Impacts of Buffelgrass (*Pennisetum ciliare*) on a Forb Community in South Texas

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Since the 1950s, many south Texas rangelands have been seeded with buffelgrass, a perennial C_4 bunchgrass native to Africa that is believed to contribute to reductions in biodiversity. Forb species represent a critical habitat component throughout the breeding period for many wildlife species as seed (summer to fall), as green vegetative material (spring to summer), and as habitat for arthropods (spring to summer). Reductions in richness and diversity of crucial ecosystem components such as forbs and arthropods have large implications for grassland birds and other wildlife. We sampled annual and perennial forbs within 1-m^2 quadrats on 15 study plots (1 ha; $n = 20$ quadrats/plot) at Chaparral Wildlife Management Area, in LaSalle and Dimmit counties, Texas, during 2005 and 2006. Study plots were divided into five light-buffelgrass plots (0 to 5% buffelgrass canopy coverage), five moderate-buffelgrass plots (5 to 25% buffelgrass canopy coverage), and five heavy-buffelgrass plots ($>$ 25% buffelgrass canopy coverage). Buffelgrass in study plots was composed of naturalized plants, and was not deliberately planted. During 2005 we observed that plots with $>$ 25% buffelgrass had a 73% reduction in forb canopy of native species, a 64% reduction in native forb species richness, and a 77% reduction in native forb stem density compared to plots with 0 to 5% buffelgrass. These trends in native forb reduction ($-$79% native forb canopy, $-$65% forb species richness, $-$80% forb stem density) were nearly identical in 2006, even with greatly reduced rainfall. Simple linear regression revealed negative relationships between buffelgrass cover, total exotic grass cover (buffelgrass and Lehmann lovegrass), and total grass cover and the richness, coverage, and density of forbs/m^2. Reductions in diversity may have larger implications regarding ecosystem function and available useable space and densities of desired bird species such as northern bobwhite.

Nomenclature: Buffelgrass, *Pennisetum ciliare* (L.) Link; Lehmann lovegrass, *Eragrostis lehmanniana* Nees.

Key words: Buffelgrass, exotic grasses, introduced species, Texas.

Biodiversity is considered an important component of ecosystem functioning (Loreau et al. 2002). Forb species represent a critical habitat component throughout the breeding period for many wildlife species (Kuvlesky 2007). Reductions in richness and diversity of crucial ecosystem components such as forbs and arthropods may have large implications for grassland birds and other wildlife.

There is growing concern that exotic grasses adversely affect diversity of native fauna and flora (Bock et al. 1986; Gabbard and Fowler 2007; Hickman et al. 2006; Williams and Baruch 2000) and disrupt ecosystem processes such as energy and nutrient flows (Bock et al. 1986; Christian and Wilson 1999), microbial soil processes (Kourtev et al. 2003), and disturbance regimes (D'Antonio et al. 1999) by out-competing and displacing native plant species (Bakker and Wilson 2001; Fairfax and Fensham 2000), which may in turn impact higher-order organisms such as arthropods and birds (Flanders et al. 2006; Kuvlesky et al. 2002). Exotic grasses tend to invade areas of recent disturbance and are capable of modifying ecosystem processes in their favor (Butler and Fairfax 2003; Christian and Wilson 1999; McIvor 2003; Milberg and Lamont 1995). Dense monocultures of exotic grasses can displace native species and reduce soil nutrient (e.g., C and N) levels (Christian and

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Interpretive Summary

Since the 1950s, buffelgrass has been seeded extensively for cattle grazing throughout south Texas. Due to the ability of buffelgrass to colonize disturbed areas many unseeded pastures and native rangeland areas have experienced increases in buffelgrass composition. The results of this study indicate that from the standpoint of species richness and diversity, areas of extensive buffelgrass coverage may exhibit a greatly simplified herbaceous vegetation community when compared to areas of native grass composition. The reduction of the richness and diversity of forbs may have larger implications regarding ecosystem functioning and the abundance and density of desired bird species such as northern bobwhite. Currently, buffelgrass is still planted extensively by private land managers in south Texas. Given the importance of wildlife (especially passerine songbirds and northern bobwhite) on private lands across south Texas it seems logical that both public wildlife officials and private landowners should understand the potential drawbacks of planting buffelgrass. Treating established patches of buffelgrass is a challenge for managers because this species is a persistent, fire-resistant, copious seed producer. Eliminating buffelgrass on a landscape scale is unfeasible, and at present the best option for managing buffelgrass may be to adopt a preventative approach.

Wilson 1999; Evans et al. 2001) and increase the frequency and intensity of fires on the landscape (Bock and Bock 1992; Brooks and Pyke 2001; Butler and Fairfax 2003; Rossiter et al. 2003). Once established, exotic grasses may persist on a landscape indefinitely in the absence of direct management, resulting in low diversity of native plants and animals (Brandt and Rickard 1994). Despite advances in management of exotic grasses (e.g., Biedenbender and Roundy 1996; Wilson and Pärtel 2003), in areas where they become abundant, their presence may be permanent.

Since the 1950s, extensive areas of south Texas rangelands have been subjected to mechanical brush management practices such as root plowing. Many of these treated rangelands were seeded to buffelgrass [*Pennisetum ciliare* (L.) Link], a perennial C_4 bunchgrass native to Africa (Ball 1964; Carter 1958; Hanselka 1988). This species is an excellent colonizer (Humphreys 1967; McIvor 2003), and often establishes along roadsides and other areas of disturbance (Búrquez-Montijo et al. 2002; Rutman and Dickson 2002).

Buffelgrass is common in northern Mexico, south Texas, and the Sonoran desert, and is still planted as a pasture grass in Texas and Mexico. Flanders et al. (2006) found increased diversity and richness of forbs and grasses (14.0 and 23.3% respectively) on native sites that were compared to buffelgrass-dominated exotic grass sites in the western Rio Grande Plains of Texas. Given that this species is one of the world's most successful colonizers, its presence in the Southwest may represent a substantial threat to stability and diversity of these ecoregions (Williams and Baruch 2000). Despite the potential ecological drawbacks of buffelgrass in rangeland ecosystems, in Texas, this species has a history of research and development for increasing seedling establishment (e.g., Mutz and Scifres 1975; Williamson and Pinkerton 1985) and development of cultivars (e.g., Texas Agricultural Experiment Station 1981), as well as recommendations for agricultural use from government agencies and academic institutions (e.g., Ruye and Schuster 1985).

Goals and Objectives. The overall goal of this study was to assess whether the abundance of buffelgrass influenced the abundance and diversity of a south Texas forb community. Specifically, the objectives were to determine the extent to which the native forb community differed among areas of heavy, moderate, and light buffelgrass composition and areas composed of native grasses during a midsummer-to-fall and spring-to-midsummer period.

Materials and Methods

Study Area. We conducted this study during spring and summer (May through August) 2005 and 2006 on the 6,154-ha (15,207 ac) Chaparral Wildlife Management Area (CWMA) in Dimmit and LaSalle counties, Texas (28°17′55.98′N, 99°24′37.27″W). The CWMA was purchased by the state of Texas in 1969 and is managed by the Wildlife Division of the Texas Parks and Wildlife Department. Management activities on CWMA are designed to maintain diversity of flora and fauna native to the south Texas ecosystem. Average rainfall at CWMA is 61.75 ± 3.5 cm/yr (24.3 ± 1.4 in/yr) (1969 to 2005; Texas Parks and Wildlife, unpublished data), but is extremely variable and patchy throughout the area.

Habitat management objectives are achieved through the extensive use of prescribed fire, high-intensity low-frequency cattle grazing, and mechanical treatments. Vegetation is dominated by honey mesquite (*Prosopis glandulosa* Torr.)–mixed brush communities characteristic of the south Texas plains (McLendon 1991). Common forb species present with importance to wildlife include legumes (Fabaceae), croton (*Croton* spp.), and western ragweed (*Ambrosia psilostachya* DC.). Buffelgrass composition varies locally from light (0 to 5%) to heavy ($>$ 25%) and stands of native bunchgrasses such as tanglehead [*Heteropogon contortus* (L.) P. Beauv. Ex Roem. & Schult.] and tumble lovegrass (*Eragrostis sessilispica* Buckley) are locally abundant. Lehmann lovegrass (*Eragrostis lehmanniana* Nees), another exotic grass species, is widely distributed throughout the area, whereas buffelgrass compositions appear to be most abundant near areas of recent disturbance and generally less abundant in areas of established native grasses. Buffelgrass was seeded on two pastures of CWMA during the 1960s; however, plots used for this study represent areas that were either colonized from the initial seeding or from outside sources. All other

Table 1. Average values ± SE and one-way ANOVA results for coverage and plant community variables per 1 m^2 in 1 ha heavy, moderate, and light buffelgrass plots at Chaparral Wildlife Management Area, 2005.

	Buffelgrass composition type[a]			
	Heavy (> 25%)	Moderate (5–25%)	Light (< 5%)	
Parameter measurement	Average ± SE	Average ± SE	Average ± SE	P value[b]
Exotic grass cover (%)	49.66 ± 3.52	23.29 ± 4.43	6.68 ± 2.19	—[c]
Buffelgrass cover (%)	49.37 ± 3.68	13.72 ± 3.44	0.53 ± 0.25	—[c]
Native grass cover (%)	0.46 ± 0.20	6.82 ± 2.29	29.41 ± 2.03	—[c]
Total grass cover (%)	50.21 ± 3.56A	30.62 ± 3.40B	35.88 ± 1.77AB	0.0018
Forb cover (%)	3.41 ± 1.16B	7.55 ± 0.87AB	11.71 ± 0.85A	0.0002
Litter cover (%)	40.41 ± 3.53A	50.10 ± 1.41A	38.50 ± 2.56A	0.0198
Bare ground (%)	6.01 ± 1.37A	11.74 ± 2.26A	13.91 ± 1.34A	0.0183
Forb species richness	2.36 ± 0.64B	4.04 ± 0.54AB	6.36 ± 0.28A	0.0005
Forb stem density	11.72 ± 3.85B	38.68 ± 9.15AB	52.83 ± 9.49A	0.0099
Forb diversity	0.56 ± 0.14	0.84 ± 0.11	1.32 ± 0.04	0.006[d]
Grass diversity	0.31 ± 0.15	1.82 ± 0.08	1.95 ± 0.04	0.007[d]
Grass species richness	2.60 ± 0.81	7.40 ± 0.40	8.80 ± 0.37	—[e]

[a] Uppercase letters after SE refer to Scheffe grouping at $\alpha = 0.01$.

[b] Testing buffelgrass composition type; df = 2, 12; $N = 15$; $n = 5$ per type.

[c] Significance testing not conducted because differences were known a priori.

[d] P value based on Kruskal–Wallis ANOVA of ranks analysis.

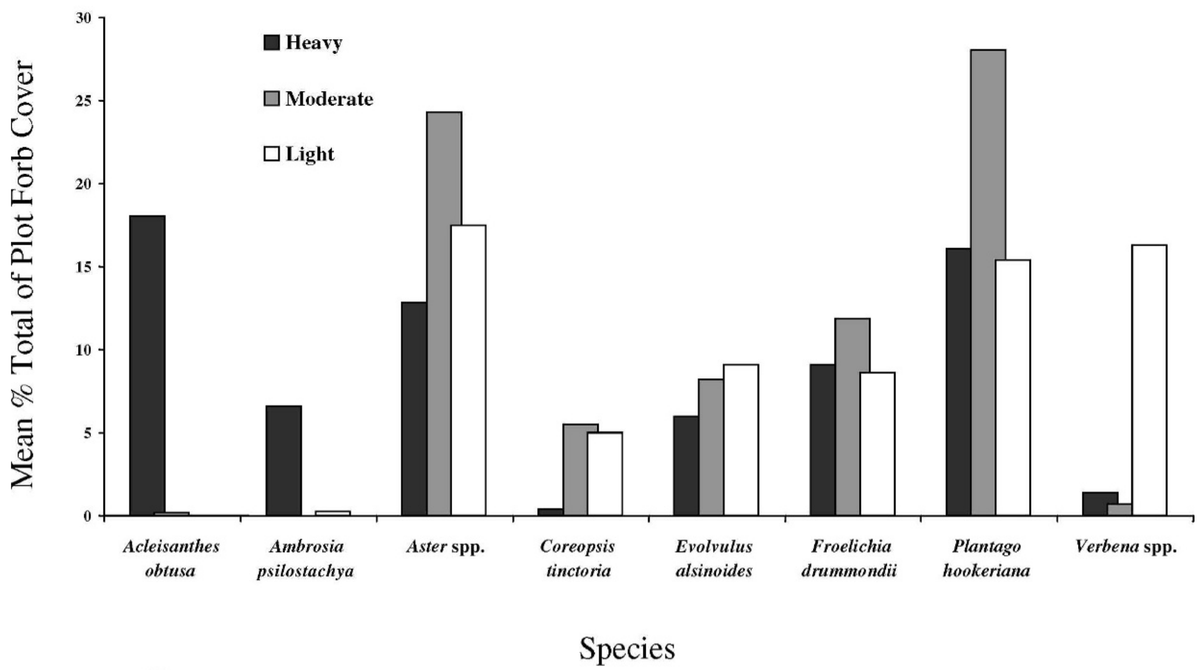
[e] ANOVA not calculated because of unequal variance between types.

exotic grasses species on the area arrived from adjacent properties. Exotic Bermuda grass [*Cynodon dactylon* (L.) Pers.] and Kleberg bluestem [*Dichanthium annulatum* (Forssk.) Stapf] can also be found in limited quantities on CWMA. Our study focused on plots in four pastures in the southeast portion of CWMA: Headquarters (≈ 188 ha), South Jay (≈ 750 ha), Hogue (≈ 258 ha), and Rosindo (≈ 362 ha). Three soil types were present on our study plots: Duval loamy fine sand, Duval very fine sandy loam, and Duval loamy fine sand (NRCS 2008), and occurrences of each soil type were proportional among plots.

Vegetation Sampling. We assessed characteristics of herbaceous vegetation (grasses and forbs) on 15 1-ha study plots: five with light (< 5%) buffelgrass canopy coverage (dominated by native grasses), five with moderate buffelgrass composition (5 to 25%), and five with heavy buffelgrass composition (> 25%). Sites were selected so that woody plant canopy cover, species composition, and management histories were similar among plots. We randomly selected and sampled 20 1-m^2 (10.8 ft^2) quadrats within each plot and accounted for a nonuniform distribution of buffelgrass among study plots by factoring out extensive areas (e.g., > 20 m by 20 m [66 ft × 66 ft]) with no buffelgrass in heavy plot types. We measured percentage of total cover of grass, forb, litter, and bare ground, and cover and density of individual forb species within 0.1-m^2 quadrats (Daubenmire 1959) in each plot, and calculated Shannon–Wiener diversity indices (Pielou 1975) using density data for forbs/m^2 quadrat, and frequency of occurrence/1-ha study plot for grasses. We assessed grass diversity on the 1 ha/plot scale because even in diverse areas the number of species of grass within a 1-m^2 quadrat tended to be low (one to three species) which would have underestimated grass diversity across the entire study plot. Plots were sampled during a midsummer to fall (June 14 to September 18) period in 2005, and a late spring to midsummer (May 16 to July 1) period in 2006.

Data Analysis. We examined 12 variables to estimate parameters of the herbaceous vegetation community in each of the three plot types: percentage of cover of buffelgrass, total exotic grass, native grass, total grass, forb, litter, and bare ground; density, richness, and diversity of forbs; and richness and diversity of grasses. These data were analyzed within univariate space using a one-way ANOVA and simple linear regression models. Percentage of coverage of exotic grasses, buffelgrass, and native grass were not tested for significance because it was recognized a priori that differences would exist between plot types. The Shannon–Wiener index of diversity is not considered continuous, so diversity data were analyzed using an analogous nonparametric technique, Kruskal–Wallis ANOVA by ranks. Differences in means were

A.



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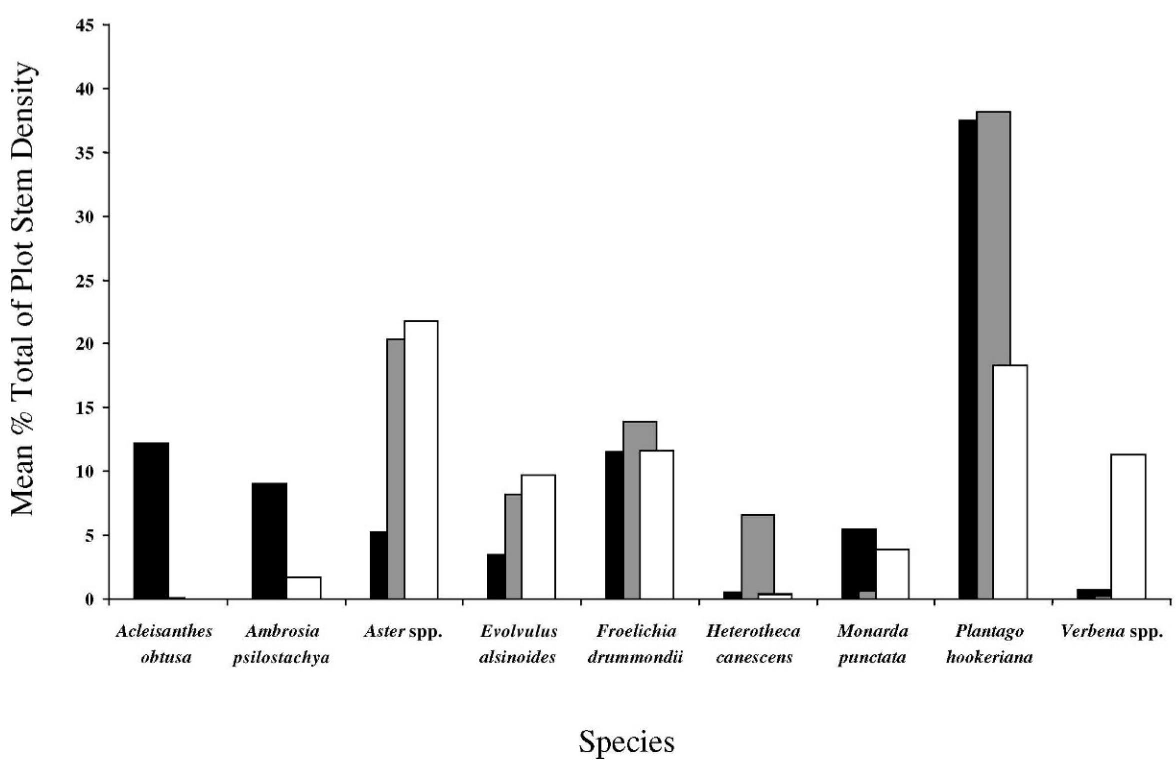

Figure 1. The most abundant forb species by mean percentage of cover (A) and mean percentage of stem density (B) and comparisons between heavy (> 25%), moderate (5–25%), and light (< 5%) buffelgrass plots (n = 5 per type) at Chaparral Wildlife Management Area, LaSalle and Dimmit counties, Texas, June 14–September 18, 2005.

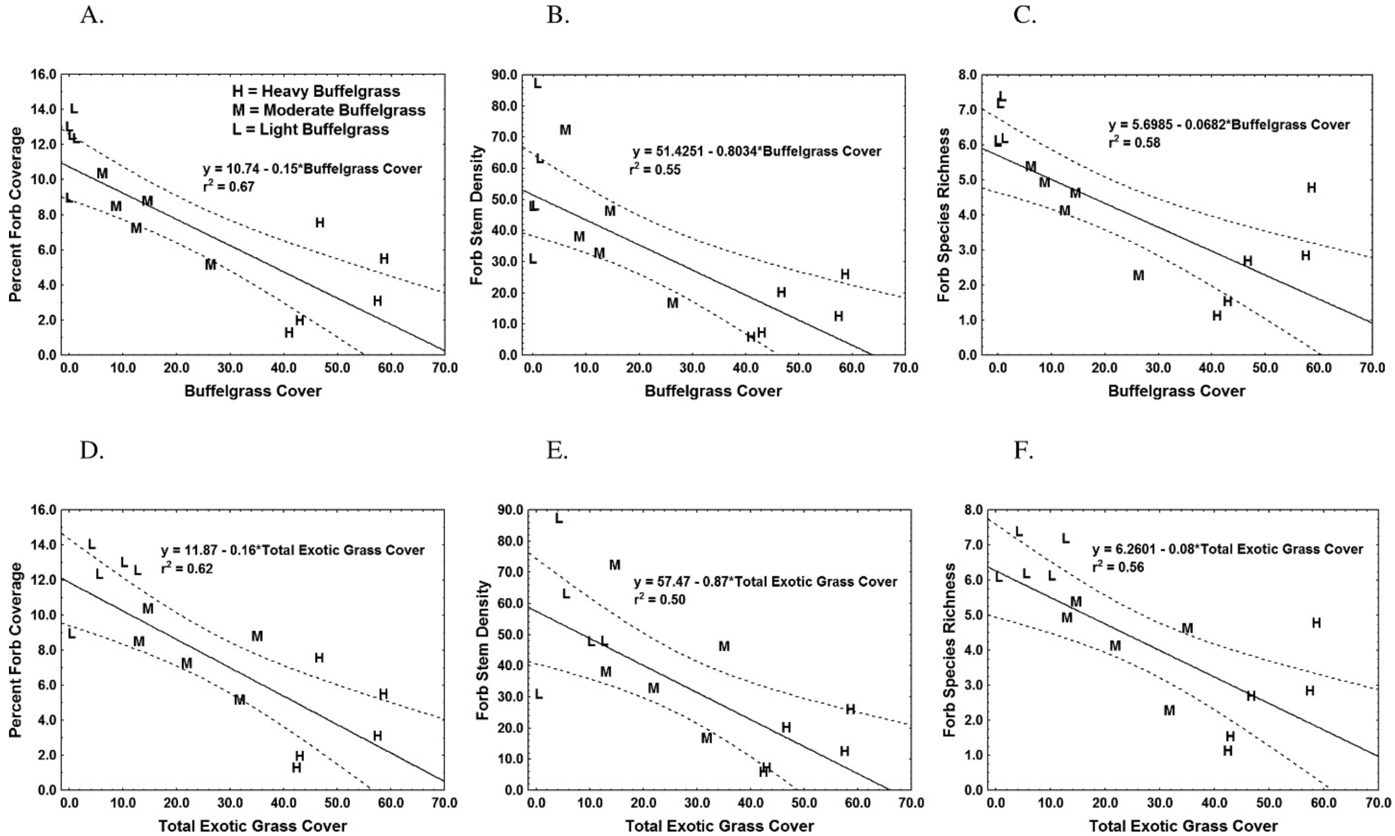

Figure 2. Linear relationships between buffelgrass (A–C) and total exotic grass (D–F) cover and the forb community within heavy (> 25%), moderate (5–25%), and light (< 5%) buffelgrass plots (n = 5 per type) at Chaparral Wildlife Management Area, LaSalle and Dimmit counties, Texas, June 14–September 18, 2005. Dashed lines represent 95% confidence interval bands.

considered significant at $\alpha \leq 0.01$ because plot types were selected arbitrarily, so a decreased probability of type I error was desired. Our objective was to evaluate potential impacts of buffelgrass on forb communities during different portions of the breeding period for grassland birds and other wildlife, so we made no attempt to pool data between sampling periods. Data analysis was conducted using SAS 9.1[1] (Cody and Smith 2006) and STATISTICA 7.1.[2]

Results and Discussion

Buffelgrass Impacts on Ground Vegetation Communities. Thirty-five herbaceous plant species were identified between heavy (32 species) moderate (27 species), and light (29 species) buffelgrass plots in 2005, and 27 species were identified between heavy (20 species), moderate (15 species), and light (16 species) plots in 2006 (Sands 2007). Forty herbaceous species were identified for all plots between 2005 and 2006. A portion of forbs (< 3%/plot type coverage; < 4%/plot type stem density) were considered unknown due to factors related to the condition of the plant including herbivory and desiccation (Sands 2007).

Midsummer to Fall 2005. ANOVA was performed on six continuous variables. Grass species richness was not included because of a failure to meet the assumption of equal variances (Levene's test; df = 2, 12; F = 4.40; P = 0.0369). Mean estimates of ground vegetation community parameters varied greatly between study plot types (Table 1). Significant differences ($P \leq 0.01$) in the means were found for nine variables, and highly significant ($P \leq 0.001$) differences were found for seven variables (Table 1). Mean estimates of forb community characteristics were generally greater on light and moderate plots than on heavy plots (Table 1). Forb diversity ($P < 0.01$) and grass diversity ($P < 0.01$) indices were significantly greater in light plots than in heavy and moderate plots (Table 1).

Though ≥ 25 forb species were identified in each plot type, the majority of forb coverage and density was composed of comparatively few species. The five most abundant genera/species in each plot type accounted for 62.7% (heavy), 77.9% (moderate), and 66.9% (light) of the total forb coverage/plot (Figure 1). This trend also occurred for stem density, with the five most abundant genera accounting for 74.7% (heavy), 87.2% (moderate), and 72.7% (light) of mean total stems/plot (Figure 1).

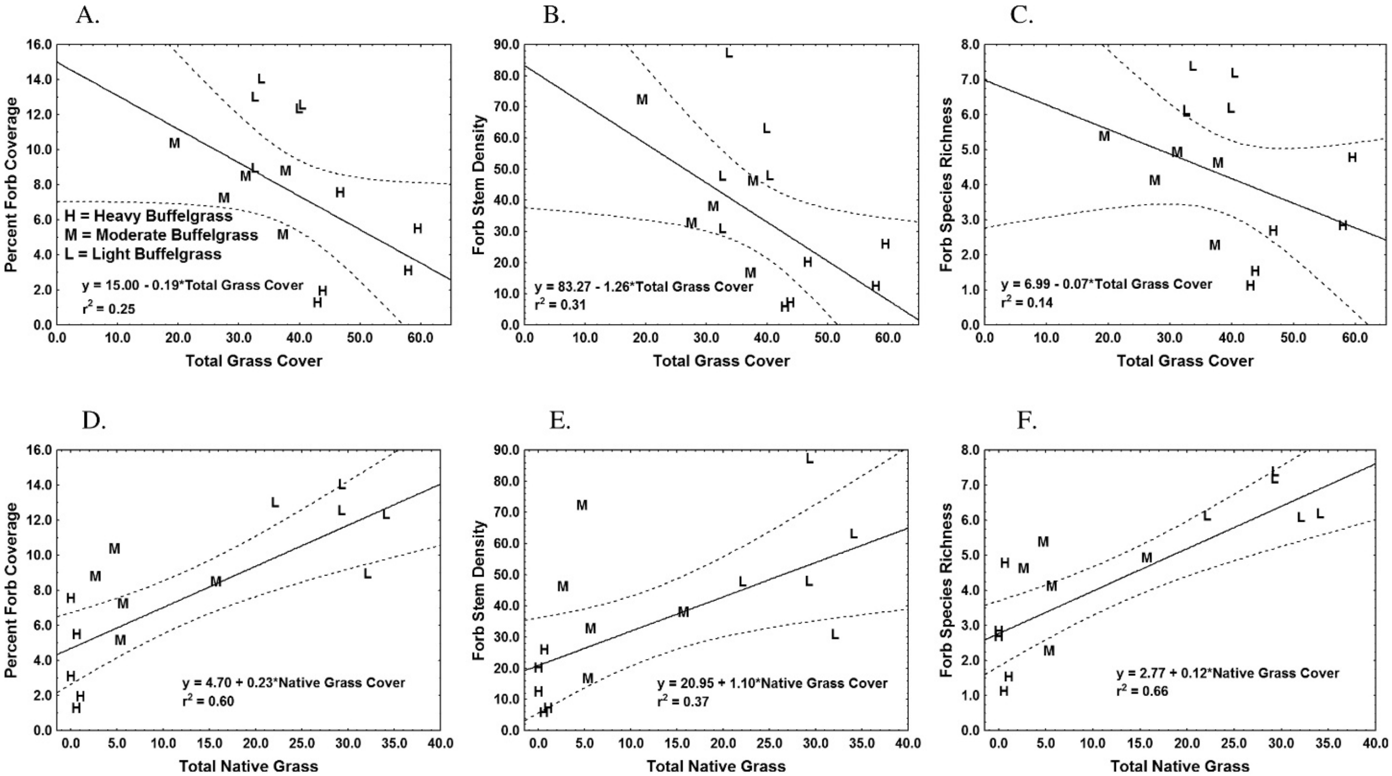

Figure 3. Linear relationships between total grass (A–C) and native grass (D–F) cover and the forb community within heavy (> 25%), moderate (5–25%), and light (< 5%) buffelgrass plots (n = 5 per type) at Chaparral Wildlife Management Area, LaSalle and Dimmit counties, Texas, June 14–September 18, 2005. Dashed lines represent 95% confidence interval bands.

Table 2. Average values ± SE and one-way ANOVA results for coverage and plant community variables per 1 m^2 in 1 ha heavy, moderate, and light buffelgrass plots at Chaparral Wildlife Management Area, 2006.

	Buffelgrass composition type[a]			
	Heavy (> 25%)	Moderate (5–25%)	Light (< 5%)	
Parameter measurement	Average ± SE	Average ± SE	Average ± SE	P value[b]
Exotic grass cover (%)	23.94 ± 4.90	17.25 ± 1.02	6.37 ± 1.62	—[c]
Buffelgrass cover (%)	22.96 ± 5.07	11.26 ± 3.09	0.68 ± 0.68	—[c]
Native grass cover (%)	0.34 ± 0.18	2.42 ± 0.54	7.09 ± 2.83	—[c]
Total grass cover (%)	24.33 ± 4.92A	19.66 ± 1.04A	13.46 ± 3.07A	0.0090
Forb cover (%)	1.00 ± 0.39B	1.43 ± 0.18B	4.90 ± 0.81A	0.0004
Litter cover (%)	50.02 ± 6.65A	41.62 ± 2.89A	40.51 ± 5.43A	0.4009
Bare ground (%)	24.65 ± 4.56A	37.29 ± 3.17A	41.15 ± 4.83A	0.0434
Forb species richness	0.80 ± 0.35A	1.01 ± 0.14A	2.27 ± 0.38A	0.0117
Forb stem density	2.63 ± 1.03A	3.77 ± 0.78A	13.10 ± 4.32A	0.0284
Forb diversity	0.16 ± 0.10	0.19 ± 0.04	0.53 ± 0.10	0.022[d]
Grass diversity	0.65 ± 0.26	1.45 ± 0.10	1.36 ± 0.08	0.063[d]
Grass species richness	3.80 ± 1.07A	5.80 ± 0.73A	5.00 ± 0.32A	0.2225

[a] Uppercase letters after SE refer to Scheffe grouping at $\alpha = 0.01$.

[b] Testing buffelgrass composition type; df = 2, 12; N = 15; n = 5 per type.

[c] Significance testing not conducted because differences were known a priori.

[d] P value based on Kruskal–Wallis ANOVA of ranks analysis.

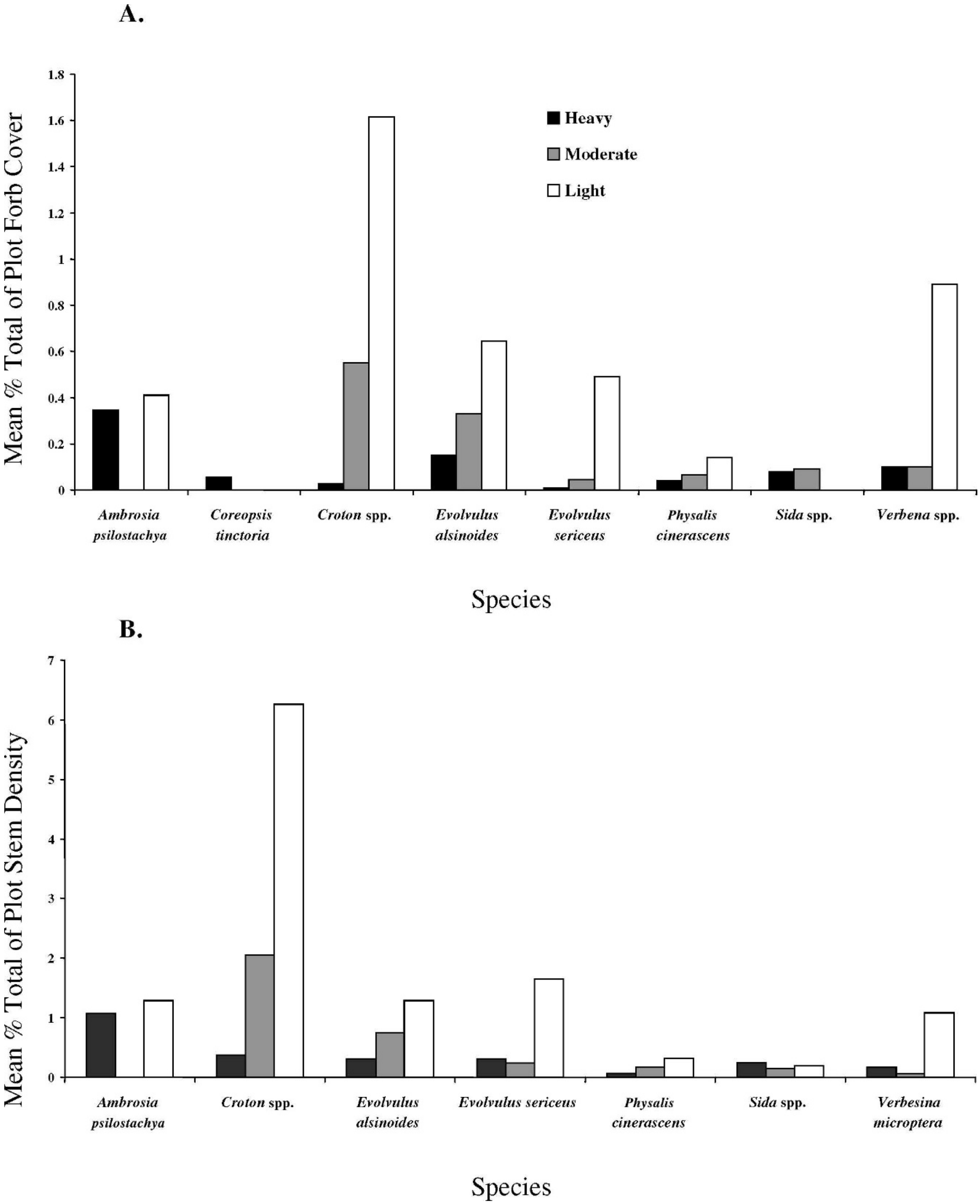

Figure 4. The most abundant forb species by mean percentage of cover(A) and mean percentage of stem density (B) and comparisons between heavy (> 25%), moderate (5–25%), and light (< 5%) buffelgrass plots (n = 5 per type) at Chaparral Wildlife Management Area, LaSalle and Dimmit counties, Texas, May 16–July 1, 2006.

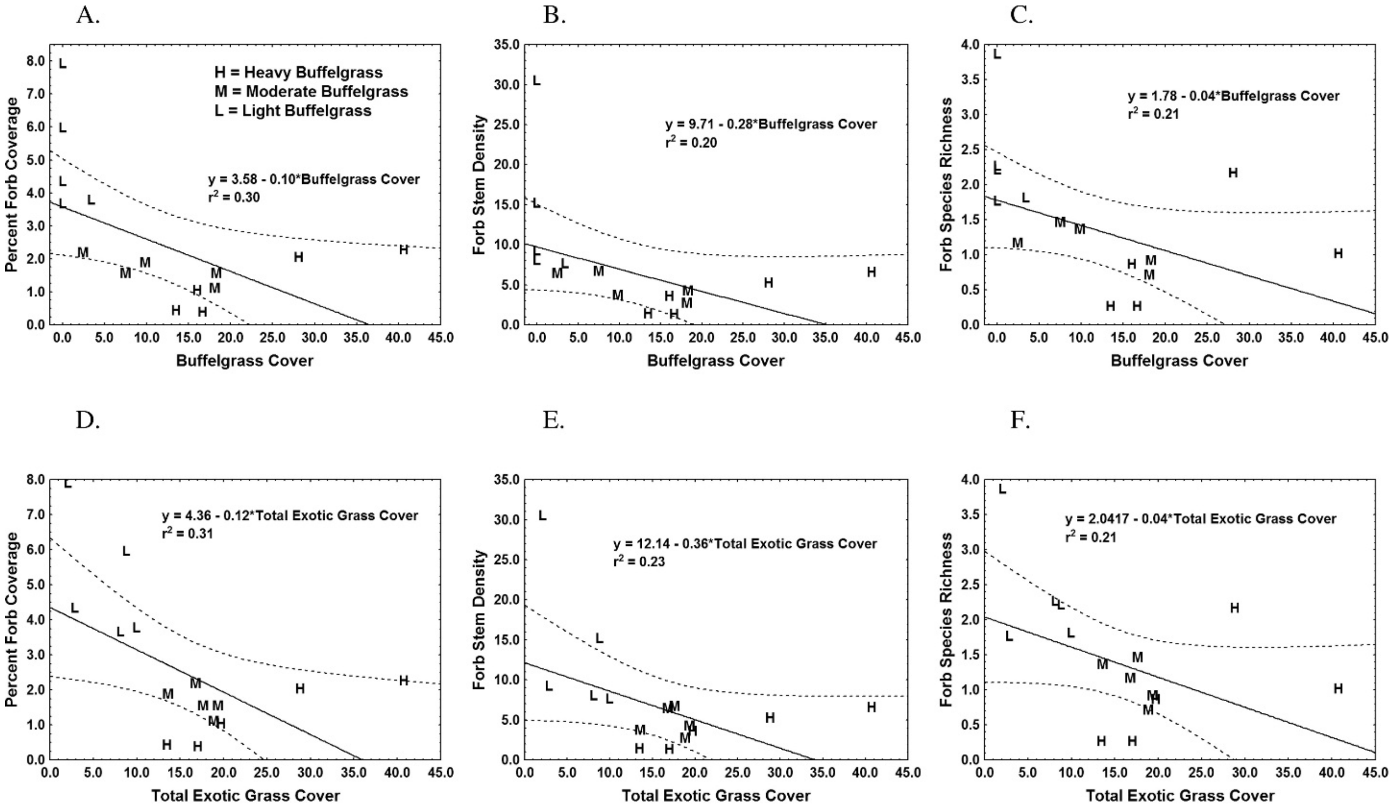

Figure 5. Linear relationships between buffelgrass (A–C) and total exotic (D–F) grass cover and the forb community within heavy (> 25%), moderate (5–25%), and light (< 5%) buffelgrass plots (n = 5 per type) at Chaparral Wildlife Management Area, LaSalle and Dimmit counties, Texas, May 16–July 1, 2006. Dashed lines represent 95% confidence interval bands.

Simple linear regression using all 15 study plots revealed negative relationships between buffelgrass cover, total exotic grass cover (buffelgrass and Lehmann lovegrass), and total grass cover and the richness, coverage, and density of forbs/m^2 (Figure 2). The relationships between buffelgrass and total exotic grass coverage (Figures 2 and 3) and the forb community were stronger than the relationship between total grass and the forb community (Figure 3). Richness, coverage, and density of forbs/m^2 were positively correlated with native grass cover (Figure 3).

Late Spring to Midsummer 2006. ANOVA was performed for seven continuous variables, and Kruskal–Wallis ANOVA of ranks was tested for two diversity variable. In this analysis, grass species richness was included in the ANOVA because the homogeneity of variance assumption was met (Levene's test; df = 2, 12; F= 2.92; P = 0.0927). Mean estimates of ground vegetation community parameters varied greatly between study plot types (Table 2). Significant differences (P $\leq$ 0.01) of means were found for five variables, and a highly significant (P $\leq$ 0.001) difference was found for one variable, percentage of forb cover (Table 2). Mean estimates of forb community characteristics were generally greater on light plots than on moderate and heavy plots (Table 2). Forb diversity (P = 0.02) and grass diversity (P = 0.063) indices were not significantly greater in light plots than in heavy and moderate plots (Table 2).

As in 2005, even though $\geq$ 15 forb species were identified in each plot type, the majority of forb coverage and density was composed of comparatively few species. The five most abundant genera/species in each plot type accounted for 73.4% (heavy), 79.6% (moderate), and 82.7% (light) of the total forb coverage/plot (Figure 4). This trend also occurred for stem density, with the five most abundant genera accounting for 74.7% (heavy), 87.2% (moderate), and 72.7% (light) of mean total stems/plot (Figure 4).

Simple linear regression using all 15 study plots revealed negative relationships between buffelgrass cover, total exotic grass cover (buffelgrass and Lehmann lovegrass), and total grass cover and the richness, coverage, and density of forbs/m^2 (Figure 5). The relationships between buffelgrass and total exotic grass coverage (Figure 5) and the forb community were stronger than the relationship between total grass cover and the forb community (Figure 6). Richness, coverage, and density of forbs/m^2 were positively correlated with native grass cover (Figure 6).

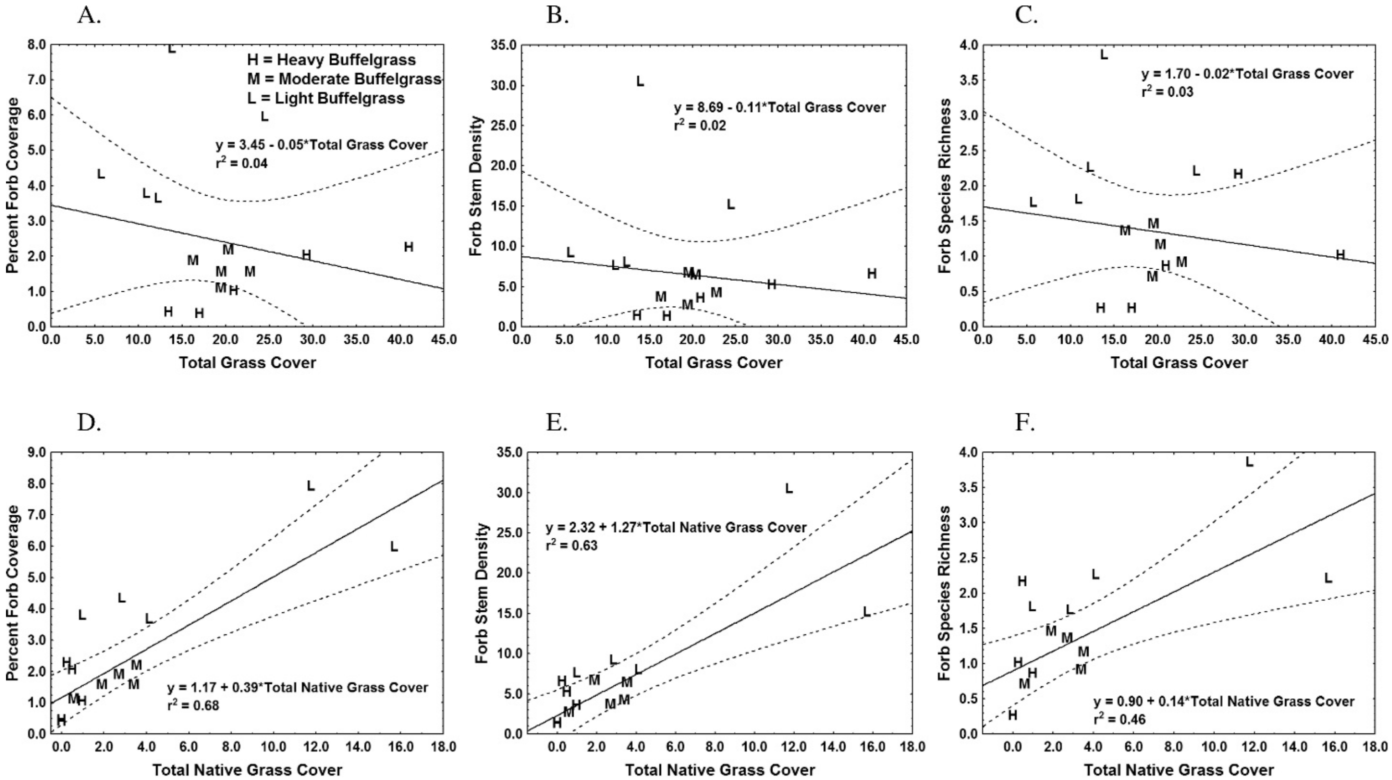

Figure 6. Linear relationships between total grass (A–C) and native grass (D–F) cover and the forb community within heavy (> 25%), moderate (5–25%), and light (< 5%) buffelgrass plots ($n = 5$ per type) at Chaparral Wildlife Management Area, LaSalle and Dimmit counties, Texas, May 16–July 1, 2006. Dashed lines represent 95% confidence interval bands.

These results indicate a negative relationship between buffelgrass cover and forb community parameters (coverage, density, species richness, and diversity), and a positive relationship between these four parameters and native grass coverage and grass diversity; though the 2006 models were generally less explanatory than the 2005 models. These results are comparable to Flanders et al. (2006) who found significant differences between the richness of grass and forbs within exotic and native grass plots in south Texas. Structural and floristic characteristics of plant communities are both important components of grassland bird habitat (Block and Brennan 1993), and the differences caused by the presence of exotic grasses such as buffelgrass can have negative impacts on avian communities (Flanders et al. 2006). In this study, the structural and floristic components varied between sampling periods for all three plot types. However, within each period the structural parameters (percentage of grass cover, litter, and bare ground) were statistically similar among plot types whereas floristic parameters differed greatly.

Precipitation patterns are patchy and highly variable in south Texas, and rainfall amounts differed greatly from 2004 to 2006 (Sands 2007). From November 2005 to June 2006 CWMA received very little precipitation (9.8 cm), a stark contrast to the comparatively wet period from November 2004 to June 2005 (24.31 cm) (Texas Parks and Wildlife, unpublished data). The drought conditions of late 2005 and early 2006 certainly impacted parameters of the ground vegetation community on CWMA, and in fact created two very different plant communities between sampling seasons. However, the relative differences in forb canopy coverage, forb stem density, and forb species richness in the heavy vs. light buffelgrass plots were strikingly similar between years, despite the large difference in rainfall.

The results of this study indicate that from the standpoint of species richness and diversity, areas of extensive buffelgrass coverage may exhibit a greatly simplified herbaceous vegetation community when compared to areas of native grass composition. Vitousek (1990) suggested that presence of certain exotic species should be able to change ecosystem processes by altering the way resources are acquired or used within an ecosystem, changing the trophic structure within the invaded area, or by altering the disturbance regime of an ecosystem. Forbs represent a critical aspect of habitat usability for northern bobwhite (*Colinus virginianus*) and other grassland birds for seed and green vegetative material, and as habitat and food for arthropods. Reductions in arthropod and avian abundance in exotic grass habitats are driven primarily by reduced species richness within native plant communities (Flanders et al. 2006). In this case, buffelgrass may be altering the trophic structure of south Texas rangeland communities through the simplification of the herbaceous vegetation component. These reductions in diversity have larger implications regarding the abundance and habitat use patterns of desired bird species such as northern bobwhite (Flanders et al. 2006; Sands 2007). Despite these negative effects, buffelgrass is still planted extensively by private land managers in south Texas. Given the importance of wildlife, especially passerine songbirds and northern bobwhite, on private lands across south Texas it seems logical that both public wildlife officials and private landowners should understand the potential drawbacks of planting buffelgrass.

Treatment methods employing disturbance (e.g., prescribed burning, discing, root plowing, etc.) are commonly used to maintain grasslands, to inhibit brush encroachment, or to provide habitat for target management species such as northern bobwhite. However, buffelgrass and other exotic grasses are adept at colonizing recently disturbed areas (Butler and Fairfax 2003; Christian and Wilson 1999; McIvor 2003; Milberg and Lamont 1995), so managers should beware of disturbing land in direct proximity to patches of buffelgrass.

Treating established patches of buffelgrass represents a challenge to managers because buffelgrass is a copious seed producer, and is fire tolerant. Research involving restoration techniques such as treating buffelgrass patches with herbicide and then seeding robust native grasses such as Arizona cottontop [*Digitaria californica* (Benth.) Henr.] and native forbs into these stands is needed (e.g., Biedenbender and Roundy 1996; Daehler and Goergen 2005). Eliminating buffelgrass on a landscape scale is unfeasible, and at present the best option for managing buffelgrass may be to adopt a preventative approach.

Sources of Materials

[1] SAS, Version 9.1, SAS Institute, Cary, NC.
[2] StatSoft, Version 7.1, Statsoft, Tulsa, OK.

Acknowledgments

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