	1.43
Non-Native Woody Plants (≤ 0.46m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.10 (0.10)	0.00 to 0.50	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.90 (0.76)	0.00 to 3.89	0.00
Unidentified Woody Plants[c] (≤ 0.46m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Woody Plants	**1.51 (0.93)**	**0.00 to 3.57**	**0.25**	**0.87 (0.49)**	**0.00 to 1.88**	**0.25**	**3.11 (1.54)**	**0.00 to 3.89**	**1.71**

Table A.2 (Continued)

Native Herbaceous Plants (≥ 0.46m - 0.91m in height)									
Forbs	10.48 (5.20)	0.00 to 27.50	7.86	8.69 (4.16)	1.11 to 22.00	2.86	9.91 (8.57)	0.00 to 44.00	0.56
Grasses	0.93 (0.42)	0.00 to 2.14	1.00	1.47 (0.92)	0.00 to 5.00	1.11	1.94 (0.85)	0.00 to 4.00	2.22
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	1.00 (0.88)	0.00 to 4.50	0.00	3.60 (2.91)	0.00 to 15.00	0.00
Rushes & Sedges	0.20 (0.20)	0.00 to 2.00	0.00	0.25 (0.17)	0.00 to 1.50	0.00	1.25 (0.69)	0.00 to 6.00	0.00
Non-Native Herbaceous Plants (≥ 0.46m - 0.91m in height)									
Forbs	0.62 (0.30)	0.00 to 1.50	0.50	0.80 (0.80)	0.00 to 4.00	0.00	0.59 (0.28)	0.00 to 1.43	0.50
Grasses	12.91 (5.52)	0.00 to 33.00	11.88	13.54 (5.41)	2.63 to 34.00	11.00	13.12 (6.75)	2.00 to 34.50	2.86
Legumes	0.33 (0.33)	0.00 to 1.67	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Rushes & Sedges	0.40 (0.35)	0.00 to 3.50	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.84 (0.78)	0.00 to 7.86	0.00
Unidentified Herbaceous Plants[b] (≥ 0.46m - 0.91m in height)	0.41 (0.28)	0.00 to 1.43	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.44 (0.44)	0.00 to 2.22	0.00
Total Herbaceous Plants	**26.28 (12.60)**	**0.00 to 33.00**	**21.24**	**25.75 (12.34)**	**0.00 to 34.00**	**14.97**	**31.69 (21.27)**	**0.00 to 44.00**	**6.14**
Native Woody Plants (≥ 0.46m - 0.91m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.18 (0.13)	0.00 to 1.25	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.00 (0.00)	0.00 to 0.00	0.00	0.20 (0.15)	0.00 to 0.75	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Non-Native Woody Plants (≥ 0.46m - 0.91m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Woody Plants[c] (≥ 0.46m - 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Woody Plants	**0.00 (0.00)**	**0.00 to 0.00**	**0.00**	**0.38 (0.28)**	**0.00 to 1.25**	**0.00**	**0.00 (0.00)**	**0.00 to 0.00**	**0.00**
Native Herbaceous Plants (≥ 0.91m in height)									
Forbs	5.70 (5.10)	0.00 to 26.00	0.00	2.10 (1.86)	0.00 to 9.50	0.00	2.60 (1.94)	0.00 to 3.00	0.00
Grasses	0.90 (0.60)	0.00 to 3.00	0.00	1.93 (0.82)	0.00 to 4.00	2.50	1.50 (1.16)	0.00 to 6.00	0.00
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	6.00 (4.85)	0.00 to 25.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00

Table A.2 (Continued)

Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Non-Native Herbaceous Plants (≥ 0.91m in height)									
Forbs	0.20 (0.20)	0.00 to 1.00	0.00	0.80 (0.80)	0.00 to 4.00	0.00	0.50 (0.50)	0.00 to 2.50	0.00
Grasses	13.10 (8.78)	0.00 to 47.00	6.00	2.03 (1.29)	0.00 to 7.00	1.50	8.25 (6.97)	0.00 to 36.00	1.50
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.25 (0.25)	0.00 to 2.50	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Herbaceous Plants[b] (≥ 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.10 (0.10)	0.00 to 0.50	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Herbaceous Plants	**19.90 (14.68)**	**0.00 to 47.00**	**6.00**	**13.21 (9.97)**	**0.00 to 25.00**	**4.00**	**12.85 (10.57)**	**0.00 to 36.00**	**1.50**
Native Woody Plants (≥ 0.91m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Non-Native Woody Plants (≥ 0.91m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Woody Plants[c] (≥ 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Woody Plants	**0.00 (0.00)**	**0.00 to 0.00**	**0.00**	**0.00 (0.00)**	**0.00 to 0.00**	**0.00**	**0.00 (0.00)**	**0.00 to 0.00**	**0.00**

a Three ≤ 30.48 m line transects on each study plot.
b Unidentified herbaceous plants were either indistinguishable based on floral characteristics or otherwise unidentifiable to species to determine native or non-native status.
c Unidentified woody plants were either indistinguishable based on floral characteristics or otherwise unidentifiable to species to determine native or non-native status.

Table A.3 Herbaceous and woody vegetation characteristics within mean percent coverage in different treatments during upland elevations in fall 2010.

Vegetation Plant Growth Form Categories During Fall 2010	Upland Elevation (N=5)[a]								
	Mowed			Reduced Mowed			Reduced Mowed/Seeded		
	Mean (SE)	Range	Median	Mean (SE)	Range	Median	Mean (SE)	Range	Median
Native Herbaceous Plants (≤ 0.46m in height)									
Forbs	2.72 (0.94)	0.91 to 5.00	1.67	2.30 (1.70)	0.00 to 8.75	0.00	2.79 (0.85)	0.00 to 5.00	3.33
Grasses	0.60 (0.60)	0.00 to 3.00	0.00	0.20 (0.20)	0.00 to 1.00	0.00	2.04 (0.98)	0.00 to 5.00	0.91
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Rushes & Sedges	0.10 (0.10)	0.00 to 1.00	0.00	0.16 (0.11)	0.00 to 1.00	0.00	0.22 (0.22)	0.00 to 2.22	0.00
Non-Native Herbaceous Plants (≤ 0.46m in height)									
Forbs	2.10 (0.95)	0.00 to 5.00	2.50	0.93 (0.61)	0.00 to 3.00	0.00	0.87 (0.65)	0.00 to 3.33	0.00
Grasses	81.42 (8.47)	55.00 to 97.50	91.82	74.64 (18.27)	6.00 to 114.00	81.25	73.58 (15.21)	14.00 to 97.27	82.5
Legumes	3.98 (3.98)	0.00 to 19.90	0.00	0.91 (0.91)	0.00 to 4.55	0.00	0.18 (0.18)	0.00 to 0.91	0.00
Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Herbaceous Plants[b] (≤ 0.46m in height)	1.50 (1.50)	0.91 to 7.50	0.00	0.00 (0.00)	0.00 to 0.00	0.00	4.75 (4.75)	0.00 to 23.75	0.00
Total Herbaceous Plants	**92.42 (16.54)**	**0.00 to 97.50**	**95.99**	**79.14 (21.80)**	**0.00 to 114.00**	**81.25**	**84.43 (22.84)**	**0.00 to 97.27**	**86.74**
Native Woody Plants (≤ 0.46m in height)									
Shrubs & Trees	0.37 (0.28)	0.00 to 2.73	0.00	0.09 (0.09)	0.00 to 0.91	0.00	0.39 (0.27)	0.00 to 2.73	0.00
Vines	7.11 (4.93)	0.00 to 25.00	0.00	1.78 (1.78)	0.00 to 8.89	0.00	3.50 (2.17)	0.00 to 11.67	1.82
Non-Native Woody Plants (≤ 0.46m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.00 (0.00)	0.00 to 0.00	0.00	0.18 (0.18)	0.00 to 0.91	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Woody Plants[c] (≤ 0.46m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Woody Plants	**7.48 (5.21)**	**0.00 to 25.00**	**0.00**	**2.05 (2.05)**	**0.00 to 8.89**	**0.00**	**3.89 (2.44)**	**0.00 to 11.67**	**1.82**

Table A.3 (Continued)

Native Herbaceous Plants (≥ 0.46m - 0.91m in height)									
Forbs	0.11 (0.11)	0.00 to 0.56	0.00	0.75 (0.75)	0.00 to 3.75	0.00	0.73 (0.36)	0.00 to 1.82	0.56
Grasses	0.40 (0.40)	0.00 to 2.00	0.00	0.76 (0.47)	0.00 to 2.00	0.00	0.75 (0.75)	0.00 to 3.75	0.00
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Rushes & Sedges	0.09 (0.09)	0.00 to 0.91	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.18 (0.18)	0.00 to 1.82	0.00
Non-Native Herbaceous Plants (≥ 0.46m - 0.91m in height)									
Forbs	0.62 (0.41)	0.00 to 2.00	0.00	1.24 (0.81)	0.00 to 4.00	0.00	0.42 (0.26)	0.00 to 1.11	0.00
Grasses	27.93 (10.68)	1.00 to 53.75	38.89	15.98 (6.81)	0.00 to 35.00	16.25	15.05 (6.30)	0.00 to 35.00	14.44
Legumes	7.98 (7.98)	0.00 to 39.90	0.00	0.18 (0.18)	0.00 to 0.91	0.00	3.45 (3.45)	0.00 to 17.27	0.00
Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Herbaceous Plants[b] (≥ 0.46m - 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	1.00 (1.00)	0.00 to 5.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Herbaceous Plants	**37.13 (19.67)**	**0.00 to 53.75**	**38.89**	**19.91 (10.01)**	**0.00 to 35.00**	**16.25**	**20.58 (11.30)**	**0.00 to 35.00**	**15.00**
Native Woody Plants (≥ 0.46m - 0.91m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.09 (0.09)	0.00 to 0.91	0.00	0.18 (0.18)	0.00 to 1.82	0.00
Vines	2.20 (2.20)	0.00 to 11.00	0.00	5.50 (5.50)	0.00 to 27.50	0.00	4.20 (4.20)	0.00 to 21.00	0.00
Non-Native Woody Plants (≥ 0.46m - 0.91m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	1.27 (1.27)	0.00 to 6.36	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.55 (0.55)	0.00 to 2.73	0.00
Unidentified Woody Plants[c] (≥ 0.46m - 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Woody Plants	**3.47 (3.47)**	**0.00 to 11.00**	**0.00**	**5.59 (5.59)**	**0.00 to 27.50**	**0.00**	**4.93 (4.93)**	**0.00 to 21.00**	**0.00**
Native Herbaceous Plants (≥ 0.91m in height)									
Forbs	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Grasses	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.42 (0.26)	0.00 to 1.11	0.00
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00

Table A.3 (Continued)

Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Non-Native Herbaceous Plants (≥ 0.91m in height)									
Forbs	0.00 (0.00)	0.00 to 0.00	0.00	0.11 (0.11)	0.00 to 0.56	0.00	0.22 (0.22)	0.00 to 1.11	0.00
Grasses	3.58 (2.19)	0.00 to 9.00	0.00	5.32 (3.27)	0.00 to 13.89	0.00	3.87 (2.64)	0.00 to 13.33	0.00
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Herbaceous Plants[b] (≥ 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Herbaceous Plants	**3.58 (2.19)**	**0.00 to 9.00**	**0.00**	**5.43 (3.38)**	**0.00 to 13.89**	**0.00**	**4.51 (3.12)**	**0.00 to 13.33**	**0.00**
Native Woody Plants (≥ 0.91m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Non-Native Woody Plants (≥ 0.91m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	1.45 (1.45)	0.00 to 7.27	0.00	0.25 (0.25)	0.00 to 1.25	0.00	0.55 (0.55)	0.00 to 2.73	0.00
Unidentified Woody Plants[c] (≥ 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Woody Plants	**1.45 (1.45)**	**0.00 to 7.27**	**0.00**	**0.25 (0.25)**	**0.00 to 1.25**	**0.00**	**0.55 (0.55)**	**0.00 to 2.73**	**0.00**

a Three ≤ 30.48 m line transects on each study plot.
b Unidentified herbaceous plants were either indistinguishable based on floral characteristics or otherwise unidentifiable to species to determine native or non-native status.
c Unidentified woody plants were either indistinguishable based on floral characteristics or otherwise unidentifiable to species to determine native or non-native status.

Table A.4 Herbaceous and woody vegetation characteristics within mean percent coverage in different treatments during lowland elevations in spring 2011.

Vegetation Plant Growth Form Categories During Spring 2011	Lowland Elevation (N=5)[a]								
	Mowed			Reduced Mowed			Reduced Mowed/Seeded		
	Mean (SE)	Range	Median	Mean (SE)	Range	Median	Mean (SE)	Range	Median
Native Herbaceous Plants (≤ 0.46m in height)									
Forbs	39.15 (11.19)	12.22 to 77.00	34.29	36.08 (11.78)	6.67 to 72.00	39.50	33.34 (6.90)	22.00 to 58.00	25.00
Grasses	6.45 (5.10)	0.00 to 26.67	2.00	1.30 (0.83)	0.00 to 4.00	0.00	2.31 (1.42)	0.00 to 6.00	0.00
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	6.70 (6.70)	0.00 to 33.50	0.00	5.90 (5.65)	0.00 to 28.50	0.00
Rushes & Sedges	3.21 (1.13)	0.00 to 11.50	2.54	3.04 (1.40)	0.00 to 14.50	2.07	6.99 (3.13)	0.00 to 31.50	3.50
Non-Native Herbaceous Plants (≤ 0.46m in height)									
Forbs	2.45 (0.86)	0.56 to 5.00	1.43	3.03 (0.96)	1.25 to 5.71	1.67	5.82 (2.19)	1.88 to 14.00	5.00
Grasses	86.88 (11.05)	48.50 to 115.71	93.50	70.57 (19.43)	10.56 to 129.29	77.50	74.12 (10.66)	37.78 to 100.71	76.50
Legumes	47.11 (15.78)	2.00 to 90.71	60.50	52.26 (14.54)	0.00 to 79.50	64.29	48.35 (14.70)	2.50 to 83.33	51.00
Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Herbaceous[b] Plants	1.71 (1.13)	0.00 to 6.00	0.56	0.85 (0.26)	0.00 to 1.43	1.00	0.47 (0.15)	0.00 to 1.43	0.28
Total Herbaceous Plants	**186.96 (46.24)**	**0.00 to 115.71**	**194.82**	**173.83 (55.90)**	**0.00 to 129.29**	**186.03**	**177.30 (44.80)**	**0.00 to 100.71**	**161.28**
Native Woody Plants (≤ 0.46m in height)									
Shrubs & Trees	0.89 (0.43)	0.00 to 4.50	0.60	1.12 (0.70)	0.00 to 7.00	0.25	1.11 (0.68)	0.00 to 7.00	0.25
Vines	1.68 (0.73)	0.00 to 3.89	1.00	0.25 (0.25)	0.00 to 1.25	0.00	1.29 (0.69)	0.00 to 3.89	0.63
Non-Native Woody Plants (≤ 0.46m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.44 (0.44)	0.00 to 2.22	0.00	0.30 (0.30)	0.00 to 1.50	0.00	1.83 (1.30)	0.00 to 6.67	0.00
Unidentified Woody Plants[c] (≤ 0.46m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.10 (0.10)	0.00 to 0.50	0.00
Total Woody Plants	**3.01 (1.60)**	**0.00 to 4.50**	**1.60**	**1.67 (1.25)**	**0.00 to 7.00**	**0.25**	**4.33 (2.77)**	**0.00 to 7.00**	**0.88**

Table A.4 (Continued)

Native Herbaceous Plants (≥ 0.46m - 0.91m in height)									
Forbs	9.65 (6.48)	0.00 to 35.00	5.71	6.17 (2.44)	0.00 to 14.50	5.71	8.75 (6.26)	0.56 to 33.50	3.57
Grasses	1.11 (1.11)	0.00 to 5.56	0.00	0.40 (0.40)	0.00 to 2.00	0.00	0.22 (0.22)	0.00 to 1.11	0.00
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Rushes & Sedges	1.89 (0.96)	0.00 to 10.00	0.60	1.49 (0.59)	0.00 to 4.50	0.75	3.07 (1.27)	0.00 to 12.50	1.61
Non-Native Herbaceous Plants (≥ 0.46m - 0.91m in height)									
Forbs	2.33 (1.30)	0.00 to 7.00	1.67	4.63 (3.53)	0.00 to 18.50	0.56	3.65 (2.72)	0.50 to 14.50	1.25
Grasses	23.96 (4.21)	11.67 to 37.14	22.50	35.75 (14.51)	10.00 to 90.56	28.00	26.53 (10.15)	8.00 to 59.44	16.00
Legumes	0.65 (0.43)	0.00 to 2.14	0.00	1.10 (0.98)	0.00 to 5.00	0.00	1.60 (1.21)	0.00 to 6.43	0.50
Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Herbaceous[b] Plants	0.50 (0.50)	0.00 to 2.50	0.00	0.40 (0.40)	0.00 to 2.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Herbaceous Plants	**40.09 (14.99)**	**0.00 to 37.14**	**30.48**	**49.94 (22.85)**	**0.00 to 90.56**	**35.02**	**43.82 (21.83)**	**0.00 to 59.44**	**22.93**
Native Woody Plants (≥ 0.46m - 0.91m in height)									
Shrubs & Trees	0.54 (0.33)	0.00 to 2.86	0.00	0.32 (0.25)	0.00 to 2.50	0.00	0.37 (0.20)	0.00 to 2.00	0.00
Vines	1.91 (1.12)	0.00 to 6.11	1.43	0.75 (0.75)	0.00 to 3.75	0.00	0.61 (0.28)	0.00 to 1.43	0.63
Non-Native Woody Plants (≥ 0.46m - 0.91m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.22 (0.22)	0.00 to 1.11	0.00	0.10 (0.10)	0.00 to 0.50	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Woody Plants[c] (≥ 0.46m - 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Woody Plants	**2.67 (1.67)**	**0.00 to 6.11**	**1.43**	**1.17 (1.10)**	**0.00 to 3.75**	**0.00**	**0.98 (0.48)**	**0.00 to 2.00**	**0.63**
Native Herbaceous Plants (≥ 0.91m in height)									
Forbs	0.00 (0.00)	0.00 to 0.00	0.00	2.10 (2.10)	0.00 to 10.50	0.00	0.90 (0.90)	0.00 to 4.50	0.00
Grasses	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00

Table A.4 (Continued)

Rushes & Sedges	0.50 (0.50)	0.00 to 5.00	0.00	1.90 (1.90)	0.00 to 19.00	0.00	0.60 (0.60)	0.00 to 6.00	0.00
Non-Native Herbaceous Plants (≥ 0.91m in height)									
Forbs	0.56 (0.56)	0.00 to 2.78	0.00	0.20 (0.20)	0.00 to 1.00	0.00	0.14 (0.14)	0.00 to 0.71	0.00
Grasses	21.93 (9.54)	0.00 to 55.63	15.00	43.01 (9.96)	10.00 to 67.78	41.00	26.21 (5.60)	12.86 to 42.00	28.00
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Herbaceous[b] Plants	0.20 (0.20)	0.00 to 1.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Herbaceous Plants	**23.19 (10.80)**	**0.00 to 55.63**	**15.00**	**47.21 (14.16)**	**0.00 to 67.78**	**41.00**	**27.85 (7.24)**	**0.00 to 42.00**	**28.00**
Native Woody Plants (≥ 0.91m in height)									
Shrubs & Trees	0.05 (0.05)	0.00 to 0.50	0.00	0.15 (0.15)	0.00 to 1.50	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Non-Native Woody Plants (≥ 0.91m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Woody Plants [c](≥ 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Woody Plants	**0.05 (0.05)**	**0.00 to 0.50**	**0.00**	**0.15 (0.15)**	**0.00 to 1.50**	**0.00**	**0.00 (0.00)**	**0.00 to 0.00**	**0.00**

a Three ≤ 30.48 m line transects on each study plot.
b Unidentified herbaceous plants were either indistinguishable based on floral characteristics or otherwise unidentifiable to species to determine native or non-native status.
c Unidentified woody plants were either indistinguishable based on floral characteristics or otherwise unidentifiable to species to determine native or non-native status.

Table A.5 Herbaceous and woody vegetation characteristics within mean percent coverage in different treatments during upland elevations in spring 2011.

Vegetation Plant Growth Form Categories During Spring 2011	Upland Elevation (N=5)[a]								
	Mowed			Reduced Mowed			Reduced Mowed/Seeded		
	Mean (SE)	Range	Median	Mean (SE)	Range	Median	Mean (SE)	Range	Median
Native Herbaceous Plants (≤ 0.46m in height)									
Forbs	17.13 (3.22)	7.78 to 26.25	16.00	18.52 (7.24)	0.00 to 43.75	13.64	16.47 (9.18)	0.00 to 48.75	8.18
Grasses	3.64 (3.64)	0.00 to 18.18	0.00	1.03 (0.76)	0.00 to 3.89	0.00	0.83 (0.53)	0.00 to 2.50	0.00
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Rushes & Sedges	0.367 (0.28)	0.00 to 2.78	0.00	0.50 (0.50)	0.00 to 5.00	0.00	0.31 (0.23)	0.00 to 2.22	0.00
Non-Native Herbaceous Plants (≤ 0.46m in height)									
Forbs	2.18 (1.72)	0.00 to 8.89	0.00	3.21 (2.42)	0.00 to 12.78	1.25	2.29 (1.80)	0.00 to 9.44	1.00
Grasses	109.55 (19.39)	67.00 to 175.00	101.25	111.01 (10.36)	76.00 to 139.09	117.50	117.63 (17.93)	52.00 to 161.00	123.33
Legumes	103.18 (18.31)	70.00 to 164.55	79.00	77.03 (12.34)	50.00 to 116.36	71.00	84.36 (16.11)	43.75 to 136.36	78.00
Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Herbaceous Plants[b] (≤ 0.46m in height)	1.07 (0.88)	0.00 to 7.78	0.00	0.00 (0.00)	0.00 to 0.00	0.00	1.75 (1.61)	0.00 to 8.18	0.00
Total Herbaceous Plants	**237.12 (47.44)**	**0.00 to 175.00**	**196.25**	**211.30 (33.62)**	**0.00 to 139.09**	**203.39**	**223.64 (47.39)**	**0.00 to 161.00**	**210.51**
Native Woody Plants (≤ 0.46m in height)									
Shrubs & Trees	0.77 (0.36)	0.00 to 2.73	0.00	0.27 (0.15)	0.00 to 1.25	0.00	0.36 (0.26)	0.00 to 2.50	0.00
Vines	1.33 (1.33)	0.00 to 6.67	0.00	2.41 (1.10)	0.00 to 5.56	2.50	2.72 (1.49)	0.00 to 6.67	0.91
Non-Native Woody Plants (≤ 0.46m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	3.27 (3.27)	0.00 to 16.36	0.00	0.18 (0.18)	0.00 to 0.91	0.00	1.82 (1.82)	0.00 to 9.09	0.00
Unidentified Woody Plants[c] (≤ 0.46m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Woody Plants	**5.37 (4.96)**	**0.00 to 16.36**	**0.00**	**2.86 (1.43)**	**0.00 to 5.56**	**2.50**	**4.90 (3.57)**	**0.00 to 9.09**	**0.91**

Table A.5 (Continued)

Native Herbaceous Plants (≥ 0.46m - 0.91m in height)									
Forbs	3.05 (2.42)	0.00 to 12.50	0.00	1.75 (1.75)	0.00 to 8.75	0.00	1.43 (0.65)	0.00 to 3.75	1.00
Grasses	1.35 (0.85)	0.00 to 4.00	0.00	1.36 (0.97)	0.00 to 5.00	0.00	0.25 (0.25)	0.00 to 1.25	0.00
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Rushes & Sedges	0.13 (0.13)	0.00 to 1.25	0.00	0.22 (0.22)	0.00 to 2.22	0.00	0.06 (0.06)	0.00 to 0.56	0.00
Non-Native Herbaceous Plants (≥ 0.46m - 0.91m in height)									
Forbs	1.29 (0.88)	0.00 to 4.44	0.00	1.76 (1.52)	0.00 to 7.78	0.00	1.53 (1.30)	0.00 to 6.67	0.00
Grasses	54.55 (14.64)	9.09 to 98.00	49.00	52.20 (7.70)	35.45 to 80.00	48.00	55.04 (12.07)	28.18 to 100.00	50.00
Legumes	14.00 (6.24)	0.00 to 35.45	12.78	7.46 (5.49)	0.00 to 29.09	3.75	11.32 (6.35)	1.25 to 36.36	7.00
Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Herbaceous Plants[b] (≥ 0.46m - 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.27 (0.27)	0.00 to 1.82	0.00
Total Herbaceous Plants	**74.37 (25.16)**	**0.00 to 98.00**	**61.78**	**64.75 (17.65)**	**0.00 to 80.00**	**51.75**	**69.90 (20.95)**	**0.00 to 100.00**	**58.00**
Native Woody Plants (≥ 0.46m - 0.91m in height)									
Shrubs & Trees	0.09 (0.09)	0.00 to 0.91	0.00	0.29 (0.21)	0.00 to 2.00	0.00	0.13 (0.13)	0.00 to 1.25	0.00
Vines	0.22 (0.22)	0.00 to 1.11	0.00	5.98 (3.18)	0.00 to 18.00	4.00	4.41 (2.98)	0.00 to 16.00	2.73
Non-Native Woody Plants (≥ 0.46m - 0.91m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.36 (0.36)	0.00 to 1.82	0.00	0.36 (0.36)	0.00 to 1.82	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Woody Plants[c] (≥ 0.46m - 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Woody Plants	**0.67 (0.67)**	**0.00 to 1.82**	**0.00**	**6.63 (3.75)**	**0.00 to 18.00**	**4.00**	**4.54 (3.11)**	**0.00 to 16.00**	**2.73**
Native Herbaceous Plants (≥ 0.91m in height)									
Forbs	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Grasses	0.00 (0.00)	0.00 to 0.00	0.00	0.60 (0.60)	0.00 to 3.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00

Table A.5 (Continued)

Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Non-Native Herbaceous Plants (≥ 0.91m in height)									
Forbs	0.75 (0.75)	0.00 to 3.75	0.00	0.51 (0.39)	0.00 to 2.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Grasses	16.21 (5.76)	4.00 to 37.78	13.00	21.60 (8.47)	4.00 to 52.00	16.67	30.02 (7.98)	7.00 to 48.89	38.75
Legumes	1.09 (1.09)	0.00 to 5.45	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.40 (0.40)	0.00 to 2.00	0.00
Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Herbaceous Plants[b] (≥ 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Herbaceous Plants	**18.05 (7.60)**	**0.00 to 37.78**	**13.00**	**22.71 (9.46)**	**0.00 to 52.00**	**16.67**	**30.42 (8.38)**	**0.00 to 48.89**	**38.75**
Native Woody Plants (≥ 0.91m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Non-Native Woody Plants (≥ 0.91m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Woody Plants[c] (≥ 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Woody Plants	**0.00 (0.00)**	**0.00 to 0.00**	**0.00**	**0.00 (0.00)**	**0.00 to 0.00**	**0.00**	**0.00 (0.00)**	**0.00 to 0.00**	**0.00**

a Three ≤ 30.48 m line transects on each study plot.

b Unidentified herbaceous plants were either indistinguishable based on floral characteristics or otherwise unidentifiable to species to determine native or non-native status.

c Unidentified woody plants were either indistinguishable based on floral characteristics or otherwise unidentifiable to species to determine native or non-native status.

Table A.6 Herbaceous and woody vegetation characteristics within mean percent coverage in different treatments during lowland elevations in fall 2011.

Vegetation Plant Growth Form Categories During Fall 2011	Lowland Elevation (N=5)[a]								
	Mowed			Reduced Mowed			Reduced Mowed/Seeded		
	Mean (SE)	Range	Median	Mean (SE)	Range	Median	Mean (SE)	Range	Median
Native Herbaceous Plants (≤ 0.46m in height)									
Forbs	31.61 (9.86)	4.00 to 58.50	36.25	26.12 (8.31)	7.22 to 52.86	24.50	28.29 (4.94)	14.00 to 38.57	35.00
Grasses	1.03 (0.58)	0.00 to 3.00	0.50	0.87 (0.65)	0.00 to 3.33	0.00	1.08 (0.56)	0.00 to 2.78	0.63
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	0.50 (0.50)	0.00 to 2.50	0.00	1.70 (1.70)	0.00 to 8.50	0.00
Rushes & Sedges	0.31 (0.17)	0.00 to 1.50	0.00	0.47 (0.15)	0.00 to 1.50	0.57	1.78 (1.09)	0.00 to 11.00	0.25
Non-Native Herbaceous Plants (≤ 0.46m in height)									
Forbs	1.15 (0.76)	0.00 to 3.75	0.00	0.89 (0.34)	0.00 to 2.00	0.71	1.83 (0.39)	0.50 to 2.50	2.22
Grasses	87.51 (21.96)	5.50 to 137.14	97.00	84.35 (20.02)	8.50 to 127.14	92.00	80.81 (16.10)	21.50 to 108.13	95.00
Legumes	12.83 (11.94)	0.00 to 60.56	1.00	0.92 (0.68)	0.00 to 3.50	0.00	25.04 (19.75)	0.00 to 103.33	7.86
Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Herbaceous Plants[b] (≤ 0.46m in height)	1.27 (0.65)	0.00 to 3.13	0.71	1.29 (1.16)	0.00 to 10.56	0.25	0.96 (0.52)	0.00 to 2.86	1.00
Total Herbaceous Plants	**135.71 (45.92)**	**0.00 to 137.14**	**135.46**	**115.41 (31.81)**	**0.00 to 127.14**	**118.03**	**141.49 (45.05)**	**0.00 to 108.13**	**141.96**
Native Woody Plants (≤ 0.46m in height)									
Shrubs & Trees	0.67 (0.33)	0.00 to 2.86	0.00	0.59 (0.41)	0.00 to 4.00	0.00	1.20 (0.46)	0.00 to 3.75	0.57
Vines	5.14 (3.28)	0.00 to 15.71	0.00	1.05 (0.66)	0.00 to 3.13	0.00	5.20 (2.39)	0.00 to 12.78	3.13
Non-Native Woody Plants (≤ 0.46m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	1.78 (1.78)	0.00 to 8.89	0.00	0.40 (0.40)	0.00 to 2.00	0.00	2.35 (2.19)	0.00 to 11.11	0.00
Unidentified Woody Plants[c] (≤ 0.46m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Woody Plants	**7.59 (5.39)**	**0.00 to 15.71**	**0.00**	**2.04 (1.47)**	**0.00 to 4.00**	**0.00**	**8.75 (5.04)**	**0.00 to 12.78**	**3.70**

Table A.6 (Continued)

Native Herbaceous Plants (≥ 0.46m - 0.91m in height)									
Forbs	30.54 (13.25)	3.13 to 77.00	27.86	21.23 (9.17)	0.00 to 51.50	24.29	11.38 (6.36)	0.63 to 35.50	4.00
Grasses	4.46 (2.47)	0.00 to 13.50	4.29	2.35 (0.67)	0.00 to 4.00	2.50	2.40 (0.70)	1.11 to 5.00	2.14
Legumes	0.40 (0.40)	0.00 to 2.00	0.00	0.50 (0.50)	0.00 to 2.50	0.00	5.30 (5.05)	0.00 to 25.50	0.00
Rushes & Sedges	0.82 (0.75)	0.00 to 7.50	0.00	0.00 (0.00)	0.00 to 0.00	0.00	1.29 (1.01)	0.00 to 10.00	0.00
Non-Native Herbaceous Plants (≥ 0.46m - 0.91m in height)									
Forbs	0.43 (0.19)	0.00 to 1.00	0.50	0.97 (0.35)	0.00 to 2.00	0.71	0.39 (0.25)	0.00 to 1.25	0.00
Grasses	53.78 (9.26)	20.00 to 73.13	55.00	46.36 (12.27)	17.50 to 83.33	35.71	44.82 (11.71)	15.00 to 77.50	42.14
Legumes	0.56 (0.56)	0.00 to 2.78	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.22 (0.22)	0.00 to 1.11	0.00
Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.54 (0.41)	0.00 to 4.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Herbaceous Plants[b] (≥ 0.46m - 0.91m in height)	0.10 (0.10)	0.00 to 0.50	0.00	0.97 (0.61)	0.00 to 2.86	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Herbaceous Plants	**91.09 (26.98)**	**0.00 to 77.00**	**87.65**	**72.92 (23.98)**	**0.00 to 83.33**	**63.21**	**65.80 (25.30)**	**0.00 to 77.50**	**48.28**
Native Woody Plants (≥ 0.46m - 0.91m in height)									
Shrubs & Trees	0.26 (0.20)	0.00 to 2.00	0.00	0.15 (0.15)	0.00 to 1.50	0.00	0.27 (0.20)	0.00 to 2.00	0.00
Vines	0.63 (0.39)	0.00 to 1.67	0.00	0.38 (0.38)	0.00 to 1.88	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Non-Native Woody Plants (≥ 0.46m - 0.91m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Woody Plants[c] (≥ 0.46m - 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Woody Plants	**0.89 (0.59)**	**0.00 to 2.00**	**0.00**	**0.53 (0.53)**	**0.00 to 1.88**	**0.00**	**0.27 (0.20)**	**0.00 to 2.00**	**0.00**
Native Herbaceous Plants (≥ 0.91m in height)									
Forbs	18.32 (15.71)	0.00 to 81.00	2.86	22.17 (17.25)	0.00 to 90.50	7.86	21.04 (19.52)	0.00 to 99.00	0.50
Grasses	0.54 (0.39)	0.00 to 2.00	0.00	2.18 (1.02)	0.00 to 6.00	1.50	4.30 (4.05)	0.00 to 20.50	0.00

Table A.6 (Continued)

Legumes	0.00 (0.00)	0.00 to 0.00	0.00	6.00 (6.00)	0.00 to 30.00	0.00	6.38 (5.92)	0.00 to 30.00	0.00
Rushes & Sedges	0.45 (0.45)	0.00 to 4.50	0.00	2.35 (2.35)	0.00 to 23.50	0.00	0.80 (0.80)	0.00 to 8.00	0.00
Non-Native Herbaceous Plants (≥ 0.91m in height)									
Forbs	0.20 (0.20)	0.00 to 1.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.43 (0.43)	0.00 to 2.14	0.00
Grasses	23.03 (8.61)	2.22 to 53.50	16.43	14.18 (6.59)	1.88 to 39.50	10.00	9.33 (4.18)	2.86 to 25.50	5.56
Legumes	2.11 (2.11)	0.00 to 10.56	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Herbaceous Plants[b] (≥ 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Herbaceous Plants	**44.65 (27.47)**	**0.00 to 81.00**	**19.29**	**46.88 (33.21)**	**0.00 to 90.50**	**19.36**	**42.28 (34.90)**	**0.00 to 99.00**	**6.06**
Native Woody Plants (≥ 0.91m in height)									
Shrubs & Trees	0.82 (0.75)	0.00 to 7.50	0.00	0.05 (0.05)	0.00 to 0.50	0.00	0.30 (0.30)	0.00 to 3.00	0.00
Vines	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Non-Native Woody Plants (≥ 0.91m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Woody Plants[c] (≥ 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Woody Plants	**0.82 (0.75)**	**0.00 to 7.50**	**0.00**	**0.05 (0.05)**	**0.00 to 0.50**	**0.00**	**0.30 (0.30)**	**0.00 to 3.00**	**0.00**

a Three ≤ 30.48 m line transects on each study plot.

b Unidentified herbaceous plants were either indistinguishable based on floral characteristics or otherwise unidentifiable to species to determine native or non-native status.

c Unidentified woody plants were either indistinguishable based on floral characteristics or otherwise unidentifiable to species to determine native or non-native status.

Table A.7 Herbaceous and woody vegetation characteristics within mean percent coverage in different treatments during upland elevations in fall 2011.

Vegetation Plant Growth Form Categories During Fall 2011	Upland Elevation (N=5)[a]								
	Mowed			Reduced Mowed			Reduced Mowed/Seeded		
	Mean (SE)	Range	Median	Mean (SE)	Range	Median	Mean (SE)	Range	Median
Native Herbaceous Plants (≤ 0.46m in height)									
Forbs	5.81 (1.18)	1.67 to 8.00	6.36	9.83 (4.42)	0.00 to 26.00	6.36	8.02 (2.21)	1.00 to 13.00	7.22
Grasses	1.10 (0.51)	0.00 to 2.50	1.00	0.00 (0.00)	0.00 to 0.00	0.00	0.78 (0.34)	0.00 to 1.67	1.00
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.11 (0.11)	0.00 to 0.56	0.00
Rushes & Sedges	0.06 (0.06)	0.00 to 0.56	0.00	0.19 (0.13)	0.00 to 1.00	0.00	0.10 (0.10)	0.00 to 1.00	0.00
Non-Native Herbaceous Plants (≤ 0.46m in height)									
Forbs	2.15 (1.00)	0.00 to 5.00	2.00	2.02 (1.16)	0.00 to 6.11	1.00	1.16 (0.72)	0.00 to 3.89	0.91
Grasses	104.54 (5.17)	89.44 to 121.25	105.00	100.04 (6.37)	79.00 to 111.25	107.27	108.66 (7.15)	90.56 to 130.00	102.73
Legumes	6.68 (2.05)	0.00 to 11.82	6.00	1.65 (0.97)	0.00 to 5.45	1.00	3.38 (2.21)	0.00 to 10.91	0.00
Rushes & Sedges	0.13 (0.13)	0.00 to 1.25	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Herbaceous Plants[b] (≤ 0.46m in height)	1.06 (0.70)	0.00 to 3.75	0.56	0.65 (0.44)	0.00 to 3.00	0.00	0.84 (0.36)	0.00 to 1.82	1.11
Total Herbaceous Plants	**121.51 (10.78)**	**0.00 to 121.25**	**120.92**	**114.38 (13.49)**	**0.00 to 111.25**	**115.63**	**123.05 (13.20)**	**0.00 to 130.00**	**112.97**
Native Woody Plants (≤ 0.46m in height)									
Shrubs & Trees	0.62 (0.35)	0.00 to 2.73	0.00	0.06 (0.06)	0.00 to 0.56	0.00	0.18 (0.13)	0.00 to 1.25	0.00
Vines	4.10 (3.57)	0.00 to 18.33	0.91	15.49 (8.17)	0.00 to 44.00	12.22	13.65 (8.54)	0.00 to 46.00	5.45
Non-Native Woody Plants (≤ 0.46m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	4.73 (4.73)	0.00 to 23.64	0.00	0.36 (0.36)	0.00 to 1.82	0.00	3.27 (3.27)	0.00 to 16.36	0.00
Unidentified Woody Plants[c] (≤ 0.46m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Woody Plants	**9.45 (8.65)**	**0.00 to 23.64**	**0.91**	**15.91 (9.13)**	**0.00 to 44.00**	**12.22**	**17.10 (11.94)**	**0.00 to 46.00**	**5.45**

Table A.7 (Continued)

Native Herbaceous Plants (≥ 0.46m - 0.91m in height)									
Forbs	2.10 (0.88)	0.00 to 4.00	2.73	3.15 (1.74)	0.00 to 7.50	1.00	4.30 (3.20)	0.00 to 17.00	1.11
Grasses	1.00 (1.00)	0.00 to 5.00	0.00	1.15 (0.70)	0.00 to 3.00	0.00	0.25 (0.25)	0.00 to 1.25	0.00
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Non-Native Herbaceous Plants (≥ 0.46m - 0.91m in height)									
Forbs	0.31 (0.20)	0.00 to 1.00	0.00	0.47 (0.29)	0.00 to 1.25	0.00	0.44 (0.44)	0.00 to 2.22	0.00
Grasses	36.88 (9.27)	18.00 to 71.00	36.25	43.63 (5.75)	25.56 to 59.00	43.75	50.97 (5.43)	38.18 to 69.00	46.25
Legumes	7.64 (7.64)	0.00 to 38.18	0.00	0.18 (0.18)	0.00 to 0.91	0.00	2.00 (2.00)	0.00 to 10.00	0.00
Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.50 (0.50)	0.00 to 5.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Herbaceous Plants[b] (≥ 0.46m - 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.20 (0.20)	0.00 to 1.00	0.00
Total Herbaceous Plants	**47.93 (18.99)**	**0.00 to 71.00**	**38.98**	**49.08 (9.16)**	**0.00 to 59.00**	**44.75**	**58.16 (11.52)**	**0.00 to 69.00**	**47.36**
Native Woody Plants (≥ 0.46m - 0.91m in height)									
Shrubs & Trees	1.11 (0.91)	0.00 to 9.09	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.27 (0.15)	0.00 to 1.25	0.00
Vines	0.00 (0.00)	0.00 to 0.00	0.00	8.40 (8.40)	0.00 to 42.00	0.00	8.00 (8.00)	0.00 to 40.00	0.00
Non-Native Woody Plants (≥ 0.46m - 0.91m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Woody Plants[c] (≥ 0.46m - 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Woody Plants	**1.11 (0.91)**	**0.00 to 9.09**	**0.00**	**8.40 (8.40)**	**0.00 to 42.00**	**0.00**	**8.27 (8.15)**	**0.00 to 40.00**	**0.00**
Native Herbaceous Plants (≥ 0.91m in height)									
Forbs	0.90 (0.56)	0.00 to 2.50	0.00	2.00 (2.00)	0.00 to 10.00	0.00	1.27 (1.27)	0.00 to 6.36	0.00
Grasses	0.40 (0.40)	0.00 to 2.00	0.00	0.80 (0.80)	0.00 to 4.00	0.00	0.36 (0.36)	0.00 to 1.82	0.00
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00

Table A.7 (Continued)

Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Non-Native Herbaceous Plants (≥ 0.91m in height)									
Forbs	0.25 (0.25)	0.00 to 1.25	0.00	1.51 (1.38)	0.00 to 7.00	0.00	0.40 (0.40)	0.00 to 2.00	0.00
Grasses	26.25 (10.16)	0.91 to 46.00	41.11	19.62 (7.51)	3.00 to 41.82	12.50	15.10 (6.35)	3.00 to 36.67	10.00
Legumes	2.55 (2.55)	0.00 to 12.73	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Herbaceous Plants[b] (≥ 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Herbaceous Plants	**30.02 (13.92)**	**0.00 to 46.00**	**41.11**	**23.93 (11.69)**	**0.00 to 41.82**	**12.50**	**17.13 (8.38)**	**0.00 to 36.67**	**10.00**
Native Woody Plants (≥ 0.91m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.27 (0.27)	0.00 to 2.73	0.00
Vines	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Non-Native Woody Plants (≥ 0.91m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Woody Plants[c] (≥ 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Woody Plants	**0.00 (0.00)**	**0.00 to 0.00**	**0.00**	**0.00 (0.00)**	**0.00 to 0.00**	**0.00**	**0.27 (0.27)**	**0.00 to 2.73**	**0.00**

a Three ≤ 30.48 m line transects on each study plot.

b Unidentified herbaceous plants were either indistinguishable based on floral characteristics or otherwise unidentifiable to species to determine native or non-native status.

c Unidentified woody plants were either indistinguishable based on floral characteristics or otherwise unidentifiable to species to determine native or non-native status.

Table A.8 Herbaceous and woody vegetation characteristics within mean percent coverage in different treatments during lowland elevations in spring 2012.

Vegetation Plant Growth Form Categories During Spring 2012	Lowland Elevation (N=5)[a]								
	Mowed			Reduced Mowed			Reduced Mowed/Seeded		
	Mean (SE)	Range	Median	Mean (SE)	Range	Median	Mean (SE)	Range	Median
Native Herbaceous Plants (≤ 0.46m in height)									
Forbs	39.51 (9.22)	11.25 to 62.50	45.71	25.22 (5.19)	10.00 to 41.00	25.71	24.12 (7.23)	5.63 to 48.00	24.50
Grasses	2.67 (1.40)	0.00 to 7.00	0.71	3.23 (0.92)	1.11 to 6.00	3.13	4.08 (1.46)	1.25 to 8.00	2.50
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.10 (0.10)	0.00 to 0.50	0.00
Rushes & Sedges	6.14 (2.33)	0.00 to 25.00	4.38	4.43 (1.56)	0.00 to 15.00	3.22	8.41 (4.40)	0.00 to 45.50	2.54
Non-Native Herbaceous Plants (≤ 0.46m in height)									
Forbs	7.87 (2.86)	0.56 to 15.50	7.14	5.30 (1.88)	0.00 to 11.00	5.00	7.53 (4.51)	2.22 to 25.50	3.13
Grasses	82.08 (21.98)	9.50 to 136.88	97.50	90.66 (11.87)	59.50 to 125.50	83.13	95.66 (14.59)	53.50 to 130.63	104.00
Legumes	27.61 (9.62)	0.00 to 51.67	20.50	32.80 (11.13)	1.00 to 63.75	27.14	38.96 (11.70)	3.50 to 70.63	48.89
Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Herbaceous Plants[b] (≤ 0.46m in height)	7.19 (4.37)	0.00 to 41.11	1.36	2.96 (1.46)	0.00 to 13.33	1.57	2.69 (1.65)	0.00 to 15.00	1.36
Total Herbaceous Plants	**173.07 (51.78)**	**0.00 to 136.88**	**177.30**	**164.60 (34.01)**	**0.00 to 125.50**	**148.90**	**181.55 (45.64)**	**0.00 to 130.63**	**186.92**
Native Woody Plants (≤ 0.46m in height)									
Shrubs & Trees	4.98 (4.24)	0.00 to 43.00	0.53	2.47 (1.70)	0.00 to 17.50	0.50	2.03 (1.21)	0.00 to 12.00	0.53
Vines	12.03 (5.77)	0.50 to 28.89	8.00	2.01 (1.13)	0.00 to 5.00	0.56	8.07 (3.81)	0.00 to 20.56	4.29
Non-Native Woody Plants (≤ 0.46m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.00 (0.00)	0.00 to 0.00	0.00	1.79 (1.46)	0.00 to 7.50	0.00	1.09 (0.39)	0.00 to 2.22	1.25
Unidentified Woody Plants[c] (≤ 0.46m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.13 (0.13)	0.00 to 0.63	0.00
Total Woody Plants	**17.01 (10.01)**	**0.00 to 43.00**	**8.53**	**6.27 (4.29)**	**0.00 to 17.50**	**1.06**	**11.32 (5.54)**	**0.00 to 20.56**	**6.07**

Table A.8 (Continued)

Native Herbaceous Plants (≥ 0.46m - 0.91m in height)									
Forbs	16.07 (12.92)	0.00 to 67.50	5.71	8.24 (3.46)	0.00 to 19.00	6.43	11.45 (9.41)	0.00 to 49.00	2.86
Grasses	0.85 (0.59)	0.00 to 3.00	0.00	0.83 (0.42)	0.00 to 2.00	0.50	1.28 (0.56)	0.00 to 2.78	1.50
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	6.60 (6.60)	0.00 to 33.00	0.00	5.40 (5.40)	0.00 to 27.00	0.00
Rushes & Sedges	1.11 (0.66)	0.00 to 5.50	0.00	0.95 (0.47)	0.00 to 4.00	0.00	1.62 (0.69)	0.00 to 5.50	0.28
Non-Native Herbaceous Plants (≥ 0.46m - 0.91m in height)									
Forbs	0.65 (0.30)	0.00 to 1.50	0.63	0.40 (0.24)	0.00 to 1.00	0.00	1.34 (1.05)	0.00 to 5.50	0.50
Grasses	23.06 (8.25)	7.22 to 55.00	18.00	25.86 (9.65)	6.43 to 60.00	16.88	23.93 (7.00)	7.00 to 41.88	19.00
Legumes	1.51 (1.24)	0.00 to 6.43	0.50	1.01 (0.41)	0.00 to 2.50	1.00	0.90 (0.51)	0.00 to 2.78	0.71
Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Herbaceous Plants[b] (≥ 0.46m - 0.91m in height)	1.78 (1.44)	0.00 to 13.33	0.00	0.59 (0.53)	0.00 to 4.44	0.00	0.20 (0.20)	0.00 to 1.00	0.00
Total Herbaceous Plants	**45.03 (25.40)**	**0.00 to 67.50**	**24.84**	**44.48 (21.78)**	**0.00 to 60.00**	**24.81**	**46.12 (24.82)**	**0.00 to 49.00**	**24.85**
Native Woody Plants (≥ 0.46m - 0.91m in height)									
Shrubs & Trees	1.11 (0.80)	0.00 to 8.00	0.00	1.03 (0.79)	0.00 to 8.00	0.00	0.37 (0.20)	0.00 to 1.50	0.00
Vines	0.44 (0.44)	0.00 to 2.22	0.00	0.63 (0.63)	0.00 to 3.13	0.00	0.44 (0.44)	0.00 to 2.22	0.00
Non-Native Woody Plants (≥ 0.46m - 0.91m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.00 (0.00)	0.00 to 0.00	0.00	0.10 (0.10)	0.00 to 0.50	0.00	0.22 (0.22)	0.00 to 1.11	0.00
Unidentified Woody Plants[c] (≥ 0.46m - 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Woody Plants	**1.55 (1.24)**	**0.00 to 8.00**	**0.00**	**1.76 (1.52)**	**0.00 to 8.00**	**0.00**	**1.03 (0.86)**	**0.00 to 2.22**	**0.00**
Native Herbaceous Plants (≥ 0.91m in height)									
Forbs	4.30 (4.30)	0.00 to 21.50	0.00	10.34 (9.79)	0.00 to 49.50	0.71	9.30 (9.30)	0.00 to 46.50	0.00
Grasses	3.95 (2.82)	0.00 to 15.00	1.88	3.16 (0.74)	1.11 to 5.63	3.00	3.34 (1.41)	0.00 to 8.50	2.50
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00

Table A.8 (Continued)

Rushes & Sedges	2.20 (1.99)	0.00 to 20.00	0.00	4.00 (3.89)	0.00 to 39.00	0.00	2.00 (2.00)	0.00 to 20.00	0.00
Non-Native Herbaceous Plants (≥ 0.91m in height)									
Forbs	0.10 (0.10)	0.00 to 0.50	0.00	1.70 (1.18)	0.00 to 6.00	0.00	0.74 (0.58)	0.00 to 3.00	0.00
Grasses	7.32 (3.87)	0.00 to 19.38	3.00	7.02 (2.34)	1.00 to 14.50	6.43	0.52 (0.33)	0.00 to 1.50	0.00
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Herbaceous Plants[b] (≥ 0.91m in height)	0.30 (0.30)	0.00 to 1.50	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Herbaceous Plants	**18.17 (13.38)**	**0.00 to 21.50**	**4.88**	**26.22 (17.94)**	**0.00 to 49.50**	**10.14**	**15.90 (13.62)**	**0.00 to 46.50**	**2.50**
Native Woody Plants (≥ 0.91m in height)									
Shrubs & Trees	0.18 (0.13)	0.00 to 1.25	0.00	0.55 (0.29)	0.00 to 2.50	0.00	0.10 (0.10)	0.00 to 1.00	0.00
Vines	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Non-Native Woody Plants (≥ 0.91m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Woody Plants[c] (≥ 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Woody Plants	**0.18 (0.13)**	**0.00 to 1.25**	**0.00**	**0.55 (0.29)**	**0.00 to 2.50**	**0.00**	**0.10 (0.10)**	**0.00 to 1.00**	**0.00**

a Three ≤ 30.48 m line transects on each study plot.

b Unidentified herbaceous plants were either indistinguishable based on floral characteristics or otherwise unidentifiable to species to determine native or non-native status.

c Unidentified woody plants were either indistinguishable based on floral characteristics or otherwise unidentifiable to species to determine native or non-native status.

Table A.9 Herbaceous and woody vegetation characteristics within mean percent coverage in different treatments during upland elevations in spring 2012.

Vegetation Plant Growth Form Categories During Spring 2012	Upland Elevation (N=5)[a]								
	Mowed			Reduced Mowed			Reduced Mowed/Seeded		
	Mean (SE)	Range	Median	Mean (SE)	Range	Median	Mean (SE)	Range	Median
Native Herbaceous Plants (≤ 0.46m in height)									
Forbs	20.40 (4.13)	9.50 to 30.00	17.50	18.84 (7.80)	5.00 to 45.00	11.00	18.39 (5.05)	5.00 to 34.00	15.45
Grasses	0.40 (0.24)	0.00 to 1.00	0.00	0.65 (0.53)	0.00 to 2.73	0.00	0.10 (0.10)	0.00 to 0.50	0.00
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Rushes & Sedges	0.85 (0.53)	0.00 to 5.00	0.00	1.64 (0.82)	0.00 to 7.50	0.46	0.62 (0.35)	0.00 to 2.73	0.00
Non-Native Herbaceous Plants (≤ 0.46m in height)									
Forbs	3.45 (1.76)	0.00 to 10.00	2.00	2.10 (0.75)	0.00 to 4.50	2.00	1.33 (0.58)	0.00 to 3.50	1.00
Grasses	102.41 (3.53)	92.00 to 111.82	101.00	100.05 (8.28)	71.00 to 122.50	102.73	104.49 (10.21)	66.00 to 126.25	108.18
Legumes	75.65 (7.40)	57.00 to 98.00	70.00	59.72 (11.30)	26.36 to 88.00	68.00	61.20 (14.30)	23.75 to 109.00	53.00
Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Herbaceous Plants[b] (≤ 0.46m in height)	1.25 (0.82)	0.00 to 7.00	0.00	1.15 (0.44)	0.00 to 2.73	1.00	0.70 (0.53)	0.00 to 4.55	0.00
Total Herbaceous Plants	**204.41 (18.41)**	**0.00 to 111.82**	**190.50**	**184.15 (29.92)**	**0.00 to 122.50**	**185.19**	**186.83 (31.12)**	**0.00 to 126.25**	**177.63**
Native Woody Plants (≤ 0.46m in height)									
Shrubs & Trees	0.10 (0.10)	0.00 to 1.00	0.00	0.68 (0.40)	0.00 to 3.75	0.00	0.25 (0.25)	0.00 to 2.50	0.00
Vines	5.53 (5.00)	0.00 to 25.50	0.91	4.20 (3.12)	0.00 to 16.50	2.00	7.74 (3.67)	0.00 to 19.50	8.18
Non-Native Woody Plants (≤ 0.46m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	4.00 (4.00)	0.00 to 20.00	0.00	0.50 (0.50)	0.00 to 2.50	0.00	2.91 (2.91)	0.00 to 14.55	0.00
Unidentified Woody Plants[c] (≤ 0.46m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.10 (0.10)	0.00 to 1.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Woody Plants	**9.63 (9.10)**	**0.00 to 25.50**	**0.91**	**5.48 (4.12)**	**0.00 to 16.50**	**2.00**	**10.90 (6.83)**	**0.00 to 19.50**	**8.18**

Table A.9 (Continued)

Native Herbaceous Plants (≥ 0.46m - 0.91m in height)									
Forbs	1.35 (0.83)	0.00 to 4.50	1.00	1.15 (0.76)	0.00 to 3.75	0.00	1.53 (0.67)	0.00 to 4.00	1.25
Grasses	0.00 (0.00)	0.00 to 0.00	0.00	0.75 (0.53)	0.00 to 2.73	0.00	0.20 (0.20)	0.00 to 1.00	0.00
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Rushes & Sedges	0.25 (0.25)	0.00 to 4.50	0.00	0.20 (0.20)	0.00 to 2.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Non-Native Herbaceous Plants (≥ 0.46m - 0.91m in height)									
Forbs	0.25 (0.25)	0.00 to 1.25	0.00	0.25 (0.25)	0.00 to 1.25	0.00	0.30 (0.30)	0.00 to 1.50	0.00
Grasses	15.71 (6.94)	0.00 to 38.00	18.75	19.52 (6.56)	4.00 to 43.50	16.36	24.11 (8.29)	2.00 to 50.50	26.25
Legumes	4.10 (2.39)	0.00 to 12.00	1.25	4.00 (2.81)	0.00 to 15.00	2.00	0.63 (0.26)	0.00 to 1.25	0.91
Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Herbaceous Plants[b] (≥ 0.46m - 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Herbaceous Plants	**21.66 (10.66)**	**0.00 to 38.00**	**21.00**	**25.87 (11.11)**	**0.00 to 43.50**	**18.36**	**26.77 (9.72)**	**0.00 to 50.50**	**28.41**
Native Woody Plants (≥ 0.46m - 0.91m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.70 (0.70)	0.00 to 7.00	0.00	0.18 (0.18)	0.00 to 1.82	0.00
Vines	0.20 (0.20)	0.00 to 1.00	0.00	0.20 (0.20)	0.00 to 1.00	0.00	0.60 (0.60)	0.00 to 3.00	0.00
Non-Native Woody Plants (≥ 0.46m - 0.91m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.18 (0.18)	0.00 to 0.91	0.00	0.73 (0.73)	0.00 to 3.64	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Woody Plants[c] (≥ 0.46m - 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Woody Plants	**0.38 (0.38)**	**0.00 to 1.00**	**0.00**	**1.63 (1.63)**	**0.00 to 7.00**	**0.00**	**0.78 (0.78)**	**0.00 to 3.00**	**0.00**
Native Herbaceous Plants (≥ 0.91m in height)									
Forbs	0.00 (0.00)	0.00 to 0.00	0.00	0.60 (0.48)	0.00 to 2.50	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Grasses	0.55 (0.55)	0.00 to 2.73	0.00	0.60 (0.40)	0.00 to 2.00	0.00	0.18 (0.18)	0.00 to 0.91	0.00
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00

Table A.9 (Continued)

Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Non-Native Herbaceous Plants (≥ 0.91m in height)									
Forbs	0.50 (0.50)	0.00 to 2.50	0.00	0.50 (0.50)	0.00 to 2.50	0.00	0.80 (0.51)	0.00 to 2.50	0.00
Grasses	8.29 (4.44)	0.00 to 23.50	5.45	7.60 (5.46)	0.00 to 28.00	0.00	4.80 (3.50)	0.00 to 18.00	0.00
Legumes	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Rushes & Sedges	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Herbaceous Plants[b] (≥ 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Herbaceous Plants	**9.34 (5.49)**	**0.00 to 23.50**	**5.45**	**9.30 (6.84)**	**0.00 to 28.00**	**0.00**	**5.78 (4.19)**	**0.00 to 18.00**	**0.00**
Native Woody Plants (≥ 0.91m in height)									
Shrubs & Trees	0.55 (0.55)	0.00 to 5.45	0.00	0.10 (0.10)	0.00 to 1.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Non-Native Woody Plants (≥ 0.91m in height)									
Shrubs & Trees	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vines	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Unidentified Woody Plants[c] (≥ 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Woody Plants	**0.55 (0.55)**	**0.00 to 5.45**	**0.00**	**0.10 (0.10)**	**0.00 to 1.00**	**0.00**	**0.00 (0.00)**	**0.00 to 0.00**	**0.00**

a Three ≤ 30.48 m line transects on each study plot.
b Unidentified herbaceous plants were either indistinguishable based on floral characteristics or otherwise unidentifiable to species to determine native or non-native status.
c Unidentified woody plants were either indistinguishable based on floral characteristics or otherwise unidentifiable to species to determine native or non-native status.

Table A.10 Number of herbaceous and woody vegetation growth forms of each species detected during fall 2010 to spring 2012.

Species Richness Detected along Line Intercepts													
		Fall 2010[a]			Spring 2011[b]			Fall 2011[a]			Spring 2012[b]		
Elevation	**Growth Forms**	Mowed	Reduced Mowed	Reduced Mowed/Seeded	Mowed	Reduced Mowed	Reduced Mowed/Seeded	Mowed	Reduced Mowed	Reduced Mowed/Seeded	Mowed	Reduced Mowed	Reduced Mowed/Seeded
Lowland	Native Forbs	39	33	26	57	49	47	61	58	51	56	47	52
Lowland	Non-Native Forbs	6	6	4	11	11	16	7	4	7	8	10	10
Lowland	Unknown Forbs	3	4	7	5	9	6	7	6	6	15	7	13
Upland	Native Forbs	9	3	7	22	22	17	16	23	20	28	23	28
Upland	Non-Native Forbs	5	3	3	6	5	6	6	5	6	7	7	6
Upland	Unknown Forbs	1	1	1	2	0	2	3	4	4	6	6	6
Lowland	Native Grasses	8	7	9	5	4	5	6	8	10	9	9	9
Lowland	Non-Native Grasses	23	25	26	28	28	29	28	29	31	25	21	22
Lowland	Unknown Grasses	0	1	0	0	0	1	0	1	0	3	3	4
Upland	Native Grasses	2	2	6	2	5	3	4	3	5	4	5	2
Upland	Non-Native Grasses	17	14	17	27	30	29	27	24	23	22	23	22
Upland	Unknown Grasses	0	0	0	2	0	1	0	1	1	1	0	1
Lowland	Native Legumes	0	2	1	0	1	2	1	1	3	0	1	1
Lowland	Non-Native Legumes	2	0	1	20	17	21	6	3	5	15	18	17
Upland	Native Legumes	0	0	0	0	0	0	0	0	1	0	0	0
Upland	Non-Native Legumes	1	1	1	18	18	19	7	5	3	16	14	16
Lowland	Native Rushes and Sedges Combined	7	3	7	13	9	13	5	7	7	14	12	15
Lowland	Non-Native Rushes and Sedges Combined	1	2	2	0	0	0	0	2	0	0	0	0
Upland	Native Rushes and Sedges Combined	2	2	2	3	1	2	1	2	1	3	8	3
Upland	Non-Native Rushes and Sedges Combined	0	0	0	0	0	0	0	0	0	0	0	0
Upland	Unknown Rushes and Sedges Combined	0	0	0	0	0	0	1	1	0	0	0	0

Table A.10 (Continued)

Lowland	Native Shrubs and Trees Combined	7	6	8	8	9	15	8	7	14	16	15	16
Lowland	Non-Native Shrubs and Trees Combined	0	0	0	0	0	0	0	0	0	0	0	0
Upland	Native Shrubs and Trees Combined	2	2	4	4	6	3	3	1	6	2	6	3
Upland	Non-Native Shrubs and Trees Combined	0	0	0	0	0	0	0	0	0	0	0	0
Upland	Unknown Shrubs and Trees Combined	0	0	0	0	0	0	0	0	0	0	1	0
Lowland	Native Vines	4	1	6	8	1	5	6	3	7	10	5	8
Lowland	Non-Native Vines	1	1	2	1	1	2	1	1	2	0	2	5
Lowland	Unknown Vines	0	0	0	0	0	1	0	0	0	0	0	1
Upland	Native Vines	3	2	3	3	6	4	2	5	4	4	3	3
Upland	Non-Native Vines	1	2	1	1	1	1	1	1	1	1	2	1

a Fall Seasons sampling were during mid-August – October
b Spring Seasons sampling were during April – June

Table A.11 Herbaceous and woody vegetation characteristics and ground litter debris in lowland elevations according to different height categories.

Vegetation Plant Growth Form Categories During Fall 2010	Lowland Elevation (N=5)[a]								
	Mowed			Reduced Mowed			Reduced Mowed/Seeded		
	Mean (SE)	Range	Median	Mean (SE)	Range	Median	Mean (SE)	Range	Median
Total Herbaceous Plants (< 0.46m in height)	79.60 (23.53)	0.00 to 86.25	68.47	88.97 (16.73)	0.00 to 88.00	94.19	84.56 (25.53)	0.00 to 94.38	85.08
Total Woody Plants (< 0.46m in height)	1.51 (0.93)	0.00 to 3.57	0.25	0.87(0.49)	0.00 to 1.88	0.25	3.11 (1.54)	0.00 to 3.89	1.71
Total Herbaceous Plants (> 0.46m - 0.91m in height)	26.28 (12.60)	0.00 to 33.00	21.24	25.75 (12.34)	0.00 to 34.00	14.97	31.69 (21.27)	0.00 to 44.00	6.14
Total Woody Plants (> 0.46m - 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.38 (0.28)	0.00 to 1.25	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Total Herbaceous Plants (> 0.91m in height)	19.90 (14.68)	0.00 to 47.00	6.00	13.21 (9.97)	0.00 to 25.00	4.00	12.85 (10.57)	0.00 to 36.00	1.50
Total Woody Plants (> 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vegetation Plant Growth Form Categories During Spring 2011	Lowland Elevation (N=5)[a]								
	Mowed			Reduced Mowed			Reduced Mowed/Seeded		
	Mean (SE)	Range	Median	Mean (SE)	Range	Median	Mean (SE)	Range	Median
Total Herbaceous Plants (< 0.46m in height)	186.96 (46.24)	0.00 to 115.71	194.82	173.83 (55.90)	0.00 to 129.29	186.03	177.30 (44.80)	0.00 to 100.71	161.28
Total Woody Plants (< 0.46m in height)	3.01 (1.60)	0.00 to 4.50	1.60	1.67 (1.25)	0.00 to 7.00	0.25	4.33 (2.77)	0.00 to 7.00	0.88
Total Herbaceous Plants (> 0.46m - 0.91m in height)	40.09 (14.99)	0.00 to 37.14	30.48	49.94 (22.85)	0.00 to 90.56	35.02	43.82 (21.83)	0.00 to 59.44	22.93
Total Woody Plants (> 0.46m - 0.91m in height)	2.67 (1.67)	0.00 to 6.11	1.43	1.17 (1.10)	0.00 to 3.75	0.00	0.98 (0.48)	0.00 to 2.00	0.63
Total Herbaceous Plants (> 0.91m in height)	23.19 (10.80)	0.00 to 55.63	15.00	47.21 (14.16)	0.00 to 67.78	41.00	27.85 (7.24)	0.00 to 42.00	28.00

Table A.11 (Continued)

Total Woody Plants (> 0.91m in height)	0.05 (0.05)	0.00 to 0.50	0.00	0.15 (0.15)	0.00 to 1.50	0.00	0.00 (0.00)	0.00 to 0.00	0.00
Vegetation Plant Growth Form Categories During Fall 2011	Lowland Elevation (N=5)[a]								
	Mowed			Reduced Mowed			Reduced Mowed/Seeded		
	Mean (SE)	Range	Median	Mean (SE)	Range	Median	Mean (SE)	Range	Median
Total Herbaceous Plants (< 0.46m in height)	135.71 (45.92)	0.00 to 137.14	135.46	115.41 (31.81)	0.00 to 127.14	118.03	141.49 (45.05)	0.00 to 108.13	141.96
Total Woody Plants (< 0.46m in height)	7.59 (5.39)	0.00 to 15.71	0.00	2.04 (1.47)	0.00 to 4.00	0.00	8.75 (5.04)	0.00 to 12.78	3.70
Total Herbaceous Plants (> 0.46m - 0.91m in height)	91.09 (26.98)	0.00 to 77.00	87.65	72.92 (23.98)	0.00 to 83.33	63.21	65.80 (25.30)	0.00 to 77.50	48.28
Total Woody Plants (> 0.46m - 0.91m in height)	0.89 (0.59)	0.00 to 2.00	0.00	0.53 (0.53)	0.00 to 1.88	0.00	0.27 (0.20)	0.00 to 2.00	0.00
Total Herbaceous Plants (> 0.91m in height)	44.65 (27.47)	0.00 to 81.00	19.29	46.88 (33.21)	0.00 to 90.50	19.36	42.28 (34.90)	0.00 to 99.00	6.06
Total Woody Plants (> 0.91m in height)	0.82 (0.75)	0.00 to 7.50	0.00	0.05 (0.05)	0.00 to 0.50	0.00	0.30 (0.30)	0.00 to 3.00	0.00
Vegetation Plant Growth Form Categories During Spring 2012	Lowland Elevation (N=5)[a]								
	Mowed			Reduced Mowed			Reduced Mowed/Seeded		
	Mean (SE)	Range	Median	Mean (SE)	Range	Median	Mean (SE)	Range	Median
Total Herbaceous Plants (< 0.46m in height)	173.07 (51.78)	0.00 to 136.88	177.30	164.60 (34.01)	0.00 to 125.50	148.90	181.55 (45.64)	0.00 to 130.63	186.92
Total Woody Plants (< 0.46m in height)	17.01 (10.01)	0.00 to 43.00	8.53	6.27 (4.29)	0.00 to 17.50	1.06	11.32 (5.54)	0.00 to 20.56	6.07
Total Herbaceous Plants (> 0.46m - 0.91m in height)	45.03 (25.40)	0.00 to 67.50	24.84	44.48 (21.78)	0.00 to 60.00	24.81	46.12 (24.82)	0.00 to 49.00	24.85
Total Woody Plants (> 0.46m - 0.91m in height)	1.55 (1.24)	0.00 to 8.00	0.00	1.76 (1.52)	0.00 to 8.00	0.00	1.03 (0.86)	0.00 to 2.22	0.00
Total Herbaceous Plants (> 0.91m in height)	18.17 (13.38)	0.00 to 21.50	4.88	26.22 (17.94)	0.00 to 49.50	10.14	15.90 (13.62)	0.00 to 46.50	2.50
Total Woody Plants (> 0.91m in height)	0.18 (0.13)	0.00 to 1.25	0.00	0.55 (0.29)	0.00 to 2.50	0.00	0.10 (0.10)	0.00 to 1.00	0.00

Table A.11 (Continued)

Percent Coverage within Treatments						
Ground Cover Characteristics	Lowland Elevation (N=5)[a]					
	Mowed		Reduced Mowed		Reduced Mowed/Seeded	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Fall Sampling Season 2010[b]						
Bare Ground	13.34 (± 9.22)	0.00-47.22	5.74 (± 4.45)	0.00-23.00	4.41 (± 3.59)	0.00-18.50
Debris[c]	17.83 (± 6.82)	4.29-39.38	23.87 (± 6.09)	2.14-36.25	19.46 (± 6.42)	4.29-43.13
Spring Sampling Season 2011[d]						
Bare Ground	8.97 (+ 4.59)	0.00-25.56	3.05 (+ 2.75)	0.00-14.00	3.93 (± 1.82)	0.00-9.29
Debris[c]	19.56 (+ 2.82)	14.50-30.00	18.86 (+ 6.19)	1.67-37.50	28.97 (± 7.58)	12.22-55.00
Fall Sampling Season 2011[b]						
Bare Ground	3.20 (+ 1.93)	0.00-10.00	0.00 (+ 0.00)	0.00-0.00	0.68 (± 0.44)	0.00-2.14
Debris[c]	8.06 (+ 3.08)	0.00-14.38	7.90 (+ 3.30)	0.00-20.00	6.79 (± 2.72)	2.00-16.88
Spring Sampling Season 2012[d]						
Bare Ground	3.04 (+ 1.61)	0.00-8.33	0.25 (+ 0.25)	0.00-1.25	0.00 (± 0.00)	0.00-0.00
Debris[c]	34.34 (+ 6.11)	17.22-50.71	29.17 (+ 5.40)	17.00-47.86	39.39 (± 3.74)	32.78-50.00

a Three ≤ 30.48 m line transects on each study plot.
b Fall Seasons sampling were during mid-August – October.
c Debris includes leaf and other vegetation litter and fine woody debris.
d Spring Seasons sampling were during April – June.

Table A.12 Herbaceous and woody vegetation characteristics and ground litter debris in upland elevations according to different height categories.

Vegetation Plant Growth Form Categories During Fall 2010	Upland Elevation (N=5)[a]								
	Mowed			Reduced Mowed			Reduced Mowed/Seeded		
	Mean (SE)	Range	Median	Mean (SE)	Range	Median	Mean (SE)	Range	Median
Total Herbaceous Plants (< 0.46m in height)	92.42 (16.54)	0.00 to 97.50	95.99	79.14 (21.80)	0.00 to 114.00	81.25	84.43 (22.84)	0.00 to 97.27	86.74
Total Woody Plants (< 0.46m in height)	7.48 (5.21)	0.00 to 25.00	0.00	2.05 (2.05)	0.00 to 8.89	0.00	3.89 (2.44)	0.00 to 11.67	1.82
Total Herbaceous Plants (> 0.46m - 0.91m in height)	37.13 (19.67)	0.00 to 53.75	38.89	19.91 (10.01)	0.00 to 35.00	16.25	20.58 (11.30)	0.00 to 35.00	15.00
Total Woody Plants (> 0.46m - 0.91m in height)	3.47 (3.47)	0.00 to 11.00	0.00	5.59 (5.59)	0.00 to 27.50	0.00	4.93 (4.93)	0.00 to 21.00	0.00
Total Herbaceous Plants (> 0.91m in height)	3.58 (2.19)	0.00 to 9.00	0.00	5.43 (3.38)	0.00 to 13.89	0.00	4.51 (3.12)	0.00 to 13.33	0.00
Total Woody Plants (> 0.91m in height)	1.45 (1.45)	0.00 to 7.27	0.00	0.25 (0.25)	0.00 to 1.25	0.00	0.55 (0.55)	0.00 to 2.73	0.00
Vegetation Plant Growth Form Categories During Spring 2011	Upland Elevation (N=5)[a]								
	Mowed			Reduced Mowed			Reduced Mowed/Seeded		
	Mean (SE)	Range	Median	Mean (SE)	Range	Median	Mean (SE)	Range	Median
Total Herbaceous Plants (< 0.46m in height)	237.12 (47.44)	0.00 to 175.00	196.25	211.30 (33.62)	0.00 to 139.09	203.39	223.64 (47.39)	0.00 to 161.00	210.51
Total Woody Plants (< 0.46m in height)	5.37 (4.96)	0.00 to 16.36	0.00	2.86 (1.43)	0.00 to 5.56	2.50	4.90 (3.57)	0.00 to 9.09	0.91
Total Herbaceous Plants (> 0.46m - 0.91m in height)	74.37 (25.16)	0.00 to 98.00	61.78	64.75 (17.65)	0.00 to 80.00	51.75	69.90 (20.95)	0.00 to 100.00	58.00
Total Woody Plants (> 0.46m - 0.91m in height)	0.67 (0.67)	0.00 to 1.82	0.00	6.63 (3.75)	0.00 to 18.00	4.00	4.54 (3.11)	0.00 to 16.00	2.73
Total Herbaceous Plants (> 0.91m in height)	18.05 (7.60)	0.00 to 37.78	13.00	22.71 (9.46)	0.00 to 52.00	16.67	30.42 (8.38)	0.00 to 48.89	38.75
Total Woody Plants (> 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00

Table A.12 (Continued)

Vegetation Plant Growth Form Categories During Fall 2011	Upland Elevation (N=5)[a]								
	Mowed			Reduced Mowed			Reduced Mowed/Seeded		
	Mean (SE)	Range	Median	Mean (SE)	Range	Median	Mean (SE)	Range	Median
Total Herbaceous Plants (< 0.46m in height)	121.51 (10.78)	0.00 to 121.25	120.92	114.38 (13.49)	0.00 to 111.25	115.63	123.05 (13.20)	0.00 to 130.00	112.97
Total Woody Plants (< 0.46m in height)	9.45 (8.65)	0.00 to 23.64	0.91	15.91 (9.13)	0.00 to 44.00	12.22	17.10 (11.94)	0.00 to 46.00	5.45
Total Herbaceous Plants (> 0.46m - 0.91m in height)	47.93 (18.99)	0.00 to 71.00	38.98	49.08 (9.16)	0.00 to 59.00	44.75	58.16 (11.52)	0.00 to 69.00	47.36
Total Woody Plants (> 0.46m - 0.91m in height)	1.11 (0.91)	0.00 to 9.09	0.00	8.40 (8.40)	0.00 to 42.00	0.00	8.27 (8.15)	0.00 to 40.00	0.00
Total Herbaceous Plants (> 0.91m in height)	30.02 (13.92)	0.00 to 46.00	41.11	23.93 (11.69)	0.00 to 41.82	12.50	17.13 (8.38)	0.00 to 36.67	10.00
Total Woody Plants (> 0.91m in height)	0.00 (0.00)	0.00 to 0.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00	0.27 (0.27)	0.00 to 2.73	0.00

Vegetation Plant Growth Form Categories During Spring 2012	Upland Elevation (N=5)[a]								
	Mowed			Reduced Mowed			Reduced Mowed/Seeded		
	Mean (SE)	Range	Median	Mean (SE)	Range	Median	Mean (SE)	Range	Median
Total Herbaceous Plants (< 0.46m in height)	204.41 (18.41)	0.00 to 111.82	190.50	184.15 (29.92)	0.00 to 122.50	185.19	186.83 (31.12)	0.00 to 126.25	177.63
Total Woody Plants (< 0.46m in height)	9.63 (9.10)	0.00 to 25.50	0.91	5.48 (4.12)	0.00 to 16.50	2.00	10.90 (6.83)	0.00 to 19.50	8.18
Total Herbaceous Plants (> 0.46m - 0.91m in height)	21.66 (10.66)	0.00 to 38.00	21.00	25.87 (11.11)	0.00 to 43.50	18.36	26.77 (9.72)	0.00 to 50.50	28.41
Total Woody Plants (> 0.46m - 0.91m in height)	0.38 (0.38)	0.00 to 1.00	0.00	1.63 (1.63)	0.00 to 7.00	0.00	0.78 (0.78)	0.00 to 3.00	0.00
Total Herbaceous Plants (> 0.91m in height)	9.34 (5.49)	0.00 to 23.50	5.45	9.30 (6.84)	0.00 to 28.00	0.00	5.78 (4.19)	0.00 to 18.00	0.00
Total Woody Plants (> 0.91m in height)	0.55 (0.55)	0.00 to 5.45	0.00	0.10 (0.10)	0.00 to 1.00	0.00	0.00 (0.00)	0.00 to 0.00	0.00

Table A.12 (Continued)

Percent Coverage within Treatments						
Ground Cover Characteristics	Upland Elevation (N=5) [a]					
	Mowed		Reduced Mowed		Reduced Mowed/Seeded	
	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Fall Sampling Season 2010[b]						
Bare Ground	13.02 (12.75)	0.00-64.00	12.20 (12.20)	0.00-61.00	19.11 (18.97)	0.00-95.00
Debris[c]	14.06 (5.70)	0.00-33.89	17.51 (6.09)	4.00-40.00	14.06 (5.85)	0.00-34.44
Spring Sampling Season 2011[d]						
Bare Ground	8.30 (6.72)	0.00-35.00	7.50 (6.89)	0.00-35.00	5.70 (5.10)	0.00-26.00
Debris[c]	7.94 (3.31)	0.00-20.00	16.76 (5.45)	1.00-31.25	11.51 (3.95)	0.00-22.50
Fall Sampling Season 2011[b]						
Bare Ground	1.75 (1.09)	0.00-5.00	8.60 (8.60)	0.00-43.00	3.42 (3.15)	0.00-16.00
Debris[c]	12.16 (5.62)	2.00-32.78	13.59 (5.02)	1.0-27.22	8.86 (3.03)	1.00-15.56
Spring Sampling Season 2012[d]						
Bare Ground	1.80 (1.80)	0.00-9.00	1.80 (1.80)	0.00-9.00	1.36 (0.97)	0.00-5.00
Debris[c]	31.99 (5.26)	17.00-48.75	35.59 (4.22)	24.00-45.45	42.48 (5.46)	29.00-55.00

a Three $\leq$ 30.48 m line transects on each study plot.
b Fall Seasons sampling were during mid-August – October.
c Debris includes leaf and other vegetation litter and fine woody debris.
d Spring Seasons sampling were during April – June.

Table A.13 Eigenvalues and Broken-stick methodology for determining Principle Component Analyses (PCA).

Year	Season	Elevation	Principal Component	Variance Explained	Cumulative Variance	Eigenvalue	Broken-stick
2010	Fall	Lowland	1	27.17%	27.17%	3.53	3.18
2010	Fall	Lowland	2	19.49%	46.67%	2.53	2.18
2010	Fall	Lowland	3	13.24%	59.90%	1.72	1.68
2010	Fall	Lowland	4	10.93%	70.84%	1.42	1.35
2010	Fall	Lowland	5	8.31%	79.15%	1.08	1.10
2010	Fall	Upland	1	32.78%	32.78%	3.28	2.93
2010	Fall	Upland	2	18.28%	51.07%	1.83	1.93
2011	Spring	Lowland	1	40.28%	40.28%	4.83	3.10
2011	Spring	Lowland	2	23.98%	64.25%	2.88	2.10
2011	Spring	Lowland	3	15.51%	79.77%	1.86	1.60
2011	Spring	Lowland	4	7.03%	86.80%	0.84	1.27
2011	Spring	Upland	1	36.00%	36.00%	3.96	3.02
2011	Spring	Upland	2	21.00%	57.00%	2.31	2.02
2011	Spring	Upland	3	15.90%	72.90%	1.75	1.52
2011	Spring	Upland	4	10.90%	83.90%	1.2	1.19
2011	Spring	Upland	5	6.00%	89.90%	0.66	0.94
2011	Fall	Lowland	1	35.18%	35.18%	4.57	3.18
2011	Fall	Lowland	2	16.75%	51.93%	2.19	2.18
2011	Fall	Lowland	3	15.09%	67.02%	1.96	1.68
2011	Fall	Lowland	4	9.80%	76.82%	1.27	1.35
2011	Fall	Upland	1	25.61%	25.61%	3.33	3.18
2011	Fall	Upland	2	19.53%	45.15%	2.54	2.18
2011	Fall	Upland	3	13.23%	58.38%	1.72	1.68
2011	Fall	Upland	4	10.97%	69.35%	1.43	1.35

Table A.13 (Continued)

2011	Fall	Upland	5	8.78%	78.12%	1.14	1.10
2011	Fall	Upland	6	7.83%	85.95%	1.02	0.90
2011	Fall	Upland	7	6.53%	92.48%	0.85	0.73
2011	Fall	Upland	8	3.13%	95.61%	0.41	0.59
2012	Spring	Lowland	1	39.46%	39.46%	4.73	3.10
2012	Spring	Lowland	2	22.67%	62.13%	2.72	2.10
2012	Spring	Lowland	3	10.52%	72.65%	1.26	1.60
2012	Spring	Upland	1	28.29%	28.29%	3.11	3.02
2012	Spring	Upland	2	20.88%	49.17%	2.30	2.02
2012	Spring	Upland	3	14.41%	63.58%	1.59	1.52
2012	Spring	Upland	4	11.18%	74.77%	1.23	1.19
2012	Spring	Upland	5	6.96%	81.73%	0.77	0.94